A Report by Chintan

Circulating Tyres in the Economy

A Waste to Wealth Approach to Old Tyres

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CHINTAN
Environmental Research and Action Group

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Chintan Environmental Research and Action Group
C14, Second Floor, Lajpat Nagar III, New Delhi 110024
Phone: +91-11-46574171 or 46574172
Email: info@chintan-india.org
Website: http://www.chintan-india.org/
Facebook: https://fb.me/ChintanIndia.org
Twitter: https://twitter.com/ChintanIndia
Instagram: https://www.instagram.com/chintan.india/

About Chintan Environmental Research and Action Group

Chintan is a registered non-profit organization with a vision of inclusive, sustainable, and equitable growth for all. Our mission is to reduce ecological footprints and increase environmental justice through changes brought about through partnerships, capacity building at the grassroots, advocacy and research, and sustainable, scalable models on the ground.

Authors

Bharati Chaturvedi (Chintan)
Rajat Rai Handa (Chintan)

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Executive Summary

Over the last two decades, the world has seen an exponential rise in the number of motor vehicles. The World Health Organization (2015) notes that 53% of the motorized vehicles are in middle-income countries and only 46% are in high-income countries. Current projections also indicate a further rise in these numbers, i.e. by 2040, the number of cars being produced will double.

Closely related are the growth trends in the global tyre industry, which currently manufactures close to over a billion tyres. The tyre industry is the largest consumer of natural rubber and is estimated to be currently consuming close to 12 billion tonnes (WHO 2015) or two-thirds of the world's production of natural rubber.

Resource-heavy growth models have made it essential to prioritize issues of sustainable management of natural resources and resource efficiency within the growth agenda. The idea that current 'waste' is an untapped resource as a potential source for secondary raw materials is core to this discussion. Across the world, it is this lens of 'waste as precious resource' that influences the approach to the issue of End-of-Life Vehicles (ELVs), i.e., scrapped, thrown and disposed of vehicles, as waste. ELVs are treated as a source for recycled steel, aluminium, plastics, rubber and copper. Tyres are just one component in ELVs, yet owing to their composition, they have a complete self-sustaining economy around them. Universally, tyres are made of high quality rubber and are considered a large potential source of raw material for the rubber industry. How large that potential is can be understood by noting that in the financial year of 2016-17, an estimated 127.4 million tyres were produced (Tinna Rubbers 2017).

Globally, dumping and stockpiling of tyres has been the most common practice of disposal. The last couple of decades have seen various governments, as well as tyre manufacturers, becoming conscious of the environmental issues and the loss of resources involved in the dumping and burning of tyres. This growing concern has translated into concerted political action wherein several countries have chosen to explore varied systems and models towards the management of End-of-Life Tyres (ELTs).

This report attempts to capture these salient policies and practices of reuse and recycle of ELTs that are being undertaken across both India and globally, while also exploring, in detail, the best possible alternative currently available to India for safe end-of-life-handling practices for tyres.

The **first section** provides insight into the scale of the problem of ELTs at both the global and the national level. This section also attempts to provide an overview of the current systems of recycling that are prevalent in the country. Given that there is not much direct documentation on the scale and pattern of recycling in the informal sector, the section draws extensively from Chintan's on-ground study and experience, which focuses on the informal sector of tyre recycling in North India. The section also provides an overview of recycling in the formal sector of ELTs with an introduction to the Indian reclaim rubber industry. This industry comprises of only 60 odd manufacturers of which 6-7 manufacturers like Balaji Group, KK Reclamations, Tinna Rubbers, GRP, Kohinoor Rubbers etc. serve as leaders.

The recycle and reuse of a tyre, especially in the informal sector, depends on its condition. The **second section** focuses on understanding the current practices of reuse and recycle of ELTs in the country. These practices can be broadly distinguished as being product reuse (retreading/regrooving and mechanical modification) and material reuse (pyrolysis and combustion). Retreading and regrooving are the most direct and cost-effective reuse of old tyres. They do not require too much specialization and ensure significant utilization of the resource, i.e., old tyres. When tyres-as-a-whole cannot be reused, they are manually shredded to obtain secondary materials– tread, bead and side walls. In some cases, large chunks of rubber are used to create items of low value.

With a further grinding of the shredded parts of the tyre, 'rubber crumb' is obtained, which is of greater value. Rubber crumb or crumb rubber serves as raw material in the production of many items such as specific moulded goods such as floor mats, rubber sheets, hose pipes and battery containers. Rubber crumb also serves as the base raw material for the reclaim rubber industry.

ELTs also play an important role in providing energy directly as Tyre Derived Fuel (TDF) and indirectly as Tyre Pyrolysis Oil (TPO). At times, ELTs are decomposed, primarily for energy and additionally for their component parts. Pyrolysis is used to reprocess tyres into fuel gas, oils, solid residue (char) and low-grade carbon black. We did not find this widely practiced. ELTs and scraps of rubber, which are easily available, also serve as a cost-effective fuel or energy source and are often used in brick kilns, in sugarcane jaggery manufacture (in North India) and as a source of heat in winter. This last use is also highly polluting.

Due to the non-biodegradability, flammability and chemical composition of tyres, when they're not recycled, they pose enormous environmental problems. The **third section** provides insight into the environmental problems related to the burning and stockpiling of tyres. Tyres, as material, can be extended post-consumption in a variety of other forms and it is important to understand this complex circular economy. This section also briefly explores the understanding of recycling and reuse in terms of this circular economy.

The **fourth section** elaborates the systems being developed globally to ensure the tyres follow a circular economy pathway. The **first part** of the section focuses on understanding the systems in ELT management in the European Union (EU), which has been a pioneer in the field. At 96%, the EU has the highest rate of recycling of ELTs currently (ETRMA 2011). This has been made possible due to the conscious alignment of the respective member states' policies to their ELT management schemes. Across the EU, there are 3 main models of managing ELTs: the extended producer responsibility, free market model and the government responsibility (tax system) model. At present, across the EU, irrespective of the model being followed, there is a push to explore innovative recycling options which take maximum advantage of the various qualities of rubber. The focus of recycling and reuse of tyres has been in the fields of housing, roads and railways through the development of applications for reclaimed rubber – as rubber fillers, Crumb Rubber Modified Bitumen (CRMB) and rubberized cement and for recovered textile.

The **fifth section** of the report focuses on understanding India's ELT management system. India currently does not have a centralized ELT management policy. It treats ELTs as 'hazardous waste' and the policies that broadly apply to this category are also applicable to ELTs. But, understanding the magnitude of the concern, the country has also tried to streamline the process of ELT management through a series of specific guidelines and rules. In the current draft guidelines of the Waste Tyres Management Rules 2017, the government has attempted to introduce ELT management through an extended producer responsibility approach. But this attempt has not been very well received by all parts of the industry and still stands as a draft, which is pending final approval. This section also explores the Indian position and policies on recycling of ELTs and scrap rubber with a specific focus on policies related to crumb rubber, reclaimed rubber and Tyre Pyrolysis Oil (TPO) processes. The last part of this section, explores, in detail, the advantage and push at the national level by the Ministry of Road Transport and Highways towards CRMB-based roads.

To conclude, it is important as a country to ensure that tyres are not just used as fuel and that other options of optimum resource efficiency are also explored. Due to the fall in the prices of crude oil, the market for TPO is limited and/or falling. The rubber reclaim sector within the country is also currently limited but has much potential to grow. Tapping into the CRMB market is one of the key ways forward. Though the initial construction costs of CRMB-based roads are noted to be 6.88% higher than bitumen-based roads, over the lifetime of the road, i.e. 15 years, there are savings of over 28.74% or INR 6,59,224 per lane/per km. Also, the renewal period in the case of roads which are laid using CRMB is at 5-7 years as opposed to roads laid using bitumen which is within 3-5 years.

Hence, in a growing economy like India with its growing volume of ELTs, there is a need to include CRMB as the alternative on scale, because while informal sector activities for reuse are important, they alone will be unable to handle the projected deluge. This will not only ensure optimum reuse and recycle of the raw materials involved but also reduce overall infrastructural costs and prevent pollution from open burning of tyre remains for fuel. To achieve this, there is a need to consciously increase the uptake of CRMB from ELTs, whether it be for strengthening and repairing older roads and highways or for building newer roads and highways. Alongside, the upgradation of the informal sector is also important.

This report concludes that adapting CRMB would serve as a concerted effort in linking the growing road infrastructure along with the increased motorization within the country. Thus, by ensuring that every kilometre of road is laid using CRMB, we are ensuring that around 3,350 ELTs are recycled in an environmentally friendly manner. Moreover, by ensuring that the estimated 2,75,000 ELTs which are disposed each day are converted to CRMB, as country we would be ensuring nearly 30,000 kms of environmentally friendly roads each year. In this process, we are also additionally ensuring that optimum resource efficiency is achieved, while simultaneously improving connectivity and ensuring better infrastructural quality. Ultimately, with a country-wide focus on CRMB, we are ensuring that we subscribe to a more sustainable, controlled and responsible development model.

Table of Contents

List of Figures

List of Photos

List of Boxes

List of Tables

1. An Explosion in the Tyre Industry

The Indian economy, while mirroring the global trends of rising incomes, coupled with aspirational high consumer behaviour, is envisaged to grow at a rate of 5-6% GDP per annum. This means that the country is currently facing a higher rate of resource consumption along with an increasing rate of urbanization. McKinsey (2010) projects that the urban population in India will nearly double by 2030. The population in cities would increase from the current 340 million to an estimated 590 million. Furthermore, cities that currently account for 58% of India's GDP (2008) would, by 2030, account for nearly 70% of the country's GDP (McKinsey Global Institute 2010). This effectively means that 8 metropolises (Mumbai, Delhi, Kolkata, Chennai, Bangalore, Ahmedabad, Hyderabad, and Pune) will become home to more than 100 million inhabitants and will come under severe pressure for resources.

Steady but isolated growth in any sectors of the economy is insufficient to support and maintain the projected growth. Innovation, especially in infrastructure related to transport, plays a vital role in ensuring the transformation of a growing economy into a vibrant one. Rapid transport-related infrastructural growth means growth in the infrastructure required to sustain these vehicles (in roadways, railways, airways and waterways) coupled with growth, particularly in the automotive and aviation sector.

India currently has the second largest road network in the world which comprises over 54,72,144 km of roads (MoRTH 2016). 60% of all goods in the country and 85% of India's total passenger traffic depend on this network. To ensure the growth of the economy, there is a lot of stress on constructing and strengthening the highways and road networks further. Reflecting this trend, the total length of highways being constructed in a year was at an all-time high in FY 2016-17. At an average pace of 22.3 km per day, 8,142 km of highways were constructed during this period (IBEF 2017).

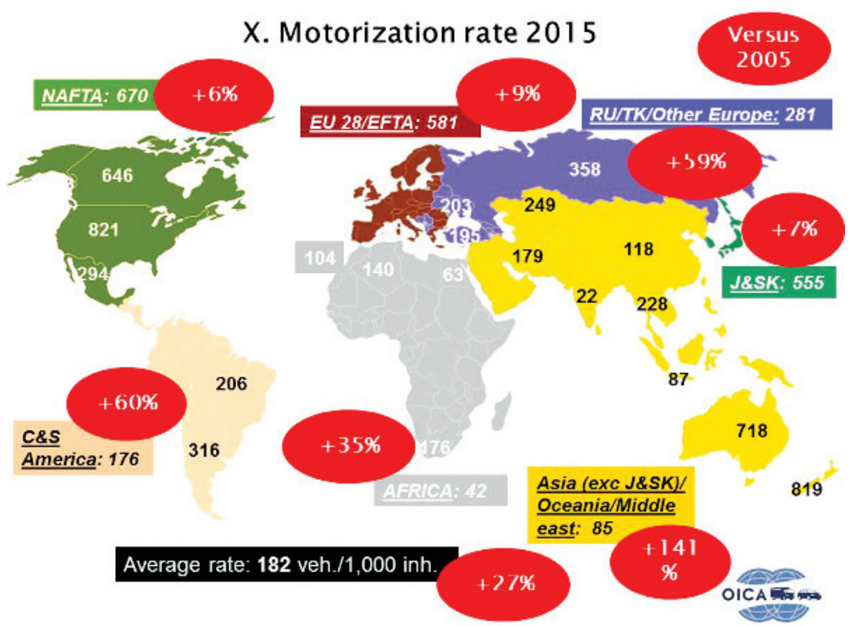
The rural road network has also seen a significant increase under the Pradhan Mantri Gram Sadak Yojana (PMGSY). The current construction in 2016-17 was 133 km of roads per day as opposed to the 73 km per day between 2011-14 (Patel 2017).

In the long run, the government, under different programs such as the National Highways Development Project (NHDP), Special Accelerated Road Development Programme in North East (SARDP-NE) and Left-Wing Extremism (LWE), plans to develop a total of 66,117 km of roads. Additionally, part of the long-term goal of the National Highway Authority of India (NHAI) is to double the length of the national highway network. By 2022, NHAI plans to build 50,000 km of roads worth approximately USD 250 Billion or INR17 Lakh Crores (PTI 2016).

On the other side, the growth of the automotive sector cannot be underestimated. Based on trends, it is projected that by 2020, India is expected to grow into the 3rd largest automobile market in the world (PTI 2017). Moreover, the Indian automotive after market i.e. the market for spare parts, accessories and components of motor vehicles, is estimated to grow at around 10-15 per cent to reach USD 16.5 billion by 2021 from around USD 7 billion in 2016. It also has the potential to generate up to USD 300 billion in annual revenue by 2026, create 65 million additional jobs and contribute over 12% to India's GDP (IBEF 2017).

Therefore, recycling and reuse of vehicles, which are currently not at the forefront of the growth discussion, will come to play a vital role in ensuring resource efficiency and sustainable development.

Figure 1: Motorization Rate of the World



Source: International Organisation of Automobiles Manufacturers (OICA)

Box 1: Did You Know?

"If 9 kg of chunk rubber equivalent is produced per tyre, then a one km long and 7.3m wide low-volume road with a 100-mm thick base built with this mix can incorporate approximately 3,350 tyres."

– (Pasalkar, et al. 2015)

1.1 Types of Tyres Manufactured

The nature and state of the tyre influence the alternatives available for recycling and reuse. Thus, this section will briefly elaborate on the tyres currently available in the automotive market.

Prior to the development of rubber, tyres were wooden wheels fitted with metal bands to prevent wear and tear. Early rubber tyres were solid, unlike the present day pneumatic variety.

Today, most pneumatic tyres are inflatable structures, comprising a doughnut-shaped body of cords and wires encased in rubber and mostly filled with compressed air forming an inflatable cushion. The tyres commonly seen fitted on cars, bicycles, motorcycles, buses, trucks, heavy equipment vehicles and even on aircraft are pneumatic tyres. The materials used to make these are synthetic rubber, natural rubber, fabric and wire, along with carbon black and other chemical compounds. The type of rubber used, the compounds used and the ratio of steel varies according to the type of tyre. Textiles are currently used only in passenger cars and light truck tyres. Radial tyres and bias/belted-bias tyres are the popular forms of pneumatic tyres currently available in the market (for more please see Box 2).

The other types of tyres being manufactured are metal tyres and solid rubber or other polymer-based tyres. Metal tyres are most commonly used in locomotives and railcars, while polymer-based solid tyres are largely used in industrial and commercial applications. They are manufactured from solid rubber and other plastic compounds. Solid tyres are commonly seen in lawn-mowers, skateboards, golf carts, scooters, and many types of light industrial vehicles, carts and trailers. One of the most common applications for solid tyres is in the heavy-weight handling machinery such as forklifts.

It has been over 77 years since the invention of synthetic rubber from petrochemicals and global road and air traffic still depends on plant-based rubber. No man-made material has yet been able to replicate its unique properties.

Tyres are manufactured with a complex mix of natural and synthetic rubber and various structural reinforcing elements including metals and chemical additives. A tyre may contain more than one compound and more than one type of rubber. For example, a car tyre has sidewall rubber, casing rubber and top tread rubber, all adding different elements to its performance. Passenger car tyres need to have 10-40% natural rubber content to allow them to stay flexible at low temperatures and to keep tiny cracks from growing. Truck and aircraft tyres require a higher percentage.

Overall, about 60% of the tyres currently in use are rubber-based tyres. This brings to the fore a sense of urgency about the need to understand and assess the volume of rubber which tends to be discarded and thrown away as waste in India.

Box 2: Different Types of Pneumatic Tyres

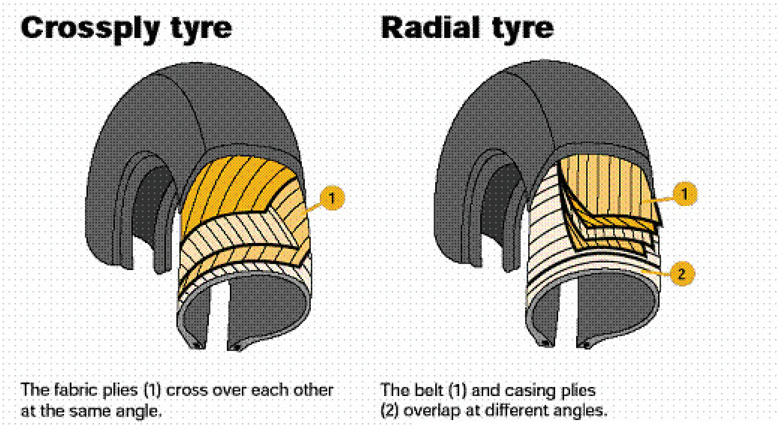
While discussing pneumatic tyres, it is imperative that we briefly discuss the popular types that are currently available in the market – radial tyres and bias, cross-ply or belted bias tyres. The design of the tyre is the fundamental difference between rubber tyres, also known as radial tyres, nylon tyres, which are also known as cross-ply tyres, and the belted-bias tyre which is popularly trademarked as 'polyglass'.

The Rubber/radial tyre is the most commonly used tyre in vehicles today. In radial tyres, there are layers of tyre materials with a layer of steel belt which acts as a reinforcing belt between them. These tyres are constructed in two parts, which allows the sidewall and the tread to function independently. The belts of the radial tyres are a combination of several rubber-coated steel piles which are very tough and cut resistant.

Nylon/Crossply/Bias tyres are mostly used in heavy loading vehicles. Crossply tyres are made up of a single working unit and have fibres of nylon layered in a diagonal manner to provide high side-wall stability to the tyres. Due to this unique construction method, their sidewalls are very tough.

Belted-bias tyres start with two or more bias-plies to which stabilizer belts are bonded directly beneath the tread. This construction provides a smoother ride that is similar to the bias tyre, while lessening rolling resistance because the belts increase tread stiffness. The "belted" tyre starts with two main plies of polyester, rayon, or nylon annealed as in conventional tyres, and then placed on top are circumferential belts at different angles that improve performance compared to non-belted bias tyres. The belts may be of fiber glass or steel.

Figure 2: Cross Sections of Crossply Tyre and Radial Tyre



Source: www.tut.fi (Tampere University of Technology)

Photo 1: Pneumatic Tyres

1.2 Understanding the Scale of End-of-Life Tyres (ELTs)

Over the years, an understanding has emerged that current waste is a source for future raw materials, i.e., it is possible to generate wealth from waste. It is understood that scrapped, disposed and End-of-Life Vehicles (ELVs) can be mined for secondary raw materials, which largely comprises of recycled steel, aluminium, plastics, rubber, copper and, of course, tyres.

Automobiles require huge quantities of rubber for production. The variety and grades of rubber used vary according to the part. Hence, the recycling process also varies substantially.

The United States of America is globally the most motorized country at an estimated 239.8 million vehicles, for its approximate 323 million population (WHO 2015). It is also the largest producer of waste tyres, at an estimation of about 290 million a year. In 1990, it was estimated that over one billion scrap tyres were in stockpiles in the United States while as of 2015, 67 million tyres of these remain (WEF 2015).

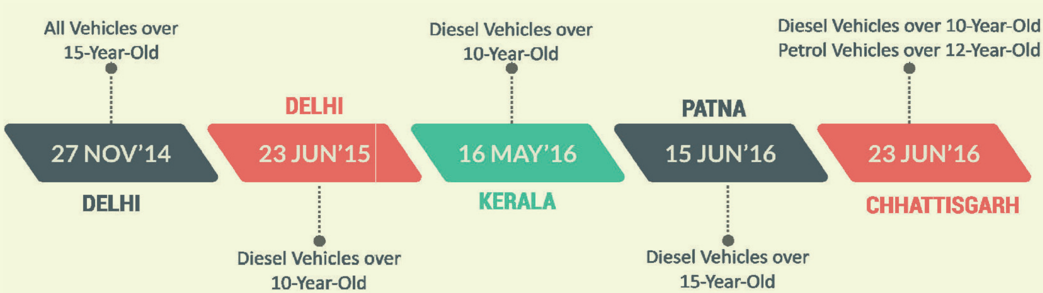
Tyres account for the largest amount of rubber utilized in a vehicle. However, End-of-Life Tyres (ELTs), or waste or scrap tyres, are tyres which are no longer safe for use because of the state of abrasion they've undergone due to wear and tear. Current estimates suggest that India has already experienced 125% increase in Annual New Vehicle Registrations and the projected vehicular growth shows that by 2035, there will be around 80.1 million passenger vehicles (cars, UVs) and 236.4 million two wheelers [Organisation Internationale des Constructeurs d' Automobiles (OICA)]. Additionally, bans on older vehicles (both private and public) mean that over the next few decades, India will witness, and must be prepared for, an exponential increase in tyres especially ELTs. (See Box 3)

Box 3: Ban on Old Vehicles on the Road Means Even More Tyres

The current ban posed by government bodies on old diesel and petrol vehicles means the number of vehicles which will reach their end-of-life stage will increase further. Under these circumstances, the demand and supply of tyres as well as the number of tyres scrapped and treated as obsolete will double.

This highlights the need to bring into specific focus the management and disposal of End-of-Life Tyres (ELTs).

Figure 3: Timeline on Ban of Old Vehicles



Source: http://events.steelmintgroup.com/after-delhi-kerala-patna-chhattisgarh-also-bans-old-heavy-vehicles/

Worldwide, the consumption of natural rubber is pegged at 1,21,67,000 tonnes which has grown from the previous year by 0.3%. Overall, India ranks 2nd in consumption and 6th in the production of natural rubber (Rubber Board 2016).

The official estimates for production of tyres in India in the financial year 2016-17 was at 127.34 million tyres and this was seen to be a 12% increase from the previous year. A 37% manifold increase in the tyre production has been observed in the two-wheeler segment, as well as a 23% increase in the tractor tyre segment and 16% in the passenger car/jeep segment (Tinna Rubbers 2017).

2. What is happening to Tyres in India?

2.1 Tyre Recycling Trends in India

The vehicle and tyre recycling industry in India is largely informal, though a limited formal sector does exist. The informal recycling sector is vast and it is hard to put a precise number on the current volume and scale of recycle.

To better understand the nature and scale of this informal sector, Chintan surveyed 23 tyre hubs which were spread across Uttar Pradesh and Delhi. Also included in the study was a hub situated in Rajasthan. Please refer to Annexure 1 for the list of the major tyre reuse and recycling hubs found across North India.

These hubs provided information on their reuse pattern of scrap tyres. For every ton of tyres received, approximately 40 kg were sent to brick kilns, which generally purchase scrap tyres at the rate of INR 6-8 per kilogram. However, many of these have now also started using coal. The hubs also shared that in practice no part of the tyre really goes to waste and there are varied uses for those tyres that are not burnt.

India has a limited reclaim rubber industry in the formal sector – pegged at about 40 odd manufacturers. Of these, India has about six to seven major players in the tyre recycling/reclaim rubber manufacturing industry. The leaders in this field are Tinna Rubbers, Gujarat Reclaim & Rubber Products Ltd., ELGI Rubber Company Ltd., Balaji Industries, Swani Rubber Industries, Gangimani Enterprise Private Limited and Kohinoor Reclamations.

The leaders in the reclaim rubber industry are mainly enterprises which have been in existence for at least four to five decades. They tend to be largely export oriented industries.

For instance, Tinna Rubber was founded in 1977 and began with the manufacture of footwear soling sheets. In 1998, Tinna Rubber began introducing additives to bitumen modifications. Since its inception, Tinna Rubber has expanded its operations across 14 plants, and in 2012, at 20,000 metric tonnes, their tyre crumbing facility became the single largest facility in the country. Presently Tinna Rubbers is producing 60,000 MT annually which makes it the largest processors of Crumb Rubber in the country.

Gujarat Reclaim & Rubber Products Ltd. was incorporated in 1974 and started production with a capacity of only 2,400 metric tonnes. A far cry from these humble beginnings, the company now reports a turnover of INR 34,638 lakhs and is valued at INR 11,247 lakhs.

Formerly known as Puneet Resins Ltd., Swani Rubber Industries has been in existence since 1970 and currently has a manufacturing capacity of 18,000 metric tonnes per annum. It exports to over 22 countries across the globe.

These enterprises, which are treated as leaders of the sector, tend to be large enterprises and often have subsidiaries and/or specific enterprises in their group which focus specifically on aspects of reclaimed rubber. For instance, ELGI Rubber Company Ltd. is a subsidiary of ELGI Group of Industries and Rubber Resources.[1] It focuses exclusively on rubber recycling. Balaji Group of Industries is a group of 5 industries which focuses on rubber products and rubber reclaim.[2] Balaji Rubber Industries Private Ltd., one of the industries which are part of the group, have been working for over three decades in the specific field of recycling rubber and focuses on natural and butyl rubber. The company currently has an annual production capacity of 45,000 metric tonnes/annum and supplies to about 18 countries.

Thus, despite the impressive growth of India's formal rubber recycling/reclaim sector, there is much scope for further innovation and expansion. The growing number of ELTs highlights the need to consciously include more recycling options of scale, which would ensure the optimum reuse and recycle of the raw materials involved, while also making the case to further expand this sector.

Tyres are made of high quality rubber and are considered a large potential source of raw material for the rubber industry. India has a big recycling industry which is pegged to be worth USD 914 million. In 2011, India produced 90,000 metric tonnes of reclaimed rubber from waste tyres (Mishra 2016).

The Indian rubber recycling industry is pegged to be second only to China in Asia, which is the largest producer of reclaimed rubber (ISRI 2016). But the scale and volume of the Indian industry are much smaller than that of China. Moreover, given the volume of ELTs currently being generated, it becomes even more important that we ensure environmentally friendly recycling of tyres.

1 For more please refer http://www.rubber-resources.com

2 For more please refer http://www.rubberreclaim.com

There is no monitoring of tyre disposal across India. Estimates vary across sources and are broadly based on the production and supply of tyres. For example, when reporting on India's ELTs trend, Rubber Asia observed that India generates over a million tonnes of ELTs each year (Matade 2016). Moreover, with the tyre industry growing at 12% per annum, the subsequent waste volumes will simultaneously rise at the same rate. Business Standard (Modi 2016)reports that India currently produces about 6,50,000 tyres and discards 2,75,000 every day. This report also notes that only a fraction of the number of discarded tyres is recycled. Pasalkar, et al. (2015) in the journal article "Comprehensive Literature Review on the use of Waste Tyres Rubber in Flexible Road Pavement" estimate that 0.6 million tonnes of tyre scrap are currently being generated annually across the country. It is estimated that India's contribution to global ELTs waste is at 6% of the total. Ground-level observations suggest that recycling is much higher, though some fractions are not recycled and these have been noted to cause a high level of pollution (Pasalkar, et al. 2015).

In India, the scrapping of automobiles is currently being handled by the micro, medium and small-scale units (MSMEs) which are largely in the informal and semi-formal sector.

Additionally, across the country, most tyre recycling units for reclaiming rubber have moved from using the water and labour-intensive pan-process to using more efficient and automated processes. It is also important to clarify that not all rubber which is recycled is put to reuse. Rather, a substantial percentage of scrapped rubber is used for fuel purposes, i.e., as Tyre-Derived Fuels.

Box 4: What is Reclaimed Rubber?

"Reclaimed Rubber is a product resulting when waste vulcanized scrap rubber is treated to produce a plastic material which can be easily processed, compounded and vulcanized with or without the addition of either natural or synthetic rubbers. It is recognized that the vulcanization process is not truly reversible; however, an accepted definition for devulcanization is that it is a change in vulcanized rubber which results in decreased resistance to deformation at ordinary temperatures."

– (Barlow 1993), p80

Depending on the condition of the tyre, they are recycled and reused in a variety of ways, the current patterns of recycling of ELTs in India can be broadly classified into the following different categories:

- Using ELTs as-a-whole (regrooving and retreading)
- Mechanical modification (as rubber crumbs or shredded rubber pieces)

- Chemical decomposition or separation of ELTs into different materials and reuse of these material components (pyrolysis)
- Tyre-Derived Fuel (TDF)

2.2 Reuse of Old Tyres: Regrooving and Retreading

Direct reuse of old tyres is possible by undertaking two simple techniques i.e. regrooving or retreading.

Regrooving Tyres

Regrooving is a time-consuming process and is most often carried out by hand. As shown in Photo 2, this process is undertaken with tyres which are in good condition overall but have worn-out treads due to usage. The process involves using a special knife to carve grooves into these tyres. Regrooved tyres are generally sold in the secondary rural market where people use them for low intensity vehicles such as bullock carts or trollies – work that mainly involves load rather than speed.

Additionally, there is a segment of regrooving which specifically focuses on heavy vehicle tyres. Regrooved tyres of heavy vehicles sold with the label of 'Regrooved Tyre' have a price advantage as they are significantly cheaper than the original. This option of regrooving tyres in heavy load vehicles such as lorries, trucks and buses means lower overhead costs for fleet operators. This plays an important role as it reduces the overall tyre cost incurred in the lifetime of the vehicle, especially since tyres along with fuel make up most of the costs incurred by the operator. The selling cost of these regrooved tyres depends on the company, make, year of manufacture and the condition of the grooves. Thus, the price of these tyres varies significantly. A broad range for an average regrooved car tyre would be INR 200- 250. The tyre would have been purchased at a bulk price of INR 50-80.

Photo 2: Manual Regrooving of Tyres at Jali Khoti Road, Kher Nagar, Meerut, UP

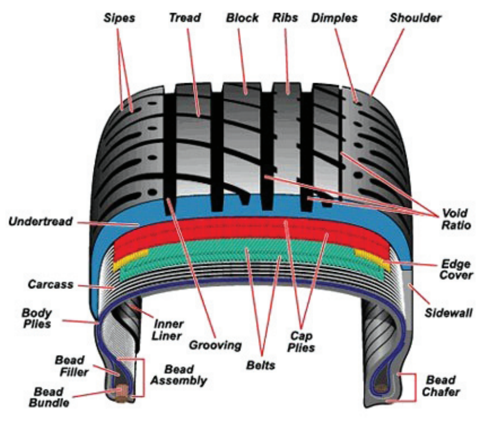
Retreading Tyres

Retreading is another well established and acceptable safe practice for recycling tyres. Any pneumatic tyre has three main parts – tread, bead and side wall (see Figure 4 for a detailed structure of a tyre). The process involves only the tread part of the tyre which is redone or retreaded. This is a more mechanized process than regrooving and involves the removal of the remaining tread by producing tyre crumb and the application which is followed by the vulcanization of the new tread (the 'camel back') using specialized machinery. In simple terms, it is the process of replacing the worn-out tread of a tyre with a relatively newer tread through a series of simple mechanical to semi-mechanical processes.

To retread a tyre, the fabricator requires appropriate and/or identical treads which may not always be available. Moreover, the demand for a particular brand or company of tyre is not predictable and constant. This means that fabricators who focus on retreading as a practice also retrieve and store treads and other parts of the tyres which are in good condition but have been discarded for various other reasons. As a return on investment, it has been observed that retreaded tyres offer a better price compared to regrooved tyres. Fabricators offering this service in the areas of Meerut, Mawana and Partapur (North India) were included in a study by Chintan.

It was observed that typically a tyre retreading unit was small-scale, employing a maximum of 4-5 employees. Additional hands were needed in the case of retreading heavy equipment vehicle tyres such as that of tractors, buses and trucks among others. These retreading units also required heavier machinery and equipment to run the process. Indag Rubber, Midas Treads, Eastern Treads, MRF Tyres, TVS and ELGI Group of Industries are some of the larger and more organised players in the retreading industry.

Figure 4: Structure of a Tyre



Source: http://www.mechanicalengineeringblog.com

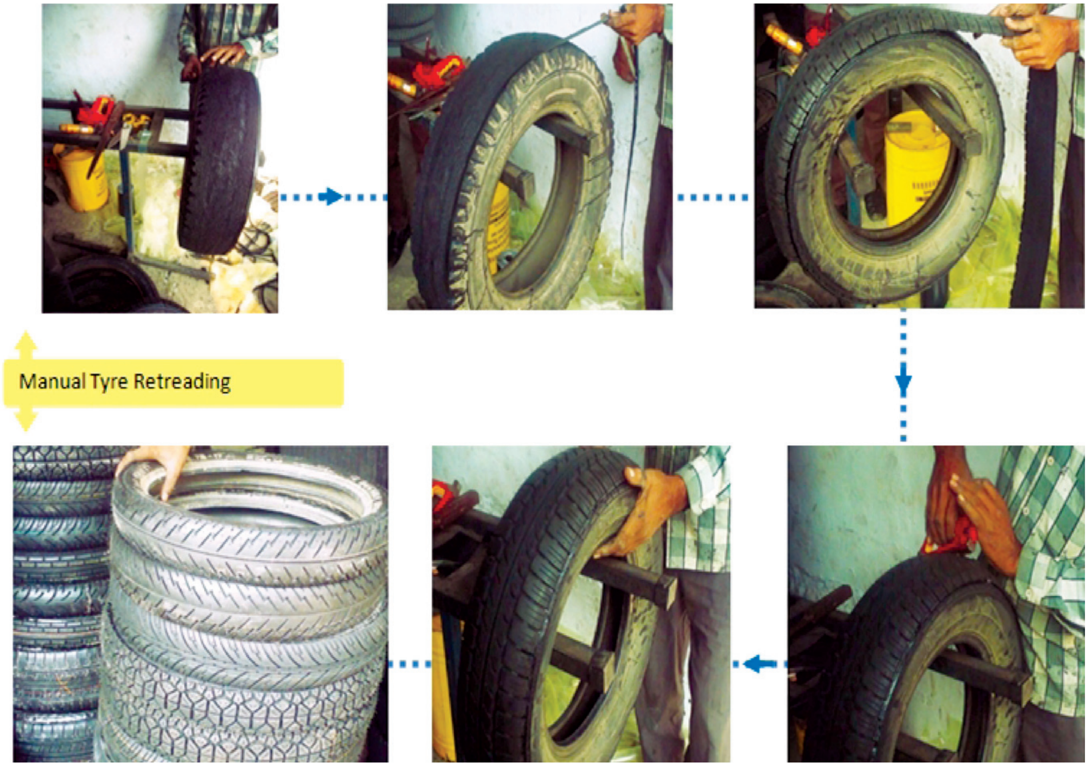


Photo 3: Manual Retreading of a Tyre in Meerut

2.3 Mechanical Modification (As Rubber Crumbs or Shredded Rubber Pieces)

Reuse of Products: Tread, Bead and Side Walls

When a tyre, in its entirety, cannot be reused either by retreading or regrooving, its body is manually cut into three parts – the tread, bead and side walls – to obtain secondary materials. The further grinding of these parts results in 'rubber crumb' which serves as a raw material in the production of several items. Traditionally, rubber crumb's use was limited to low value items such as shoe soles, slippers, water containers etc., but with newer available technology and on fine grinding, the same rubber crumb has found greater value. It can now be used to make tyres and other value-added products while also not impairing the properties of the compound or compromising its performance. Chintan found that some fabricators who focussed on the recycling and reuse of ELTs were also manufacturers of shoes and sandal soles, doormats, pots, dustbins and bicycle pedals. The economic value received for the rubber crumb is dependent on the quality of the rubber in the tyre, the shape, weight, form and/or volume. Hence, there is a wealth from waste aspect that dominates the informal sector.

Given the projected volume and scale of ELTs, it is important to note that the options of regrooving and retreading may be unable to use the entire volume produced. These will have to be upgraded and formalized, along with scalable uses such as 'rubber crumb' or 'crumb rubber' as it is popularly called. Rubber crumb is also the base raw material for the reclaim rubber industry and has found use in the manufacture of specific moulded goods such as floor mats, rubber sheets, hose pipes and battery containers.

It is estimated that within the automotive industry 3-5% rubber crumb and up to 10% reclaim rubber is used in the manufacture of automobile tyres (Ram, Adhikari and Sugumar 2015). The increasing volume of the automotive and tyre industry has meant that the quantum of use of reclaimed rubber is also simultaneously increasing. The bicycle industry is the other major industry which uses reclaimed rubber in the manufacture of tyres and tubes. It has been estimated that in India, about 6,00,000 to 7,00,000 bicycle tyres are produced every day. Ralson[3] is a major company in this market and is estimated to produce about 1,00,000 bicycles and 1,50,000 tubes each day (Ram, Adhikari and Sugumar 2015).

Radial tyres are designed such that the cord plies are arranged at 90 degrees to the direction of travel, or radially (from the centre of the tyre). Given its design, the side wall of radial tyres is specifically more valuable and while recycling, care is taken to extract the iron strips from within it. Fabricators use a special pulley-based contraption to completely extract the iron strips, which are then sold in the local markets. As compared to all the other products extracted from the discarded tyre, the greatest monetary return for the fabricator is from the sale of the iron strips.

Making of downstream value-added products is rapidly evolving into an organised industry where India has a clear competitive advantage. It has the most environment friendly disposal/use of ELTs and holds immense potential for growth. Currently, the best alternative reuse of rubber crumb is as an additive to bitumen for road surfacing. There is extensive data available which confirms that road made with Crumb Rubber Modified Bitumen (CRMB) is superior in properties as compared to regular bitumen.

2.4 Decomposition: Thermo-Chemical and Combustion

Pyrolysis: Thermo-Chemical Decomposition

"Pyrolysis is the chemical decomposition of organic material at elevated temperature in the absence of oxygen or any other reagents, except possibly steam at about 4300 C in the horizontal batch process system" (Rani and Agnihotri 2014).

3 For more please refer to https://www.ralson.com.

Rubber when it undergoes pyrolysis softens and the rubber polymers break down into smaller molecules. Pyrolysis is used to reprocess tyres into fuel gas, oils, solid residue (char) and low-grade carbon black, which cannot be used in tyre manufacture.

The smaller molecules of rubber polymers created by pyrolysis eventually vaporise and exit the reactor. These vapours can be burned directly to produce power or can be condensed into an oily type liquid, generally used as a fuel. Some molecules are too small to condense. They remain as a gas which can also be burnt as fuel. 40% of minerals (by weight) that are part of the tyre are removed as solid ashes. However, typically, in cases of incomplete combustion, air pollution poses a rather immediate and pertinent concern.

About 40-45% of the recycled material which is obtained in the pyrolysis process is pyrolysis oil. The purest quality of pyrolysis oil, with a flash point between 66 degrees Celsius, is seen as equal to industrial diesel. The selling price of this quality of oil is equivalent to that of the industrial light diesel oil (Rani and Agnihotri 2014). In the pyrolysis process, 30-35% of the total quantity is carbon black or charcoal. The carbon black/charcoal produced through this process is specifically used for industrial and commercial use. Metal wires which are found in tyres can also be separated from the carbon black by using magnets and this metal can be resold in the market. With regards to the hydrocarbon gases released during the process, Rani and Agnihotri (2014, 167) theorize that it is the slighter molecules which ultimately vaporize and that if they are channelized properly they can burn directly to create power or can also be condensed into an oily type liquid, which does not condense at room temperature and pressure. However, this is a theoretical argument which still needs further experimentation and was not observed by Chintan to be practiced anywhere in the semi-formal sector.

Tyres as Fuel (TDF)

India is the second-largest brick producer in the world, with a yearly production of 200 billion bricks, comprising 13% of the global production (D'Monte 2016). Fuel expenses make up about half of the total cost of making a brick. Punjab State Council for Science and Technology estimates that 1,25,000 kilns in the country consumes 35-40 million tons of coal per annum. ELTs serve as a cheap fuel supplement for coal or gas kilns which are also used to produce Portland cement, lime and steel. Visits to brick kilns in Uttar Pradesh by Chintan suggest that the use of tyres here causes intense air pollution. Yet, tyre use persists as it is a cost-effective and easily accessible fuel.

At the local level, scrapped rubber and ELTs are easy to access and a cheap source of warmth in the winter months (Ram, Adhikari and Sugumar 2015). Chintan observed that small shredded pieces of leftover tyre parts were manually cut down into pieces which were smaller and specific-sized. These pieces were then used by local farmers to produce sugarcane – jaggery. The shredding of the leftover rubber into small pieces was done with the help of a machine known as *'Kohlu'* and *'Kalesar'* (as seen in Photo 4). This enterprise is seasonal in nature and the demand for it is only during the winter months. There is no official estimate of the percentage of ELTs that are consumed as TDF.

Apart from ELTs, the shredded pieces of leftover tyres and small pieces of scrap rubber are also used as fuel. This practice of the use of ELTs as a source of energy is not just confined to India but is a common practice worldwide. Australia acknowledges the relevance of TDFs as a valid source of energy and is working on methods to reduce the pollution caused by the process of combustion.

To conclude, though the burning of rubber for fuel purposes is seen as the reuse of raw material, it is not an optimum means of reusing rubber for two main reasons:

1. **Burning of ELTs causes major air pollution:** The process of burning rubber results in the emission of carcinogenic pollutants such as such as polycyclic aromatic hydrocarbon, dioxin, furans and oxides of nitrogen which are extremely hazardous to the environment and to health.
2. **Low Resource utilization and efficiency:** On comparing energy consumed to prepare rubber to the energy acquired from burning rubber, it is observed that 32 kWh/kg is the energy consumed to manufacture a tyre while only 9 kWh/kg thermal energy is released during the incineration of scrap tyres (Ram, Adhikari and Sugumar 2015).

Photo 4: Kohlu or Kalesar being operated to manually shred waste rubber for burning

3. The Problem with Tyres

3.1 Environmental Pollution

While discussing tyres, it is also important to understand the problems and consequences of tyres being thrown away and ending up in landfills or being stockpiled. The large volume and non-biodegradable nature of tyres means that dumped tyres tend to quickly occupy a lot of space. Overall about 60% of waste tyres end up being dumped and/or incinerated, causing land pollution in both urban and rural areas (Gupta, Chopra and Kumar 2013). Tyres also trap methane gas which then causes them to become buoyant and/or bubble to the surface. The 'bubbling' effect has the potential to damage the landfill liners that are installed to help keep landfill contaminants in check, thus, leading to a higher probability of polluting not just the ground surface but also the groundwater.

Although modern tyres are fundamentally rubber products, they are a complex mix of natural and synthetic rubbers, and various structural reinforcing elements including metals, nylon and other chemical additives. This complexity means that stockpiling, dumping and diverting used tyres to landfills also exposes local communities to additional environmental and health-related risks. For example, water stagnation is relatively common in stockpiled tyres and these prove to be extremely good breeding grounds for mosquitoes and rodents. Often epidemics related to mosquitoes and rodents such as malaria, dengue, yellow fever are found in areas where there are stockpiled tyres.

Stockpiling, over time, has also been known to cause the leaching of toxic substances into the soil. Long term studies on the leaching of chemicals show that tyres become hazardous when they come in contact with certain materials and react over time, which causes leaching of toxins into the surrounding soil and water bodies. The Basel Convention (2013), clause 33 stresses on the difficulty in gauging the eco-toxicity of used and waste tyres. Conclusions regarding the toxicity and risks to human health from diverse studies vary significantly.

An experimental study focussing on identifying toxic components that leach, when tyre rubber is in prolonged contact with water, observed that the choice of chemical additives in tyre rubber was found to greatly affect the toxicity of the leachate. Moreover, “some literature on the potential of chemicals to leach from used tyres concluded that the impact of used tyres on the subsoil of roads or surface water under neutral environmental conditions was negligible with regard to groundwater and surface water quality and the aquatic environment” (Basel Convention 2013). Box 5 provides further information on some studies related to eco-toxicity of tyres.

Box 5: Eco-Toxicity of Tyres: Some Studies

- In 2003, tests conducted by Birkholz in California using rubber fragments taken from a tyre-disposal site showed toxicity for bacteria, invertebrates, fish and green algae. After three months, new samples were tested, showing a 59 per cent reduction in the toxicity levels detected in previous tests.
- Long-term investigations indicate that some types of tyres such as those with high aromatic oil content, may, under specific conditions, leach significant amounts of polycyclic aromatic hydrocarbons into the aquatic environment, thereby influencing the population dynamics of wood frogs, for example.
- Other studies show that leaching of heavy metals and organic chemicals such as phthalates and polycyclic aromatic hydrocarbons from recycled car tyres for use as infill in artificial turf systems is well within the limits set in the Netherlands for soil and surface water quality. Leaching of zinc is an exception. Dissolved organic carbon and organic nitrogen appear to decrease very rapidly at the outset and are then minimized in a time-dependent, substance-specific manner. During testing, very low polycyclic aromatic hydrocarbon concentrations of the granules were found at an identical level in the blank sample (a gravel layer without a surface); these correspond to ambient (ubiquitous) contamination levels.
- The assessment of the long-term impact of the leaching of zinc from artificial turf, three INTRON studies conducted in 2008 and 2009 provide useful information. Based on the new observations, INTRON concludes that, after 7 years of use, zinc does not penetrate the underlays. This is consistent with the laboratory tests performed in the 2009 zinc adsorption study where calculations were updated based on the actual adsorption capacity of the sand layer instead of a theoretical one used in the previous study. After 7 years, there is also no evidence that the use of rubber infill poses a risk in terms of the leaching of zinc and the results indicate that during the technical lifetime (fifteen years) of the synthetic turf field, with environmentally sound management, there is limited risk to the environment due to the leaching of zinc.

(Excerpts from Basel Convention: Technical Guidelines, UNEP 2013, 13-15)

Tyres do not spontaneously combust yet they are prone to heat retention and because of their open structure, stockpiled tyres increase the risk of fires. Important to note, though, is the fact that once ignited, these fires are extremely difficult to control and put out.

Additionally, the residue left in the soil after a fire increases the probability of causing two kinds of pollution. Firstly, a pollution which is a result of liquid decomposition products penetrating the soil, and secondly, a gradual pollution because of leaching of ash and other unburned residues. Both types of pollution, i.e., the immediate and gradual is mainly caused by rainfall and water penetration at the site (Basel Convention 2013).

In India, there are no recorded instances of fires specifically caused by stockpiled tyres, but in various parts of the country, there have been much-reported fires in landfills. The stockpiled tyres and scrap rubber present in the garbage dump/landfills add to the toxicity of the fumes.

Photo 5: A towering cloud of smoke rising from the Rhinehart tyre fire, Virginia 1983

Credit: Scott Mason/Winchester Star/AP

Historically, the largest fire began in Wales in 1989, at Heyope. It was caused by 10 million stockpiled tyres and took nearly 15 years to extinguish (Rowe 2002). There have also been instances in the recent past, such as in May 2016 when 9,000 people living near a "toxic cloud" from a burning tyre dump near Madrid, Spain were told to leave their homes (BBC 2016). An environmental disaster at a Virginia tyre pile 30 years ago helped advance fire-monitoring methods and spark a recycling revolution (Ritter 2013). India must ensure it can create wealth from waste tyres to prevent such an environmental crisis from ever happening.

4. What is the World Doing?

Given the increasing world pressure on raw materials, there is a realisation of the need to look at ELTs as potential sources of raw material and thereby the need to increase the recycling of ELTs. This understanding is most pronounced in the more resource-deficit developed countries which not only have to import raw materials such as minerals but also rubber. As a first step, the commitment to recycling of tyres has meant regulating the disposal of used ELTs in landfills. The nature of regulation varies from explicit banning as in the case of the European Union to partial bans across several countries and regions like the USA and Australia. Box 6 provides an insight into some of these regulations.

Box 6: International Commitment to Sustainable Management of Natural Resources

By recycling and reusing rubber in the most efficient manner possible, we will be a step closer to achieving the Sustainable Development Goals (SDGs) related to material reuse, sustainable development and resource efficiency. These indicators are:

SDG 8.4: Endeavour to decouple economic growth from environmental degradation in accordance with the 10-year framework of programs on sustainable consumption and production with developed countries taking the lead.

SDG 12.2: By 2030, achieve sustainable management and efficient use of natural resources.

SDG 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse.

Source : http://indicators.report/targets/

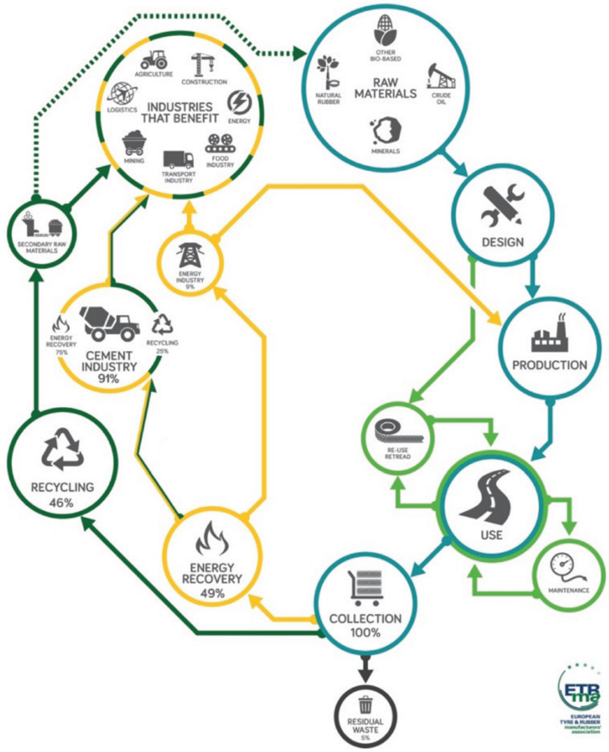
Can We Create a Circular Economy of Tyres?

Automobile ownership worldwide has been increasing at a higher rate than the global population. In 2010, it reached more than 1 billion units (Sousanis 2011). Obsolete vehicles or ELVs have become a global concern as automobiles have become popular worldwide. Tyres, as noted before, are only one component of ELVs, but as demonstrated in Section 2, tyres sustained a complete economy around them.

The increase in material consumption and global increase in raw material prices (steel, copper, aluminium etc.) has meant that instead of treating ELVs and ELTs as waste, they are now seen as and treated as a valuable resource for a variety of raw materials. Therefore, the key task at hand is resource recovery of the maximum possible secondary raw materials through efficient recycling measures (Sakai, et al. 2014). Tyres also serve as a wonderful example of extreme resource use especially given the post-consumption economy of tyres.

It is of strategic importance that in the economy of tyres, this resource loop is closed, i.e., the post- consumption economy is fully utilized (Figure 5). To achieve this, there is a need for the amalgamation of both the practices and systems of ELT management which also require being driven by both the sides, i.e., the government as well as the industry.

Figure 5: Circular Economy of Tires



Source: End of Life Tyres Report, ETRMA 2015

Many developed countries such as the European Union (EU) have realized this need and now have an organized, systematic and modern recycling and recovery industry. The ELT management industries and policies in these economies are separate from those of ELV management and policies. As opposed to this, developing economies do have some policies for management and disposal but they do not have waste recycle and recovery models that are as systematic and automated, especially regarding ELV and ELT management policies and systems. But at the same time, these developing economies also tend to play a major role in the recycling and reuse of rubber by tapping into the international trade related to recycling and recovery from waste. Section 4.2 maps how ELTs, instead of being stockpiled or burnt, are effectively managed as resources and recycled across the globe.

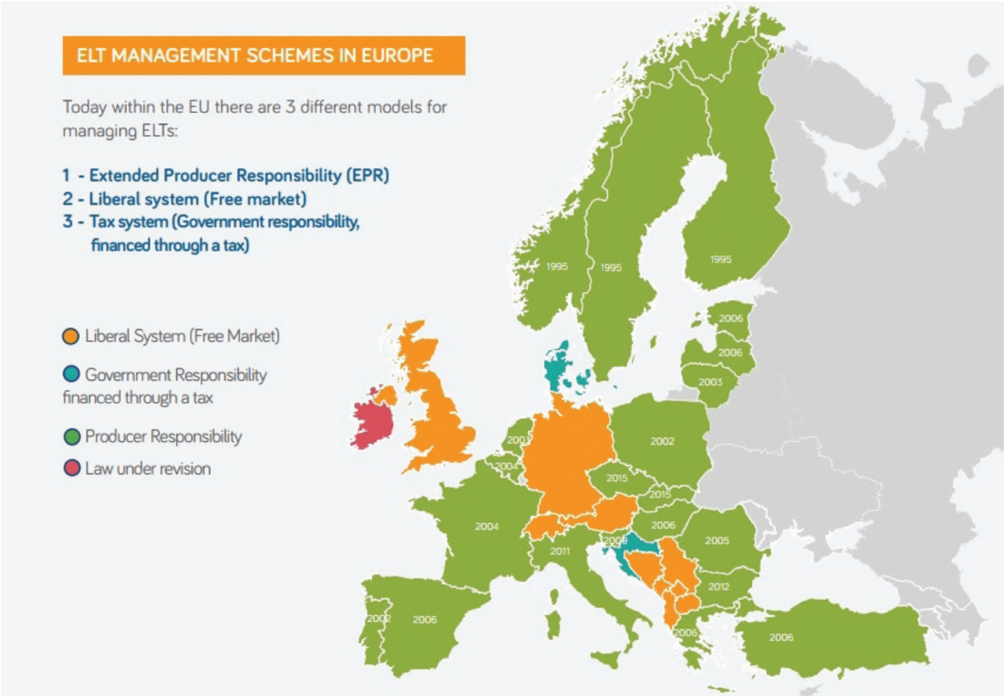
4.1 EU Policy on ELT Recycling

The European Union has been a pioneer in the management of ELT and currently has the highest rate of recycling of ELTs. This has not always been the case. Rather, the rate here of tyre recycling in 1994 was a mere 25%, while in 2013 it has increased manifold to 96% (ETRMA 2015). This has been made possible by the conscious alignment of government policies to their ELT management schemes. Across the EU there are 3 main models of managing ELTs:

- extended producer responsibility,
- free market model
- and the government responsibility (tax system)

Drawing from ETRMA's report on the ELTs, Figure 6 maps the ELT management models across the different governments. ETRMA is the association of tyre and rubber manufacturing industries in the European Union.

Figure 6: ELT Management Schemes in Europe



Source: End of Life Tyres Report, ETRMA 2015

Extended Producer Responsibility

Extended Producer Responsibility means the producer's full or partial operational and/or financial responsibility for a product extends to the post-consumer state of a product's life cycle. This, in effect, means, that under this system, the original manufacturer of the tyre must take the responsibility to ensure that ultimately the tyre manufactured by them has been disposed of responsibly (ETRMA 2015). This model effectively moves the onus of responsibility for the generated waste from the consumer to the producer.

There are multiple ways for the management of ELT under this model. A single ELT management company could deal with the ELT collection and treatment throughout the country. This is the preferred model in countries such as Portugal, Netherlands and Sweden. Other countries like Italy, France and Spain prefer multiple ELT management companies managing the processes. On the other end of the spectrum, countries such as Hungary take the view that it is an individual producer's responsibility to ensure appropriate waste tyre disposal (ETRMA 2015, 8). Systematic and obligatory reporting to the national government agencies has aided in setting the standards of reliability and traceability.

The EU's experience with extended producer responsibility has demonstrated that given a conducive political environment, tyre manufacturers seem to prefer this system. As of today, Extended Producers' Responsibility is the widest spread system in Europe where in total 21 countries (most of EU's 28 countries, Norway and Turkey) have adopted this legal framework which assigns the responsibility to the producers (tyre manufacturers and importers) to organise the management chain of ELTs (ETRMA 2015, 9).

Free Market

The free market follows a liberal system, i.e., there is no specific group/industry/person who is identified as being responsible for ELT management. Rather, under this system, the legislation sets the objectives to be met and all the operators in the recovery chain contract under free market conditions and act in compliance with the legislation. Austria, Switzerland and Germany are countries in the EU who along with the UK choose to operate in the free market system. In some cases, the liberal system may also be backed up by voluntary cooperation between companies to promote best practices.

Government Responsibility

This model is essentially financed through taxes levied on tyre producers, which is subsequently passed on to the consumer while the initiative is spearheaded by the government. Thus, each country then becomes responsible for the management of ELTs. Denmark and Croatia are the member states of EU who have chosen to manage their ELTs through this tax system.

Box 7: Regulation on Disposing of Tyres in Landfills: Some Perspectives

Partial Ban

Type 1: California, Florida and Oregon State (USA)

In USA, policy on waste is defined by the state; hence their position on the disposal of tyres in landfills varies across states. In some states of the USA such as in California under the California Code of Regulations (CCR), Title 14, the policy establishes that waste tyres may not be landfilled in a solid waste disposal facility, unless they are permanently reduced in volume prior to disposal. The law in the states of Florida and Oregon requires that tyres be reduced in volume by methods of slicing or shredding before being disposed in landfills.

Type 2: Western Australia

In Australia, the Environmental Protection Regulations 1987 allows for the disposal of tyres by incineration, or other disposal options. In Western Australia, by setting the boundaries for a Tyre Landfill Exclusion Zone (under Schedule 5 of the same Act) in specific areas ensures that these landfills are partially restricted for disposal of tyres. In those areas where disposal of tyres is permitted as landfill wastes, there are specific disposal requirements which require adherence, such as disposal normally involving the burial of batches of tyres at a landfill with a minimum cover and separation distance between tyre batches to minimise fire risks. Additional requirements also include either:

- Previous written approval by the Chief Executive Officer of the Department of Environment Regulation when disposal occurs within the Tyre Landfill Exclusion Zone;
- Disposal at a local government district outside the Tyre Landfill Exclusion Zone

Complete Ban: European Union

The European Union: Council Directive 99/31/EC of 26 April 1999 on landfill waste ("Landfill Directive") introduces in landfills a ban on the disposal of shredded and whole waste tyres, excluding tyres used as engineering material. This ban does not apply to bicycle tyres and tyres with an outside diameter above 1.4 m. This directive is applicable to all the member states who are part of the union.

Transboundary Initiative: EU's International Trade of ELTs

The importance to tap into potential secondary raw materials which are contained in waste has been the motivation of the EU since 2006-07 and has guided the recycle and reuse policies. This understanding effectively subscribes to the view that it is not just about recycling for the environment but rather that there is a market for waste. Thus, the policy and system consciously treat waste as a source of revenue and as a potential tradable good.

Currently, EU is the world's largest exporter of non-hazardous waste destined for recovery (recycling), which is substantially higher than both the US and China. 34% of the global exports of EU's waste comprises non-hazardous waste which is exported to be recovered and 20.3% of global imports are of non-hazardous waste destined for recovery (European Commission 2015). India, which follows China (which is at 30.7%), at 11.5% receives the 2nd largest exports of non-hazardous waste for recycling and recovery from the EU.

In certain market systems (liberal and government responsibility), there are opportunities created to trade ELTs, as valuable waste commodities meant for recycle and recovery, with countries like India, Pakistan and Malaysia. In the case of international trade of waste, there are additional laws in REACH or Registration, Evaluation, Authorisation and Restriction of Chemicals standards which are required to be followed to ensure that these exported ELTs meet the EU's waste shipment norms and are also treated to the same environmental standards as in Europe. See Box 8 for Understanding REACH.

Box 8: Understanding REACH

The EU is currently the largest trader of recycled goods while keeping in place high ethical and environmental standards. **REACH or Registration, Evaluation, Authorisation and Restriction of Chemicals** is the ethically informed policy document which came into force since June 2007.

REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. It also promotes alternative methods for the hazard assessment of substances to reduce the number of tests on animals.

REACH is a stipulation by which not only tyres, but recycled products made from tyres, must be toxic free. This enables EU countries to regulate and eventually reduce the toxics in the environment. This is one means by which the EU controls the toxicity of tyres from circulating in the ecosystem.

For more please do refer to https://echa.europa.eu/regulations/reach/understanding-reach

Yet, it is important to note that when the ELT recycling is not managed internally and leaves EU borders, it may not always be fully traceable up to its final destinations. To overcome this issue, trade in rubber and ELTs requires mandatory registration of the entire value-chain, i.e., "the obligation to register the substances lies with the producer or importer of the substance (on their own, in preparation or in articles), who has the obligation to register the substance for own use(s) as well as for the uses he intends to place the substance on the market" (ETRMA REACH Guidelines 2008).

Article 2.1 (Box 9) on exemptions is applicable for goods made from rubber exported by the EU for recycling into different forms such as the most popular rubber mats. The rationale for exemption is that these imported goods are made from exported ELTs which already adhere to REACH standards, hence they are exempted from re-registering by the community (ETRMA REACH Guidelines 2008, 12-13).

Additionally, Article 3 provides details of the required standards and registration processes required by downstream users and importers to the EU. The key export markets for ELTs from EU is India, China and Pakistan which includes with it exports for both recycling as material as well as reuse as TDF (European Commission 2015).

Box 9: Article 2.1: Exemptions from the Duty to Register

- Substances on their own or in preparations, that have been registered, exported from the community by an actor in the supply chain and re-imported into the community by the same or another actor in the same supply chain who shows that:
  1. (i) the substance being re-imported is the same as the exported substance;
  2. (ii) he has been provided with the information in accordance with an SDS or equivalent information when no SDS is required relating to the exported substance.
- Substances, on their own, in preparations or in articles, which have been registered under REACH and which are recovered in the community if:
  - (i) the substance that results from the recovery process is the same as the substance that has been registered.
  - (ii) he has been provided with the information in accordance with an SDS or equivalent information when no SDS is required relating to the exported substance.
- Polymers (limited to Registration and Downstream user requirements)

(Source: ETRMA REACH Guidelines 2008, p 11-13)

Box 10: Sustainability Victoria: Tyres in Australia

Sustainability Victoria is a statutory body established under the Sustainability Victoria Act 2005 and has a board appointed by the Minister for Environment and Climate Change in Australia. This body also has obligations under the Environmental Protection Act 1970 to ensure state-wide waste management and planning. This initiative, though spearheaded by the national government, receives support and patronage from both the state governments as well as the industry.

The aim of this initiative is to grow a market for tyre-derived products and/or fuels and reduce used tyre stocks. The crux of this initiative lies in the understanding that better management of ELTs will ensure that fewer tyres end up in landfills, thereby eliminating environmental and health risks while creating viable market development opportunities. Sustainability Victoria achieves its goal through two main programs:

1. Tyre Stewardship Australia

This is a state government and industry supported initiative formed to implement the Tyre Product Stewardship Scheme by promoting the development of a viable market for ELTs. Tyre Stewardship Australia consists of representatives from across the tyre supply chain including tyre retailers, manufacturers, recyclers and collectors. It supports in the pick-up and centralized recycle and reuse of tyres.

For more please refer to www.tyrestewardship.org.au.

2. National Market Development Strategy for Used Tyres

The Victorian Market Development Strategy for Recovered Resources (Strategy) seeks to address the challenges faced in resource recovery and to realise the full economic value of resource recovery opportunities. The strategy draws from the understanding that resource recovery presents opportunities for a government intervention within a market-based system. The focus of the strategy is additionally to ensure that while meeting the need of resource recovery, they are also protecting the environment, community amenity and public health.

4.2 Recycling Options of ELTs Globally

Apart from the government policies (both, of the EU and its individual member states) which support ELT management, there is systematic innovation and research being undertaken on the possible recycling opportunities available. The recycling of ELTs such that they are completely reused in the automotive and tyre industry would be ideal but this is not always possible. Hence, viable alternatives before uptake are broadly assessed based on the parameters of use and the economies of scale. This section focuses on understanding some of these viable alternatives that are currently available and/or being explored in the EU.

The EU recognizes that increasing the use of the rubberized asphalt/CRMB market is an innovative way to plug rubber from ELTs back into the new tyre manufacture process. The view is that this option addresses both the discussions on optimum resource reuse as well as the economies of scale debate. Thus, this is recognized as being the ideal plug-back into the circular economy of ELTs (ETRMA 2015) (Turer 2012).

Use in Roads

Tyres-as-a-whole or cut tyre parts are sometimes used in roads in multiple ways. For example, they can be used to maintain slope stability or as a land fill option. At other times, they're used under the road to improve stability. At embankments, large chunks of ripped tyre pieces are directly used as lightweight infill material. Without much modification, ELTs are used for drainage around building foundations, erosion control for rainwater run-off barriers, wetland establishment and crash barriers at the sides of race tracks (Turer 2012, 198).

Box 11: Some Facts about the Global Use of Crumb Rubber Modified Bitumen (CRMB)

- Rubberized Bitumen or CRMB has been used in roads in the USA since 1960.
- As of today, there are an approximate 20,000 miles of road made of recycled tyres.
- Currently, the states of Arizona, Florida, Texas and California in the USA use 2 million tonnes of CRMB.
- CRMB-based roads are also popular in China, Brazil, Australia, Spain and Germany.
- In the developing nations of Latin America, use of CRMB roads has been increasing.
- CRMB is very popular in Australia for chip sealing wearing courses and layers.
- The state of California in the USA has enacted a law to use CRMB.
- The Belgian Road Research Centre encouraged the use of CRMB on freeways.
- Due to ever increasing oil and bitumen prices, South African companies are encouraging the use of rubber modified mixes.

Rubberized Asphalt or CRMB is made by breaking down used tyres into rubber crumbs which are then added to bitumen and crushed stone, which is typically used to make asphalt. The material used in the EU takes the form of rubberized asphalt, while in the rest of the world as Crumb Rubber Modified Bitumen (CRMB) and is used to build, repair and replace existing roads and highways as well as construct new ones. Overall, CRMB as rubberized asphalt is popular in Europe while the rest of the world is yet to adapt at scale. Thus, the global market for CRMB has much growth potential.

Table 1: Advantages of CRMB over Bitumen

Disadvantages of Bitumen	Advantages of CRMB
Adverse to Excessive Heat	
Bitumen melts as softening values are lower than the surface temperature of the road. The softening point of plain bitumen is a maximum of 50 degrees Celsius.	Higher softening values as the softening point of CRMB is a minimum of 65 degrees Celsius.
Overloading	
Bitumen-based roads crack under heavy loads due to lower elasticity i.e. maximum elasticity of 10.	CRMB has an elastic recovery which is over a minimum 60%. This helps in improving the road's load carrying capacity by nearly doubling it.
Effect of Water	
Once bitumen encounters water, it loses its property.	By introducing rubber, CRMB ensures that it reduces the effect of water by nearly 25%.
Oxidization	
Higher rates of oxidization as the oils available in bitumen get evaporated.	Given that rubber is a bad conductor of heat, it absorbs the oil and substantially delays the process of oxidization.

CRMB is estimated to be the single largest market for rubber crumb, which currently uses approximately 220 million pounds or roughly 12 million tyres each year (National Science Foundation 2014). In 2013, it was established that recycled car tyres could be used on the surface of roads to make them quieter. One of the busiest roads in Scotland was resurfaced in 2012 with asphalt containing shredded rubber from old tyres. Tests were performed on grip and skid resistance, with engineers reporting that the rubber road, on a stretch of dual carriage way between Perth and Dundee, resulted in a quieter drive. The technique has been found to cut traffic noise by about 25% (Bentley 2013).

Use in Athletic Tracks

Rubber crumbs have been used not just in asphalt and road-way constructions but are also extremely good raw material for building athletic tracks, sports equipments and playing grounds.

Currently, there are experiments and a few projects undertaken in the US and Europe where athletic tracks are manufactured by 100% recycled ELTs. Aliapur and Technisol are the sports surface manufacturers who have pioneered this concept. It has been observed that these tracks satisfy the expectations of athletes by absorbing shock, deformation (flexibility) and slide (grip) (ETRMA 2015). The surface is made by mixing rubber crumbs manufactured from ELTs and combining them with various other polymers and chemicals.

Once validated in the laboratory, using this method, the Gauthier stadium, funded by Michelin, was built by ASM Omnisports in Clermont-Ferrand. This was a 16-mm thick surface and 3,800 square meters total surface area stadium which included a 400-m circuit with 5 lanes, 6 straight sprint lanes, a semi-circle for the high jump area as well as a run-up track for the long jump and triple jump. The track was installed in 2012 and required 40 tonnes of granulate from 9,000 passenger vehicle tyres *(ibid.).*

Use in Rubberized Cement

Similarly, there are experiments being undertaken to incorporate rubber in cement. This rubberized cement has the capacity to reduce its weight while at the same time increase its tensile strength. The incorporation of rubber into concrete by increasing its performance also increases its resistance to cracking and reduces the capacity for deformation (ETRMA 2015). Hence, in roads which are presently using concrete, there is a push to include rubberized cement as it has broadly the advantages which are available to rubberized asphalt, i.e., flexibility, higher tensile strength and better drainage. Given that the concrete market across Europe is huge, with a volume in excess of 39.4 million cubic metres of concrete being produced across the EU, there is much R&D being conducted across Europe on the use of recycled/reclaimed rubber *(ibid.).*

Rubberized concrete of this nature is especially useful in earthquake prone areas and ETRMA (2015) notes that there are currently experiments being undertaken on the use of rubberized concrete as an earthquake prevention tool. Turer (2012, 204) reflecting on this, stressed on the need to undertake further experiments on the influence of the quality of rubber on the concrete. Turer (2012) also notes that the steel cords inside tyre layers have similar effects to the steel layers inside an elastomeric isolator. Similarly, ELTs are useful to create post-tensioned elastic walls and would serve as a useful and cheap raw material for the same purposes.

Clean steel wire is also important to the concrete industry and the demand for tyre wire is now growing for concrete reinforcement. Additionally, with the aim of strengthening structures, there have been various architectural experiments in the use of scrap tyres as confinement and peripheral materials for concrete cement (Turer 2012).

Use of Recovered Textile

Across Europe, ETRMA (2015) reports an increasing acceptance of recovered textile from tyres as a new insulation product by the national building standards agencies. Textile fibres recovered during pyrolysis can also serve as a source of energy. There is a need for further research on the reuse of this material. In Europe, there is currently ongoing research into the use of textiles from tyres as reinforcement in concrete.

Use in Rail Transport

Much of the material derived from ELTs can be used in the rail and tramway sector. Throughout the world, there are many projects which tap into the reuse of tyres to the advantage of the rail and tramway sector (ETRMA 2015) (Turer 2012). Recycled rubber is also useful in reducing noise as well as the impact made by the rail tyres on the rails into which they are bedded.

Use of Rubber to Reduce Noise Pollution

Initially, the use of rubber reduced noise pollution by -5dB, but since 2000, there has been much innovation in this area and currently the reduction of noise pollution has increased by four times to -20dB (ETRMA 2015).

Tapping into the natural quality of rubber to reduce noise pollution has meant that since 1978, the Swiss National Rail has chosen to include recycled rubber base into its design. And since 1998, in Europe, STIB, the Société des Transports Intercommunaux de Bruxelles, has lined 97% recycled rubber filler blocks on both sides of the tramway. Over time, it has been systematically used in various parts of Europe and has been observed to reduce the noise pollution caused by the tramway (ETRMA 2015).

Overall, recycled rubber is viewed as a useful and viable long-term option to reduce noise pollution from including it in urban spaces such as in the roads, to creating screens and protectors among others, particularly in high traffic areas.

Innovation from Other Parts of the World

Across the world, there is much innovation and R&D currently underway on trying to find innovative ways of reusing rubber. One such innovation is the 'Polymer Injection Technology', which converts old rubber tyres into metal alloys or 'green steel'. This could be a major breakthrough globally in helping to deal with the growing problem of disposal of waste tyres. This technology taps into the chemical composition of rubber which is inherently a good source of hydrocarbons while aiming to substitute the use of coke in the conventional electric arc furnace (Sahajwalla 2016).

Box 12: Clarion Call to Move to a Circular Economy

In 2011, globally:

- 7% of the total waste tyres were recycled on site
- 11% were burned for fuel
- 5% were exported for processing elsewhere.
- 77% were sent to landfills, stockpiled, or illegally dumped, i.e., approximately 765 million tyres a year are wasted

Can the planet afford to waste such precious resources? Why don't we look for alternatives?

Source: Interview with Prof V Sahajwalla, The Hindu (Sahajwalla 2016)

5. Indian Policy on ELT Recycling

The Ministry of Environment, Government of India's rules on the recycle of ELTs keeps with the international Basel Convention-UNEP guidelines. Hence, the mandate is on the reuse of those tyres which have not been completely worn out and can serve their original purpose. The focus thereafter is on material reuse of rubber by either retreading tyres or using rubber crumb in various applications and lastly through recycling and reuse of reclaimed rubber. The Ministry of Environment, Forests and Climate Change also recognizes that shredded rubber can be used for energy recovery purposes as a TDF.

The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, April 2016 recognizes waste tyres and ELTs in the country as 'Hazardous Waste' (MoEFCC 2016). The Act stresses on recycling and/or on resource recovery of ELTs, rather than disposing of ELTs by dumping them in landfills or burning them. The new rule puts down a ban on the import of waste tyres for direct reuse purposes though it allows for the import of waste tyres specifically for pyrolysis and recycling. In this regard, the Ministry of Environment clarifies that the import of waste pneumatic tyres is permitted for three main applications – for crumb rubber and downstream products, utilization/co-processing in cement kilns, and for extracting of Tyre Pyrolysis Oil (TPO).

The government memo dated 24th November 2015 specifically deals with the recycle and reuse of ELTs and the generation of TPO from ELTs. Since November 2015, a special import license is required to import ELTs for Tyre Pyrolysis Oil (TPO) purposes. The Ministry of Environment has subsequently issued additional protocols for ensuring safety and avoiding fire hazards during pyrolysis. A detailed discussion on these additional safety protocols is included later in this section. Regarding the environmental standards, each processing unit would also have to take consent from the Central Pollution Control Board (CPCB) or its concerned state unit. Similar requirements are also imposed on those crumb rubber manufacturing units that wish to import ELTs for this purpose.

5.1 Draft Guidelines of the Waste Tyres Management Rules 2017

The Government of India is in the process of preparing a new set of guidelines to manage waste tyres wherein the large part of the onus of responsibility is on the tyre companies as well as dealers, i.e., extended producer's responsibility. The new guideline draws largely from the EU's circular economy approach towards dealing with the issue of ELTs. To understand the extended producer responsibility in the draft plan, it's important to grasp the concepts of the Integrated Waste Tyre Management Plan (included within it is the authorized waste tyres collection and storage centres) and the course of action involved in cases of breach of responsibility.

The draft guidelines in the Waste Tyres Management Rules 2017 state that tyre companies would be expected to prepare and execute an 'Integrated Waste Tyre Management Plan' which would include within it the "operational mechanisms for collection and disposal of waste tyres equivalent to its annual production and/or import quantity". In other words, an individual extended producer responsibility approach is taken wherein the tyre makers will need to follow through with their own waste management plan and comply with it within a given time.

Tyre dealers will have to accept waste tyres in lieu of new ones bought by customers and will be responsible for disposing them off. The draft emphasizes that the customers, while purchasing new tyres, would have the option to leave the waste tyres with the tyre retailer/dealer from whom the new tyres are purchased. The tyre retailer/dealer thereof, may "choose to provide an adjustment value to the consumer as it may deem fit on the value of the new tyres purchased for the equal number of waste tyres collected". This valuing of the old tyres will depend on their condition.

However, the tyre retailer can only accept as many waste tyres as new ones bought by the customer and will only be responsible for sending the waste tyres collected from the customers to the 'Authorized Waste Tyres Collection and Storage Centres'. According to the Act, at any time a dealer/retailer shall not stock more than "250 numbers or 5 tonnes of waste tyres, whichever is more". Under this rule, the customer can also give the waste tyres directly to the 'Authorized Waste Tyres Collection and Storage Centres', but they would not be paid anything for these ELTs.

Thus, tyre manufacturers would need to provide an assessment of the quantities and types of tyres that are produced or imported and would eventually become waste tyres. They are also required to indicate how the waste tyres will be managed. This plan will also provide options for the recycle and reuse of the waste tyres and/or recovery of the energy from the waste tyres as well as identify the mechanism to ensure that this will be achieved.

Included within it is not just a detailed design plan but also the cost-benefit model and the details of the circular economy of collection, management, reuse, recycle and the processes of plugging back of the loop. There will also be a detailed demarcation of responsibilities and obligations of the various actors in this economy.

Additionally, the new policy also emphasises the need to indicate the measures which will be put in place by the producer to address the stockpiles of waste tyres and indicate the percentage of the stockpile that the producer will be taking responsibility for.

Breach of Responsibility

Under the new rules, non-compliance will attract fines of up to INR 1 lakh. If the contravention continues, then a fine of up to INR 5000/day for as long as the contravention continues can be levied. If the contravention continues beyond a year, the offender can face simple imprisonment up to a year.

Industry Response to the Act

Given its emphasis on extended producer's responsibility, this draft has not found much favour with tyre manufacturers. This is specifically so, since the tyre producer will "not be allowed to produce, import, distribute and/or sell new tyres, unless it complies with the relevant provisions of these rules".

Additionally, the new policy also emphasises the need to indicate the measures which will be put in place by the producer to address the stockpiles of waste tyres and indicate the percentage of the stockpile that the producer will be taking responsibility for.

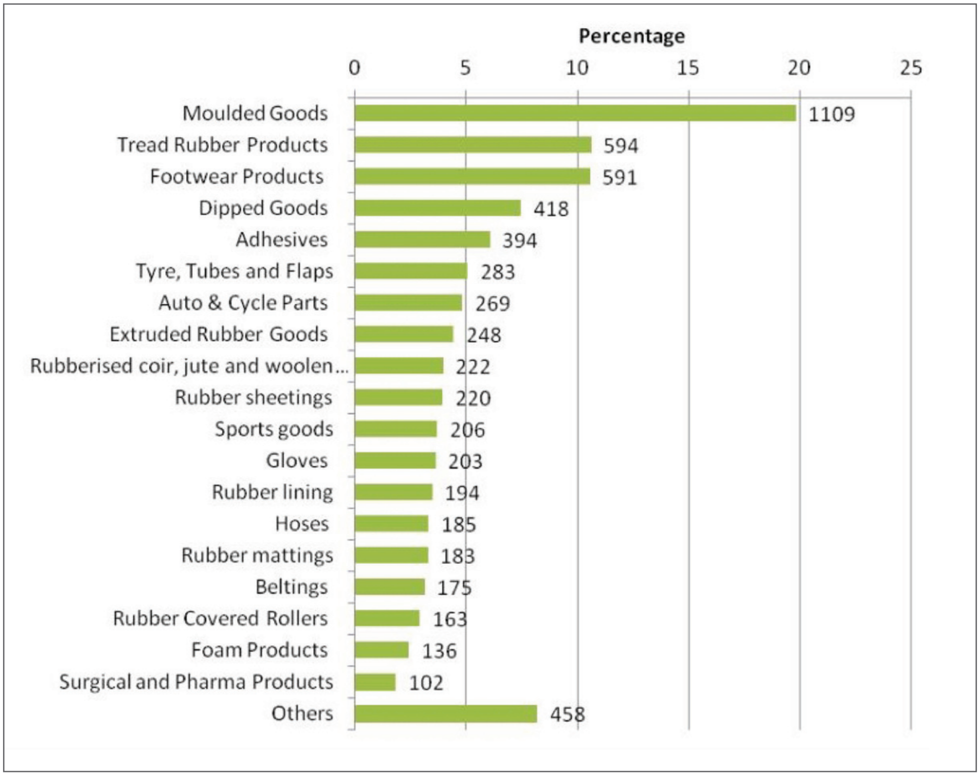
5.2 Recycling Options for ELTs in India

The Rubber Skill Development Council of India estimates that the Indian rubber industry has a current turnover of INR 32,000 crores (2014-15) while providing employment to more than 3.70 lakh persons. From the overall demand for rubber, it is estimated that two-thirds of this demand is from the tyre industry and only the remaining one-third is from the non-tyre industry. The Rubber Council of India notes that the non-tyre industry is currently largely focused on the crumb rubber related manufacturing industries. Thereby, the focus has been on the manufacture of moulded goods, tread rubber products, footwear, dipped goods and adhesives. For more please refer to Figure 7.

Production of Crumb Rubber and Reclaimed Rubber

As discussed in the various sections of the report, by being available for versatile use within the rubber economy, reclaimed rubber plays a significant role in the plugging back of the loop. Moreover, given the property of reclaimed rubber, in certain situations, it is more useful than natural rubber and with the aim of improving productivity; reclaimed rubber is often mixed with natural rubber. The biggest advantage of reclaimed rubber comes from the fact that it has a low consumption of power during breakdown and mixing. During manufacture, reclaimed rubber has already been thoroughly plasticised, so when compared to virgin rubber, it breaks down and mixes more quickly. Due to the cross-linked structure of reclaimed rubber, its compounds are less thermoplastic than virgin rubber compounds and therefore when extruded and cured in open stream, they tend to hold their shape better (Rubber Board 2002).

Figure 7: Non-Auto Tyre Rubber Sector (India)



Source: State of Indian Non-Tyre Manufacturing Industry (RSDC 2016)

Though reclaimed rubber is one of the major commercial uses derived from ELTs, it has been adversely affected by the global slowdown. "Getting waste tyres for making reclaimed rubber has not been a problem for us. But now, the market is going through a tough phase. This is primarily because of the drop in prices of natural rubber, which has reduced the incentive for rubber users like tyre and conveyer belt manufacturers to use reclaim rubber. Both local and export markets are down. If the situation continues, it will be difficult to run the business," says one of the biggest reclaimed rubber makers in India (Matade 2016).

Globally, between 2001 and 2014, reclaimed rubber as a percentage of total rubber consumed jumped from 2.1% to 5.4%. China and India exceeded the world's average last year with estimated reclaim shares of 11.3% and 8.2% respectively (Matade 2016).

The Rubber Board of India estimates that the production and consumption of reclaimed tyres have marginally decreased from an approximate 1,29,000 metric tonnes in 2014-15 to 1,19,000 metric tonnes in 2015-16. The overall demand and consumption for reclaimed rubber from auto tyre manufacturers is reported to have only marginally decreased from 51,398 metric tonnes in 2014-15 to 48,613 in 2015-16 (Rubber Board 2016). There is currently only a difference of approximately 10,000 metric tonnes between the production and consumption of reclaimed rubber. Given the magnitude of the industry, it is believed that there is much scope to further expand and exploit this sector.

The Indian government strategy on recycling and reuse of rubber places a critical emphasis on the production of crumb and reclaimed rubber. In the production process, the central concern of the Ministry of Environment is the need to move from the current partial mechanization process to a more fully automated process. The safety protocols put forth in the official memo on ELTs dated 24th November 2015 focuses on not just reducing but preventing environmental pollution and to ensure the safety of workers. In cases where any machine processes (such as the de-beading machine, strip cutter and chip making machines) require manual intervention, there is now a requirement to place additional safety guards to ensure the worker's safety.

Similarly, to prevent air pollution, there is a need to have an adequate arrangement in place to extract fibres and fine particles (either through suction and bag filters) in the grinder/ pulveriser machines. Lastly, there is more stress on the need to have a proper ventilation system along with appropriate fire and environmental safety mechanisms in the manufacturing and vulcanization processes.

Box 13: Innovative Uses of ELTs: Some Examples

Chinnalapatti in Tamil Nadu's Dindigul district has made substantial efforts at recycling through segregation of waste. The town today is known and is visited for the recycled tyre figures inspired by animals. The peacocks, gorillas and eagles created with waste tyres and crafted by local craftsmen along with the local administrative support is a source of inspiration for other communities and is one of many creative ways of partnering to recycle waste.

Similarly, in the Burma camp area of Dimapur, Nagaland, a section of the community is making efforts to get the best out of tyres by locally reusing and recycling them. The community is turning them into various utility items like buckets, flower pots and cauldrons. This has resulted in not just creating local employment opportunities but also a healthier life as well as a cleaner and greener environment.

– Source: ANI News YouTube (2017)

Box 14: Understanding India's Mat Export to the EU

India's exports of floor coverings and mats, between 2010-2015, experienced a 103% growth, i.e., an average of 25.7% annual growth rate. In 2014-15, the export within this segment was pegged at INR 389 crores or USD63 million. India's exports to the US were the highest at 27%. This was followed by the UK at 16% and the Netherlands, Russia and Ireland at 6% each.

The innovative aspect of India's export to the EU countries has been that the raw material for the floor covering and rubber mats exported came from the ELTs which were imported from the EU. Over the years, many enterprises by getting ISO and REACH certified have tapped into the potential of the EU market of recycle and recovery of rubber from ELTs.

Fishfa Rubbers Ltd is a well-established firm in the field of depolymer and butyl rubber reclamation and is also a major exporter to the EU and US. Fishfa Rubbers Ltd, like most other large reclaim rubber industries, has taken a long time – 45 years – to grow to its present capacity. It is because of tapping into the recycling potential of reclaimed rubber and gathering necessary certifications (included here are the various ISOs, REACH and other quality assurance certifications) that the firm has grown. Currently, Fishfa Rubbers Ltd is an established and listed Public Limited company. Presently, more than 90% of their production is exported across 22 countries including The US, UK and Europe.

In order to provide the impetus for other smaller enterprises to grow to this level, there is a need to not only conditionally ease import restrictions but also to tap into the varied related government schemes. In the current environment, there is a need to keep a check on the duties applied to the import and export of rubber products, especially to the import of raw materials and export of finished products. This will help ensure that the product is financially viable for export. There is also a need for enterprises to be able to link with the relevant government schemes, such as the programs and schemes under the Rubber Skill Development Corporation, Make in India, Skill India and Mudra Yojana.

Thus, as the rubber mat experience demonstrates, it is only when there are raw materials available at a globally competitive price along with the requisite skill and infrastructural development can the competitiveness of the domestic rubber industry increase.

Tyre Pyrolysis Oil (TPO)

The single highest volume and quickest way of reusing rubber is through using ELTs as an energy source, more so since the market for recycled rubber material has slowed down (ETRMA 2015). Thus, while discussing the pyrolysis process for deriving Tyre Pyrolysis Oil (TPO), it is imperative that the controversies around it are also included in the discussion.

In 2011, the Gujarat Pollution Control Board (GPCB) shut 45 oil-producing pyrolysis units on the pretext of harm being caused to the environment (i.e. air pollution). According to reports, the units were found to be using substandard technology which was imported from China (TOI 2011). GPCB additionally found that the units were emitting higher than the permissible amount of carbon particles and methane emission. The latter was also identified as the source of the foul odour. Substandard plants tend to emit chemicals such as toluene, ethylbenzene and xylenes to differing degrees. These are harmful to the nervous and respiratory systems. They also, to differing degrees, tend to emit carcinogenic chemicals such as benzene, dioxins, furans, 1,3-Butadiene and polycyclic aromatic hydrocarbons. Due to environmental concerns, the process of developing TDFs through imported ELTs today requires special permissions, licences and permits from the Ministry of Environment, Forests and Climate Change.

The Standard Operating Procedures (SOP) by the Ministry of Environment, Forest and Climate Change, Government of India in dealing with the recovery of TPO from ELTs through the block process prescribes the need for the entire process to be automated with strict measures in place to ensure that all steel is separated before undertaking the process. There is a further requirement to ascertain that only liquid or gas fuel is used for the initial heating. Subsequently, pyro gas generated in the plant should ideally be used for this heating purpose. To ensure the proper diffusion of gases and to prevent environmental and health hazards, the ideal height of the production unit's chimney must be over 30 metres. Oil from condensers should be collected in closed vessels and their storage should also be in closed tanks that have vents. The protocol specifically mentions that at no stage of the manufacturing process should there be any manual handling. For the entire process, there is also a need to design and implement a complete waste disposal and treatment plan. The continuous process additionally requires an air-lock feeding mechanism as well as an appropriate system for suction of the collected fugitive fibre.

From Waste to Wealth: Crumb Rubber Modified Bitumen (CRMB)

The technology of Crumb Rubber Modified Bitumen (CRMB) was introduced in India in the year 1996. While it was only in 1999, with the Indian Road Congress accepting the research of the Road Research Institutes, that CRMB came to be accepted as a viable option in the country. The Indian Road Congress then issued a tentative guideline for the use of modified bitumen in road construction. In 2001, the Crumb Rubber Modifier and CRMB were finally introduced and started being used across the country.

After much research, the road research institutes also concluded that the roads made with rubberized bitumen or CRMB had a much superior performance as compared to just bitumen-based roads. Moreover, CRMB was observed to nearly double the life expectancy of the road. Although bitumen is the only binder for flexible roads, it has some inherent weaknesses and rubberized bitumen helps in overcoming these weaknesses (See Table 1 given earlier on Advantages of CRMB as compared to Bitumen).

Box 15: Some Facts about the use of CRMB in Indian Roadways

Over 1,25,000 km of road has been laid so far using CRMB. Based on MORTH directives, approximately 30 km of road is to be constructed every day, wherein approximately 750 MT of bitumen is to be used for wearing course.

If waste tyre crumb is to be used with bitumen for wearing this course, approximately 2,500 tyres' waste can be consumed in roads every day (which is calculated at an average weight of a tyre of 50 Kg with 75% rubber or 37 Kg).

Approximately, 6-8 lac MT of bitumen is being imported annually in India. By adding crumb rubber to bitumen, we can reduce the import of bitumen by 12-14% of import quantity thus saving our country's valuable foreign exchange. Moreover, it will also help in utilizing waste tyres in an environmentally friendly manner.

In the year 2002, the Ministry of Road Transport and Highways, Government of India, based on the recommendations of the road research institutes, and due to its significant advantages (in terms of improved pavement performance, riding quality, durability and cost), decided to use CRMB in all the major National and State Highways. Since then the Ministry of Road Transport and Highways has systematically been pushing for the uptake for CRMB. Similar directions have been issued by all leading road making agencies such as the BRO, AAI, MES, NRRDA, and State PWDs of almost all the state governments of India.

The major push for the state governments to use CRMB in the repair and construction of new roads came with the addition of the clause 4.10.5 in the Rural Roads Manual, IRC SP-20, 2002. This clause clearly states the advantages of using modified bitumen and it was with the inclusion of this directive that an institutionalized push came from the centre to the state on the need to use modified bitumen in all future road constructions. This has meant that since October 2002, the various state governments have also issued orders to support the use of CRMB in its road surfacing programmes. Also, currently it is mandatory that all roads laid under the road works component of the Pradhan Mantri Gram Sadak Yojana (PMGSY) use CRMB (Government Order- DO#T020/2002/NRRDA).

Quality control on the manufacture of crumb rubber modifiers was a major challenge. To overcome this challenge, the Ministry of Petroleum and Natural Gas in 2000, on the recommendations of the Ministry of Road Transport and Highways, issued a directive to all refineries to commence the production of CRMB. Currently, it is mandatory for government bodies and their contractors to purchase quality controlled CRM and CRMB from these designated oil refineries. The production of CRMB initially began at CPCL Chennai and was followed by IOCL Panipat, HPCL Mumbai and Vizag, BPCL Mumbai, IOCL Mathura and Haldia and MRPL Mangalore.

Despite government directives, field trial evaluations and its successful performance on roads, CRMB has not been completely accepted by road contractors. The resistance in accepting the product is thought to be because the presence of rubber in the bitumen essentially means it cannot be converted to the black burning oil (substitute of furnace oil) whereas normal plain bitumen can be converted to oil. Hence, there is a reluctance in the uptake and scaling up of this venture which tends to be reflected in the price advantage argument, wherein it is understood that using CRMB means the overall price of the road increases. But this is not completely true. The detailed cost analysis and cost advantage of using CRMB are given in the next part.

Box 16: Advantages of CRMB-based Roads

The roads built with CRMB have demonstrated to have the following advantages:

- Lower susceptibility to daily and seasonal temperature variations.
- Higher resistance to deformation at elevated pavement temperatures.
- Better age resistance properties.
- Better adhesion between aggregate and binder.
- Higher fatigue life of mixes.
- Delay of cracking and reflective cracking.
- Overall improved performance in extreme climatic conditions and under heavy traffic conditions.
- Perform better in high rainfall and snow bound areas and in situations where the aggregates are prone to stripping.

Source: Circular dated- 19th July 2011, Ministry of Road Transport and Highways, GOI (No. RW/NH-33041/3/2001-S&R(R)

Box 17: Landmark Research Findings on CRMB

Prof. Justo et al (2002), at the Centre for Transportation Engineering of Bangalore University compared the properties of the modified bitumen with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive up to 12 percent by weight. Therefore, the life of the pavement surfacing using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen.

Shankar et al (2009) blended crumb rubber modified bitumen (CRMB 55) at specified temperatures. Marshall's mix design was carried out by changing the modified bitumen content at constant optimum rubber content. Subsequent tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70). This has resulted in much improved characteristics when compared with straight run bitumen and that at reduced optimum modified binder content (5.67 %).

Mohd. Imtiyaz (2002) concluded that the mix prepared with modifiers shows higher resistance to permanent deformation at higher temperature.

Excerpts from an Overview on Use of Waste Rubber Tyres in Construction of Roads (Baraiya 2013)

Cost Analysis Using Bitumen VG 30 v/s CRMB 60

The cost of maintenance of the road can be drastically reduced by using modified bitumen as the intervention period of resurfacing can then be extended by 2-3 years. Though the initial construction cost of CRMB-based roads is 6.88% higher than bitumen-based roads, over the life-time of the road, i.e. 15 years, there are savings of over 28.74%. Also, the renewal period in the case of roads which is laid using Bitumen VG 30 is within 3-5 years as opposed to those roads laid using CRMB 60 which is at 5-7 years.

Table 2: Initial Road Construction Cost

	Bitumen VG 30 (in MT)	Cost (in INR)	CRMB 60 (in MT)	Cost (in INR)
Prevailing Cost #		25,433		28,623
Bituminous Mix (Aggregate + Bitumen)	330	-	330 MT	-
Bitumen and CRMB Requirement @ 5% of Mix	16.5	4,19,644	16.5 MT	4,72,279

	Bitumen VG 30 (in MT)	Cost (in INR)	CRMB 60 (in MT)	Cost (in INR)
Aggregate in the Mix (@ INR 1,100 PMT)	313.5	3,44,850	313.5 MT	3,44,850
Total Cost Per Lane Km (in INR)		7,64,494		8,17,129

*Estimates calculated based on a 1 km lane which is 3.5 m wide and 40 m thick

Cost calculated at the prevailing rate on 1st June 2017 at Panipat

Thus, the additional cost incurred in using CRMB 60 is only fifty-two thousand six hundred and thirty-five rupees (INR 8,17,129- INR 764,494= INR 52,635), i.e. 6.88% higher than Bitumen VG 30 mix. (Tinna Rubbers)

If the life cycle is considered to be 15 years, the renewal cycle will be:

Table 3: Road Renewal Cost

	After 5 years (in INR)	After 7 years (in INR)	After 10 years (in INR)	After 14 years (in INR)	After 15 years (in INR)	Total Cost (in INR)
Bitumen VG 30	7,64,494		7,64,494		7,64,494	22,93,482
CRMB 60		8,17,129		8,17,129		16,34,258

The difference in the overall maintenance cost is at six million fifty-nine thousand two hundred and twenty-four rupees (i.e., 22,93,482 – 16,34,258 = INR 6,59,224). Based on these estimates, it can be noted that the renewal period in the case of roads which is laid using bitumen VG 30 is within 3-5 years as opposed to those roads laid using CRMB 60 which is at 5-7 years (Tinna Rubbers).

6. Conclusion

This report believes there is a lot of potential within the country's road, railways and housing sectors to leverage these unique qualities of recycled/reclaimed rubber on a large-scale. Two key action paths for upgrading the handling of tyres must be initiated, for preparedness as the tyre deluge unfolds:

6.1 Upgrade the Way the Informal Sector Works

There is no doubt that the informal sector is able to reuse tyres, at the current volume being produced today. The hubs listed in Annexure 1 are indicative of this important activity. To enable this to upgrade and continue to contribute to recycling, the following forms of assistance are most required by them:

- A means of recognition of their work as legal and legitimate, through registration and authorization
- Standardization of some common processes
- Help in inventorising and other forms of documentation to ensure adequate paper trail
- Training for occupational and worker safety
- Working to create an alternative value chain for such ELT parts that are currently being sold for open burning or burning as fuel

6.2 Use ELTs in roads

The large number of tyres in the coming years requires national level preparedness for proper handling. Chintan identifies the use of CRMB/rubberized asphalt and rubberized concrete in the construction, repair and reconstruction of paved and unpaved roads as well as national highways as a key way forward.

As per MORTH directives for NHAI that approximately 30 km of road is to be constructed every day and it is estimated that between 2001-2011, the approximate growth rate of the road network has been 3.4% per annum (with it being 5% p.a. urban, 4.4% p.a. rural and national highways are at 2.1%). The cost and infrastructural advantage of CRMB 60 in road construction need to be adequately leveraged in a growing economy like India.

This data also shows how the growth of ELTs and roadways synchronizes, making the use of ELTs in roads a good means of achieving circular economy.

While there exist various policy measures towards this, several other steps by various agencies are essential, if the policy is to turn into practice. These are:

Ministry of Surface Road Transport and Highways

- The Ministry should enforce its circular 2000 and the implementation and usage of CRMB for the construction of roads.
- A clear directive should be issued to NHAI and other lead road making agencies to gradually increase the use of CRMB and to bring it to the level of 35-40% of the total bitumen consumption which at present stands at approximately 2-3%.

Ministry of Environment, Forest and Climate Change

- Issue directions to all the State Road Transport Corporations to sell discarded tyres to authorized tyre recyclers or license holders in the country and to keep a track of their proper disposal/recycling, involving the State Pollution Control Boards.
- Directions to be issued to the users of natural rubber (tyre manufacturers and manufacturers of other rubber products like mats, conveyor belts etc.) to include part of crumb rubber/reclaim rubber in their compound as this will help in the proper utilization of waste tyres. Identify fiscal and non-fiscal incentives for such products.
- Work and assist the Ministry of Road Transport and Highways to issue directions to road making agencies to use the maximum quantity of CRMB, as this will only help in waste tyre disposal in an environmentally friendly manner.
- Set up a capacity enabling team to help informal sector upgrade their work, along with the Central Pollution Control Board and other State Pollution Control Boards.
- Ensure that the informal sector in tyre reuse is included in the Rules to be notified.

Rubber Skill Development Council

- In India, there is a need to further encourage the informal sector that handles the ELTs economy for these enterprises by providing the requisite infrastructural and market support.
- Provide further marketing and credit support to MSMEs who are handling the recycling of ELTs.
- Provide support for innovation in the possible reuse and recycle of ELTs at the local/ community level, including in the informal sector.
- Standardize operations in the informal sector to ensure occupational and environmental safety, and train operators in this.

State Road Transport Corporations

- The State Road Transport Corporations (STCs) periodically auction obsolete diesel and petrol-based ELVs and do not monitor or maintain a check on the post-consumer value chain.
- STCs must ensure that ELTs are sold to authorized tyre recyclers in the country and to keep a track of proper disposal/recycling of the same. Where licensed semi-formal sector actors come into play, the unused sections must be sold only to licensed users, not kilns etc.

Together, these are some key steps forward to ensure safe tyre management using the emerging idea of feeding a circular economy.

To conclude, the deluge of tyres in our economy is only going to increase as the large network of roads being built, along with increase in the number of automobiles being manufactured, will inadvertently lead to more and more tyres. The informal sector is playing an important role in circulating tyres in the economy but may not be able to effectively manage the deluge of tyres. Current practices like oil and brick kilns are highly polluting and unsustainable. Globally, tyres have proven to be an environmental menace and it is imperative that India learns from other countries experiences and prevents similar crises here. An important way forward is Crumb Rubber Modified Bitumen (CRMB), which can be used in roads, as part of the expansion of highways across India. While there are several government notifications already in place for using CRMB in roads, they have not yet been implemented. A stronger focus is thus required at multiple levels at the earliest, to make it a mainstream practice in order to deal with the upcoming onslaught of hundreds of millions of tyres in a sustainable and economically viable manner.

Annexure 1:
List of Tyre Hubs in North India

Sr. No	State	City	Area
1	Uttar Pradesh	Meerut	Khairnagar
2	Uttar Pradesh	Meerut	Transport
3	Uttar Pradesh	Meerut	HapurAdda (Bus Stand)
4	Uttar Pradesh	Meerut	Soti Ganj
5	Uttar Pradesh	Meerut	Pratapur
6	Uttar Pradesh	Muzaffarnagar	
7	Uttar Pradesh	Shamli	Shamli bus stand
8	Uttar Pradesh	Sharan Pur	Near railway station
9	Uttar Pradesh	Hapur	Near Hapur bus stand
10	Uttar Pradesh	Ghaziabad	Near Delhi Gate
11	Uttar Pradesh	Sitapur	Sitapur
12	Uttar Pradesh	Gonda	Gonda Basti
13	Uttar Pradesh	Bijnor	Bijnor
14	Uttar Pradesh	Muzaffarnagar	Jansath near Baisuma
15	Uttar Pradesh	Mawana	Near Mawana police station

Sr. No	State	City	Area
16	Uttar Pradesh	Moradabad	Moradabad
17	Uttarakhand	Rudrapur	Jalhodra Tyre, Rudrapur
18	Uttar Pradesh	Kota	Kota
19	Delhi	Delhi	Gokul Puri
20	Delhi	Delhi	Dilshad Garden
21	Delhi	Delhi	Mayapuri
22	Delhi	Delhi	Jama Masjid
23	Delhi	Delhi	Burari
24	Delhi	Delhi	Tangawalan near Azad Market
25	Rajasthan	Kota	Kota

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Circular issued by BRO - No.RW/. 80695/DGBR/Pol/FRi/D&S dated 6th January 2012 and 23rd December 2011

List of Interviewees

Name & Designation	Organisation & Location	Date	Remarks
Mr. I V Rao, Senior Advisor, Maruti	Maruti Udyog, Vasant Kunj Delhi	June 22, 2017	To understand tyre reclamation in MUL
Dr. U. K. Guru Vittal HoD, Chief Scientist, Geotechnical Engg	Central Road Research Institute (CRRI) Delhi	June 18, 2017	To understand potential of Tyre reuse in roads or any such civic construction in India
Dr. N. N. Rao Sr. Scientist	National Environmental Engineers Research Institute NEERI	June 15, 2017	Telephonic Interview - To understand the Pyrolysis business and get contact of people in Rajasthan and Gujarat
Captain N S Mohan Ram Advisor	Society of Indian Automobile Manufacturers (SIAM)	June 12, 2017	Telephonic Interview - To get reference of work done on tyre recycling by SIAM and/or TVS Motor Company Limited
Dr. Shruti Bhardwaj Scientist – D	MoEFCC	May 11, 2017	Informal Conversation - To understand the Legislative stand on tyre recycling and also on their import and Pyrolysis
Mr. Amardeep Raju Scientist – D	MoEFCC	May 09, 2017	

Name & Designation	Organisation & Location	Date	Remarks
Mr. B. L. Chawla Sr. Environmental Engineer	Delhi Pollution Control Committee DPCC		Telephonic Interview - To understand Pyrolysis practices and its network in Delhi NCR and get contacts
Mr. Vinay Vijayvargia Secretary	Indian Tyre Technical Advisory Committee C/o Automotive Tyre Manufacturers Association (ATMA)	June 14, 2017	To understand the formal arrangements of tyre recycling with tyre manufacturing companies, import trends, recycling data and practices, etc., and data on formal tyre recyclers
Mr. Rahul Vachaspati Joint Director			
Mr. Raj Kumar Sr. Manager	ATMA Thane, Mumbai	June 06, 2017	Telephonic Interview - To understand the formal arrangements
Mr. Kamal Sharma	CII Delhi	June 06 2017	Telephonic Interview - To understand the formal arrangements
Mohammad Aabid Old Tyre Trader	Kher Nagar (Near Chatriwali Peer) Meerut City, UP	March 23, 2017	Informal Old Tyre Trade Practices (The person was not very supportive)
Mohammad Tareekh Old Tyre Trader			
Salman Old Tyre Fabricator Regroovіng	Jali Kohti Road Kher Nagar, Meerut City, UP		Regrooving of all kinds of tyre but mainly High Load Tyres (Lorrey, Trucks, Busses, etc)
Abdul Wahid Old Tyre Trader	Khar Nagar Meerut		Informal Old Tyre Trade Practices
Mohammad Ishrar Old Cars Trader	JaliKohti Road, Kher Nagar, Meerut City, UP		To get links and understand the old / recycling market
Mobin Ahmad Engine Boring	Near Badpat Adda Meerut City, UP		To get links of Old Cars Manufacturers
Mohammad Saleem Retreading Unit for High Load Tyres	Mawana City, UP	March 24, 2017	Plant for High Load tyres (tractor, bus, trucks) etc and was on slightly larger scale with heavier machinery, equipment and around 4-5 employees.

Name & Designation	Organisation & Location	Date	Remarks
Mr. Sanjay Gupta London Sports Equipment's	Partapur Industrial Area, Meerut Delhi Road, Meerut UP	March 2017	To understand Retreading, informal sector, potential Reuse and contact of Pyrolysis Plants
Mr. Manish Sharma Meerut Police	Sadar Police Thana, Meerut City UP	March 2017	To understand the Informal setup and get contacts and some information on tyre recycling network
Mr. Sachin Malik Inspector, Meerut Police	Sadar Police Thana, Meerut City UP	March 2017	
Mr. Jayant Singh ChaukiIn charge	Madhavpurum Police Station, Meerut, UP	March 2017	Telephonic Interview
Chaudhary Mahinder Singh Brik Kiln Manufacturer	Meerut Bypass Road, Kankarkhera, Meerut	March 25, 2017	To understand Energy Reclamation use from old Tyres and process, etc
Mr. Padam Singh Brik Kiln Manufacturer	Sardhana Road, Meerut IP		
Saqib Tyre cutting plant	Meerut Delhi Road, BasantpurSatli, UP		To understand tyre cutting, material reclamation (Iron wires) and network and process of energy reclamation in Bricks Kilns, etc.
Babu Tyre Cutting plant			
Mr. Pradeep Chaudhary ELV Trader	Mayapuri Industrial Area, E-Block, New Delhi	May 19, 2017	To understand the informal arrangements concerning the Old Tyre coming-out of the Mayapuri ELV Dismantlers and the trade and reuse of Old Tyres.
Balram Singh Fabricator			
Amar Singh ELV Trader	Golulpuri Old Market, East Delhi	May 20, 2017	

With over 54 lakh kilometres of roads, India currently has the second largest road network in the world. There are plans to construct another 50,000 kilometres of roads at a cost of approximately Rs 17 lakh crore by 2022. This has contributed to a boom in the automobile sector, as well as the tyre industry with 127.34 million tyres produced in 2016-17, demonstrating a 12% increase from the previous year. However, such resource-heavy growth models call for sustainable management of natural resources and resource efficiency. The world over, the idea that waste is an untapped source for secondary raw materials is influencing the approach to scrapped automobiles. Tyres are just one component in automobiles, but owing to their composition, tyres have been found to have a complete self-sustaining economy around them. This study on tyres draws from Chintan's extensive experience in informal waste management and recycling in northern India to shed light on the economic and environmental benefits of utilising Crumb Rubber Modified Bitumen (CRMB) made from tyres for road construction and maintenance in India.

Chintan Environmental Research and Action Group

C-14, Second Floor, Lajpat Nagar III
New Delhi-110024
Tel: +91-11-46574171/72
Fax: +91-11-46574174
Website: www.chintan-india.org

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Environmental Research and Action Group