Study of Reverse logistics of End-of-Life Vehicle (ELV) in automotive industries and field study for exploring the potential of NRPW in Co-processing

Thesis submitted in partial fulfillment of
the requirements for the degree of

MASTER OF ENGINEERING IN AUTOMOBILE ENGINEERING UNDER FACULTY OF ENGINEERING AND TECHNOLOGY

By

ABHISHEK KUMAR

Class Roll No.: 002011204014
Examination Roll No.: M4AUT22014
Registration No.: 154347
Academic Session: 2020-2022

Under the guidance of

PROF. DR. SADHAN KUMAR GHOSH

DEPARTMENT OF MECHANICAL ENGINEERING, FACULTY OF ENGINEERING & TECHNOLOGY (FET), JADAVPUR UNIVERSITY

KOLKATA – 700032

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FACULTY OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
JADAVPUR UNIVERSITY
KOLKATA-700032

CERTIFICATE OF APPROVAL*

The foregoing thesis entitled ***"Study of Reverse logistics of End-of Life Vehicle (ELV) in automotive industries and field study for exploring the potential of NRPW in Co-processing"*** *is hereby approved as a creditable study of an engineering subject carried out and presented in a satisfactory manner to warrant its acceptance as a prerequisite for the degree of "Master of Automobile Engineering" under Department of Mechanical Engineering, Jadavpur University, Kolkata 700032, for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn there in but approve the thesis only for the purpose for which it is submitted.*

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled ***"Study of Reverse logistics of End-of Life Vehicle (ELV) in automotive industries and field study for exploring the potential of NRPW in Co-processing"*** *is a bona-fide work carried out by* ***Abhishek Kumar*** *under our supervision and guidance in partial fulfillment of the requirements for awarding the degree of Master of Engineering in Automobile Engineering under Department of Mechanical Engineering, Jadavpur University during the academic session 2020-2022.*

Countersigned

Prof. Dr. Sadhan Kumar Ghosh

Thesis Advisor
Department of Mechanical Engineering
Jadavpur University

Prof. Dr. Amit Karmakar

Head of the Department
Department of Mechanical Engineering
Jadavpur University

Dean
Faculty of Engineering and Technology
Jadavpur University

FACULTY OF ENGINEERING AND TECHNOLOGY (FET)
DEPARTMENT OF MECHANICAL ENGINEERING
JADAVPUR UNIVERSITY
KOLKATA – 700032

DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I, ***Abhishek Kumar,*** *hereby declare that the thesis entitled "****Study of Reverse logistics of End-of Life Vehicle (ELV) in automotive industries and field study for exploring the potential of NRPW in Co-processing****" contains literature survey an original research work by the undersigned candidate, as a part of* ***MASTER OF ENGINEERING IN AUTOMOBILE ENGINEERING*** *studies during academic session 2020-2022. All information in this document have been obtained and presented in accordance with the academic rules and ethical conduct. I also declare that, as required by these rules of conduct, I have fully cited and referenced all the material and results that are not original to this work.*

Name: Abhishek Kumar
Class Roll Number: 002011204014
Examination Roll Number: M4AUT22014
Date:

(Signature)
ABHISHEK KUMAR
DEPARTMENT OF
MECHANICAL ENGINEERING
Jadavpur University,
Kolkata700032
FACULTY OF ENGINEERING & TECHNOLOGY

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ABHISHEK KUMAR
M.E (Automobile Engineering)
2nd Year, Final Semester
Department of Mechanical Engineering
Jadavpur University, Kolkata

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ABSTRACT

Reverse logistics implementation in automotive industries for End-of-Life vehicle (ELV) is very important nowadays as transportation played a great role in society in the civilization. Through the life cycle of vehicles, the impact on the environment takes place in various ways: energy and resource consumption, GHG emission, waste generation during manufacturing and use, and disposal at the end of their useful lives. To support the disposal of End-of Life Vehicle (ELV) waste, recovery processes are in use especially, the reuse of appropriate parts, the recycling of plastics, glasses, ferrous and non-ferrous metals, fabrics, and other materials for making various recycled products. However, the use of ELV wastes does not guarantee the use of 100 % materials leading to dumping in the waste dump yards. Co-processing utilizes waste to recover energy as well as material to the extent of 100%. The global ELV (end-of-life vehicles) generation is estimated to be 40 million ELV/ year contributed by only 4% of total global automobile ownership. It is estimated that in India the number of vehicles to become ELV will be 2,18,95,439 by 2025. There are significant economic and environmental benefits in recovering materials from ELVs. It has been estimated that passenger cars contain about 70% steel and 7-8% aluminium. The rest 20-25% is plastic, rubber, glass, etc. ELV waste contains a significant quantity of fiber-reinforced polymer (FRP) on which the literature does not mention any recovery processes but land filling. FRP and other unused plastics need an appropriate recovery process. This study focuses on the potential recovery process through co-processing rout in cement plants that may help implementation of circular economy concepts as well as reduce adverse impacts on environment. This study reviews the possibilities of using ELV Plastic in co-processing in cement plants for resource circulation.

CHAPTER 1

INTRODUCTION

1.1 Background

Plastic has concurred an irreplaceable part of our daily life, opening a new window of extravagance, making people adopt the policy of use and throw to the greatest. The unconventional variations it exhibits in its nature, such as its high resistance to corrosion, increased flexibility, and plasticity, which could be easily manufactured at an affordable cost, has opened numerous research opportunity in the field of material research and overwhelmed the whole world, especially the industrial sector by its unprecedented development implying the necessity of immediate actions need to be taken by the scientific community to take care of the growing pile of generated plastic wastes which is reaching an approximate average 5-15% of the municipal solid waste with a volumetric proportion equalling to 20-30% by taking advantage over its luxury of liner consumption which applies to all of its varieties which includes thermoplastics such as polypropylene, polyethylene, polyethylene terephthalate, and high-density polyethylene. This review foresight the necessity that people should be informed about the risk and pollution hazards corroding the environment caused due to excessive quantity of plastic consumption. (Junaid Saleem et.al 2015).

"Since 1950 around 8.3 billion plastic has been produced globally, out of which 79% have ended up in landfills or open environment" (jambeck, 2015). And at present, the global annual production of plastic is 330 million metric tonnes (Mt) for 2016 (Plastics Europe, 2017). It is estimated that this rate of production will be doubled in the next 20 years. Compared to the aspect of the developing nation like India, the daily plastic waste generation is around 25,940 tons per day, according to the survey among the 60 major cities of India carried out by the Central Pollution Control Board (CPCB) to exploit the maximum plastic waste generation of the country it is estimated that 9.46 million tons per annual of plastic waste are generated in India.

Due to its indestructible nature, plastic waste takes hundreds of years to decompose and is ultimately dumped into landfills or eventually found in the oceans creating several consequences to the natural ecosystem, especially in the ocean eco system reported to a pollution level of over 150 million tonnes of plastics. Expecting that the ocean will contain one tonnes of plastic for every 3 tonnes of fish, lurking our future with more plastic than fish (by weight) in the ocean. Marine debris originates primarily from land sources (80%) like municipal and industrial waste dumped into the sea and from littering by tourists in coastal areas. The disposed waste by ships, boats and the lost or discarded fishing gears also contribute to the marine environment (Lee, 2015; Katsanevakis, 2011).

Today, vehicles are a necessary component of our society, and demand for them is rising day by day. However, vehicles have various environmental impacts throughout the course of their life cycle, including resource and energy consumption, waste generation during production and use, and disposal after their useful lives. End-of-Life Vehicles (ELVs), which are mainly made of metal, can be recycled to an extent of around 75%, with the remaining 25% of the vehicle being disposed of in open areas or in landfills as waste (N. Kanari et al., 2015).

The cement industry is one of the largest in the world, and approximately 3-5 MJ of thermal energy are normally consumed to dry, decompose, and sinter carbonate minerals to make one kg of "clinker," which is then pulverised to cement powder and blended with other components (A.C. (Thanos) Bourtsalas, 2018). Fossil fuels (Coal) have been used as source of energy in cement production but limitation on availability, growing pressure for lower operational cost and reduced environmental impact has directed the global cement industry to use "waste" materials as alternative fuels (AF).

1.2 Reverse logistics in automotive industries

Reverse Logistics implementation in automotive industries is presented in four aspects: product return, automotive recall, cost saving, environment protection during production processes, and recycling of waste products in reverse logistics. Reverse logistics and reverse processes emphasized green logistics for the first time, indicating environmentally logistics strategies including product return, recycling, waste disposal, refurbishing, repair, and re-manufacturing (Mao & Jin, 2014). The present situation of reverse logistics in the automotive industry indicates that reverse logistics has a vital role in the development of the automotive industry. The empirical findings show all daily work related to reverse logistics.

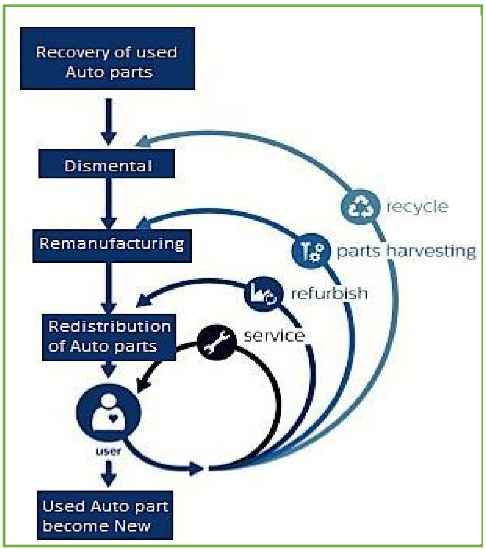

Fig.1: Reverse logistics in automotive industries

It indicates that nowadays, the high technology content of the product causes difficulty, costly and protracted production of the manufacturing processes in the automotive industry. They need to adopt reverse logistics. Automating automotive reverse logistics, based on the corporate view, helps improve enterprise logistics service levels, enhances operational efficiency, and reduces production costs (Mao & Jin, 2014).

1.3 Strategy and technologies used for the reverse logistics process in automotive industry.

It is impossible to deny the importance of reverse logistics in the automotive industry. It can be easily understood that the concept of reverse logistics has become so crucial in the present automotive industry. Reverse logistics are significant for a number of reasons. The frequent product recalls, emphasis on environmental sustainability, waste management, changing regulatory requirements, altered legislative strategies, etc. are a few of the causes. Increased requirement of reduce, reuse and recover the returned vehicle to enhance the environmental concern with the passage of time. The most important aspect to analyse in this aspect is that despite the various advantages of the reverse logistics to the industry of automobiles, not many manufacturers have successfully implemented the reverse logistics process (Aitken & Harrison, 2013).
Strategy and technology used for reverse logistics are Close Loop Supply Chain (CLSC)

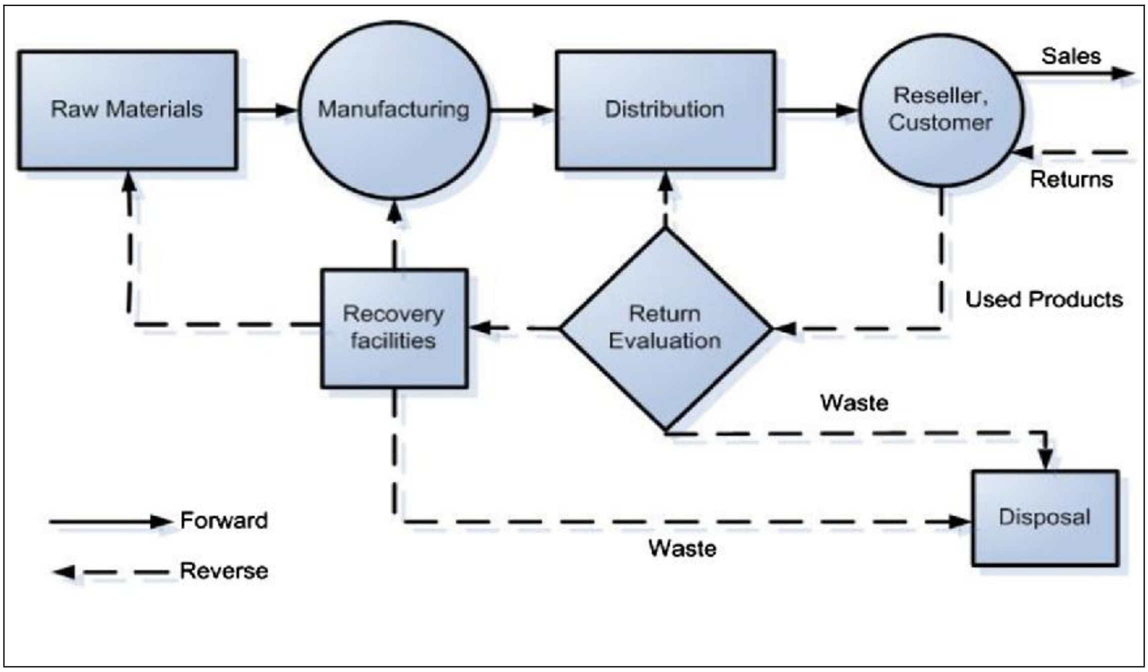

Figure 2: Close Loop Supply Chain (CLSC) (G. Kannan et al., 2015)

1.4 Co-processing of plastic waste in cement plant

Co-processing is the use of appropriate waste materials in industrial processes for energy and/or resource recovery, to replace conventional fuels and/or raw materials resulting in a reduction in the usage of those materials through substitution (UNEP, 2011).

Through co-processing, waste materials are used in energy-intensive industries as an alternative fuel and raw material (AFR). As a cement kiln needs a high temperature to operate, different wastes material can be fed to the kiln or disposed of without any harmful emissions and residue. The Ambuja Cement Ltd. (Ambuja), Associated Cement Ltd. (ACC), initiated co-processing formally in India in 2006 with the brand name “geocycle” (S.K Ghosh et al., Sustainable Management of Wastes Through Co-processing).

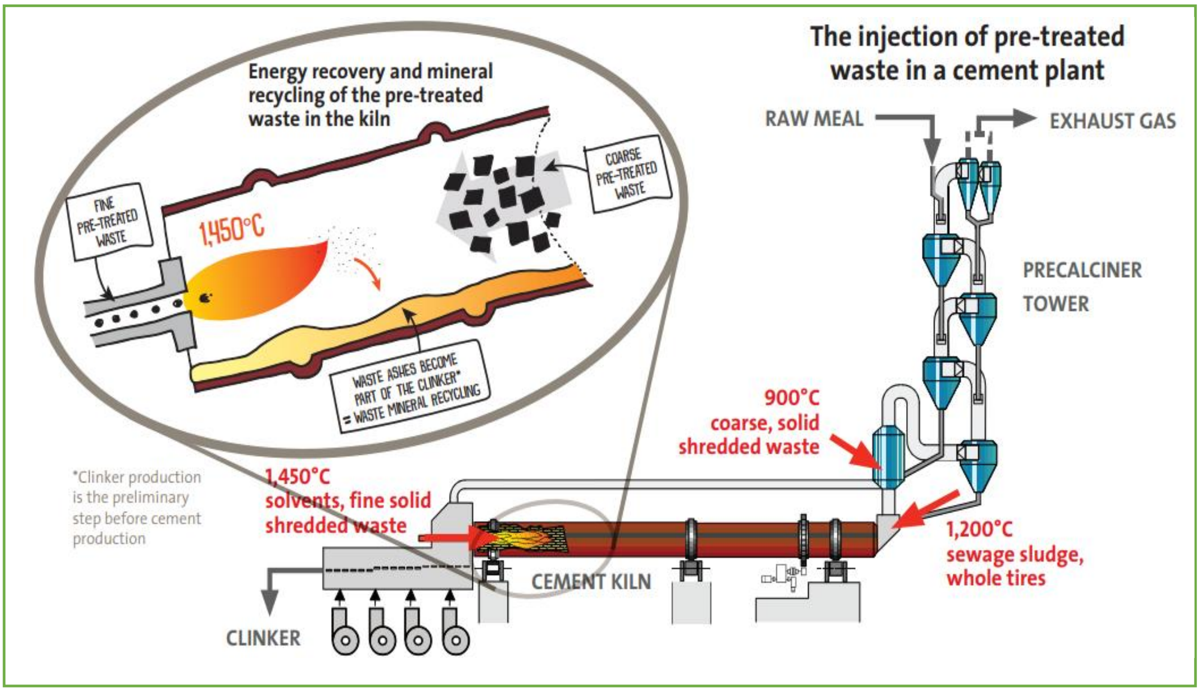

Fig. 3: Co-processing of waste in cement kiln (Geocycle)

It is a sustainable and environmentally friendly method compared to landfilling and incineration. As land filling is the only option for NRPW, co-processing is the best suitable treatment process for it. Co-processing offers various environmental as well as social benefits too some of them are,

- conservation of natural resources: coal, crude oil, gas, gypsum, limestone, clay, etc.
- indirect reduction of greenhouse gas emissions that would be generated if waste was landfilled or incinerated in special waste incinerators.
- diminution of environmental hazards (uncontrolled landfilling, soil and water pollution, etc)

- avoidance of controlled landfilling shortage
- a healthier and cleaner environment (Benefits of Waste Co-Processing, HOLCIM).

Co-processing can be a good business model for any industry. At the cement plant level, the sources of income include tipping fees and savings from reduced coal consumption, whereas the expenditures are RDF handling and management costs, co-processing costs, production loss, and pre-processing costs. It has been observed that after all these expenditures cement industries make a reasonable profit from co-processing**.** (CPCB Guidelines for Co-processing of Plastic Waste in Cement Kilns, 2017).

Co-processing in cement plants refers to the use of waste material as an alternative fuel and raw material (AFR) in the cement production process to recover energy and material from them, rather than using conventional fuel (Coal, Natural gas, Pet coke, etc.). The use of alternative fuels as a substitute for coal reduces reliance on fossil fuels, and emissions of carbon dioxide (CO2) (Karstensen, 2010, 2007; WBCSD, 2014). Different types of waste can be efficiently disposed of without harmful emissions due to the high temperature in the cement kiln (1450^{o}c). The utilization factor of co-processing in a cement kiln is 100% as no residue material comes out from the cement kiln.

1.5 "OPTOCE" Research project & the introduction

The project "Ocean Plastic Turned into an Opportunity in Circular Economy – OPTOCE", conducted and managed by SINTEF, is a regional effort to address the main reason for microplastics in the Ocean, namely inadequate treatment capacity for plastic wastes on land. OPTOCE aims to explore and demonstrate how the involvement of energy-intensive sectors, such as cement manufacturing, can enhance the treatment capacity for Non-Recyclable Plastic Waste (NRPW) and therefore contribute to the reduction of plastics released into the sea.

While this academic collaboration aims to build capacity, to strengthen research capacity, and support science-based policy and decision making, the OPTOCE initiative will generally support all of the Bangkok Declaration's objectives.

The goal of the Academic Collaboration is to increase competence in Non-Recyclable Plastic Waste (NRPW) treatment options, as well as to provide better knowledge about the NRPW situation in the country and the possibility of involving local energy intensive industries in waste problem solving. Some main objectives of this project is given below.

- Evaluate current plastic waste problems and management practice in the pilot demonstration area (and country if possible), including possible environmental impacts.

- Evaluate the feasibility/environmental benefits of using local cement industry to recover energy/co-process NRPW compared to current plastic waste management practice in the pilot demonstration area.
- Estimate t/y of NRPW co-processed and coal saved in pilot sites in 2022 compared to current plastic waste management practice (year 2019/2020) and provide an estimate of future co-processing potential by scaling up the practice to all cement plants in the country.
- Documented the number of cement plants co-processing NRPW in the country by 2022 and provide an estimate of future potential by involving all "feasible" cement plants.

1.5.1 The major activity in the research studies

- Literature review and baseline studies.
- Initial field visits including cement plants for data collection and conducting feasibility studies.
- Waste sampling and data collection from different sources and locations.
- Conducting feasibility studies at the pilot demonstration sites.
- Analysis of NRPW & micro plastics composition.
- A survey using questionnaire & Data collection.
- Data analysis using statistical tools & simulation methods

1.6 Use of NRPW and other material in co-processing as Alternative fuel

The use of Non-Recyclable plastic waste as an alternative fuel to replace fossil fuels (Coal) in cement kiln is defined as co-processing of NRPW in cement kiln. Plastic waste is collected from dumpsites or other sources like paper mills, food factories, etc., and segregated into NRPW which contains waste consisting of thermo-set plastic, single-use plastic, multi-layer packaging, contaminated plastic scrap, etc. Non-recyclable plastic waste is packaged properly and transported to a cement plant for co-processing. These wastes are initially stored in the storage facility of the cement plant and samples are taken for testing. After getting approval from the lab these wastes are pre-processed. Size gets reduced up to 50mm depending on the requirement according to the cement plant and co-processed in a cement kiln.

1.7 Potential use of waste developed in ELV in co-processing

Global ELV generation is estimated to be 40 million units per year, accounting for 4% of total global automotive ownership. (Sakai et al. 2013). By 2025, it is expected that 2,18,95,439 vehicles will be turned to ELV. (CPCB report "Analysis of ELV sector in India", 2015). Both ferrous and nonferrous metals are recovered and reused during the recycling process. It is estimated that passenger cars contain approximately 70% steel and 7-8% aluminium that can be recycled directly by recycler or used by the automotive industry itself as secondary raw material. The rest 20-25% is plastic, rubber, glass, etc. which generates huge waste that can be used for co-processing in cement kiln for environmentally safe disposal.

1.8 Summary of the Research activity in this thesis

This study is based on detail literature review in the selected area such as reverse logistic in the automotive industry end-of-life vehicle (ELV), co-processing of NRPW in cement plant, potential of ELV plastic waste generation and scope of co-processing of ELV plastic waste in cement plant.

In this paper also perform field study to know the potential of NRPW generation in dumpsite to be utilized for co-processing in cement plant in various places of West Bengal and Odisha.

In this thesis also developed a model for ELV recycling and rout to co-processing of ELV plastic waste in cement plant for sustainable disposal.

CHAPTER 2

LITERATURE REVIEW: PLASTIC WASTE AND CO-PROCESSING IN CEMENT KILN

2.1 Definition of the type of plastic including NRPW

Plastics are composed of long chains of hydrocarbons derived from petroleum. Plastic is a material composed of polymer-like Polyethylene Terephthalate, high-density polyethylene, polyvinyl, low-density polyethylene, polypropylene, polystyrene resin, or a combination of materials such as acrylonitrile butadiene styrene, polyphenylene oxide, polycarbonate, and polybutylene terephthalate. (CPCB, April 2018).

Non-recyclable plastic waste(NRPW)

The portion of plastic that cannot be recycled using standard recycling techniques is referred to as non-recyclable plastic i.e., plastic that can not be remolded on heating. These types of materials mainly comprise multilayered structures made up of thermoset or thermoplastic. Due to its complex structure, it cannot be separated, hence called non-recyclable (CPCB, April 2018).

Types of plastics

Thermoplastics: Thermoplastics, or thermosoftening polymers, are plastics like PET, HDPE, LDPE, PP, PVC, and PS that soften when heated and can be moulded into the required shape.

Thermosets: Thermoset or thermosetting plastics that cannot be remoulded or recycled on heating include Sheet Molding Compounds (SMC), Fiber Reinforced Plastic (FRP), Bakelite, and others.

Table 1: Different types of plastic, recyclability, and their uses

Code	Name of plastic	Recycling nature	Uses
1	Polyethylene Terephthalate(PET)	Recyclable	Water bottles, soft drink bottles, films, food jars, sheets, carpets, furniture, paneling etc.
2	High-density Polyethylene(HDPE)	Recyclable	bottles, Milk pouches, carry bags, recycling bins, playground equipment, base cups, etc.
3	Polyvinyl Chloride(PVC)	Recyclable	Sheets, Pipes, hoses,wire cable insulations, multilayer tubes, fencing, window profiles, lawn chairs, children's toys, etc.
4	Low-density Polyethylene(LDPE)	Recyclable	Various containers, Plastic bags, dispensing bottles, tubing, wash bottles, etc.

5	Polypropylene(PP)	Recyclable	Disposable cups, bottle caps, auto parts, straws, dishware, industrial fibers, etc.
6	Polystyrene(PS)	Non-Recyclable	Plastic utensils, Cafeteria trays, toys, insulation board, video cassettes and cases, clamshell containers, etc.
7	Other	Non-Recyclable	Thermoset Plastics, Bakelite, Multi layer and Laminates, FRP, Polycarbonate, Nylon SMC, etc.

Source: CPCB, 2017

2.2 Global plastic generation

based on the baseline plastic waste report from the United Nations Environmental Program (UNEP). Figure 1 shows the plastic waste produced in various countries. It is noted that the UNEP report does not contain information about India's production of plastic waste; based on the Annual Report submitted by the SPCBs/PCCs. India is ranked fifth in the world for producing plastic waste, according to observations.

Table 2: Plastic waste generation in different countries (CPCB, 19-20)

Countries	Plastic waste	Reference year
China	61	2016
US	34.5	2015
Indonesia	9.6	2018
Japan	8.9	2018
India	3.5	2020
Canada	3.2	2016
Australia	2.5	2016
Sweden	1.6	2016
UK	1.5	2016
Israel	0.9	2018
Switzerland	0.78	2019
Denmark	0.35	2017
Zimbabwe	0.3	2019

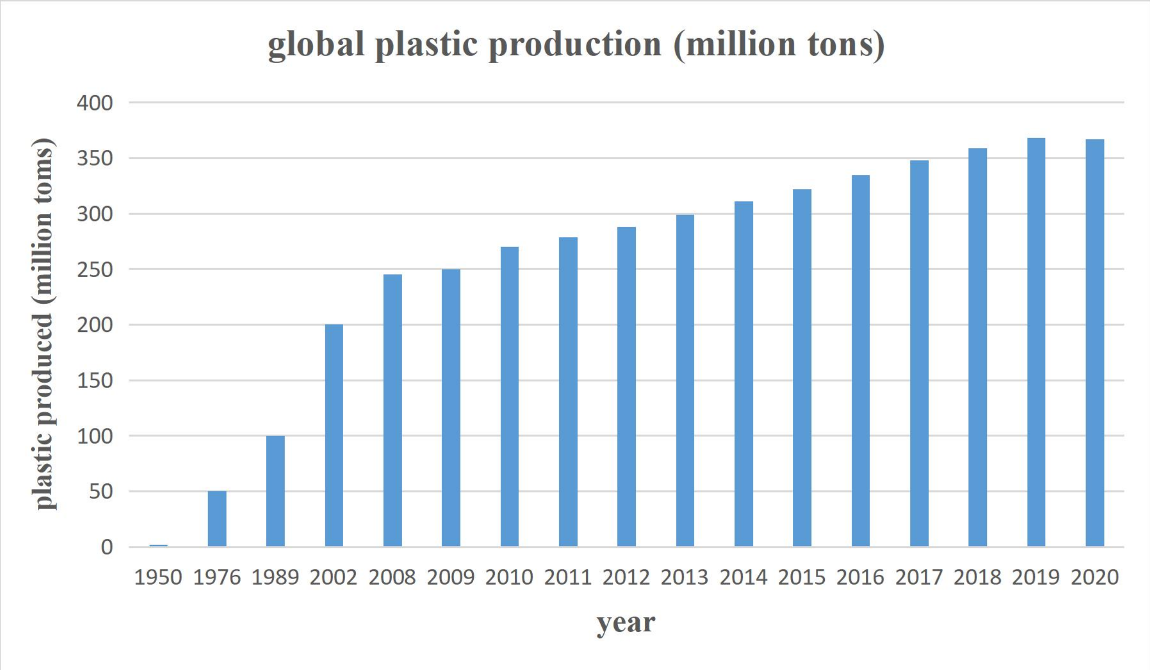

Fig. 4: Global plastic production in 1950-2020 (Statista 2021)

2.3 Plastic production & consumption in India

In 2018-19 estimated plastic waste in India generated is around 3.36 million tons (CPCB, 2019). As per the given figure below, States and UTs like Andaman & Nicobar Island, Arunachal Pradesh, Daman Diu & Dadra Nagar Haveli, Himachal Pradesh, Lakshadweep, Mizoram, Nagaland, Puducherry, Sikkim & Tripura having a plastic waste generation of less than 10000 tons per annum, while States like Maharashtra (12%), Tamil Nadu (12%), Gujarat (11%), West Bengal (9%), Karnataka (8%), Uttar Pradesh (8%) & Delhi (7%) are highest producers of plastic waste.

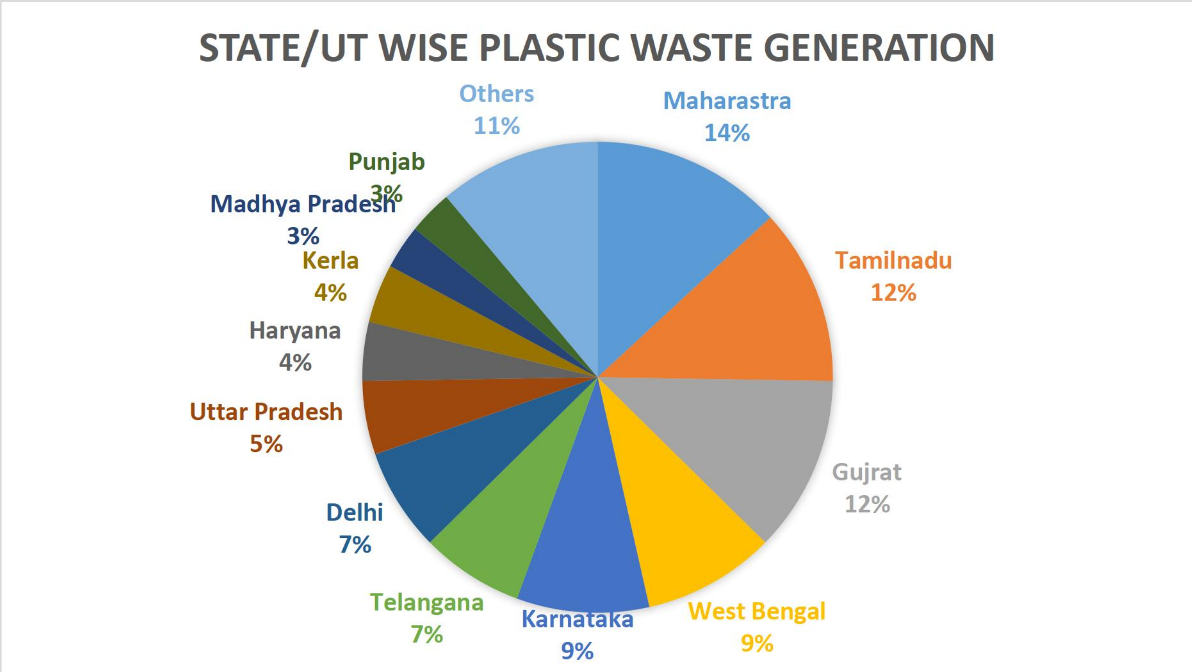

Fig. 5: State/UT wise Plastic waste generation in India

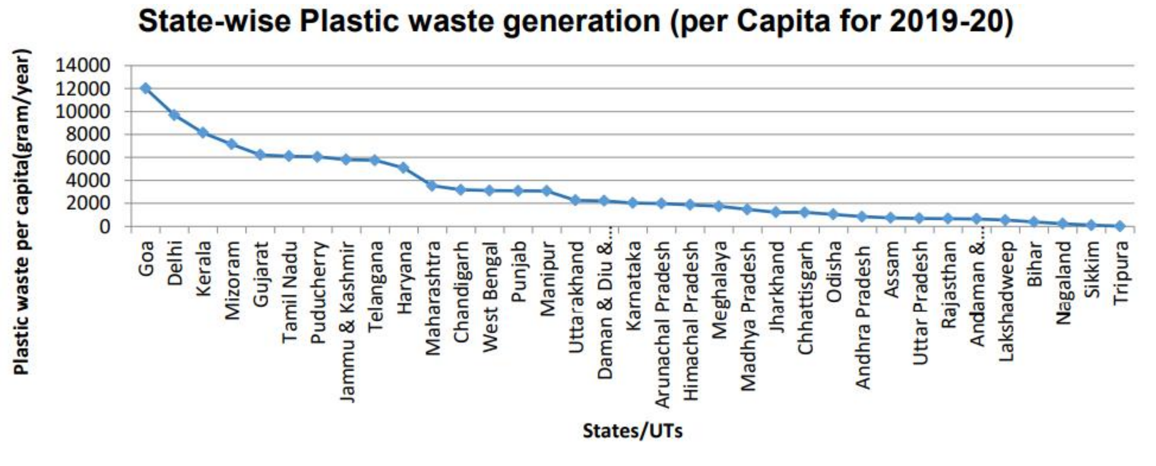

Fig. 6: State-wise per capita plastic waste generation(CPCB, 2019-20)

based on the central pollution control board's report, India generates around 9.46 million tons of plastic annually, which is around 26000 Tons/day (CPCB, 2018). As per the study conducted in different dumpsites in India, it has been found that on an average 7 % of total municipal solid waste is plastic waste, but in some cities like Delhi, Kolkata, Surat, etc. it is more than 10% (CSE,2020).

2.4 Plastic Waste and Co-processing status in India

(Source: CPCB Report, 2019)

Table 3: Plastic waste generation and management in States & UTs of India

SL No	Sates & UTs	Plastic waste generated (TPA)	Treatment methods	Treated amount (Tons)
1	Andhra Pradesh	46222	co-processing in cement plants, road construction	-
2	Andaman & Nicobar Island	387	Road construction	24.6 MT
3	Arunachal Pradesh	2721	Road construction	-
4	Assam	24971	disposing of non-recyclable plastic waste in cement kiln.	-
5	Bihar	41365	Recycling	-
6	Chandigarh	6746	RDF processing plant	-
7	Chhattisgarh	32850	co-processing in cement kiln	-
8	Daman and Diu & Dadra Nagar Haveli	1948	Recycling	-
9	Delhi	230525	Recycling & waste to energy plants	-
10	Goa	26068	co-processing	-
11	Gujarat	408201	incineration	94000 T
12	Haryana	147734	material recovery facilities.	-

13	Himachal Pradesh	13683	Co-processing and road construction	-
14	Jammu & Kashmir	74826.33	-	-
15	Jharkhand	43332	Co-processed, used in road construction	-
16	Kerala	131400	Plastic is used for tarring roads	-
17	Karnataka	296380	Recycling, co-processing	75000 Tonnes were sent for recycling and 50000 Tonnes were sent for co-processing
18	Lakshadweep	46	Material Recovery facilities	-
19	Madhya Pradesh	121079	Co-processing, pyrolysis, road construction, recycle	Over 1,00,000 Tonnes of plastic waste are co-processed; 75000 Tones processed by recyclers; 2000 T are used in road construction; 150 Tonnes are used in a pyrolysis plant.
20	Maharashtra	443724	Co-processing, pyrolysis, road construction	Recycling & coprocessing (>2,70,000 T); Pyrolysis & Road construction > 5000 TPA each

21	Manipur	8293	recycling, coprocessing & road construction	-
22	Meghalaya	5043	Coprocessing to be initiated; Plastic usage in road construction started	-
23	Mizoram	7909	Road construction	-
24	Nagaland	565	road construction	-
25	Odisha	45339.4	construction of road	-
26	Punjab	92890	Recycling, road construction, co-processing, RDF plant, waste to oil	recycling: 23.62 TPD, Road Construction: 0.60 TPD, Co-processing: 0.042 TPD, RDF: 39.84TPD, waste to Oil: 3.39TPD and in other purposes 19.39 TPD
27	Pondicherry	11753	road construction and co-processing	-
28	Rajasthan	51966	Recycling	-
29	Sikkim	69	road construction	-
30	Tamil Nadu	431472	Road construction, pyrolysis,	655 tonnes of plastic waste used for constructing,

			co-processing	more than 400 Tonnes of waste used in pyrolysis plants, 20000 MT in cement plant for co-processing
31	Telangana	233655	Road construction, recycled, RDF, waste to oil, co-processing.	Road construction: 11.44 MT Recycled: 187 MT RDF: 330 MT Waste to oil: 17.2MT Co processing: 13.5 MT
32	Tripura	32	Road Construction	28 TPA.
33	Uttarakhand	25203	Road construction	-
34	Uttar Pradesh	161148	Co-processing and road construction, recycling	693 TPD
35	West Bengal	300236	Recycling, & Road construction	-

2.5 Source and application of NRPW

Non-recyclable plastic waste(NRPW) is plastic that can not be recycled by available conventional recycling methods i.e., plastic waste which can not be remolded on heating. Such material mainly consists of a multilayered structure, which may be made up of thermoplastic or thermoset material, but due to its complex structure, it can not be separated, hence called non-recyclable. (CPCB, April 2018). Non-recyclable plastic waste is mainly generated from food packaging industries, Pharmaceutical & cosmetics products industries, Electrical & electronic goods industries, Automobile industries, etc.

Table 4: Source and application of Non-recyclable plastic(CPCB, 2018 & CII, 2016)

Sources	Application
Food packaging industries	Multilayered films are used in the packaging of biscuits, namkeen, chips, edible oil, and juice, etc.
Pharmaceutical & cosmetics products	Multilayered packing is used for the packing of medicines & cosmetics.
Electrical & electronic goods	A multi-layer film such as bubble wrap and laminates is used for the packing of electrical and electronic goods.
Items used for food storage & serving	Thermocol products such as plates, cups, etc. to serve food & are also used as fillers in the packing of food items.
Transportation	Seat covers and fillings Seats, overhead compartments, headrests and armrests, Textile carpets, Roof liners, Curtains, Insulation panels, Sidewall and ceiling panels, Internal structures, including dashboards and instrument panels, Electrical and electronic equipment, Stereo components, Electrical and electronic cable coverings, Battery cases and trays, Car bumpers, GPS and other computer systems.

2.5.1 Plastic Waste from Cities and Municipalities

(Source: CPCB Report, 2019)

Table 5: Plastic waste in MSW from Cities and Municipality

SL. NO.	Cities and Municipalities	Total Municipal Solid Waste (MT/DAY)	Plastic Waste (Kg/MT)
1.	Lucknow (Dodouli Dumping yard)	1200 MT/ Day	59.03Kg/MT
2.	Allahabad(Badshi Bandh and Karamati chowki dumping grounds)	350 MT/day	53.89Kg/MT
3.	Chandigarh(Daddu Nagar site)	500 MT/ Day	30.98Kg/MT
4.	Delhi(Gazipur, East Delhi)	6800 MT/ Day	101.44Kg/MT
5.	Faridabad(Bandhwari Village)	700 MT/Day	112.95 Kg/MT

6.	JAMMU CITY(Bhagwati Nagar dumping ground)	300 MT/ Day	72.26Kg/MT
7.	Srinagar(Achan Saidpura dump site)	550 MT/Day	51.17Kg/MT
8.	Simla(Darini ka bagicha dump site)	50 MT/Day	44.502 Kg/MT
9.	AMRITSAR CITY(Bhagtawala dumping site)	550 MT/Day.	44.40Kg/MT
10.	DEHRADUN CITY(Sahastradhara dumping ground)	220 MT/Day	66.53Kg/MT
11.	AGRA CITY(chhalesar dumping site)	520MT/Day	78.87 Kg/MT
12.	MEERUT CITY(Lohia Nagar Hapur Road, Mangat Puram, Delhi Road dumping site)	52 MT/Day	64.22 Kg/MT
13.	VARANASI CITY(Sheer Govardhan and Tenura Mau Dam)	450 MT/Day	57.59 Kg/MT
14.	KANPUR CITY(Panci Bhausing dumping ground)	1600 MT/Day	66.86 Kg/MT
15.	PATNA CITY(Bairia)	220 MT/Day	57.25 Kg/MT
16.	RANCHI CITY(Jhiri Dump site)	140 MT/Day	59.20 Kg/MT
17.	JAMSHEDPUR CITY(Bhuiandhri Dump site)	28 MT/Day	33.55 Kg/MT
18.	DHANBAD CITY(Telipada & Matkudiya dumping yard)	150 MT/ Day	50.16Kg/MT
19.	LUDHIANA CITY(	850 MT/Day,	59.62Kg/MT

20.	CHENNAI CITY(Perungudi and Kodungaiyur dump sites)	4500MT/Day	95.42 Kg/MT
21.	BENGALURU CITy(Mavallipura Dumpsite)	3700 MT/Day	84.83Kg/MT
22.	COIMBATORE CITY(vellalur dumpsite)	700 MT/ Day	94.73 Kg/MT
23.	KOCHI CITY(Brahmapuram dump sites)	150MT/Day	62.88 Kg/MT
24.	MADURAI CITY	450 MT/Day	50.59 Kg/MT
25.	PORT BLAIR CITY	45 MT/Day	100.07 Kg/MT
26.	THIRUVANANTHAPURAM CITY(Vilappilsala dump sites)	250 MT/Day	60.22 Kg/MT
27.	PUDUCHERRY CITY(Karuvadikuppam dumping yard)	250 MT/ Day	250 MT/ Day
28.	KAVARATTI CITY(Common Depository Place)	24 MT/Day	120.92 Kg/MT
29.	HYDERABAD CITY(Jawaharnagar dumpsite)	4200 MT/Day	47.46Kg/MT
30.	VIJAYAWADA CITY(Pathapadu Pit No.10)	600 MT/Day	72.87 Kg/MT
31.	VISHAKHAPATTNAM CITY(Kapuluppada dumping ground)	334 MT/ Day	90.33 Kg/MT.
32.	AHMEDABAD CITY (Ahmedabad Municipal Corporation)	2300 MT/Day	105.07 Kg/MT
33.	DAMAN CITY	25 MT/Day	46.37 Kg/MT
34.	DWARKA CITY(Charakala Road (Vermi Plant	18 MT/Day	80.79 Kg/MT

	Compost)		
35.	GANDHINAGAR CITY	97 MT/Day	48.06 Kg/MT
36.	MUMBAI CITY	6500 MT/Day	62.81 Kg/MT
37.	NASIK CITY	350 MT/Day	58.22 Kg/MT
38.	PANJIM CITY(Animal welfare center)	25 MT/Day	44.71 Kg/MT
39.	PUNE CITY (Fursangi Processing Plant)	1300 MT/ Day	77.96 Kg/MT
40.	RAJKOT CITY	230 MT/Day	69.28 Kg/MT
41.	SILVASSA CITY(khadoli Village)	35 MT/Day	61.12 Kg/MT
42.	SURAT CITY(varachha and Anjana sites)	1200 MT/Day	124.68Kg/MT
43.	VADODARA CITY(Makarpura Tarsali Bye Pass NH.8)	600 MT/Day	45.69 Kg/Tons
44.	JAIPUR CITY(Meena Transport Site)	310 MT/Day	50.26 Kg/MT
45.	ASANSOL CITY(Kalpahari)	210 MT/Day	60.09 Kg/MT
46.	BHUBANESWAR CITY(bhuasuni dumping ground)	400 MT/ Day	79.79Kg/MT
47.	KOLKATTA CITY(dump site located at Dhapa Check Post)	3670 MT/Day	116.09 Kg/MT
48.	GUWAHATI CITY(Boragoan Dumpsite)	204 MT/Day	50.36 Kg/MT

49.	IMPHAL CITY (Lamphel)	120 MT/DaY	51.32 Kg/MT
50.	GANGTOK CITY(Martham dumping ground)	26 MT/Day	89.51 Kg/MT
51.	AIZWAL CITY(Tuirial dumping site)	107 MT/Day	79.48 Kg/MT
52.	ITANAGAR CITY (Karsengsa Place)	102 MT/Day	53.52 Kg/MT
53.	KOHIMA CITY(Kohima Dumping ground)	45 MT/ Day	50.13 Kg/MT
54.	SHILLONG CITY(Borapani dump site)	97 MT/Day	54.36 Kg/MT
55.	AGARTALA CITY(Happania Dumping site)	102 MT/Day	57.13 Kg/MT
56.	BHOPAL CITY(	350 MT/Day	65.94 Kg/MT
57.	JABALPUR CITY(Rental Dumping site)	400 MT/Day	51.75 Kg/MT
58.	INDORE CITY(Devgudariya Trenching ground Nemavar road)	720 MT/Day	88.05 Kg/MT
59.	NAGPUR CITY	650MT/Day	70.70 Kg/MT
60.	RAIPUR CITY(Sarona, Ring road No.1, near Kharun River)	224 MT/Day	106.07 Kg/MT
AVERAGE		**845MT/DAY**	**71.43Kg/MT**

2.6 EPR (Extended Producer Responsibility)

EPR refers to the responsibility of manufacturers and brand owners to manage product disposal after use. It is a type of reverse collecting system that ensures recycling of end-of-life, post-consumer waste. It is based on the well-known and significant international environmental law principle of Polluter Pays, which states that the polluter must pay to keep the environment clean and undamaged. (NITI Aayog – UNDP Handbook on Sustainable Urban Plastic Waste Management)

Extended producer responsibility may be defined as, "a policy principle to promote total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer of the product to various parts of the entire life cycle of the product, and especially the take-back, recycling and final disposal of the product" (Lindhqvist 2000)

Important definitions

(a) **"Brand owner"** refers to a person or business that sells any product with a registered brand label.
(b) **"Extended Producer's Responsibility"** indicates a producer's obligation for the environmentally sound management of a product till the end of its life;
(c) **"Importer"** means, unless otherwise specifically exempted, a person who holds an importer-exporter code number and imports or wants to import.
(d) **"Manufacturer"** means and incorporates a person, entity, or organisation involved in the manufacturing of plastic raw materials used as raw materials by the producer.
(e) **"Multilayered packaging"** implies any material used or designed for packaging, whether in the form of a laminate or co-extruded construction, that contains at least one layer of plastic as well as one or more layers of another material, such as paper, paper board, polymeric materials, metalized layers, or aluminium foil.
(f) **"Producer"** comprises enterprises or people who manufacture or import carrying bags, multilayered packaging, plastic sheets, or similar products, as well as those who use plastic sheets, covers made of plastic sheets, or multilayered packaging to package or wrap the product.

2.6.1 Indian ELV EPR Policy Implementation

From the knowledge of the EPR policy implementation in European Union (EU), Korea, Japan and Taiwan, we note that they have a specific legislation & policy to manage their ELVs efficiently. A separate ELV law is necessary within the framework of the extended producer responsibility and so these countries are having an EPR based ELV law which helped them in curbing the number count of ELVs on the road. These countries have designed tactics towards recovery of ELV because of environmental awareness, lack of availability of landfill sites and natural resource depletion. These countries are best example to understand the gap where India is lagging in its policies towards circular economy. The main points marked below is required to have a successful implementation of extended producer responsibility in India:

1. End users should willingly declare their vehicles as ELVs & there should be mandatory scrappage policy and its implementation by the Indian government.
2. There should be proper network of collection system of ELVs as there is lack of take back system.
3. Good salvage value of ELVs should be given by the manufacturers/ producers as compared to informal sector.
4. There should be good coordination between the local government such as municipality and other stakeholders such as the manufacturer/ producer/ importer.
5. The manufacturers should be mandated to design for efficient & ecologically sound recovery of products in ELVs.
6. Manufacturers and importers should setup separate handling facility to deal with the ELVs they receive.
7. Manufacturers should design for disassembly, adopt material substitution, adopt labelling of parts and reduce the variability in material usage.
8. There should be an electronic fund management system to keep a record of the recycling fees that is needed at the time of disposal of ELVs.
9. Manufacturers/ importers should impose an advance recycling fees on the first user at the time of sale of the vehicle which will be collected in the ELV management fund.
10. Proper auditing committees should be appointed by the government to monitor the ELV fund flow.

2.6.2 Proposed Framework for EPR implementation in Indian context

Based on the country-wise examples, the Indian EPR policy should be setup to bring informal sector and formal sector together with the help of the manufacturers/ importers by setting up recycling plants and encouraging the take back of the ELVs through proper channeled network without any adverse effect on environment. In India there is no proper fund management system to handle the cost of recycling as other developed countries have. This fund that should be collected from the users by the manufacturers/ dealers can be used to develop infrastructure for the recycling of ELVs.

As in India, we do not have any shredder facility for ELVs because it requires huge investment, this fund can be used to setup a shredding plant which is the need of the hour in India. On the basis of the prevailing system of EPR implementation in developed countries, we have proposed a model for the Indian context as given in figure as shown.

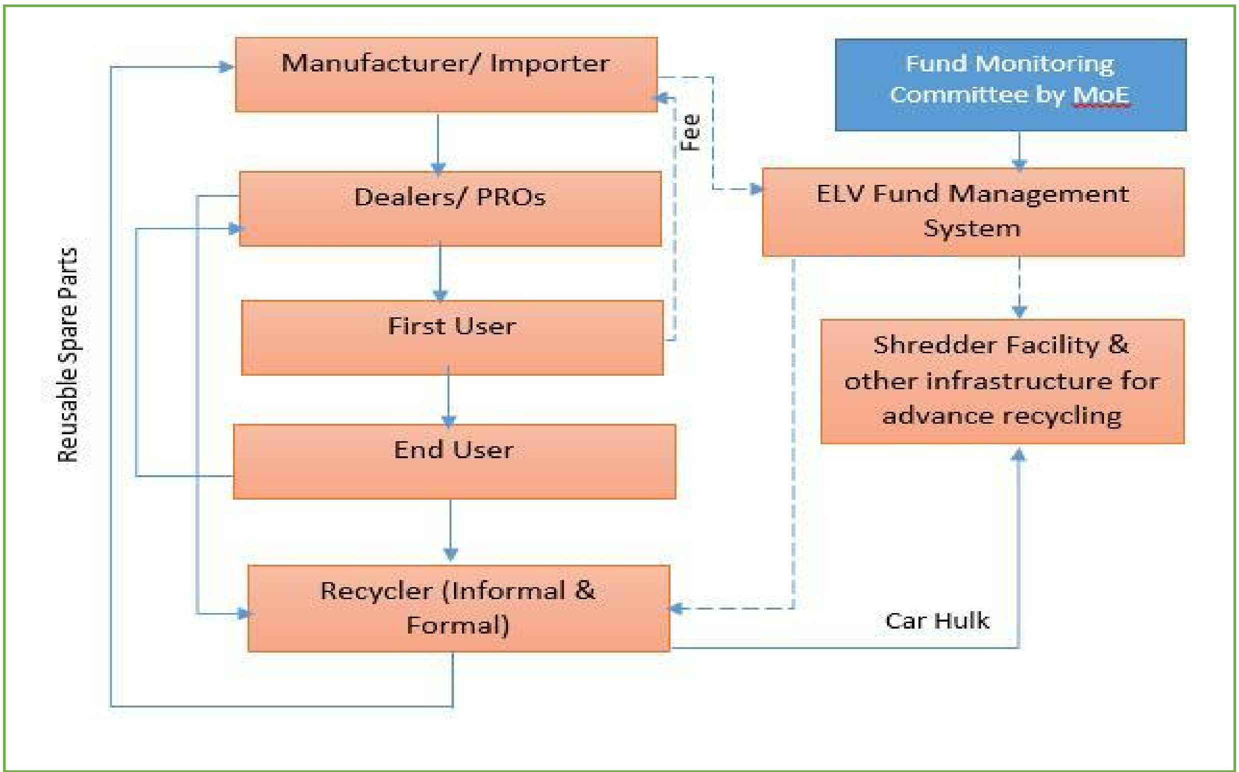

Figure 7: Proposed framework for EPR implementation in India

This flowchart depicts the proposed flow of vehicles from new vehicle to used scrap vehicle and the stakeholders involved at each stages of the vehicle life. At the top notch management there is monitoring committee formed by the Ministry of Environment just to ensure proper ELV fund management. The dotted blue lines depict the money flow whereas the solid blue lines depict the ELV flow.

2.7 Potential of plastic waste generation from ELV

Plastic materials are increasingly being used in the automotive industry, for both environmental and economic reasons. Their low density decreases automobile weight, lowering fuel consumption and gas emissions, while their well-known flexibility and durability allow for a wide range of design options, lowering production and maintenance costs (EC, 2020). Every year, approximately 6 million vehicles in Europe reach the end of their useful life and are deregistered through official programmes (Eurostat Database, 2020), becoming end-of-life vehicles (ELVs).

Plastic from scrapped vehicles is currently managed in the European Union without attention for polymer recovery. reducing the amount of residue sent to combustion or landfill (from 984 kt/y to 232 kt/y) and enhancing the impact of major environmental categories In comparison to the existing scenario, carcinogens, non-carcinogens, global warming, and non-renewable energy are reduced by 138%, 100%, 42%, and 114%, respectively.

2.8 Definition of ELV waste

Natural ELVs and Premature ELVs are the two types of ELVs. Natural ELVs are vehicles that have reached the end of their useful life due to wear and tear. Premature ELVs are vehicles that have reached the end of their useful life due to accidental causes such as an accident, fire, flood, or vandalism damage (ASM 2015). According to the definition stated in the European Union Directive of 2000, a 'end-of-life' vehicle is one that has been discarded. When a vehicle is no longer safe to drive or does not meet emission requirements, the last owner usually identifies it as an ELV. In some circumstances, a vehicle is considered obsolete just because it is old (guidelines for environmentally sound management of end-of-life vehicles, CPCB).

2.8.1 Global generation of ELV waste

End-of-life vehicles (ELV) have become a worldwide concern as automobiles have grown in popularity. Table shows automobile ownership (including automobiles, buses, and trucks, based on 2010 data) and the estimated generation of ELV. In 2010, global automobile ownership surpassed one billion. The EU and the US accounted for half of the total, with 270 million and 240 million units, respectively. According to another report, global automotive ownership is expected to reach 2.4 billion by 2050. As a result, proper ELV recycling/treatment techniques are an essential requirement all over the world. (Shin-ichi Sakai et al. 2014)

Table 6: Global and country/state estimates of automobile ownership and ELVs. (Shin-ichi Sakai et al. 2014)

Country	Automobile ownership (units)	Deregistered automobiles (units/year)	Number of ELVs (units/year)
European Union	271,319,000	14,077,000	7,823,211
Germany	45,261,188	2,570,137	500,193
Italy	41,649,877	1,835,293	1,610,137

France	37,744,000	2,002,669	1,583,283
England	35,478,652	1,810,571	1,157,438
Spain	27,750,000	996,718	839,637
Russian Federation	41,224,913	300,000	Not available
USA	239,811,984	20,419,898	12,000,000
Canada	21,053,994	1,321,658	1,200,000
Brazil	32,100,000	1,058,064	1,000,000
Japan	75,361,876	4,080,000	2,960,000
China	78,020,000	6,000,000	3,506,000
Korea	17,941,356	849,280	684,000
Australia	15,352,487	600,311	500,000
Subtotal	**792,185,610**	**57,921,599**	**29,673,211**
Global total	**1,016,763,420**	**15,805,275**	**40,176,051**

2.8.2 ELV Waste generation in India

Because of India's growing vehicular population, it is expected that more than 87 lakh vehicles will achieve ELV classification by 2015, with two-wheelers accounting for 83% of the total. It is anticipated that by 2025, there will be 2,18,95,439 ELV vehicles. Two-wheelers are likely to account for 80% of this total. (Akolkar et al. 2015).

Table 7: Total ELV count in 2015 (Akolkar et al. 2015)

Type of vehicle	Total ELV count in 2015
Two Wheelers	72,89, 442
Three Wheelers	2,62,439
Private Cars/SUVs	7,21,558
Commercial passenger Vehicles	46,522
Commercial goods vehicles	4,11,230
Total vehicle likely to be ELV in 2015	87,31,185

Table 8: Total ELV count in 2025 (Akolkar et al. 2015)

Type of vehicle	Total ELV count in 2015	Total ELV count in 2025
Two-wheelers	7,289,442	17,723,951
Three-wheelers	262,439	757,932
Private cars/SUVs	721,558	2,809,966
Commercial passenger vehicles	46,522	94,757
Commercial goods vehicles	411.230	1,188,833
Total vehicles likely to be ELV	8,731,185	21,895,439

2.9 Overview of different technologies that may be applied in utilization of different waste and NRPW

2.9.1 Co-processing in cement kilns

Co-processing is the replacement of natural mineral resources (material recycling) and fossil fuels like coal, petroleum, and gas in industrial processes, primarily in energy-intensive industries (EII) like cement, lime, steel, glass, and power generation. Waste is used as raw material, as a source of energy, or both. Waste materials used for Co-processing are referred to as alternative fuels and raw materials (AFR).

All types of waste can be effectively disposed of without any harmful emissions due to the high temperature and long residence time. Plastic waste is fed into the kiln during co-processing as an alternative fuel and raw material (AFR). In this process, energy is recovered from the burning of the plastic waste, and the inorganic part of the waste gets added with clinker. The states where cement plants are situated are incorporating this waste into energy technology. Some of these states are Himachal Pradesh, Madhya Pradesh, Odisha, Tamil Nadu, Karnataka, Gujarat, etc. The process of co-processing plastic waste in cement kilns is illustrated in the flow diagram. **(CPCB, September 2017)**

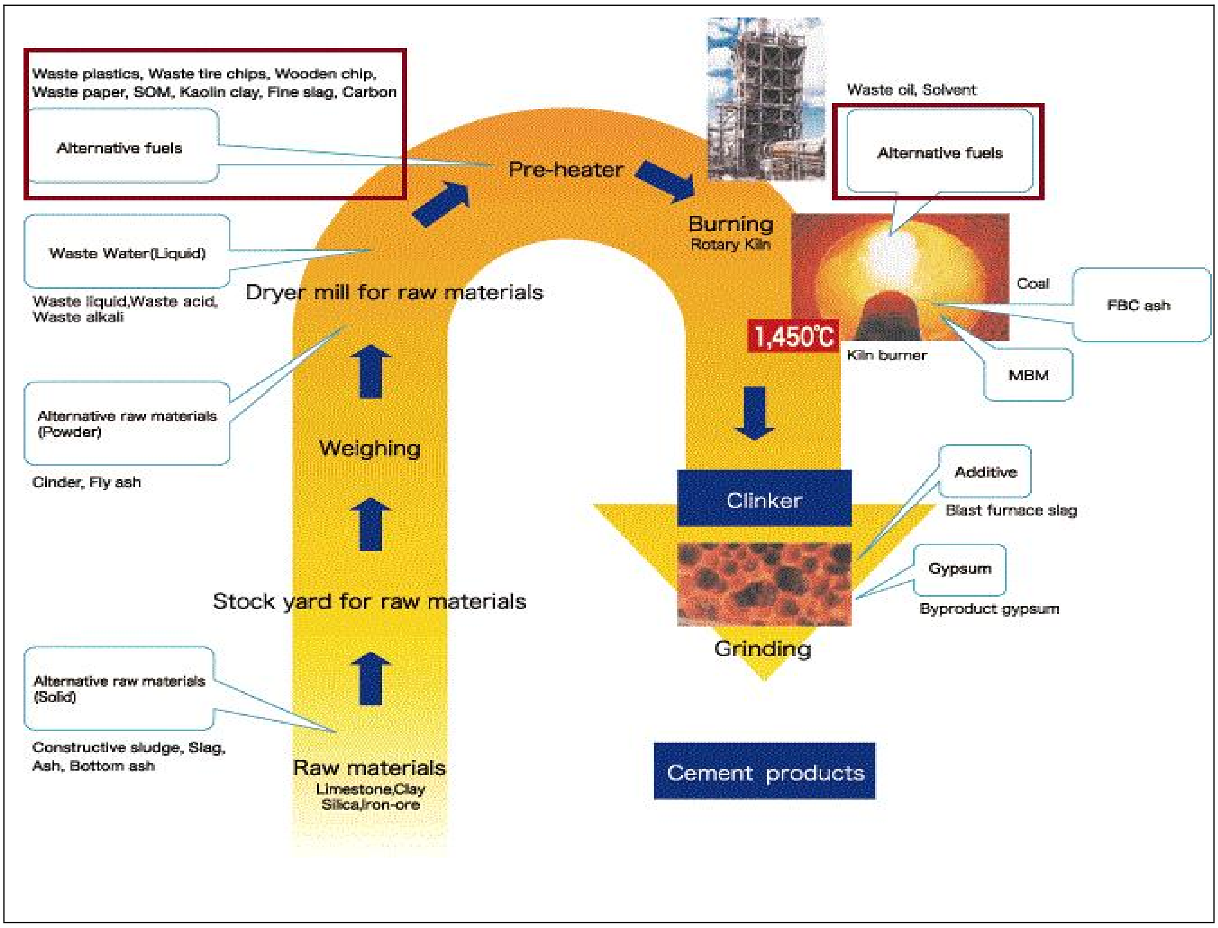

Fig. 8: Process flow diagram for co-processing of plastic waste in cement kilns (Source: Ghosh S K et al., 2019)

2.9.2 Incineration with energy recovery(olcstage.worldbank.org)

The term "incineration with energy recovery" refers to the controlled combustion of waste in presence of oxygen at temperatures of 850°C or higher in order to recover heat and energy. Modern incineration facilities include a storage area to sort and store incoming waste, a crane to lift the waste into the combustion chamber, a heat recovery system that uses the heat from incineration to produce steam in a boiler to generate electricity, an ash handling system to capture non-toxic bottom ash (ash that collects at the bottom of the system), and an APC system to capture toxic particles that rise with the gaseous emission (fly ash). The daily capacity of MSW for incineration facilities can range from 5 to over 1,000 tonnes, however the majority of facilities burn between 200 and 700 tonnes per day.

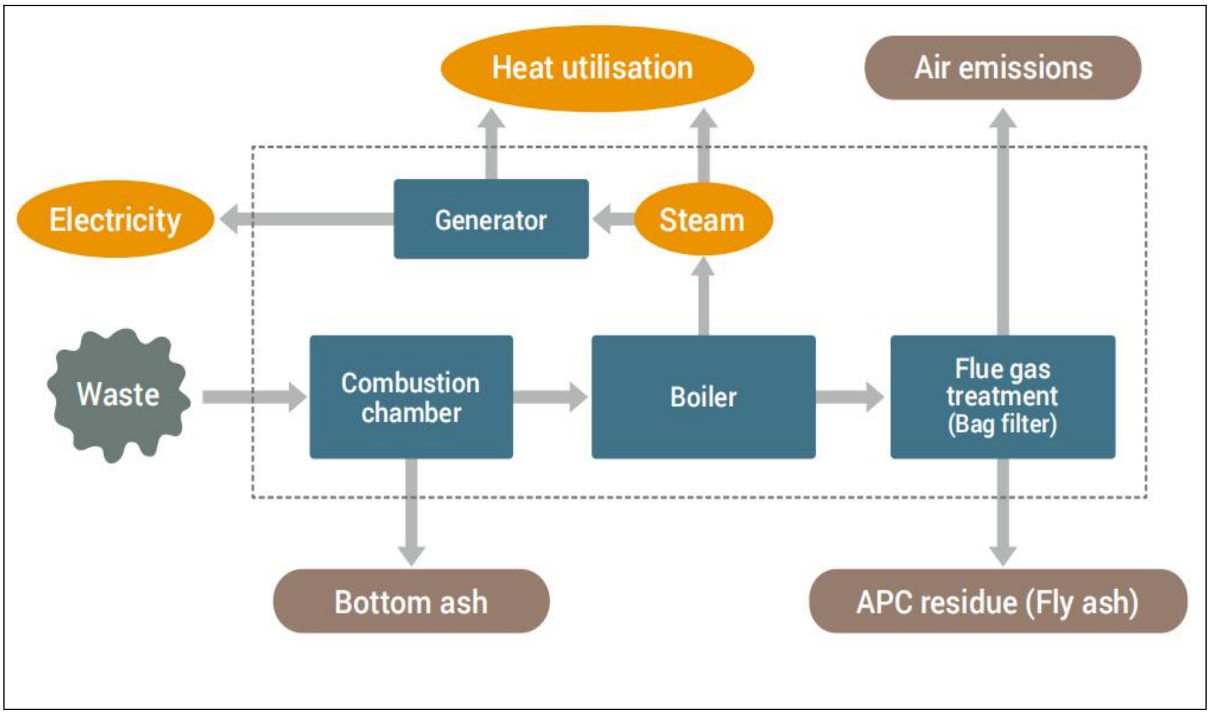

Fig. 9: Typical flow chart of WtE incineration plant (Source: UNEP,2020)

The main difference between incineration and open or uncontrolled burning is that incineration uses a container plant where combustion takes place at a very high temperature, reducing the production of toxic air pollutants. A steam generator and heat exchanger are both capable of producing electricity from heat and steam. Open burning takes place at a significantly lower temperature exposed to the atmosphere.

Table 9: Comparison of incineration and open burning

	Incineration	Open burning
Control of burning	Strict limits on the volume and types of waste handled, as well as the furnace temperature	Uncontrolled
Energy Recovery	Potential for heat or electricity	There is no potential.
Toxic Emissions Pollution	Low because of high-temperature combustion, advanced APC equipment, and often strict government emission rules.	compared to emissions from incineration, may be 45 times higher. Instead of being collected, they are released into the atmosphere.

2.9.3 Pyrolysis - plastic to fuels

Pyrolysis is a common technique for converting plastic waste into energy in the form of solid, liquid, and gaseous fuels. Pyrolysis is the thermal decomposition of plastic waste at different temperature (300-900°C) in the absence of oxygen to produce liquid oil. (Rehan et al., 2017)
Pyrolysis converts waste into high-energy liquid and gaseous materials, making it a useful method for recycling energy from waste. Depending on the pyrolysis process and materials used, temperatures for the pyrolysis of plastic waste range from 200°C to 1300°C. The typical process of pyrolysis of plastic waste is depicted in Fig.10. First, the plastic is consistently heated to a fixed temperature range with little temperature variation, and then oxygen is evacuated from the pyrolysis chamber. The carbonaceous char (byproduct) is then processed before being utilised as a heat insulator to limit heat transfer to the plastic. Finally, pyrolysis specific fractionation and condensation give a high-quality distillate. Aside from plastic waste, biomass is an essential fuel that can be utilised in the pyrolysis process to produce bio-char, bio-oil, and gases. The organic components in the biomass substrate begin to break down about 350 to 550 ° c and continue until 700 to 800 ° C, Long polymeric cellulose chains, lignin hemicellulose, pectin, and other substances account for the majority of biomass. Bio-char is the main byproduct of the low temperature (less than 450 °C) and low heating rate pyrolysis process. A larger amount of ash and gaseous products are produced at temperatures more than 800 ° c and a high heating rate. Bio-oil is often produced at intermediate temperatures and comparatively high heating rate.

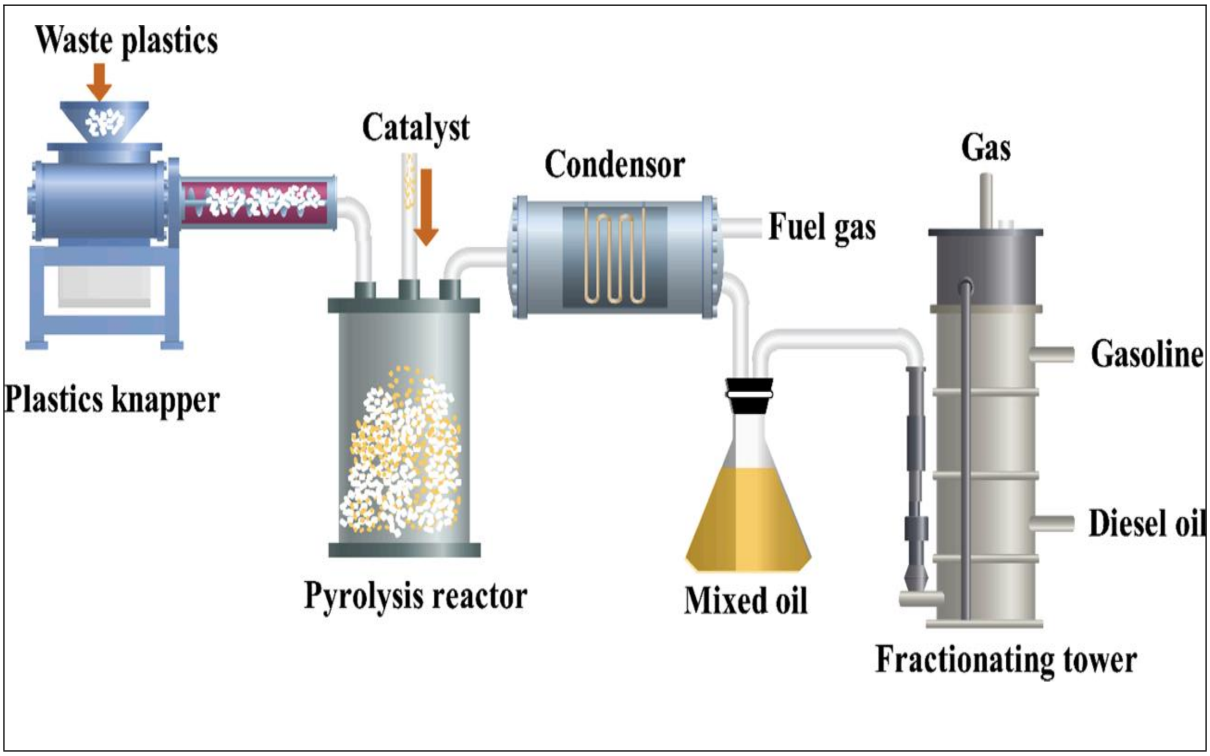

Fig. 10: Flow chart of the process of plastic waste pyrolysis

There are various categories of pyrolysis processes based on working parameters such as temperature, heating rate, and residence time (Fig. xxx). It can be broadly divided into three categories: slow pyrolysis, fast pyrolysis, and flash pyrolysis. Other categories of pyrolysis include hydro-pyrolysis, oxidative pyrolysis, catalytic pyrolysis, steam pyrolysis, vacuum pyrolysis, microwave pyrolysis, plasma pyrolysis, and electrical heating pyrolysis shown in figure 11, and the major operational parameters for pyrolysis process are shown in Table 10.

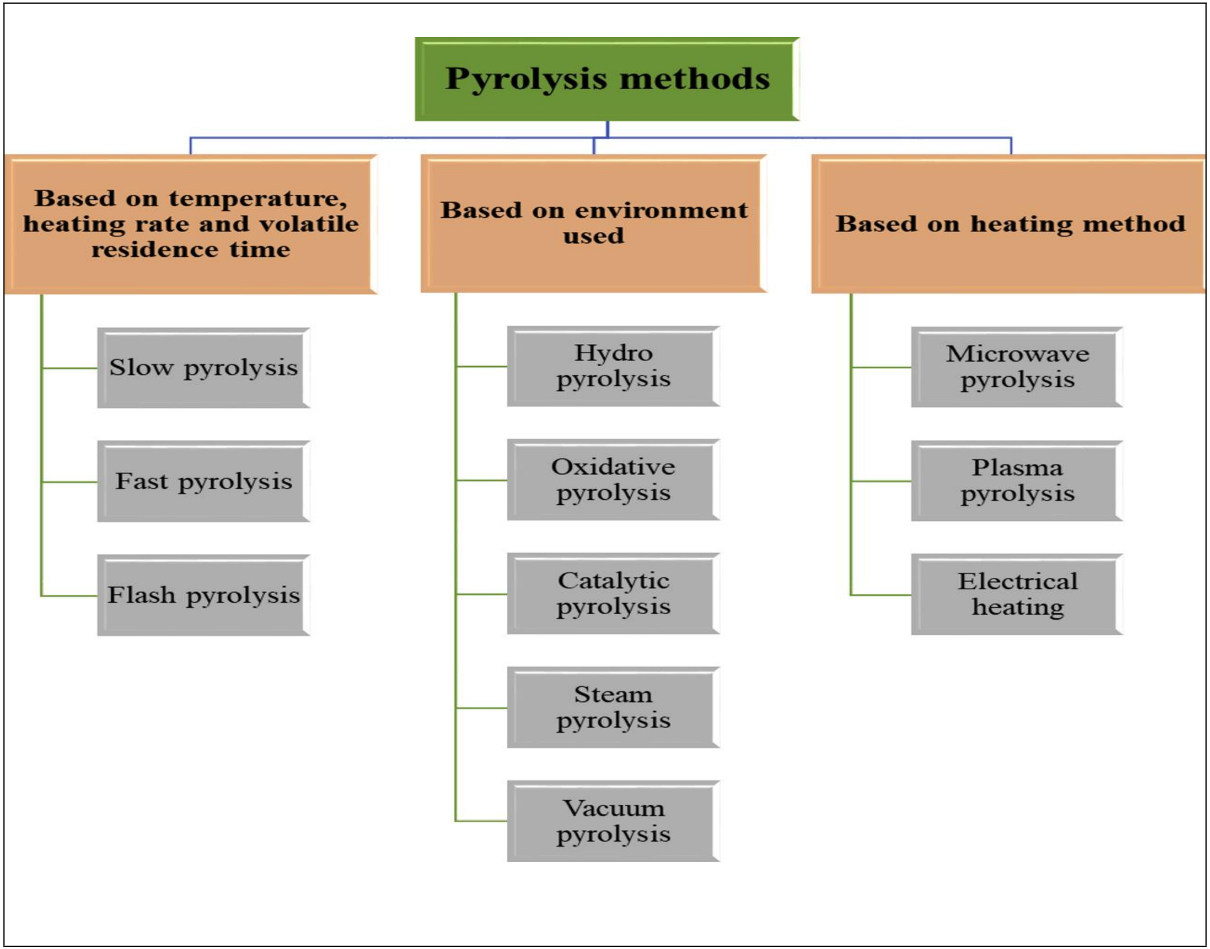

Fig. 11: Pyrolysis process based on various categories

Table 10: Important parameters for pyrolysis process

SL NO.	Parameters	Slow/ conventional pyrolysis	Fast pyrolysis	Flash pyrolysis
1.	Temperature (◦C)	550 ~ 900	850 ~ 1250	1050 ~ 1300
2.	Heating rate (◦C/ s)	0.1~ 1	10 ~ 200	>1000
3.	Particle size (mm)	5 ~ 50	<1	<0.2
4.	Solid residence (s)	300 ~ 3600	0.5 ~ 10	<0.5

2.9.4 Using NRPW in road construction

The use of non-recyclable plastic waste in road construction must follow the IRC: SP:98-2013 titled "Guidelines for the use of waste plastic in the hot bituminous mix (dry mixing) in wearing courses". In road construction, plastic waste is mixed with bitumen. Nowadays many roads have been constructed with this technology.
First of all, waste plastics are collected from different sources. Then they are segregated from mixed MSW. Chlorinated/brominated plastic waste is also screened. The segregated plastic waste goes for drying. The dried plastic waste is then shredded to a size of 2-4mm and heated. The heated plastic is mixed with aggregate where the aggregate gets coated by the plastic. Hot bitumen is blended with the coated aggregate. Bitumen is mostly utilised here for laying and compaction. Plastic waste is being used in road construction in many states, including West Bengal, Himachal Pradesh, Tamil Nadu, Nagaland, Pondicherry, etc.
Characteristics of the Polymer-Bitumen Road: -

- Increased Marshal Stability Value for a stronger road.
- Improved resistance to rainwater and water stagnation.
- There will be no stripping and no potholes.
- Improved mix bonding and increased binding.
- Decreased aggregate pores, which results in reduced rutting and ravelling.
- One tonne of plastic is utilised for every 1km x 3.75m of road, saving one tonne of bitumen in the process.
- The cost of road construction is reduced since bitumen is saved.
- Adding value to waste plastics .(CPCB)

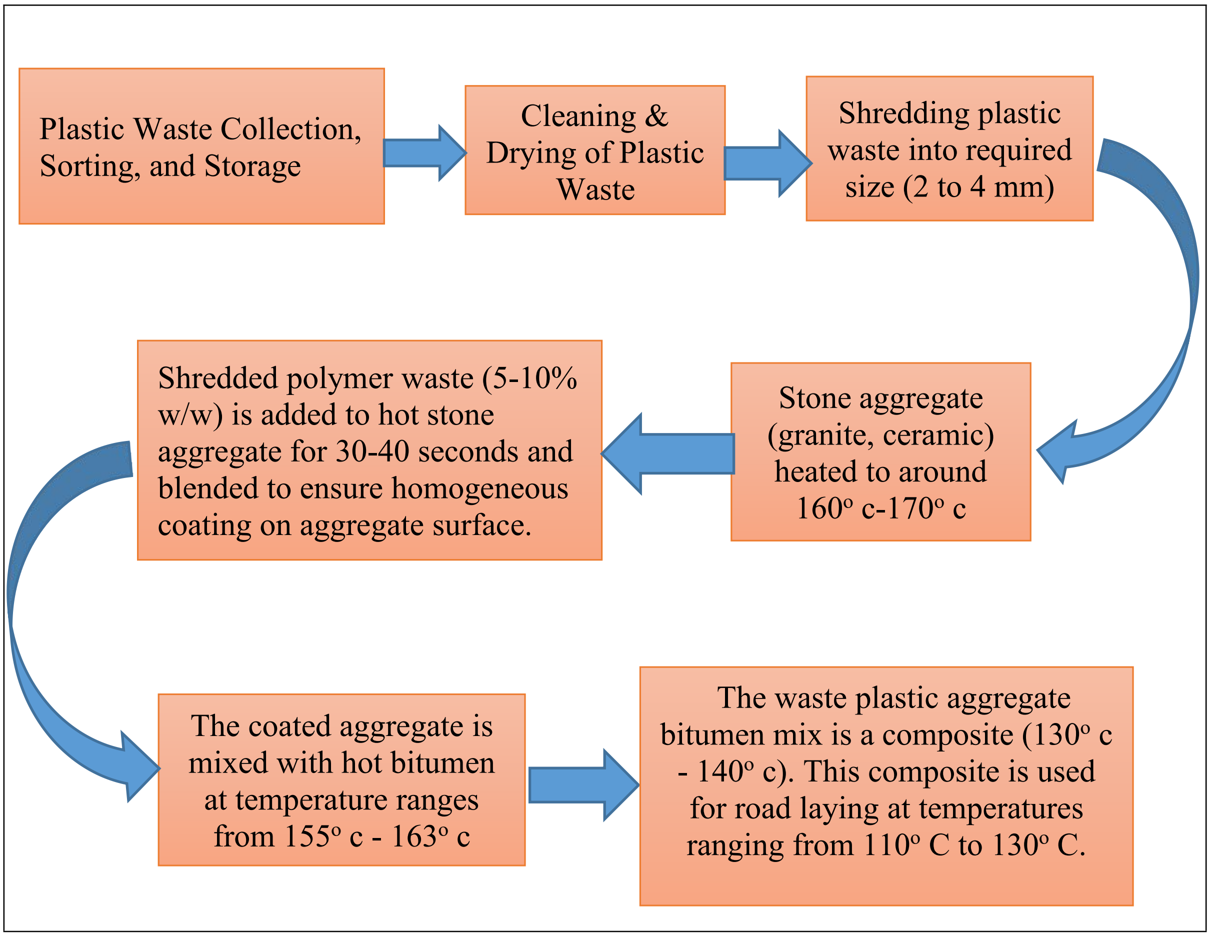

Figure 12: Flow diagram of Construction of Bitumen polymer road (CPCB)

2.10 Co-processing

It refers to the use of waste as a source of energy (Alternative fuel), raw material, or both to replace natural mineral resources and fossil fuels such as coal and natural gas in energy-intensive industries such as cement, steel, and power generation, etc. Co-processing is a proven sustainable development concept that conserves natural resources by reducing demands, pollution, and landfill space ultimately leading to a reduction in the environmental footprint. Co-processing technology is unique because it comprises both material recycling and energy recovery within an existing industrial process.

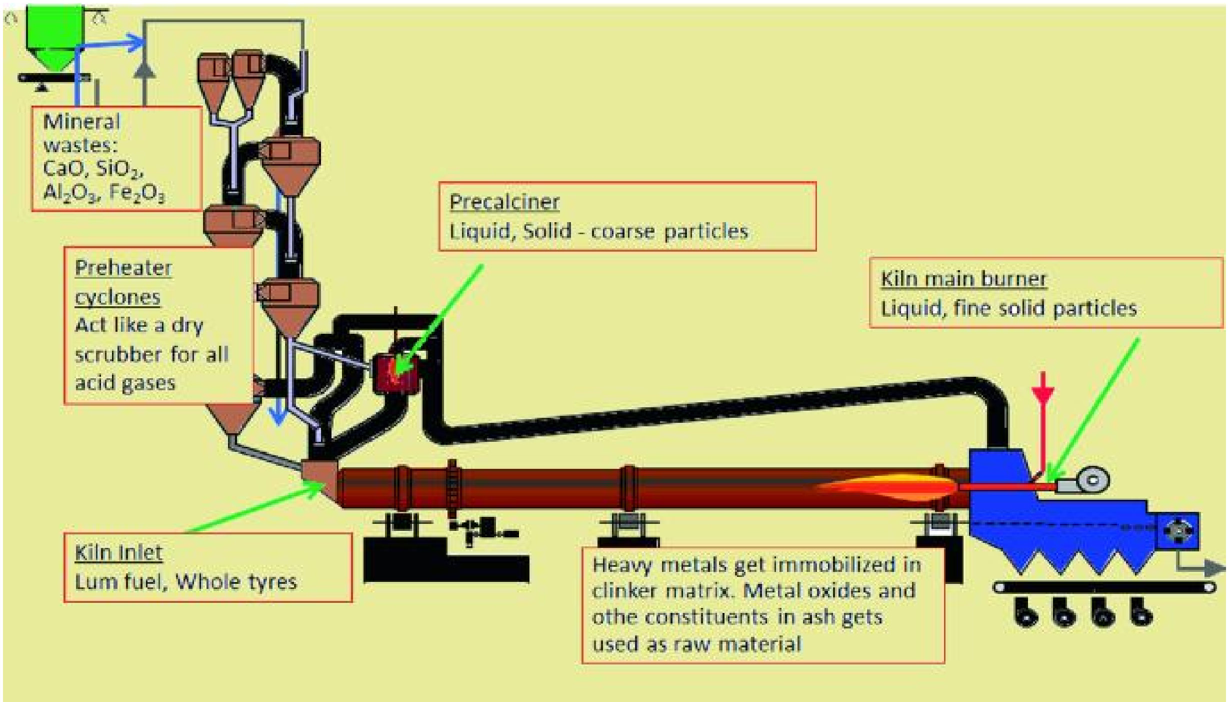

Figure 13: Different feeding point of waste in kiln (Ghosh S. K. et al., 2021)

The entry of waste into the kiln system for co-processing is determined by the properties of the waste material, as shown in Fig.13. The following are the waste's different characteristics.

- Lumpy waste: Tyres, waste drums, and waste-filled bags are all examples of waste. These are fed into the kiln at the inlet.
- Coarse solid waste: coarsely shredded plastic and RDF material, as well as solid portions These are fed into the calciner.
- Fine solid waste: Finely shredded plastics, RDF, and powdered material are co-processed through the main burner.
- Liquid wastes: Organic and aqueous liquids These are fed into the pre-calciner and the main burner [atomization is required]. (Source: S. K. Ghosh et al., Sustainable Management of Wastes Through Co-processing)

Currently, for India, the thermal substitution rate is about 4-5% as compared to >40% in Europe and >70% in Norway. So, India has enormous potential for using waste as a source of energy and raw material in cement kilns.

The economic and environmental benefits of Co-processing of RDF in a kiln are much greater than other plastic waste management techniques such as Incineration, Pyrolysis, and Gasification.

- Complete destruction of waste streams due to high temperatures (1450-2000 ◦c), alkaline environment, oxygen excess, and long residence time
- The specific temperature range (1450-2000 ◦c) doesn't allow the formation of dioxins and furans.
- The ash component of RDF is fully utilized for the raw material requirement for clinker formation. So, these processes don't leave any residue that needs to be landfilled.
- Here the waste substitutes the fossil fuel resulting reduction in greenhouse gas emissions and all the emissions are within the range of CPCB.
- The energy and mineral value of the waste materials are recovered resulting preservation of non-renewable fossil fuels and natural resources

The long residence time and high temperature in the cement kiln about 1450 ◦c makes the cement kiln well suited for utilizing a wide range of waste streams with more efficiency in energy and raw material recovery in an environmentally friendly manner(Kare, 2012). The mineral part of the waste is utilized as the raw required for clinker production and the combustible part provides the energy required for clinker production. As a result, 100% of the waste input is recycled or utilized without producing any additional residue.

2.10.1 Alternative fuel and raw material

It refers to properly selected waste and by-products that can be co-processed in cement manufacture (CSI, 2014). Alternative Fuels (AF) contain recoverable energy content (calorific value), which substitutes energy needs from a portion of conventional fossil fuels. Alternative Raw Materials (AR) comprise useful minerals such as calcium, silica, alumina, iron, and sulphur and can be used to replace natural raw materials in clinker manufacture or mineral elements in cement production. Because of the detrimental impact on products and processes, every waste cannot be used in co-processing. There are some criteria to consider for the selection of waste as an AFR for co-processing in cement kiln are as follows:

Types of AFRs

There are five types of AFRs.

1. Gaseous substances like landfill gas, pyrolysis gas, and coke oven gases.
2. Hydraulic oils, low-chlorine wasted solvents, insulating oils, distillation byproducts, lubricating, and vegetable oils and fats are examples of liquids.
3. Planer shavings, granulated plastic, powdered waste wood, animal flours, sawdust, fine crushed tyres, agricultural residues, dry sewage sludge, and food industry residues can all be pulverised.

4. Crushed tyres, waste wood, re-agglomerated organic matter, and rubber/plastic waste are examples of coarse waste.
5. Lump such as material in sacks and drums, entire tyres, and plastic bundles,
Mixing and homogenization will improve trash feeding and combustion behaviour. To avoid risks, waste should only be mixed according to a recognised and documented procedure.

Pre-Processing of AFRs

There are several waste pre-processing procedures these are as follow

a) Mixing liquid wastes to get the desired level of composition, heat content, and/or viscosity.
b) Packaged waste and bulky combustible waste are treated by shredding, crushing, shearing, and other methods.
c) wastes being mixed in a bunker.
d) To produce refuse-derived fuel (RDF) by the processing of source-segregated combustible garbage and/or other non-hazardous material.

Co-processing of AFRs

The waste categories that can be accepted for co-processing at a specific plant are determined by the local raw material and fuel chemistry, as well as the availability of equipment for handling, feeding, and controlling waste materials.

a) Input control

Consistent long-term availability of appropriate wastes is required to maintain stable conditions during kiln operation. It is necessary to specify and control the content of various elements of concern in them such as metals, VOCs, fluorine, sulphur, chlorine, nitrogen, and other elements are among them. Their product and/or process limitations must be established and defined. While feeding waste to the kiln, it is important to make sure that the waste materials are getting exposure to:

- Sufficient mixing conditions.
- Sufficient oxygen.
- Sufficient retention time.
- Sufficient temperature.

The appropriate feeding point for the waste is determined by the waste type and composition. If waste contains organics, it should not be fed as part of the raw mix feed and should not be fed during start-up and shutdown. Automated monitors should be used to alert operators; for example, in the event of a sudden pressure drop caused by a pipe rupture or pump failure, a pressure transducer should automatically turn off the waste fuel pump. The pressure transducer is located in the waste piping near the kiln's entrance. When the normal fuel or feed supply and/or the combustion air flow are interrupted, interlocks should automatically stop the flow of waste. When CO levels indicate a problem, interlocks should also stop the flow.

b) Selection of the feed point

A constant feed rate and waste material quality are required to ensure that the use of AFRs does not disrupt the kiln's smooth operation. This is also necessary to ensure that the site's normal environmental performance or product quality is not compromised. Depending on the type of waste being used, the feed point for wastes into the kiln must be chosen.

- For co-processing highly chlorinated organic compounds and persistent organic pollutants, only the main burner must be used (POPs). This is done to ensure that their destruction occurs to the desired level due to the kiln's long retention time and high combustion temperature. Other feed points are chosen only when tests show high levels of destruction and removal efficiency (DRE).
- High volatile organic content AFRs need to be fed directly into the high-temperature zones of the kiln system.

2.10.2 Guidelines for use of alternative fuel and raw material in cement kiln

The prevention of unsuitable and unacceptable wastes from being co-processed is ensured through the principle of these guidelines and to ensure that the co-processing activity doesn't influence emissions from co-processing activity.

Common concerns of AFR co-processing in cement kilns are the following:

- Spills, accidents, and exposure while handling.
- Emissions during handling/pre-processing and co-processing.
- Contamination of the product. (Source: S. K. Ghosh et al., Sustainable Management of Wastes Through Co-processing)

As per the CPCB guidelines any waste material can be used as an alternative for fuel and raw material in a cement plant if they satisfy any one of the following:

- If GCV of the material > 2500 Kcal/kg and raw material = 0%
- If ash content > 50% and raw materials in ash > 80%
- If raw material > 0% and GCV of the balance > 2500 Kcal/kg
- Solve the local waste management problem

Banned wastes:

The following waste materials are not permitted for co-processing. Some are prohibited materials for both pre-processing and co-processing. Some industries may exclude additional materials due to local circumstances, statutory requirements, or company policy.

Materials Banned for pre-processing and co-processing	Materials Banned for co-processing after pre-processing
1. Infectious and biological active medical waste. 2. Explosives. 3. Asbestos. 4. Radioactive waste. 5. Unknown/unidentified wastes.	1. Entire Batteries. 2. Electronic waste. 3. Mineral acids and corrosives. 4. Unsorted municipal waste.

2.10.3 Refused derived fuel (RDF):

Solid waste from the municipalities, and industry can be converted into alternative fuel so-called RDF by mechanical and combined mechanical biological treatment. The RDF production principle is to recover quality fuel fractions from waste, particularly by removing recyclable particles such as metal and glass, and to convert the raw waste into a more usable form of fuel with uniform particle size and higher calorific value than raw MSW.

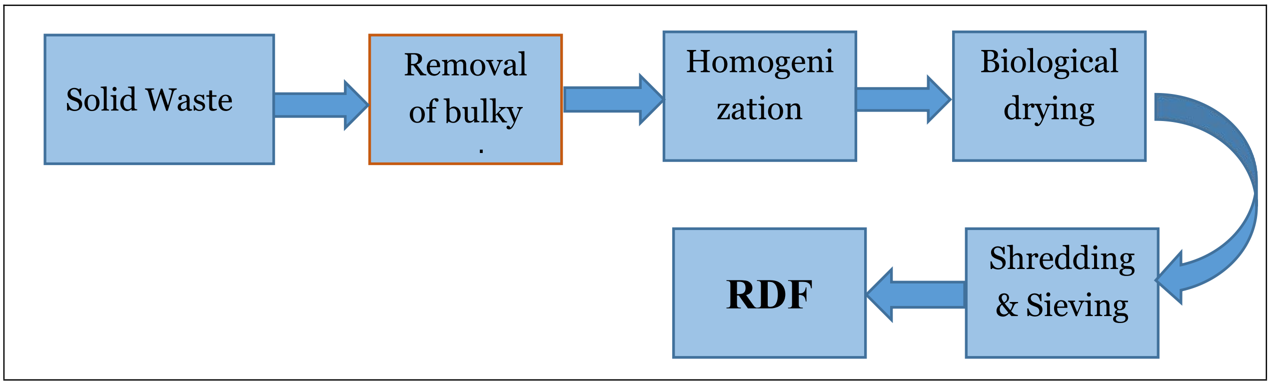

Figure 14: Generic process flow of MBT for the generation of RDF (GIZ, 2017)

There are different grades of RDF available. These grades depend on the size, ash content, moisture content, chlorine, sulpher and calorific value of respective RDF product.

Table 11: Standard of RDF based on various parameter

Sl.no.	Parameters	RDF - Grade III	RDF - Grade II	RDF -Grade I
01	Intended Use	For co-processing directly or after processing with other waste materials in cement kiln	For direct co-processing in cement kiln.	For direct co-processing in cement kiln
02	Size	< 20 mm depending upon use in ILC or SLC, respectively		
03	Ash – maximum permissible	<15 %	<10 %	<10 %
04	Moisture – maximum permissible	< 20%	<15 %	<10 %
05	Chlorine –maximum permissible	< 1.0 %	< 0.7	< 0.5
06	Sulphur – maximum permissible	<1.5 %		
07	Net Calorific Value (NCV) – in Kcal/kg (Average figure of every individual consignment)	>3000 KCal/kg net	>3750 KCal/kg net	> 4500 KCal/kg net
08	Any other parameter	RDF – any offensive odour to be controlled.	RDF – any offensive odour to be controlled.	RDF – any offensive odour to be controlled.

2.11 Research gap

As per the literature review I have found that there are still some points to discussed are as follows:

- Importance of Reverse Logistics implementation in Automotive industries and and problem faced by industries during the implementation of Reverse logistics.

- Lack of practices and policy to handling End-of Life Vehicles (ELVs) such as collection, dismantling, shredding, recycling and disposing etc.

- Method of segregation and collection of NRPW from dumpsite as well as from household and market.

- Potential of dumpsites for NRPW as raw material for co-processing in cement kiln.

- Potential of ELV plastic waste to be utilize for co-processing in cement plant.

- Impact on scavenger involved in waste supply chain and processing of waste towards Co-processing.

2.12 Research question

- What is the importance of reverse logistics in the Automotive Industry?

- What are the existing problems of reverse logistics in the Automotive Industry?

- How to improve the efficiency of reverse logistics management based on an environmental view?

- How reverse logistic of ELV works in automobile industries?

- What are the problems that arise in the identification and quantification of plastic waste management?

- What are the major sources of NRPW and how much quantity of NRPW is generated in India and efficient way of collection and segregation of NRPW from source?
- What is the potential of ELV plastic waste to be utilize for co-processing in cement plant?

- What is the potential of ELV plastic waste to be utilize for co-processing in cement plant?

- What is the role and impact on scavengers involved in the waste supply chain towards co-processing?

2.13 Research objective

- To analyse the importance of reverse logistics in automotive industries and identify the challenges while implementing the reverse logistics.

- Analyse the flow process of End-of Life Vehicle by utilizing reverse logistic system.

- To identify and quantify NRPW from major sources and identify the problem occurs during collection and segregation of NRPW from different sources.

- Collect and analyze data for co-processing of plastic waste used in cement plants in India.

- To analyse the quantity of ELV plastic waste generated which can be used for co-processing in cement plant.

- To design a ELV recycling model to understand the scope for co-processing of ELV plastic waste.

- Analyse the impact on scavenger involved in waste picking and processing by conducting interview.

CHAPTER 3

CO-PROCESSING A TRANSITION TO CIRCULAR ECONOMY

3.1 Introduction

A sustainable development approach called the circular economy (CE) is being put out to address the pressing issues of resource shortages and environmental deterioration. The creation of policies and strategies to minimize the damaging effects of production and consumption on the environment is the result of the rapid environmental deterioration occurring throughout the world. Several nations have passed legislation and regulations to establish the circular economy's principle for recycling (Heshmati A, 2017).

For the last 150 years, the linear economy model has dominated the evolution of the industry. The traditional linear economy model idea is based on the product that are produced from raw materials, used, and then discarded as waste. This model is sometimes described as a to-take-make-use-destroy paradigm. The influence on societal capital, including human resources, as well as on the preservation of natural resources are not taken into account by this approach. The circular economy model, on the other hand, takes into account elements that can lower waste and more closely monitor resource consumption. By reusing existing materials, the circular economy reduces the demand for new, raw materials, and this approach can be achieved by rethinking how the product operates in a closed loop (Govindan K, 2018).

It is necessary to sift from a linear economy to a circular economy before an increase in demands for natural resources put pressure on the environment. Reducing the consumption of natural resources, waste production, greenhouse gas emissions, hazardous substance use, and shifting to renewable and sustainable energy sources are some of the target objectives of the circular economy. This will lessen the burden on the supplier. The circular economy can improve value production in each link of the system while decreasing value destruction in the overall system (Bastein et al. 2013).

Additionally, a circular economy will reduce waste through product recycling and reuse, which will create positive effects on the environment and the economy. It will also extend the useful life of items and present the possibility of adding additional jobs if it is put into practice. In the European Union, there will be between 1.4 - 2.8 million new job opportunities by 2020, according to a recent report due to decreasing in resource consumption (MacArthur 2012). Additionally, according to the Ellen MacArthur Foundation, a circular economy might help reduce carbon dioxide emissions by 2030 (MacArthur 2015).

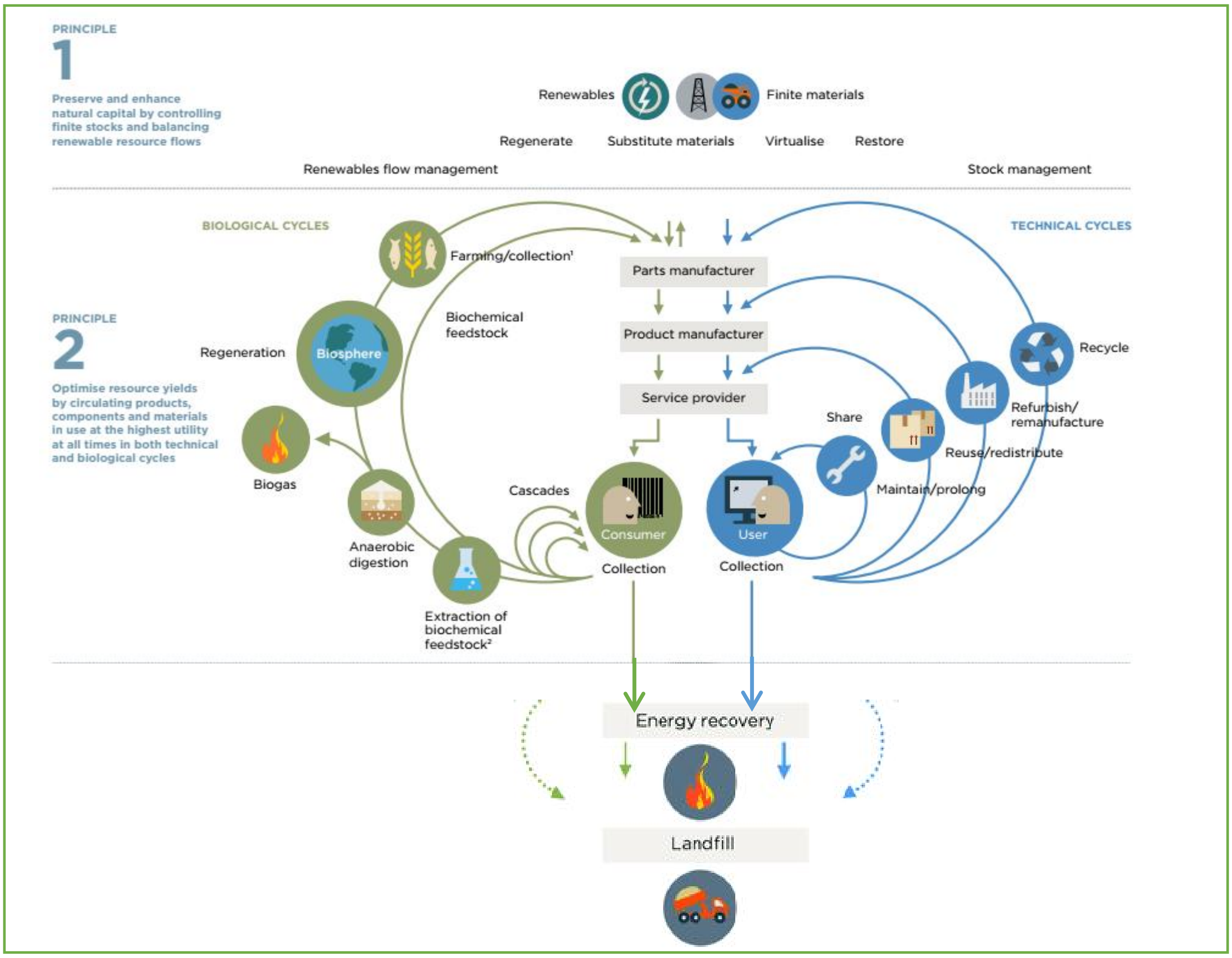

Fig.15: Outline of circular economy (MacArthur 2015)

3.2 Definition of circular economy (CE)

The circular economy idea has a long history. Since the late 1970s or early 1980s, practical applications to modern economic systems and industrial processes have accelerated. It is necessary to design products, processes, and materials so that their life cycles are safe for both the environment and human health. After the materials are used to make a certain product, a system should be created to mobilize and recover the value of the materials. The cradle-to-cradle framework served as the foundation for the circular economy idea. The cradle-to-cradle framework puts an emphasis on designing products that have a beneficial impact and minimizing the detrimental effects of commerce through efficiency.

The circular economy has been defined in various ways by a number of researchers. As the concept develops, the contributions to the topic and implementation experience produce a lot of queries and clarity. (Ghosh S.K, 2019).

Some of the definitions or interpretations of Circular economy are as follows:

A circular economy is a systems-level approach to economic growth that represents a paradigm shift from the traditional concept of a linear economy model of extract-produce-consume-dispose (epcd2) to an elevated echelon of achieving zero waste by resource conservation through the changed concept of design of production processes and selection of materials for increased life cycle, conservation of all types of resources and material and/or energy recovery all through the processes, and at the end of the product's life cycle for a particular use, the product will still be suitable for use as the raw material to a new production process in the value chain with a close loop materials cycles that enhance resource productivity, benefit businesses and society, create job opportunities, and provide environmental sustainability. (Ghosh S.K, 2019).

Opportunities for well-being, growth, and job creation are provided by CE, which also reduces environmental pressures. In principle, the idea can be used with any type of natural resource, including biotic and abiotic materials, water, and land (EEA, 2016). "The production and consumption of goods via closed-loop material flows that absorb environmental externalities associated with the exploitation of virgin resources and the production of waste (including pollution)" (Sauvé et al. 2016). The circular economy is defined as one "Where the value of products, materials, and resources is retained in the economy for as long as feasible, and the generation of waste is minimized,". An "important contribution to the EU's efforts to establish a sustainable, low-carbon, resource-efficient, and competitive economy" would be made by the shift to a more circular economy. (European Commission 2015).

3.3 Plastic waste & circular economy

We need to rethink the way we consume plastic. Plastics are versatile materials, but the way we use them is terribly wasteful and uneconomical. Earth's natural resources, oil, and gas are needed to produce plastic products, many of which are disposable after a single use. This is what we referred to as a take-make-waste linear model. Millions of tons of plastic, valued at approximately billions of dollars, are disposed of in landfills, burned, or released into the environment every year. Every year, an astounding 8 million tonnes leak into the ocean, and that number is increasing day by day. By 2050, there will be more plastic in the ocean (by weight) than fish if we don't think twice about how we use it. (Ellen MacArthur Foundation).

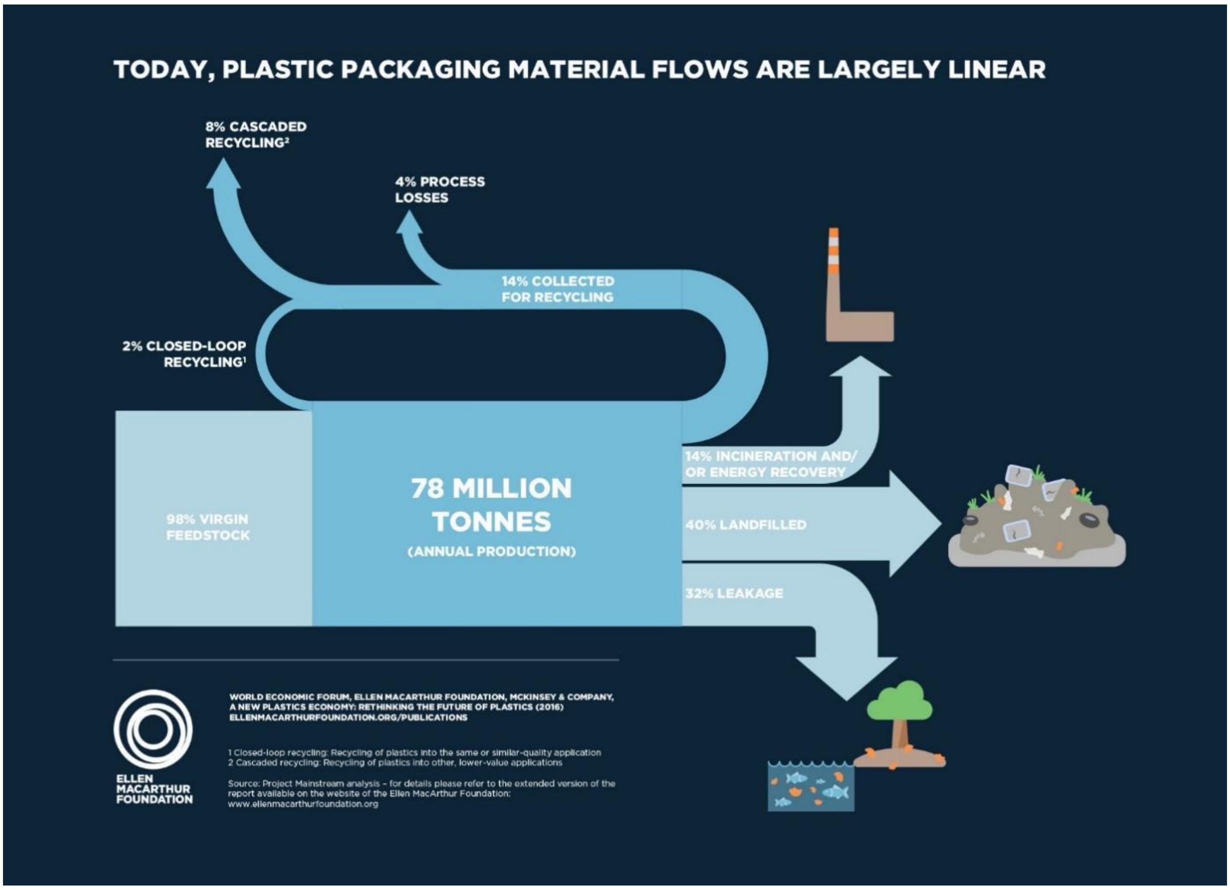

Fig. 16: The linear plastic system (Ellen MacArthur Foundation 2017)

A survey from the Foundation in 2016 revealed that most plastic packaging is only used once, and that only 14% of it is collected for recycling. The economy loses 95% of the value of plastic packaging material, which is about USD 80–120 billion yearly. (Ellen MacArthur Foundation 2016).

A CIRCULAR ECONOMY FOR PLASTIC: In an economic system known as the circular economy, materials are made to be used, not wasted. Products and the systems they are a part of should be built from the ground up to guarantee that no materials are lost, no toxins are released, and that every process, material, and component is used to its full potential. The circular economy is advantageous for society, the environment, and the economy when used properly. (Ellen MacArthur Foundation 2017).

Regardless of whether it is a system for reuse, recycling, or composting, all packaging should be made to fit within it. This figure xxx demonstrates how we would use plastics in the circular economy.

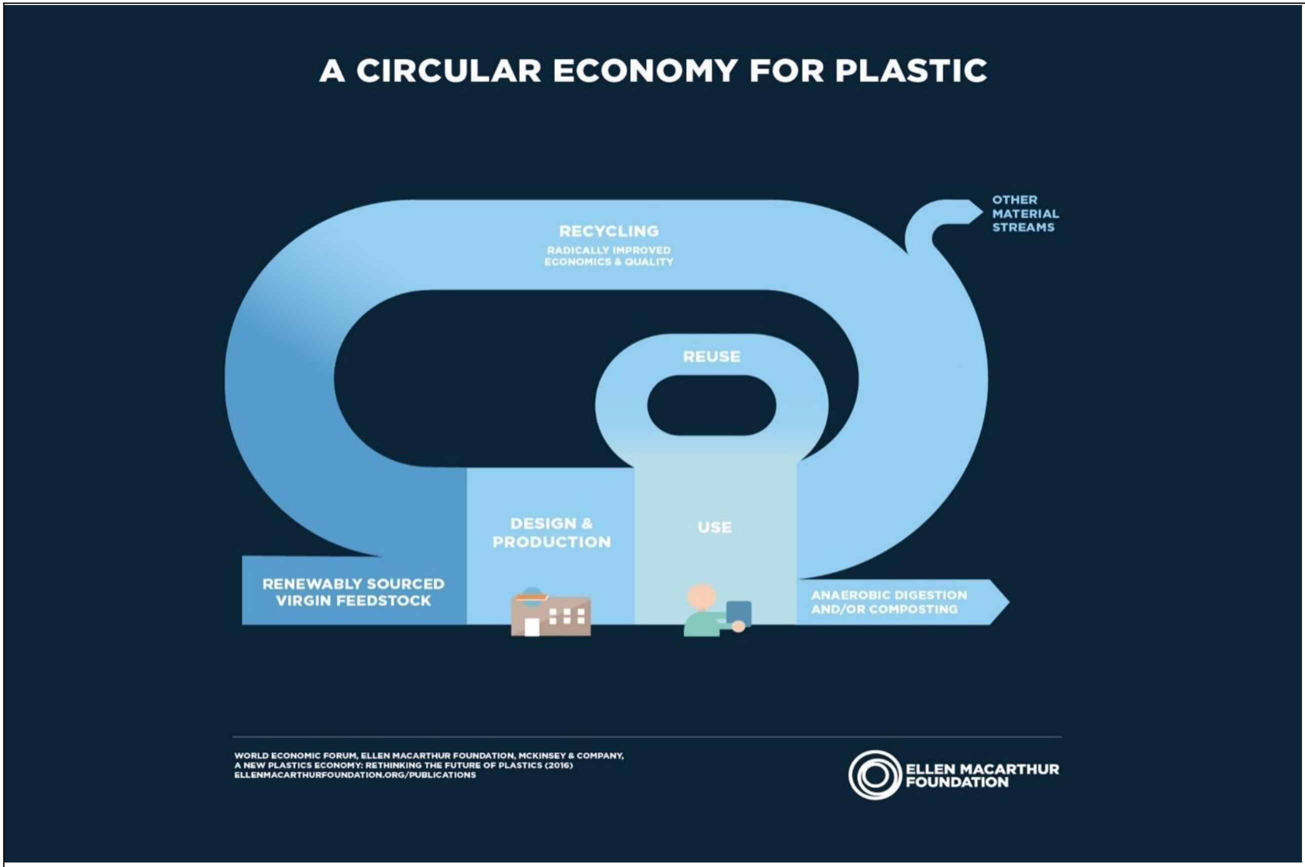

Fig. 17: A circular economy model for plastic (Ellen MacArthur Foundation 2017)

3.4 Co-processing of plastic waste in cement plant – A transition to circular economy

With increase in plastic product generation and consumption is leading to a greater plastic waste generation which has also difficulties with their management. In India, majority of plastic waste are left untreated and find their place at dumpsite or getting into different water streams and finding its way to marine littering.

The global CO2 emissions from the cement industry contribute nearly 7% of all emissions. The equivalent percentage for India comes to around 7%. Due to the release of emissions including Particulate Matter, SOx, NOx, and VOCs, among others, the cement business also contributes to environmental pollution. The cement industry is launching a number of measures to solve these environmental, economic, and social issues in order to be sustainable. The corporations are doing the following actions as projects related to sustainability. reducing waste, increasing investment in renewable energy, decreasing CO2 emissions, and supporting organizations that encourage sustainability.

A model has been proposed to solve this problem. The following model shows a brief life path of plastics turning into waste, leading to landfills and oceans. The model also suggests with proper collection and segregation in material recovery facility, it is possible to use those plastics as fuel, thereby preventing its way to oceans and landfills which results in promotion of circular economy and enhance the resource circulation.

Recyclable plastic can be collected by kabadiwala and rag-pickers and send it to recycling plants for recycling. NRPW from common dustbin, landfill, roadside dumping, marine litter and industrial waste can be collected by ULBs and cab be stored in a material recovery facility provided by government or can transfer to a private company who convert this plastic waste into Refuse Derived Fuel (RDF). This final product can be transferred to cement plant where it can be used as AFR in cement kiln. Reuse of plastic waste for co-processing in cement plant promotes circular economy. Figure xxx demonstrate the proposed model for prevention of marine littering through the implemented legislation on co-processing and marine litter

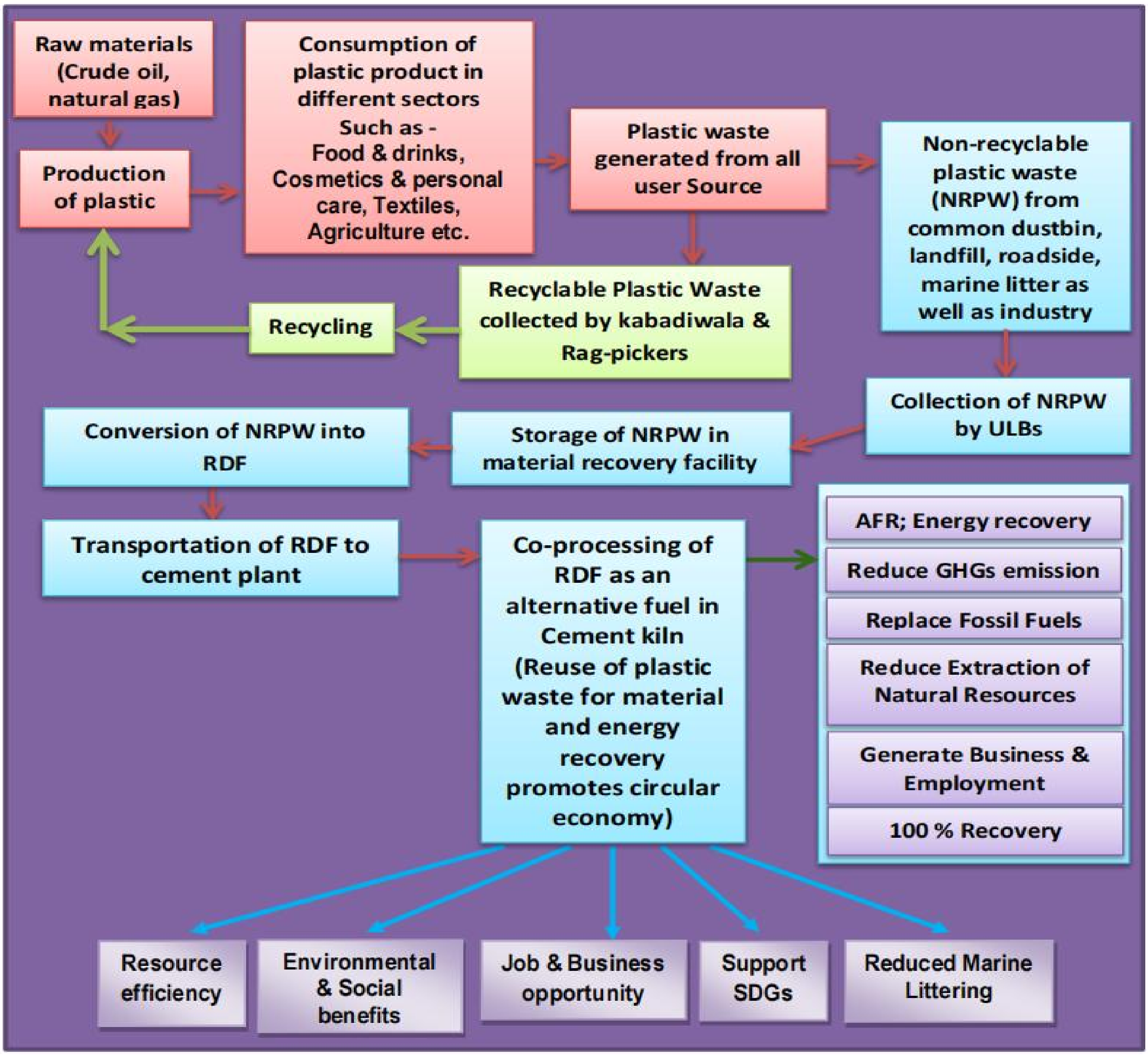

Fig. 18: Circular Economy model in plastic waste management trough co-processing in cement plant

CHAPTER 4

POTENTIAL OF NRPW IN CO-PROCESSING - FIELD STUDY AND DATA COLLECTION

4.1 Introduction

This chapter is about a field study on potential of NRPW in co-processing through sampling and composition analysis of plastic waste in different dumpsites in and around Kolkata, West Bengal. Four different dumpsites of Kolkata and Berhmpore **(named Baruipur, Maheshtala, Berhmpore, and Murshidabad)** and different dumpsite of various cities of Odisha such as **Bhubneshwar, Cuttack, Berhampur, Sambalpur, Angul, Keonjhar, Rourkela and Sundargarh** are selected for waste sampling and data collecion samples were collected from all the dumpsites to quantify the amount of NRPW generated from different cities to know the potential. Sample collected from different dumpsite are send to the laboratory for testing of various parameter such as calorific value, moisture content, chlorine content etc.

Other part of field study is about interview of scavenger who is involved in waste processing to know the social, economical, health and environmental impact causes by doing this job.

4.2 Objectives

1. Sampling in different dumpsites for analysis of the composition of waste in landfills as well as type and measure of plastic waste specifically non-recyclable in municipal solid waste.
2. Potential of dumpsites for co-processing of non-recyclable plastic waste in cement plant.

4.3 Methodology adopted for sampling and data collection of NRPW from Dumpsite

- Selection of proper Dumpsite
- Taking Pictures of the overall dumpsite
- Communicate with the authority who is in charge of waste collection and preceding. Sampling is to be conducted in Coning and Quartering Sampling Procedure

  [Ref: 1. Solid biofuels — Sample preparation; BS EN 14780:2011; BSI Standards Publication

  2. Swachh Bharat Mission; Municipal Solid Waste; Management Manual; Part II]
- A definite amount of 64 kg of fresh solid waste is to be collected.
- Samples from all heterogeneous sampling points shall be mixed thoroughly.[Initially, the fresh waste consists of concentration variations in different points; they are to be mixed well to get almost equal concentrations in different points of waste collected]

- The sample is placed on a clean plain surface in the form of a heap.
- The total amount of waste taken for sampling are to be divided into 4 parts, using straight lines, perpendicular to each other, where each possesses a similar weight (16 kg each), as in figure 1.

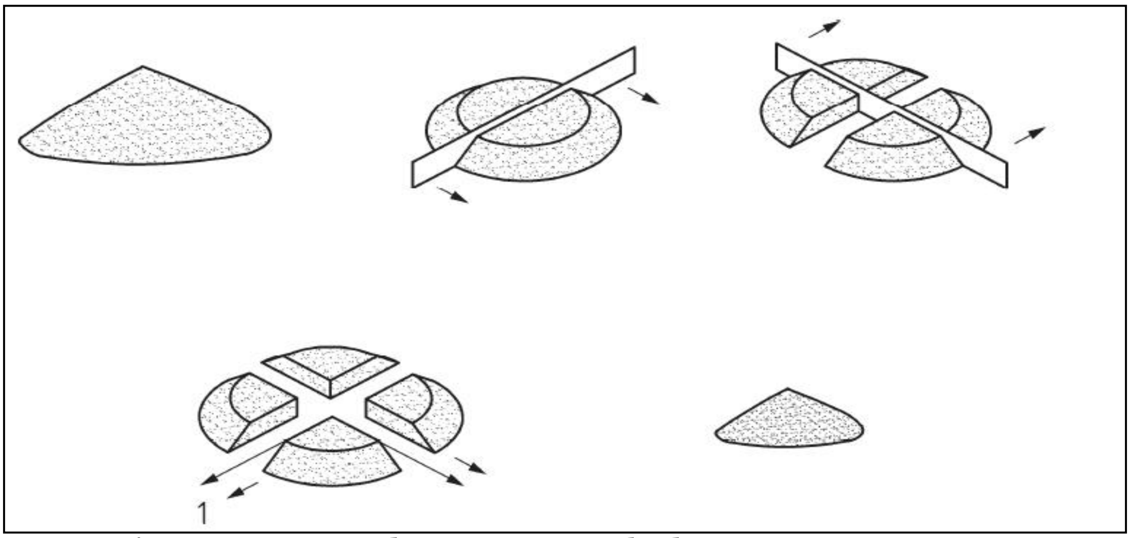

Fig. 19: Coning and Quartering Method [BS EN 14780:2011; P-14]

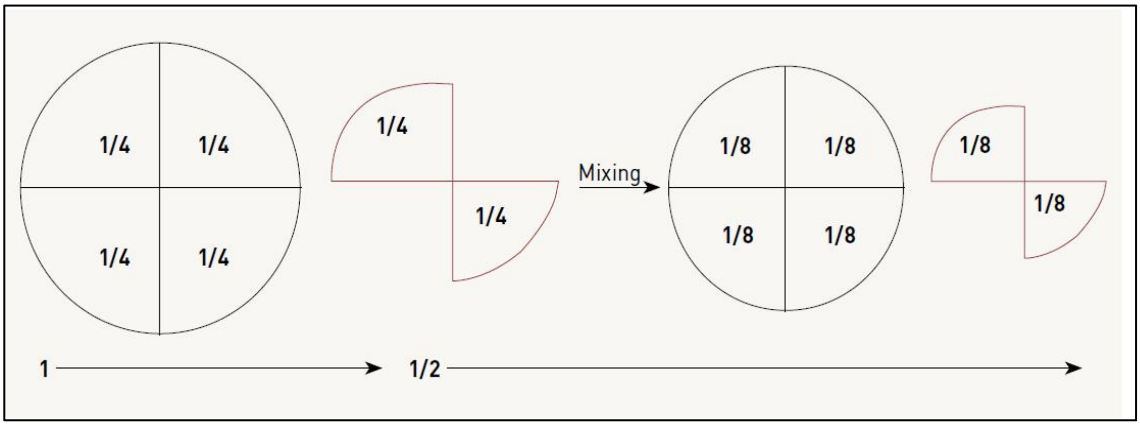

Fig. 20: Characterization of Municipal Solid Waste through Quartering Method [Swachh Bharat Mission; Municipal Solid Waste; Management Manual; Part II, 2016]

- Waste from opposing corners of the divided heap is removed to leave half of the original sample. The remaining portions (16+16 = 32 kg) are to be thoroughly mixed.
- The mixed waste is to be separated into 4 parts (8 kg each) similarly and 2 diagonal portions are taken removing the other 2 portions
- The remaining portions (8+8= 16kg) are to be mixed well.
- New samples are to be placed in fresh containers.

- The amount of plastic waste is to be separate from the total mixed waste of 16 kgs and weighed properly. And the plastic wastes are to be sorted into different containers.
- Weighing: Before and after washing & cleaning.
- Plastic wastes are to be washed and dried properly to segregate the residues and impurities. After dried up completely, plastic waste is to be weighed and residue fraction can be measured from plastic waste.
- After sorting out the plastic waste, they are to be identified and separated further according to 7 different categories of plastics (PET, HDPE, PVC, LDPE, PP, PS& OTHER) and non-recyclable plastics.
- Few clear videos and photos are to be captured of the overall sampling and segregation procedure.
- all the packets of cleaned plastics are to be kept with labels and dates, and location for testing.
- These collected plastics will be taken to the lab for different testing.

Sampling Tools & Equipment

- Weighing machine (100 kg precision)
- Digging Hoe (Kodal), Belcha
- Plastic sheet (120 x 100 mm)
- Containers
- Gloves for waste handling
- Labours
- Washing Facility

4.4 Sampling of plastic waste in different dumpsites in Kolkata, Murshidabad, and different city of Odisha

4.4.1 Sampling at Baruipur dumpsites of West Bengal

- **Location of the Dumpsite:** kirtonkhola, ward-08, Baruipur, 19 km from Jadavpur university
- **Age of Dump site:** Over 60 years
- **No. of words covered:** 17 (Baruipur municipalities)
- **Types of waste compositions:** Mixed waste
- **No. Of scavenger/waste pickers(Formal/Informal):** 110 (20/90)
- **Area of dumpsite:** 2.03 acre
- **Total solid waste accumulated daily:** 33 to 34 tons
- **Types of vehicles-** used for disposal of waste: Tractors, Lorry, Dumper, compactors, paddle tricycles, battery-operated trippers, and fuel operated trippers

4.4.1.1 Sampling Procedure of plastic waste at the dumpsite:

- 64 kg of mixed solid waste is taken from 2 different places for sampling.
- Total waste (64 kg) is divided into 4 square parts having an equal amount of waste and mixed well.
- 2 diagonals are taken from them and are mixed properly.
- Again, 32 kg of waste is taken and divided into 4 square parts having an equal amount of waste and mixed well.
- 2 diagonals are taken from them and are mixed properly.
- Again, 16 kg of waste is taken and divided into 4 square parts having an equal amount of waste and mixed well.
- 2 diagonals are taken from them and are mixed properly.
- Plastic waste from a total of 8 kg of mixed solid waste is separated and weighed properly.
- 2 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
    - Mixed waste #sample-01 (8.5 kg): 2.5 kg
    - Mixed waste #sample-02 (4 kg): 0.5 kg

Fig. 21: Sampling Procedure of Plastic Waste at Baruipur Dumpsite

Figure 1: Researcher at Baruipur municipality

Figure 2: Total 64 kg of mixed solid waste was mixed well for sampling and placed in a clean fresh surface

Figure 3: The mixed solid waste taken; divided into 4 parts, each having 16 kg

Figure 4: Waste from opposing corners of the divided heap was removed to leave half of the original

Figure 5: The remaining waste was mixed thoroughly again placed in a clean fresh surface

Figure 6: The mixed waste was divided into 4 parts in similar fashion, each having 8 kg

Figure 7: Similarly divided into 4 parts each having 4 kg

Figure 8: Wastes from opposite corners were mixed & plastic wastes are separated

Figure 9: The plastic waste separated was collected, labeled and weighed

4.4.2 Sampling at Maheshtata dumpsites of West Bengal

Location of the Dumpsite: Budge Budge Trunk Rd, Balarampur, Maheshtala, West Bengal 700140
Age of Dump site: 16 years
Area of dumpsite: 49 bigha
No. of words covered: 35
Total solid waste accumulated daily: 180 metric ton
Waste composition: Mixed waste, kitchen garbage
Types of vehicles: Paddle Tri-Cycle, Tractor, Eicher car, Tata 407, Ashok ley land, Tata ACE, JCB, JCB Hydra, Excavator, Tata V30, Dumper, Hyva compacter, Tri Cycle van.
No of scavengers working at the dumpsite: 19 (Informal)

4.4.2.1 Sampling of plastic waste at the dumpsite:

- Plastic waste from final sample of 4.5 kg mixed solid waste is separated and weighed properly.
- Weight of plastic waste from
  - Mixed waste #sample-01 (4.5 kg): 1 kg

Fig. 22: Sampling Procedure of Plastic Waste at Maheshtala Dumpsite

Figure 1: Total 64 kg of mixed solid waste was mixed well for sampling and placed in a clean fresh surface

Figure 2: The mixed solid waste taken; divided into 4 parts, each having 16 kg

Figure 3: Waste from opposing corners of the divided heap was removed to leave half of the original sample

Figure 4: The sample was mixed thoroughly again placed on a clean fresh surface

Figure 5: The mixed waste was separated into 4 in similar fashion

Figure 6: Diagonal portions were taken removing the other 2 portions

Figure 7: The mixed waste was separated into 4 in similar fashion

Figure 8: Wastes from opposite corners were mixed & plastic wastes are separated

Figure 9: The plastic waste separated was collected, labeled, and weighed

4.4.3 Sampling at Berhampore dumpsites of West Bengal

- **Location of the Dumpsite:** Berhampur
- **Age of Dump site:** 30 years (Approx.)
- **Total solid waste accumulated daily**: 120 TPD
- **Types of vehicles-** used for disposal of waste: Tractors, Lorry, Dumper, Pay Ladder

4.4.3.1 Sampling of plastic waste at the dumpsite:

- At last 2 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
  - Mixed waste #sample-01 (4 kg): 0.42 kg
  - Mixed waste #sample-02(4 kg): 0.435 kg

Fig. 23: Sampling Procedure of Plastic Waste at Berhampore Dumpsite

Figure 1: Total 64 kg of mixed solid waste was mixed well for sampling and placed in a clean plane surface

Figure 2: The mixed solid waste taken; divided into 4 parts, each having 16 kg

Figure 3: Waste from opposing corners of the divided heap was removed to leave half of the original sample

Figure 4: The sample was mixed thoroughly again placed on a clean fresh surface, total weight is 32 kg

Figure 5: Again the mixed waste was separated into 4 in similar fashion

Figure 6: Waste from opposing corners of the divided heap was removed to leave half of the original sample

Figure 7: The sample was mixed thoroughly again placed on a clean fresh surface, total weight is 4 kg

Figure 8: Wastes from opposite corners were mixed & plastic wastes are separated

Figure 9: The plastic waste separated was collected, labeled, and weighed

4.4.4 Sampling at Lalbag Murshidabad dumpsites of West Bengal

- **Location of the Dumpsite:** Lalbag municipality Murshidabad
- **Age of Dump site:** 3 years
- **Area of dumpsite:** 5 acres
- **No. of words covered:** 16
- **Total solid waste accumulated daily:** 32 metric ton
- **Waste composition:** Mixed waste, kitchen garbage
- **Types of vehicles:** Paddle Tri-Cycle, Tractor, Eicher car, Tata 407, Ashok ley land, Tata ACE, JCB, JCB Hydra, Excavator, Tata V30, Dumper, Hyva compacter, Tri Cycle van.

4.4.4.1 Sampling of plastic waste at the dumpsite:

- Quantity of plastic waste from
  - Mixed waste #sample-01 (4 kg): 0.495 kg
  - Mixed waste #sample-02(4 kg): 0.685 kg

Fig.24: Sampling Procedure of Plastic Waste at Murshidabad Dumpsite

Figure 1: Total 64 kg of mixed solid waste was mixed well for sampling and placed in a clean plane surface

Figure 2: The mixed solid waste taken; divided into 4 parts, each having 16 kg

Figure 3: Waste from opposing corners of the divided heap was removed to leave half of the original sample

Figure 4: The sample was mixed thoroughly again placed on a clean fresh surface, total weight is 32 kg

Figure 5: The mixed waste was separated into 4 in similar fashion

Figure 6: Waste from opposing corners of the divided heap was removed to leave half of the original sample

Figure 7: The sample was mixed thoroughly again placed on a clean fresh surface, total weight is 4 kg

Figure 8: Wastes from opposite corners were mixed & plastic wastes are separated

Figure 9: The plastic waste separated was collected, labeled, and weighed

4.4.5 Sampling at Bhubneshwar dumpsite of Odisha

- **Location of the Dumpsite:** Bhuashani
- **Age of Dump site:** 15 years (Approx.)
- **Total solid waste accumulated daily**: 190 TPD
- **Types of waste compositions:** Mixed solid waste
- **Types of vehicles-** used for disposal of waste: Tractors, Lorry, Dumper, Pay Ladder

4.4.5.1 Sampling of plastic waste at the dumpsite:

- 2 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
    - Mixed waste #sample-01 (8.275 kg): 1.42 kg
    - Mixed waste #sample-02(7. 924 kg): 0.90 kg

Fig.25: Sampling Procedure of Plastic Waste at Bhubneshwar Dumpsite

4.4.6 Sampling at Cuttack dumpsite of Odisha

- **Location of the Dumpsite:** Chakradharpur
- **Age of Dump site:** 14 Years (2008 onwards)
- **No. of wards:** 59 Nos
- **Area of the dumpsite:** 27 Acre
- **Total solid waste accumulated daily**: 150 TPD
- **Types of waste compositions:** Mixed solid waste
- **Types of vehicles-** used for disposal of waste: Battery-operated vehicles, Tracks, Hyva

4.4.6.1 Sampling of plastic waste at the dumpsite:

- 2 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
  - Mixed waste #sample-01 (4.67 kg): 0.695 kg
  - Mixed waste #sample-02 (5.87 kg): 0.790 kg

Fig. 26: Sampling Procedure of Plastic Waste Cuttack Dumpsite

Figure 1: Collection of freshly dumped waste

Figure 2: A total of 64 kg of mixed solid waste was mixed well for sampling and placed on a clean fresh surface

Figure 3: The mixed solid waste is taken; divided into 4 parts, each having 16 kg

Figure 4: Waste from opposing corners taken and removed from half of the original sample

Figure 5: The sample was missed thoroughly again placed on a clean fresh surface

Figure 6: Again divided in four parts each having 8 kg

Figure 7: Diagonal portions were taken removing other 2 portions.

Figure 8: Wastes from opposite corners were mixed & plastic wastes are separated

Figure 9: The plastic waste separated was collected, labeled, and weighed

4.4.7 Sampling at Berhampur dumpsite of Odisha

- **Location of the Dumpsite:** Mahuda
- **No. of wards:** 42 Nos
- **Total solid waste accumulated daily**: 100 TPD
- **Types of waste compositions:** Mixed solid waste
- **Types of vehicles-** used for disposal of waste: Battery-operated vehicles, Tracks, Hyva

4.4.7.1 Sampling of plastic waste at the dumpsite:

- 2 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
  - Mixed waste #sample-01 (8.985 kg): 0.935 kg
  - Mixed waste #sample-01 (10 kg): 1.035 kg

Fig. 27: Sampling Procedure of Plastic Waste Berhampur Dumpsite

 **Figure 1: Total 64 kg of mixed solid waste was mixed well for sampling and placed on a clean fresh surface**	 **Figure 2: Mixed waste is divided in 4 equal parts each having 16 kg**	 **Figure 3: Waste from opposing corners of the divided heap was removed to leave half of the original sample**
 **Figure 4: The sample was missed thoroughly again placed on a clean fresh surface in square shape**	 **Figure 5: Again divided in 4 equal parts each having 8 kg**	 **Figure 6: Diagonal portions were taken removing other 2 portions**
 **Figure 7: Again mixed thoroughly and make a square**	 **Figure 8: Again divided in 4 equal parts each having 4 kg**	 **Figure 9: taking opposite corner and plastic waste separated and weighed**

4.4.8 Sampling at Angul dumpsite of Odisha

- **Location of the Dumpsite:**
- **No. of wards:** 23 Nos
- **Area of dumpsite:** 2 acres
- **Total solid waste accumulated daily**: 15 TPD
- **Types of waste compositions:** Mixed solid waste
- **Types of vehicles-** used for disposal of waste: Battery-operated vehicles, Tracks, Hyva

4.4.8.1 Sampling of plastic waste at the dumpsite:

- 1 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
    - Mixed waste #sample-01 (8.275 kg): 0.80 kg

Fig. 28: Sampling procedure of plastic waste at Angul dumpsite

4.4.9 Sampling at Sambalpur dumpsite of Odisha

- **Location of the Dumpsite:** Sikirdi
- **Age of Dumpsite: 7 Years (2015 onwards)**
- **Total solid waste accumulated daily**: 37 TPD
- **Types of waste compositions:** Mixed solid waste
- **Types of vehicles-** used for disposal of waste: Battery-operated vehicles, Tracks, Hyva

4.4.9.1 Sampling of plastic waste at the dumpsite:

- 2 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
  - Mixed waste #sample-01 (4.19 kg): 0.220 kg
  - Mixed waste #sample-02 (4.69 kg): 0.330 kg

Fig.29: Sampling Procedure of Plastic Waste Sambalpur Dumpsite

Figure 1: Collection of freshly dumped waste

Figure 2: A total of 64 kg of mixed solid waste was mixed well for sampling and placed on a clean fresh surface

Figure 3: The mixed solid waste is taken; divided into 4 parts, each having 16 kg

Figure 4: Waste from opposing corners taken and removed from half of the original sample

Figure 5: The sample was missed thoroughly again placed on a clean fresh surface

Figure 6: Again divided in four parts each having 8 kg

Figure 7: Diagonal portions were taken removing other 2 portions

Figure 8: Wastes from opposite corners were mixed & plastic wastes are separated

Figure 9: The plastic waste separated was collected, labeled, and weighed

4.4.10 Sampling at Keonjhar dumpsite of Odisha

- **No. of wards:** 21 Nos
- **Types of waste compositions:** Mixed solid waste
- **Types of vehicles-** used for disposal of waste: Battery-operated vehicles, Tracks, Hyva

4.4.10.1 Sampling of plastic waste at the dumpsite:

- 2 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
  - Mixed waste #sample-01 (7.93 kg): 1.52 kg
  - Mixed waste #sample-02(7.86kg): 0.98 kg

Fig. 30: Sampling Procedure of Plastic Waste Keonjhar Dumpsite

Figure 1: A total of 64 kg of mixed solid waste was mixed well for sampling and placed on a clean fresh surface

Figure 2: The mixed solid waste is taken; divided into 4 parts, each having 16 kg

Figure3: Waste from opposite corners of the divided heap was removed to leave half of the original sample

Figure 4: The sample was again mixed thoroughly and placed on a clean fresh surface

Figure 5: The mixed waste was separated into 4 parts in a similar fashion

Figure 6: Diagonal portion taken removing other two portion

Figure 7: Plastic waste separated, Collected, labeled, and weighed

4.4.11 Sampling at Sundargar dumpsite of Odisha

- **No of wards: 19**
- **Types of waste compositions:** Mixed solid waste
- **Total solid waste accumulated daily:** Around 35 TPD
- **Types of vehicles-** used for disposal of waste: Battery-operated vehicles, Tracks, Hyva

4.4.11.1 Sampling of plastic waste at the dumpsite:

- 1 sampling of plastic waste had been taken from mixed solid waste.
- Quantity of plastic waste from
  - Mixed waste #sample-01 (7.93kg): 1.2 kg

Fig. 31: Sampling Procedure of Plastic Waste Sundargarh Dumpsite

Figure 1: Total 64 kg of mixed solid waste was mixed well for sampling and placed on a clean fresh surface

Figure 2: Mixed waste is divided in 4 equal parts each having 16 kg

Figure 3: Waste from opposing corners of the divided heap was removed to leave half of the original sample

Figure 4: Diagonal portions were taken removing other 2 portions and mix well

Figure 5: Wastes from opposite corners were mixed & plastic wastes are separated

Figure 6: The plastic waste separated was collected, labeled and weighed

Table 12: Data of sampling of waste at different dumpsites

Sl. No.	Location of the dumping ground with GPS	Date of Visit	Sample No.	Type of the fresh solid waste taken	Weight of NRPW in 16 kg of solid waste	Weight of NRPW in 64 kg of solid waste	Average weight of NRPW in 64 kg of solid waste (Kg)
1.	Promodnagar [22.646, 88.369]	21.12.2020	1	Mixed	0.3	4.8	**7.015 Kg (10.96%)**
			2	Mixed	0.325	5.2	
2.	Baidyabati [22.788, 88.317]	22.12.2020	1	Dry	0.45	7.2	
			2	Mixed	0.268	4.3	
			3	Mixed	0.316	5.06	
3.	Budgebudge [22.473, 88.189]	11.01.2021	1	Mixed	0.305	4.08	
			2	Mixed	0.277	4.44	
4.	Sonarpur-Rajpur [22.422, 88.425]	14.01.2021	1	Mixed	0.212	3.4	
			2	Mixed	0.237	3.8	
			3	Mixed	0.237	3.8	
			4	Mixed	0.277	4.4	
5.	Dhapa [22.538, 88.422]	18.01.2021	1	Mixed	0.362	5.8	
			2	Mixed	0.33	5.28	
6.	Baruipur [22.35, 88.43]	23.03.2022	1	Mixed	0.48	7.68	
			2	Mixed	0.453	7.248	
7.	Maheshtala [22.51, 88.25]	29.03.2022	1	Mixed	0.562	8.992	
			2	Mixed	0.536	8.576	
8.	Berhmpore [24.124, 88.261]	09.04.2022	1	Mixed	0.42	6.72	
			2	Mixed	0.435	6.96	
9.	Murshidabad [24.175, 88.28]	09.04.2022	1	Mixed	0.495	7.92	
			2	Mixed	0.685	10.96	
10.	Bhubneshwar	21.06.202	1	Mixed	2.74	10.98	

	(Bhuashani)	2	2	Mixed	1.817	7.268	
11.	Cuttack (Chakradharpur)	21.06.2022	1	Mixed	2.38	9.52	
			2	Mixed	2.15	8.61	
12.	Berhampur (Mohuda)	22.06.2022	1	Mixed	1.66	6.65	
			2	Mixed	1.65	6.624	
13.	Angul (Panchamahalla)	22.06.2022	1	Mixed	1.54	6.18	
			2	Mixed	1.74	6.96	
14.	Sambalpur (Durgapalli)	23.06.2022	1	Mixed	1.68	6.72	
			2	Mixed	2.25	9.00	
15.	Keonjhar	23.06.2022	1	Mixed	3.06	12.26	
			2	Mixed	1.99	7.97	
16.	Sundargar	25.06.2022	1	Mixed	2.42	9.68	
			2	Mixed	2.62	10.49	

4.4.12 Results of sampling at dumpsites in Kolkata, *Murshidabad and different district of Odisha.*

The sixteen dumpsites having an average amount of 7.015 Kg of Non-recyclable plastic waste from a sample of 64 Kg of solid mixed waste which is around 10.96%. It gives an idea that the municipal solid mixed waste of Kolkata, Murshidabad, and major city of Odisha having approximately 10.96% of non-Recyclable plastic waste.

Table 13: Data for incoming waste per day at different dumpsites in Kolkata, Murshidabad, and major city of Odisha.

Sl. No.	Dumpsite	Incoming waste (Tons/day)
1.	Promodnagar	315
2.	Baidyabati	50-60
3.	Budgebudge	30-35
4.	Sonarpur-Rajpur	25-30
5.	Dhapa	5000
6.	Baruipur	33-34
7.	Maheshtala	180
8.	Berhmpore	150

9.	Murshidabad	32
10.	Bhubneshwar	520
11.	Cuttack	150
12.	Berhampur	00
13.	Angul	20
14.	Sambalpur	37
15.	Keonjhar	00
16.	Sundargar	00
	Total	**6552 (approximate)**

A total of 6552 tons of municipal solid waste is generated from sixteen major dumpsites in Kolkata, Murshidabad, and Odisha per day. According to the sampling result out of 6552 tons of municipal waste around **718 tons** (@10.96%) is non-recyclable plastic waste. This waste can be used in cement plant as an alternative fuel or any other alternative technology.

Chemical analysis of collected sample

The samples from the dumpsites were collected and stored in different containers after proper labeling and washed well in freshwater with detergent. After clean up all waste plastics, they are spread in the open air for air dry. When dried out we shred them with scissors at around 1' x 1' size for testing. The Test results are shown below

QUALITEK LABS PRIVATE LIMITED

Qualitek Labs

D2/18, Mancheswar Industrial Estate, Bhubaneswar – 751 010, Odisha, India
Contact: Website: www.qualiteklab.com;
E-mail id: customerservices.bbsr@qualiteklab.com; Phone: 0674-2952347

Analysis Details:

Discipline: Chemical
Group: Solid Waste

Analysis start date: 15/03/2022
Analysis end date: 17/03/2022

Sr. No	Test Parameters	Unit of measurement (UOM)	Test Method	Specifications	Test Result
1.	Gross Calorific Value	Kcal/ kg	QLB/STP/EW/067	NA	2892

Remarks:

1.0- NA- Not Applicable

Reviewed by:
Name: Dr. Md. Motiar Rahaman Khan
Designation: Manager Q.A.

Authorized by:
Name: Partha Ulal
Designation: Group Leader (Environment & Water)

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End of Test Report

Fig. 32: RDF test result for gross calorific value

Comment: After getting the test results, compared with the permissible limits of CPCB (2500 Kcal/kg)for using the AFR in the cement industry.The gross calorific value (GCV) is in the range mentioned in the guideline, which is a good sign for utilizing the waste as AFR in cement plants.

4.5 Interviews with scavengers (informal) in waste management (environmental, economic, social and health & safety aspects)

In the view of municipal solid waste management (MSWM), the informal waste management refers to the waste recycling activities of scavengers and waste pickers. In developing countries, including India, are majorly collected by the informal waste sector. In India, the survey sites have been chosen on the basis of the population density of the region. Among The selected seven sites, four sites are in Kolkata and outer Kolkata , others are in Berhampore, Murshidabad district.

Kolkata is the capital of the state of West Bengal and one of India's four metropolitan cities. The city is located at latitude 22 0 34 North and longitude 88 0 24 East, about 30 kilometres from the Bay of Bengal, and the river tides in Kolkata

exceed 4 metres. According to the 2011 India census, Kolkata is the seventh-most populated city in India, with a population of 45 lakh (4.5 million) residents within the city limits and a population of over 1.41 crore (14.1 million) residents in the Kolkata Metropolitan Area. KMC report says that on average 4,000 MT of waste is generated in KMC Area every day.
In Kolkata, two open dumpsites and two clean cities compactor has been chosen for survey in Baruipur and Jadavpur, Palbazar respectively. In mahamayatala, the data was gathered through the interview of household waste collectors.

Murshidabad is located in the centre of West Bengal, between 23°43'N and 24°52'N latitude and 87°49'E and 88°44'E longitude, with headquarters at **Berhampore.** Berhampore a city of Murshidabad district situated in West Bengal state, with a population 137864(2020). Being located in residential area, the waste generation is also observed in high amount.

In the sites, the waste picker samples are collected randomly. On the basis of environmental, economic, social and health & safety aspects, the interview of scavengers has been done. The simple random sampling method has been chosen for this study.

4.5.1 Methodologies adopted for interview

This study utilized a systematic review of literature to identify and explore the environmental, social, economic hazards and health outcomes associated with informal waste picking.

- The purpose of this study was to thoroughly examine the complete range of environmental, social, economic, and health risks connected with informal waste picking.
- These procedures included identifying articles, screening them, assessing their eligibility, and finally finalising the articles that would be presented.
- For the purposes of this study, informal has been defined as being free of municipal or government regulation. The criteria included publications and sources with information about informal waste pickers, as well as all other similar terms (e.g., collector, scavenger, and recycler), social and economic hazards associated with informal waste picking, health outcomes associated with informal waste picking, particularly for women and children, and English language articles.
- For the interview, the close-ended questionnaire has been formed to ask the scavengers on the aspect of social, economic and health hazards due to involving in this occupation. On the site, the scavengers has been chosen randomly and asked the questions to follow the questionnaire. The primary data was recorded for further study.

4.5.2 Interview of Informal scavengers

Table 14: Details of the scavenger's interview

Site location	Type of site	Date of survey	No of interviews taken
Baraipur	Open dumpsite	23/03/2022	7
Maheshtala	Open dumpsite	29/03/2022	8
Jadavpur	Clean city waste compactor	19/04/2022	6
Palbazar	Clean city waste compactor	19/04/2022	7
Murshidabad	Open dumpsite	08/03/2022	8
Berhampore	Open dumpsite	08/03/2022	6
Mahamayatala	Collected waste vehicles	09/05/2022	11

4.5.3 Results of Interview conducted with Formal & Informal scavengers

4.5.3.1 Socio-Economic Aspect

GENDER - In this occupation, the male proportion is always high than the female. Specially, in the study area, Maheshtala, the female waste pickers are mainly observed otherwise, the proportion of males are high in other sites.

Table 15: the proportion of males & females among scavengers

Location of the interview	No. of interview with scavengers	Male	Female
Palbazar	7	6	1
Jadavpur	6	6	
Mahestala	8		8
Mahamayatola	11	11	
Baharampur	6	5	1
Baruipur	7	7	
Murshidabad	8	7	1
Total	**53**	**42**	**11**

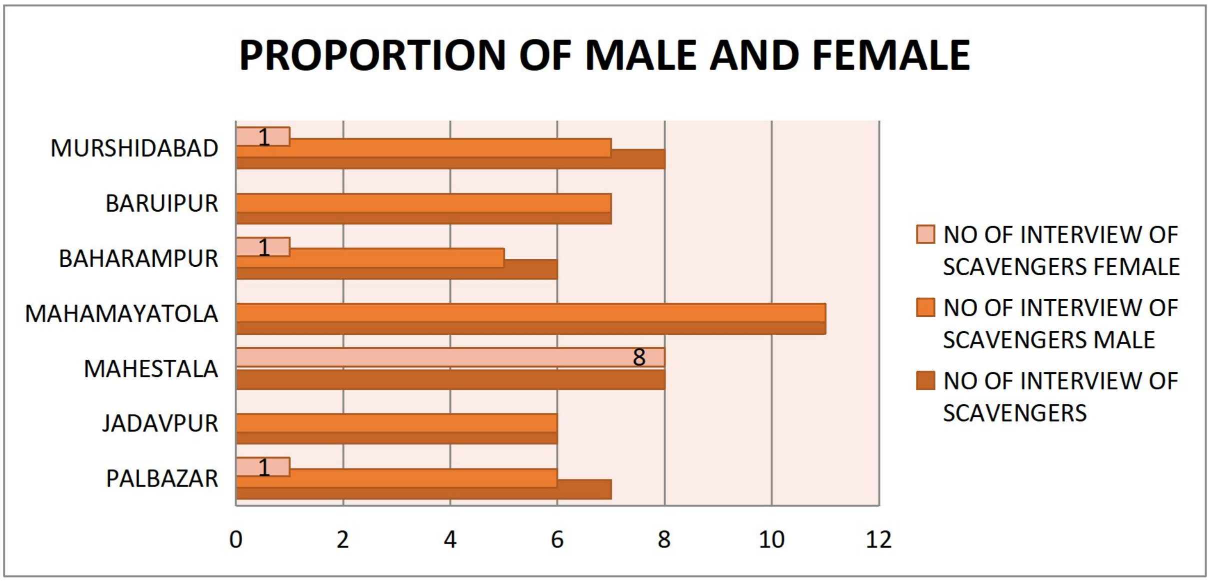

Fig. 33: Proportion of male and female scavengers in waste management

YEARS OF EXPERIENCE – In the studies, the women and male waste pickers has been observed engaging with this occupation average above 10 years. Though most male population are engaged with 15 years and above. In this job, the waste pickers are mostly engaged due to the easy getting job, lack of skill, lack of education etc. For the same reason, in Palbazar, the above 20 years experienced waste picker has been found for this study.

Table 16: The engagement in occupation at various sites

Location of the interview	No of interviews of scavengers	Engagement in occupation				
		Below 5 years	6- 10 years	11-15 years	16-20 years	Above 20 years
Palbazar	7	1	2	3		1
Jadavpur	6	2	2	1	1	
Mahestala	8	1	4	1	2	
Mahamayatola	11	2	6	2	1	
Baharampur	6		1	5		
Baruipur	7		2	4	1	
Murshidabad	8		2	3	3	

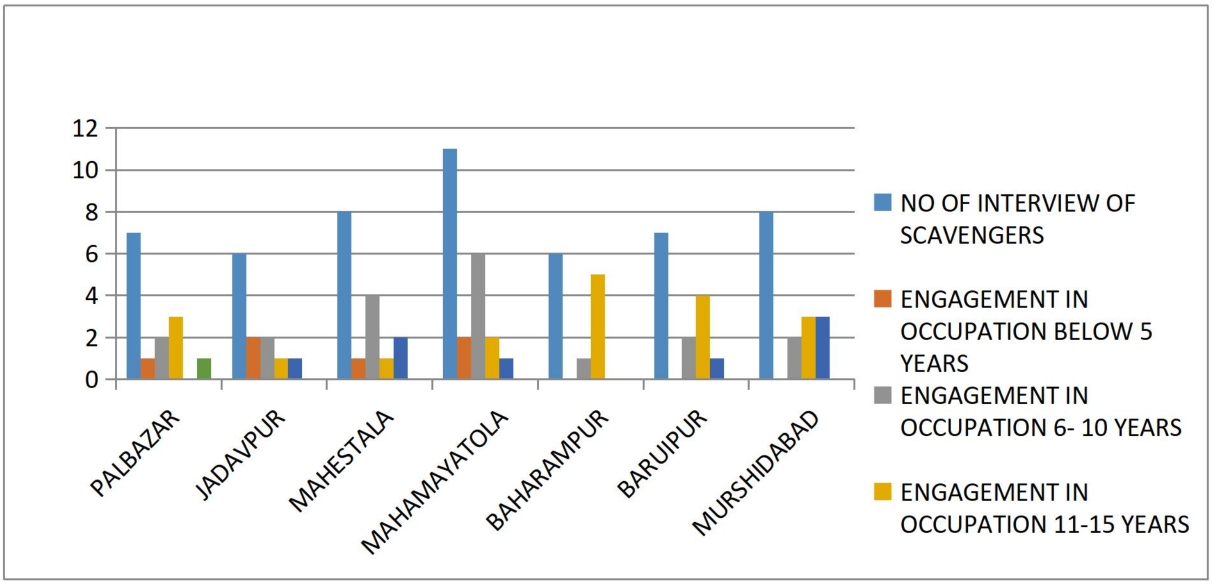

Fig. 34: engagement in occupation at various sites

AGE-GROUP- In these studies, the adults above 18 years and teenage below 18 years also engaged in this job due to the poverty and family size. In Mahestala, Mahamayatala below 18 years are also engaged to help their parents, and they also get daily wag, but in less amount than adults. Mostly in the major cities, the >30 age group people are engaged in this waste picking. Above 30 aged Women's engagement in these sites is mainly observed.

Table 17: Age group of scavenger engaged in waste processing

Location of the interview	**No of interviews of scavengers**	**Age groups**				
		Below 18 Years	**18-30 years**	**30-40 years**	**40-50 years**	**Above 50 years**
Palbazar	7		1	2	3	1
Jadavpur	6			3	2	1
Mahestala	8	1	1	4	1	1
Mahamayatola	11	1	3	3	2	2
Baharampur	6		3	2	1	1
Baruipur	7		2	3	2	1

HABITAT - In the poor habitat system, the slum area, temporary settlements near dumpsites are common for waste pickers. In habitat, there is lack of hygienic, no as such facilities of pure drinking water, food, which indicates the vulnerability of the waste pickers. In Maheshtala and Mahamayatala, maximum waste pickers are having in rent.

EDUCATION - As this job is not required as such no education criteria, the engaged maximum people are illiterate or primary educated .In study areas, it has been observed that the no of illiterate is also high while only 13 scavengers got opportunity in secondary education. They are mainly engaged for their family responsibility and large family size while there is not required as such education in this job. In this case, a major issue is notable that despite being a megacity, there is lack of getting opportunity in education among waste pickers in Kolkata.

Table 18: The literacy ratio of scavengers in various sites

Location of the interview	No of interviews with scavengers	Education		
		Illiterate	Primary education	Secondary education
Palbazar	7	5	1	1
Jadavpur	6	1	4	1
Mahestala	8	4	2	2
Mahamayatola	11	4	2	5
Baharampur	6	1	3	2
Baruipur	7	4	3	1
Murshidabad	8	45	3	1

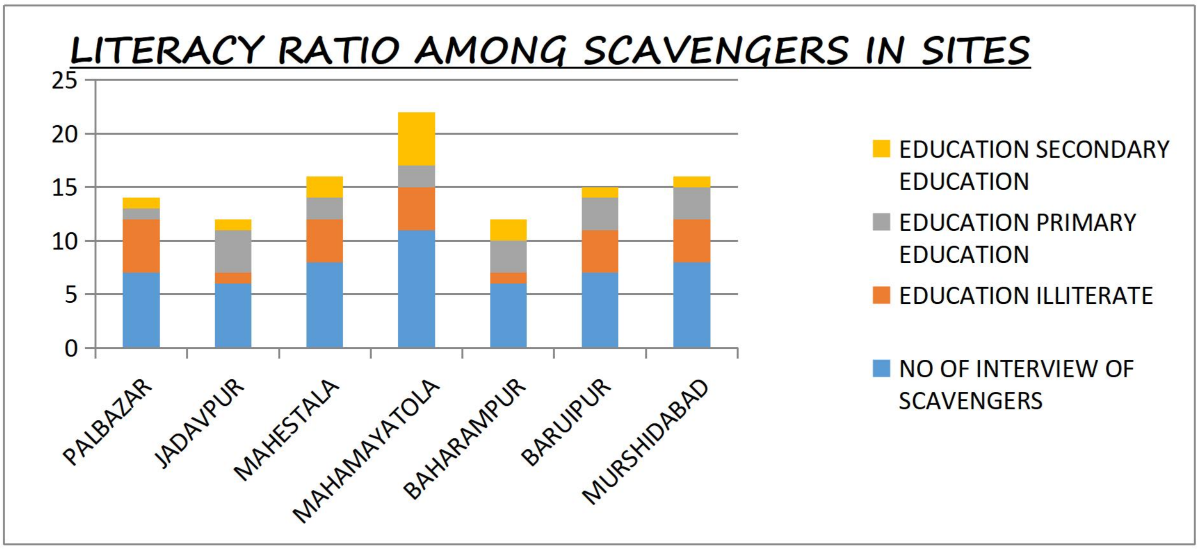

Fig. 35: Literacy ratio of scavengers

4.5.3.2 HEALTH ASPECT

PHYSICAL HAZARDS

In the physical hazards, the most common diseases are skin diseases, injury, respiratory diseases, and musculoskeletal symptoms among waste pickers. In most of the sites, the skin diseases and injuries are around 75%, the physical weakness about 60% which is high ranged due to involvement in physical hard working job.

Table 19: The health aspect of scavengers in various sites

Sl. No.	Survey area	Health impact				
		No. Of scavengers served	Injury	Musculoskeletal symptoms	Skin diseases	Addiction
1	Palbazar	7	2	5	4	5
2	Jadavpur	6	5	6	4	3
3	Mahestola	8	5	5	2	3
4	Mahamayatola	11	8	3	5	9
5	Baharampur	6	2	3	2	5
6	Baruipur	7	4	5	5	6
7	Murshidabad	8	6	7	5	7

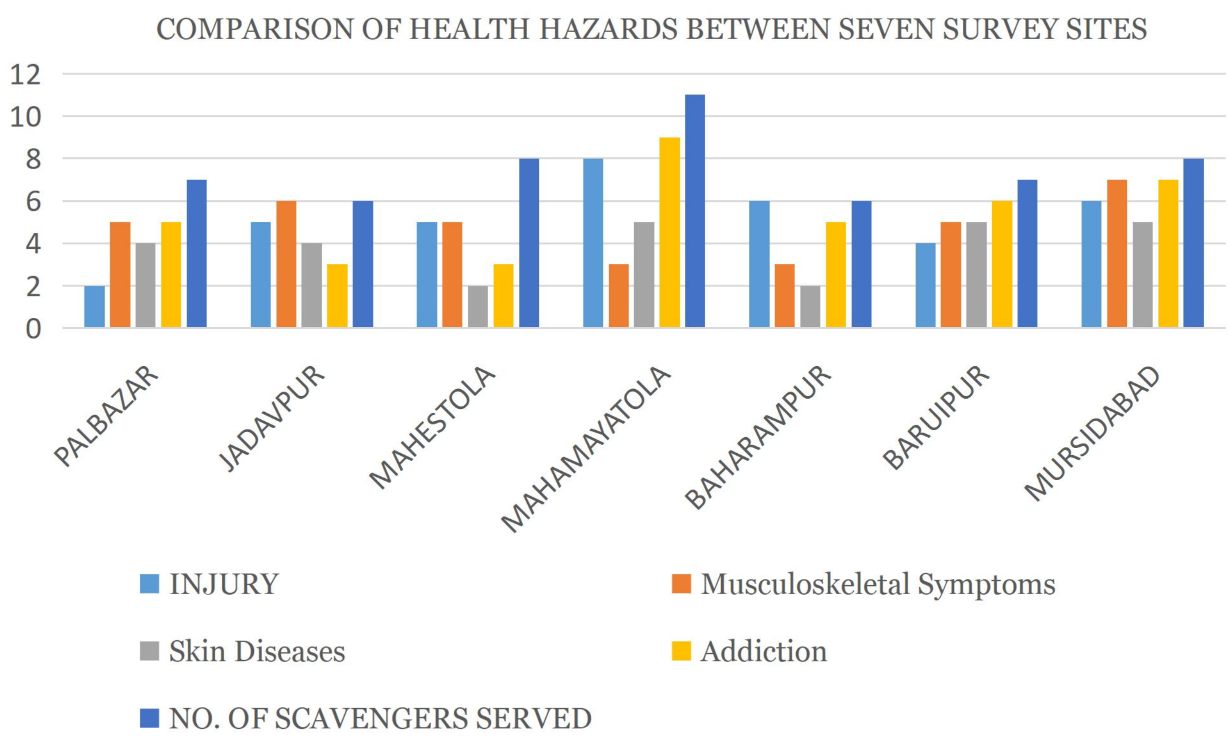

Fig. 36: Health hazards faced by scavengers

MENTAL DISORDERS

In these studies, it has been observed that the mental disorder like anxiety, tension are most common factor among waste pickers as their low-income, uncertainty job and most importantly high- priced daily foods in major cities. Among urban poor, existence of low income, poor livelihood is the reason of getting addiction like smoking, drinking etc, which is not good at all for their health and society. In the site Mahamayatala , The responded male is more badly addicted due to poverty and lack of education.

4.5.3.3 ECONOMIC ASPECT

AVERAGE INCOME

Among seven sites, the average monthly income of waste picker is around 6000-6500rs. Due to contractual job, the fixed wage is not sufficient at all for scavengers. In the southern Kolkata, mainly in Baruipur, the wages of the scavengers is high among the seven sites.

Table 20: The average income of scavengers at various sites

Sl No	Location Of The Interview	Average Income	Average Income
		5001-7000	7001-9000
1.	**Palbazar**	4	3
2.	**Jadavpur**	5	1
3.	**Mahestala**	6	2
4.	**Mahamayatola**	8	3
5.	**Baharampur**	1	5
6.	**Baruipur**	1	6
7.	**Murshidabad**	3	5

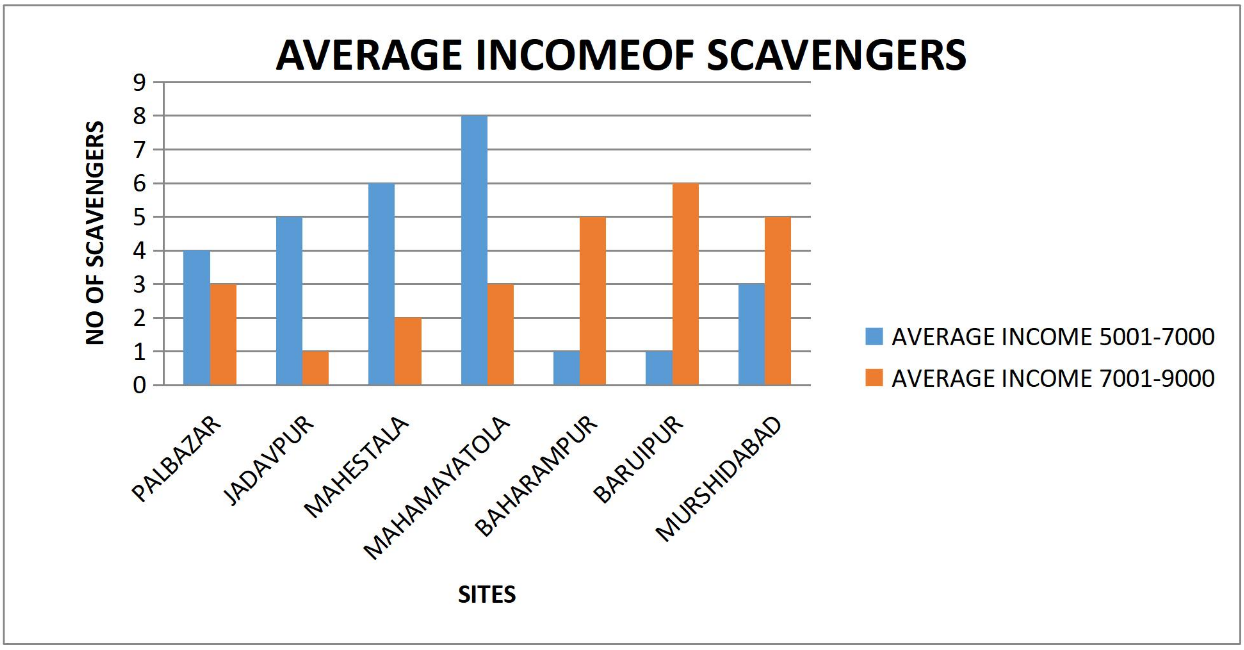

Fig. 37: Average income of scavenges

MEDICAL EXPENSES AND WELFARE SCHEMES

Due to getting involved in unhygienic and unhealthy job, the medication expenses are getting regular and in high. The average expenses are round 250-500rs in most of the sites whereas also the rate is also low, below 250rs in Mahamayatala. The welfare scheme, Swastha Sathi Card among scavengers is common in most of the site.

4.6 Conclusion

Data collected from the field study in dumpsites of Kolkata, Murshidabad, and Odisha tells us that there is a huge potential for producing RDF from the non-recyclable part of plastic waste dumped at those dumpsites for co-processing of plastic waste in cement kilns. As per the CPCB guidelines on the use of waste as an alternative fuel and raw material in cement plants, The GCV of the RDF produced from the NRPW from the MSW is 2892 Kcal/ kg, which is within the permissible limit.

The survey on informal scavengers involved in waste picking gives us an idea about the socioeconomic and health, safety problems. To strengthen waste management in the observed cities, it is very important to address the problems faced by the scavengers during their involvement in waste management works.

CHAPTER 5

ROLE OF REVERSE LOGISTICS IN DISPOSAL OF ELV WASTE IN CO-PROCESSING

5.1 Introduction

One of the earliest descriptions of reverse logistics was given by Lambert and Stock in 1981. They described it as “going the wrong way on a one-way street because the great majority of product shipments flow in one direction” (Lambert and Stock 1981, p. 19). This is similar to a definition by Murphy in 1986, and by Murphy and Poist in 1989 who defined reverse logistics as the “movement of goods from a consumer towards a producer in a channel of distribution.” Throughout the 1980s, the scope of reverse logistics was limited to the movement of material against the primary flow, from the customer toward the producer.
In general, logistics indicates the products are transported from producer to customer, while reverse logistics is the opposite. Environmental awareness and recycling regulations have put pressure on many manufacturers and consumers to dispose of used products responsibly. Reverse logistics is a subset of return management, which is a broader supply chain management process. Reverse logistics is a growing field in both the practical and academic worlds, dealing with the physical flow of products, components, and materials from users to re-users.

Recovering used parts and being environmentally and socially responsible on the one hand, and profiting on the other, through internal culture development, adoption of new structural arrangements and processes, and the establishment of reverse distribution channels in industries to refuge recovery products.
In recent years, there has been a growing emphasis on environmental protection, as well as the optimal allocation of resources, a concept that "Reverse Logistics" has produced with "Return Management," which is being promoted internationally. This study states how to implement Reverse Logistics in industries. Reverse logistics is not always as mature as forward logistics, which has serious environmental consequences as well as a loss of profitability and customer satisfaction. This study helps by providing information on how to design effective reverse logistics and integrate them with forwarding logistics.
Many of the objectives of sustainable development can be fulfilled in an economical and environmentally responsible manner by remanufacturing. Remanufacturing completes the material use cycle and creates a manufacturing system that is practically closed-loop. Instead of only recovering the raw materials or recycling, remanufacturing focuses on recovering the value added. Creating a supply chain for the recycling and remanufacturing of waste items is one way to improve reverse logistics. Many nations have created laws that mandate manufacturers take responsibility for waste product recycling in order to address this issue.
Remanufacturing reverse logistics has been termed the most complex aspect of manufacturing technology and only uses about 50% to 70% of the human and material resources that made used or discarded products back to like-new products,

or in the functional characteristics and durability for at least the same level with the original products. The closed-loop supply chain is a supply chain system that coexists in remanufacturing and manufacturing. Reverse logistics offers a fruitful and appealing research area in the field of operations management because of its interdisciplinary and cross-functional nature.

Forward logistics and reverse logistics are both necessary components of a complete supply chain. Reverse logistics activities are subsequently increased by forward logistics operations, which plays an important for the organization's performance.

5.2 Reverse Logistics

Reverse logistics refers to a group of activities used to recover value from products after they have been sold, including servicing, refurbishing, and recycling. Reverse logistics is sometimes referred to as retrogistics, aftermarket supply chain, and aftermarket logistics. All operations involving product returns, maintenance, recycling, and dismantling are referred to as "reverse logistics." In order to maximize value, it includes moving products reverse through the supply chain.

The several aftermarket procedures that a product can go through in reverse logistics include:

- Remanufacturing - recreating the item with reused, repaired, or new parts
- Refurbishment - reselling a returned item that has been repaired or evaluated as being in good condition
- Servicing - customer service, field service, and product returns, such as the issuance of return merchandise authorizations
- Returns management
- Recycling and waste management

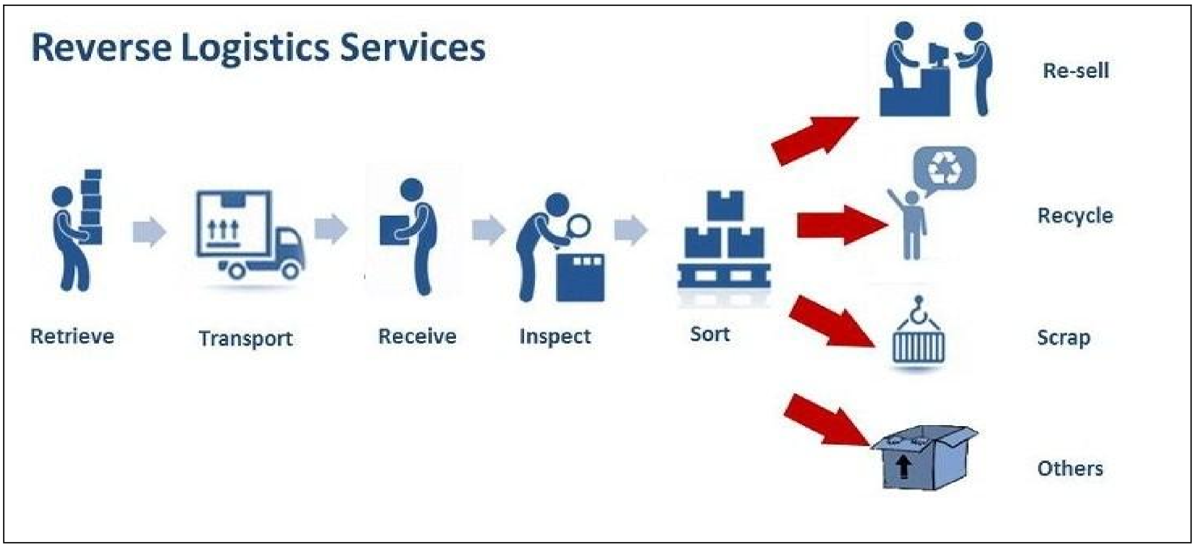

Fig. 38: Reverse Logistics Adapted from Mr. Siddhank Heda et al. (2017)

5.2.1 Green Reverse Logistics

Traditional logistics may be described as transport, warehousing, packaging, and inventory management from producer to user, but in order to protect the environment, consideration for recycling and waste disposal is critical. Green Reverse Logistics seeks to reduce environmental externalities by addressing logistics-related issues such as transportation, warehousing, and inventories. These issues include greenhouse gas emissions in logistics operations, noise, and accidents. Green product design means that before manufacturing a product, the environmental impact is considered, such as the used materials and whether the products can be recycled or not when they reach the end of their service life.

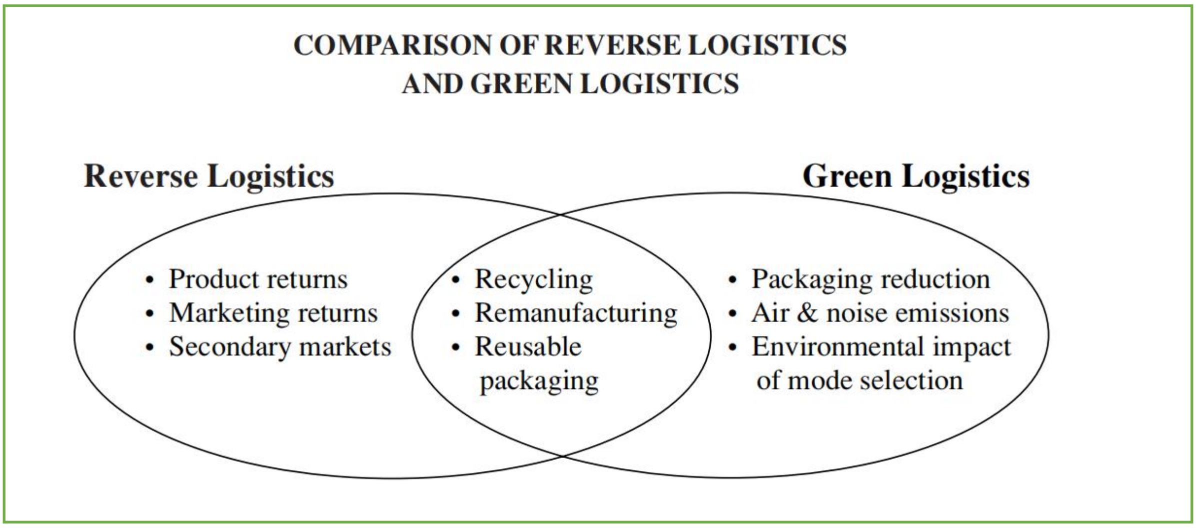

Fig. 39: Comparison of Reverse Logistics and Green Logistics

5.2.2 Reverse Logistic Supply Chain

Supply Chain Management is a term associated with reverse logistics processes. The world's best industries are discovering a powerful new source of competitive advantage for reverse logistics. Supply chain management refers to all of the integrated activities that bring a product to market and create and maintain a satisfied customer. It is also the involvement of a third party in the entire process that provides a better solution to the remanufacturer.

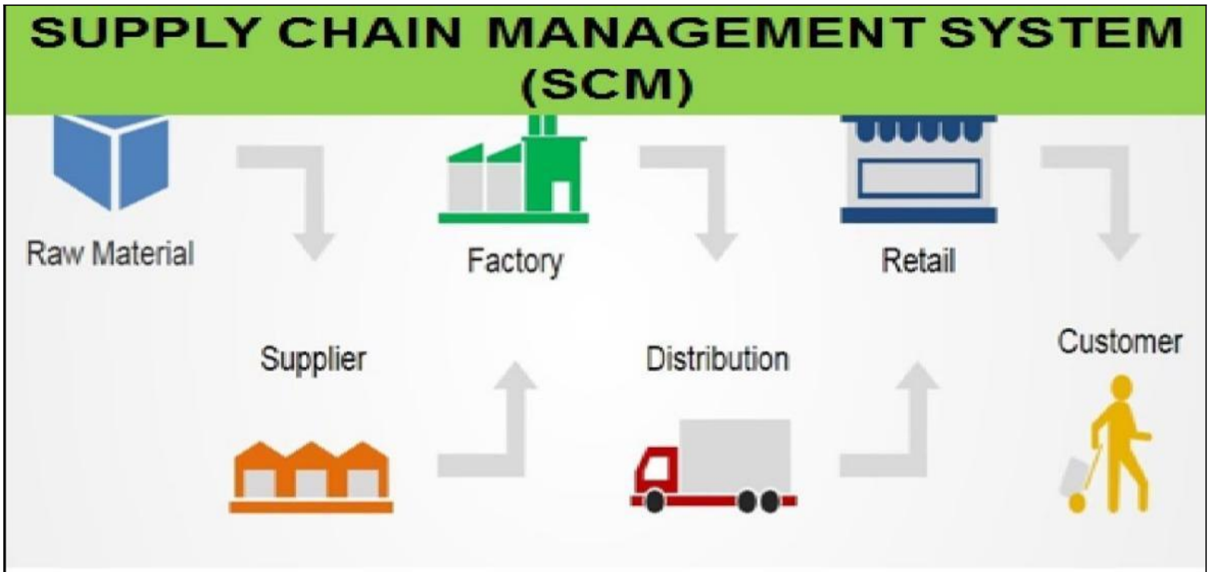

Fig. 40: Supply chain management Adapted from siddhant heda et al. (2017)

5.2.3 Close Loop Supply Chain Management

Reverse logistics was first conceptualized a very long time ago, although it is impossible to pinpoint exactly when it was first used. In the 1980s, the idea was motivated by the movement of flows against conventional flows in the supply chain (reverse distribution, reverse channel) Reverse logistics was defined at the end of the 1990s as recovering the value of the items and processes involved; presently, a comprehensive view of the supply chain is provided by taking both forward and reverse flow into account from a business viewpoint, the so-called close loop supply chain (CLSC).(Sergio Rubio et al., 2014)

5.3 Reverse Logistics In Automotive Industry

The current state of reverse logistics in the automotive sector suggests that reverse logistics is crucial to the growth of the industry. The empirical results indicate that reverse logistics is a part of daily work.
It shows that nowadays high product technological content makes manufacturing procedures in the automotive industry difficult, expensive, and time-consuming. Reverse logistics is a necessity for them to adopt. According to corporate, the implementation of automotive reverse logistics not only contributes to higher enterprise logistics service levels and increased operational effectiveness but also lowers production costs.

5.4 End Of Life Vehicles(ELVs)

Natural ELVs and Premature ELVs are the two main categories of ELVs. Natural ELVs are vehicles that have reached the end of their useful lives as a result of wear and tear. Premature ELVs are vehicles that have reached the end of their useful lives as a result of unnatural events such an accident, fire, flood, or vandalism damage. (ASM 2015).
According to the definition provided in the European Union Directive of 2000, an 'end-of-life' vehicle is one that has been discarded. When a vehicle is no longer safe to drive or does not meet emission standards, the last owner usually designates it as an ELV. In some cases, a vehicle is considered end-of-life simply because it is old.Such vehicles are not permitted to operate on the road or be exported outside of the European Union, according to the EU Waste Shipment Regulations.

The vehicles that have been permanently removed from the national fleet are known as ELVs in Australia. This can happen in a number of reasons, including damage, unroadworthiness, the age of the vehicle, or at the owner's request. End-of-life vehicle is defined as "a vehicle that, at the choice of its last owner, is ready to be discarded" in the Automotive Industry Standards (AIS 129, AIS Committee 2015).

Figure 41: Vehicles dumped as waste after its use termed as ELVs

5.5 Status of ELV Waste Recycling in India

ELV recycling has existed in India since the introduction of automobiles in the country, for recycling and waste management in India mainly the semi-formal sector is involved. The majority of recycling is done by scrap dealers and dismantlers in big cities such as Mayapuri in Delhi, Pudupet in Chennai, Ukkadam in Coimbatore, Mallick Bazaar in Kolkata, and Lohar Chawl in Mumbai are a few of these centres that are well-known.

In India, the semi-formal recycling of ELVs has both strengths and weaknesses. On the one hand, the current system provides benefits, most notably the creation of thousands of jobs and the addition of value to materials that would otherwise be discarded.

On the other hand, several issues related to the inefficient and harmful processing of ELVs result in significant environmental costs that are borne by society as a whole. Promoting available strengths and addressing weaknesses in the ELV sector will help the proposed ELV policy framework succeed. A large amount of scrap metal is generated during the automobile recycling process, which includes both ferrous and non-ferrous metals. These are recovered and used again. Scrap metals such as sheet metals, aluminium, and plastics are typically recovered and reused. Rubber parts (except tyres), insulation materials, glasses, and other unusable items are discarded in municipal waste. Although there are formal regulations regarding the disposal of used batteries, batteries are sold to spare shops.

Regulations exist for the return and recycling of batteries, although they are not strictly enforced. Hazardous compounds receive very little treatment. In recycling facilities, this causes pollution of the air, water, and land.

The most common materials or components recovered are the vehicle body frame, windows, tyres, batteries, wires, and so on. Elements such as zinc, magnesium, tin, platinum, and cobalt are also recovered. Steel and iron are the most commonly recycled metals. The current trend of lightening vehicle weight by using light metals such as aluminium will help. Non-metallic materials, such as polymers, are not fully recyclable, but their use in vehicles for weight reduction, comfort, and design is increasing.

In general, ELVs are made up of a lot of metal and other materials. this needs recycling and a sustainable and environmentally sound method of recovery and disposal so that they can be effectively reintroduced into the economy. This substitution has the potential to reduce the environmental impacts of primary material mining. Furthermore, primary metal processing requires more energy than secondary metal processing.

According to the CPCB, up to 70% of a vehicle's components are dismantled and directly reused or sold to other manufacturers. According to CPCB guidelines, passenger cars contain approximately 70% steel and 7-8% aluminium. The remaining 20-25 percent is made up of materials such as plastic, rubber, and glass. which is difficult to recycle, the recovery of this material is critical because data shows that India is heavily reliant on imports of most of these materials, and thus a recycling and reuse strategy can reduce reliance on imports.

Table 21: Types and percentage of the plastics used in automobile (Hongshen Zhang et al., 2014)

TYPE OF PLASTIC	PERCENTAGE
PP (Polypropylene)	21.1
PU (Polyurethane)	19.6
PVC (Polyvinyl chloride)	12.2
Thermosets Composite	10.4
ABS (Acrylonitrile butadiene styrene)	8
PA (Polyamide)	7.8
PE (Polyethylene)	6
PC (Polycarbonate)	2.6
PPO [Poly (p-phenylene oxide)]	1.9
POM Polyoxymethylene)	1.8
Thermoplastic Polymer	1.5
Others	7.1

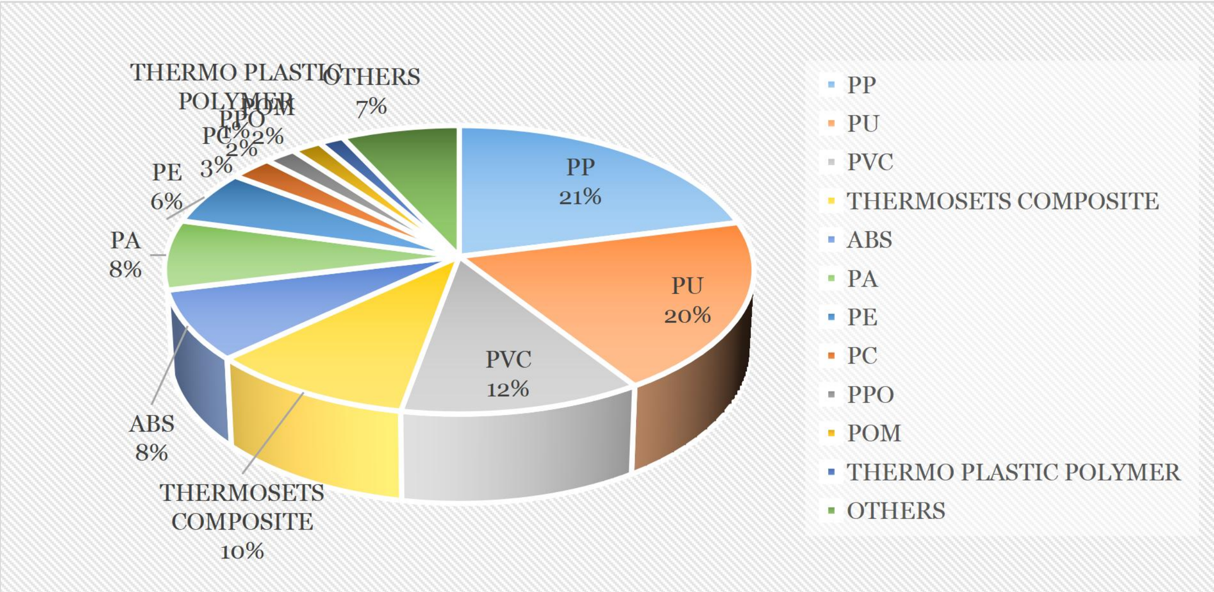

Fig. 42: Types and percentage of the plastics used in automobile

Total recycling and reuse rate of end-of-life vehicles, 2008–2019

(% of weight of vehicles)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27 (¹)	*82.9*	*82.0*	*83.5*	*84.4*	84.6	*85.3*	85.4	87.0	87.1	87.9	87.3	*89.6*
Belgium	88.0	88.4	89.0	88.2	88.7	88.2	89.2	91.3	92.1	93.2	93.5	92.9
Bulgaria	81.0	82.7	88.9	90.0	89.5	93.2	94.1	94.4	94.6	97.6	94.8	95.8
Czechia	80.0	80.3	80.3	80.3	80.3	80.3	80.3	90.2	90.3	91.9	95.5	93.3
Denmark (²)	82.7	82.0	90.5	92.8	92.4	*86.6*	86.0	91.2	88.8	91.5	89.9	94.6
Germany	89.2	82.9	95.5	93.4	92.3	89.8	89.5	87.7	89.3	89.5	87.1	86.9
Estonia	92.4	87.2	77.3	76.1	80.9	77.7	87.0	86.0	85.8	85.9	87.1	87.6
Ireland	75.9	78.9	77.0	80.5	81.8	80.4	82.1	83.3	86.0	85.9	86.4	87.4
Greece (³)	85.7	86.5	84.5	85.2	82.8	88.8	80.4	64.5	*100.0*	91.9	98.7	69.7
Spain	82.5	82.6	82.8	82.9	83.0	83.6	84.3	85.0	85.4	85.8	85.9	86.0
France	79.9	78.6	79.0	80.8	82.4	85.3	85.9	87.5	86.9	87.4	86.9	87.1
Croatia	:	:	:	:	97.2	100.0	89.5	92.8	93.9	99.3	97.4	96.3
Italy	84.3	81.8	83.2	84.8	80.8	82.2	83.4	84.6	82.5	83.2	82.6	84.2
Cyprus	78.3	87.1	81.1	84.0	84.7	84.3	87.7	89.1	90.3	89.2	89.8	88.7
Latvia	87.0	85.0	85.7	85.4	97.6	92.4	92.2	86.6	94.3	84.0	96.0	88.9
Lithuania	85.0	86.0	88.1	87.2	89.2	92.1	93.5	94.6	94.9	94.8	92.4	93.5
Luxembourg	84.0	81.0	85.0	82.9	85.0	84.0	87.0	87.0	86.0	94.3	94.1	96.7
Hungary	83.0	84.4	82.1	84.4	84.4	90.7	90.3	94.6	95.4	95.5	95.1	94.4
Malta (⁴)	:	:	64.2	87.0	95.8	91.9	45.0	77.7	54.4	56.1	81.0	:
Netherlands	84.4	84.1	83.3	83.1	83.7	86.0	86.1	87.7	88.9	87.1	87.1	87.2
Austria	83.7	82.9	84.2	82.8	83.4	85.0	85.8	86.9	87.2	86.6	86.2	87.3
Poland	79.5	87.1	88.8	89.5	90.4	88.6	85.5	94.7	94.3	95.7	93.4	118.8
Portugal	80.8	84.3	82.8	82.9	82.7	82.9	83.8	84.0	83.5	85.2	86.1	88.2
Romania	83.7	80.1	80.9	82.9	84.0	83.8	84.1	85.1	85.1	85.0	85.2	:
Slovenia	87.6	84.1	88.6	86.1	100.0	:	85.9	90.2	91.6	102.9	97.6	89.5
Slovakia	88.4	88.8	88.4	93.1	89.9	92.5	94.8	88.4	96.1	95.7	95.1	95.5
Finland	81.0	81.0	82.5	82.5	82.5	82.5	82.8	82.8	82.8	82.8	82.8	84.7
Sweden	83.0	86.0	84.4	84.4	85.0	84.6	84.4	84.6	86.7	88.2	86.8	87.4
Iceland (⁴)	98.2	83.0	95.2	82.0	100.0	99.6	97.7	98.5	96.8	97.5	:	:
Liechtenstein	96.0	76.0	76.0	80.0	77.2	78.2	78.7	80.5	75.6	75.1	74.5	75.7
Norway	82.2	83.0	83.9	73.6	75.5	75.4	82.9	85.2	85.2	86.2	87.7	85.2

(:) not available

(¹) Eurostat estimates between 2008 and 2011 as well as in 2013 and 2019.

(²) 2013 data: estimated.

(³) 2016 data: estimated.

(⁴) 2012 data: low reliability.

Source: Eurostat (online data code: env_waselvt)

Reuse/recovery and reuse/recycling rate for end-of-life vehicles, 2019

(% of weight of vehicles)

Note: Countries are ranked in decreasing order by reuse/recovery.

(¹) Eurostat estimate.

(²) 2018 data instead of 2019.

(³) 2017 data instead of 2019.

Fig. 43: Total reuse and recycling rate of end-of-life vehicle (Source - Eurostat)

5.6 Proposed model for ELV recycling and Co-processing of ELV plastic in cement kiln

By carrying out literature review for ELV recycling and management a model is proposed which shows the whole life cycle of a vehicle from the manufacturer to final destination recycling, reuse, and disposal of the vehicle.

- The process of ELV recycling begins at the dismantling or treatment facility, where it is first de-polluted and subsequently dismantled. De-pollution involves removing highly hazardous components and chemicals such as the battery, fuel, other fluids, airbags, and any mercury-containing components. Due to the hazardous nature of the removed materials such as explosive, corrosive, etc. de-pollution must adhere to strict health and safety regulations and environmental contamination must be avoided.

- After the vehicle has been depolluted, it is dismantled. This procedure include separating and collecting recyclable and reusable components such as engines, tyres, bumpers, and other parts.

- The remaining component is referred to as car hulk after being dismantled and parts from the ELV recovered. This hulk is flattened and compressed before being put through a shredder to collect the scrap metal. The vehicle is effectively pulverized by the shredder into small chunks, which are then moved by conveyors to separate using magnetic separation, eddy current, laser, and infrared systems (depending on the availability of the systems).

- The final processing of ELV by shredding generates many fractions and a residue also known as automobile shredder residue (ASR) containing a variety of materials that could not be recovered by any of the processes employed. Numerous studies have been conducted to determine how to use this residue, which has become a big issue in many nations. There are two fractions in ASR, a light fraction that consists 10–24% of the weight of the original vehicle and a heavy fraction that consists 2-8% of that weight. The ASR generated through ELV recycling is estimated to be 15-17% of the original vehicle weight. Initially, ASR was being Landfilled (CPCB Report, 2019). According to recent research, combustible fraction of ASR could be utilized for energy such as co-processing in cement kiln, Incineration Pyrolysis etc.

The below proposed model shows the each step of ELV recycling and disposal of combustible fraction for energy recovery.

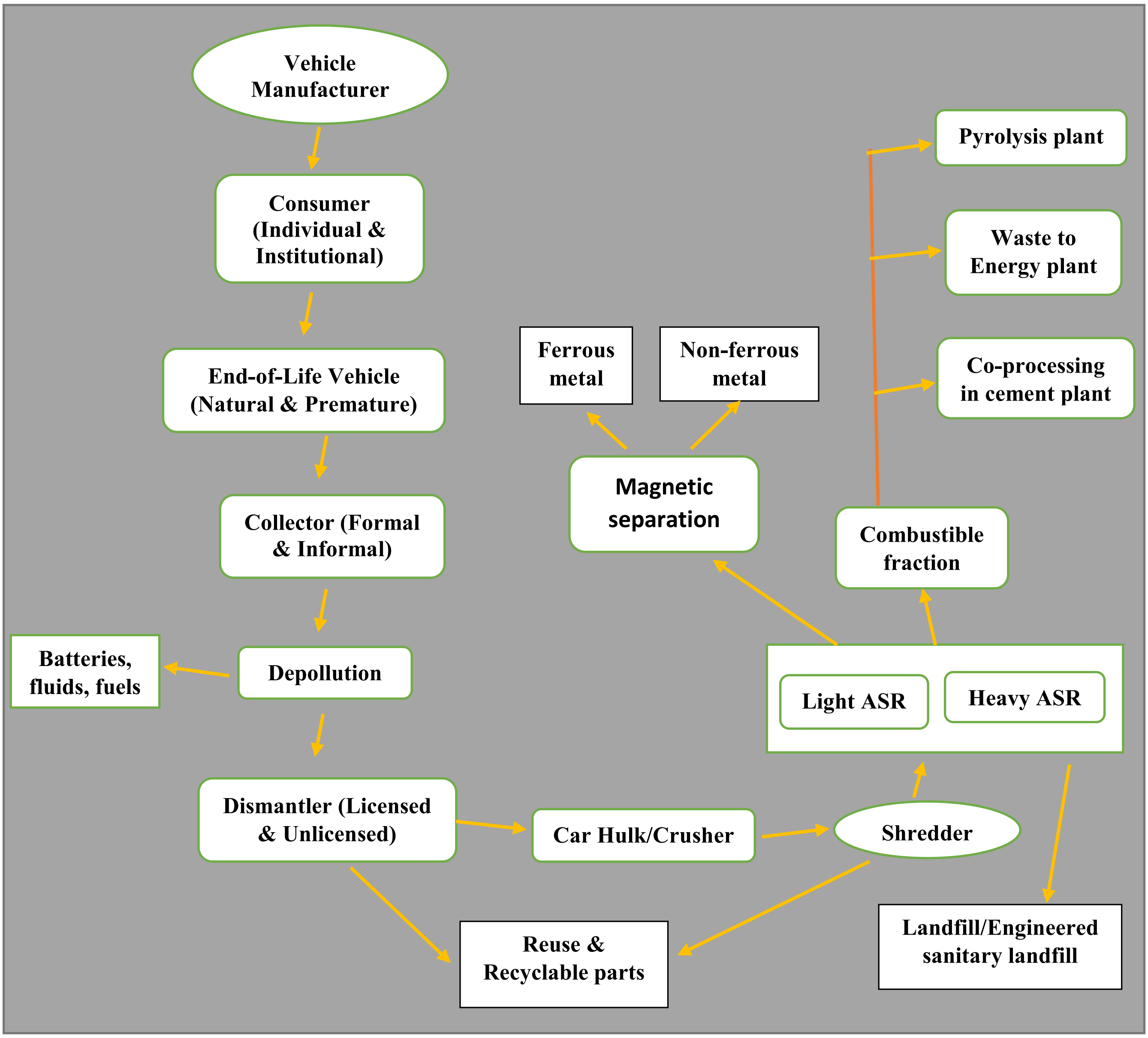

Figure 44: Proposed model for ELV recycling and co-processing of ELV plastic in cement kiln

5.7 ELV waste generation in India and global

The worldwide annual production of passenger cars and commercial vehicles was 70 million and 25 million respectively in 2018 (Statista, 2019). China alone had production of 27,809,196 vehicles, whereas France had production of 2,270,000 vehicles, India had 5,174,645 vehicles and Canada had production of 2,020,840 vehicles with the total production of more than 95 million vehicles throughout the world (oica.net, 2018). Indian producers manufactured 30.92 million motor vehicles in 2018-19 which includes 4.03 million passenger vehicles making India the fourth largest vehicle manufacturer in the world in 2018 (knowindia.net, 2020).

Around the globe, the European Union (EU) generation of ELV is approximately 9 million tons annually (CPCB, 2016). There are some 308.3 million motor vehicles in circulation on the EU's roads that is more than one for every two Europeans. Average age for passenger cars is 11.1 years old, for vans 11 years and for heavy duty commercial vehicles 12 years (ACEA 2017). India has one of the highest growth rates of motor vehicles globally and roughly had around 200 million vehicles by 2015. The expected number of vehicles attaining their end of life by 2015 was more than 8.7million, and the expected number in 2025 is 21 million (Arora, N, et al, 2019). The lack of treatment facilities and specific regulations on ELVs is the major barrier to combat with such high rates of motorization throughout the world.

5.8 ELV plastic waste management through co-processing

ELV management in India is mostly done in the informal sectors, i.e. the various dismantlers and scrap traders/dealers collect the vehicle after its life from various sources such as by auctions organized by the several auctioning agencies/ companies. Government vehicles are also auctioned in bulk or lots through government websites of MSTC. Likewise vehicles are collected from the source and dismantlers use it for the business. Various stakeholders responsible for the ELV management are dealers/scrap traders, manufacturers, users and government. The dismantling is the main business in ELV sector of India. Mostly the process of dismantling in India is manual with the help of labors. Various types of tools and machineries involved for dismantling of ELV. The flow of ELVs from its collection to its final disposal in other developed countries with the help of a flow diagram.

Figure 45: ELV flow from collection to final disposal in developed nations such as EU

European Union member states, has a structured way of recycling ELVs which acts as a reference for countries do not having proper recycling methodology and facilities. Also many countries having ELV legislations follow almost the same method of recycling as that of EU with some modification. The basic processes such as Collection, Depollution, Dismantling and Shredding remaining the same. Depollution is the first stage of removal of oils, and other fluids out of the vehicle once it is received. Dismantling is the second stage where the parts/components are removed and segregated as: directly reusable parts and recyclable/recoverable parts. Then the remaining car hulk is sent for shredding operation after which again the metals and non metals are separated by using air separation method by using density. Metals are further segregated into ferrous and non ferrous metals through magnetic separation. The remaining waste is termed as Automotive Shredder Residue (ASR) which is again of high energy value which is generally landfill. The ASR can be sent to cement industries for co-processing in cement kiln to utilize energy. However Indian ELV management system lacks the shredding operation which makes the ELV recycling incomplete. In India, the vehicle is brought down to small parts and pieces which is then sent to material specific recyclers instead of having shredding operation.

5.9 Reverse logistics involvement in co-processing of ELV plastic waste

The ELV management system is efficient only if it has a good network of collection system. It is easier if reverse logistic process is involve for collection to disposal of ELVs. Generally it is found that the ELVs are collected from various sources such as second hand car dealers and showrooms of the company such as True Value showrooms, accidental vehicles from insurance companies by auctioning, administrative usage cars of the automobile companies, crash tested cars and sometimes the user directly disposes off to dismantlers. The figure shows the Elvs waste management through reverse logistic process. We can use this channel of movement of ELV plastic waste co-processing as we can see that Automotive Shredder Residue (ASR) and Hazardous waste which goes to mainly landfill site which pollute the environment. Because it contain high energy value these waste can be used as Alternative Fuel and Raw Material for co-processing in cement kiln.

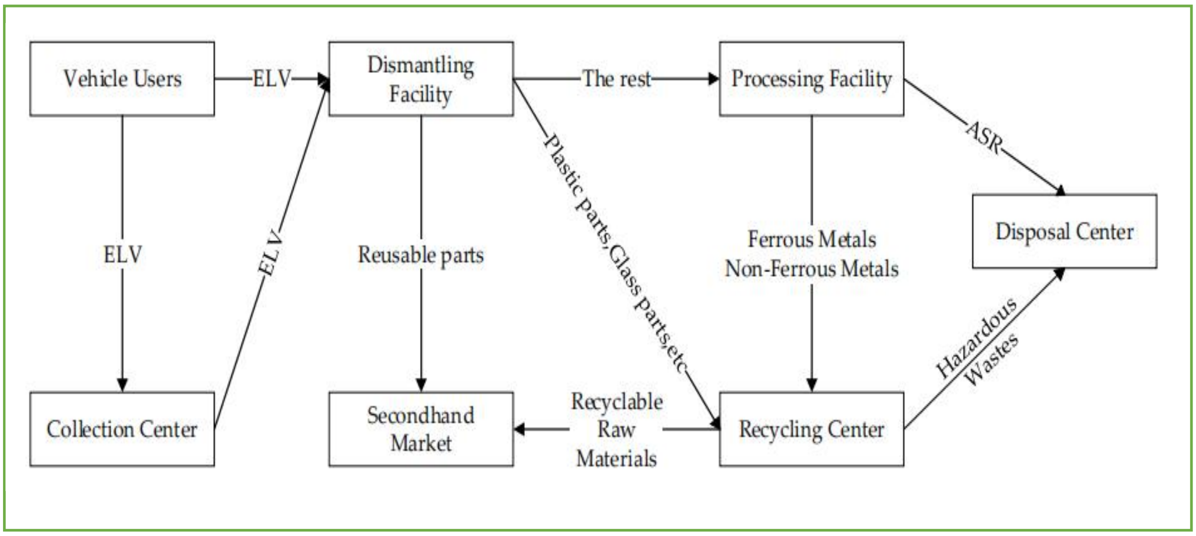

Figure 46: The reverse logistics process of end-of-life vehicles (ELVs)

5.10 Conclusion

The importance of reverse logistics in automobile industries is significant for developing reverse logistics logistics systems. It not only emphasized automobile returns and recycling scrapped automotive components, but also realized resource conservation and environmental protection, which is accomplished through resource reduction, refurbishment, restructuring, and recycling. Customers are paying greater attention to after-service in the current state of scarcity of resources in this area, therefore the automotive industry should put a higher priority on establishing and improving reverse logistics systems.

Therefore, it is crucial for the automobile sector to optimize end-of-life vehicle management from an environmental perspective. It sounds recycling system of scrapped automobiles, which motivates large manufacturers to take on responsibilities for recycling scrap vehicles. Reverse logistics seems to have a significant profit margin in this field to allows enterprises reduce cost in the present automobile reverse logistics market.

CHAPTER 6

COMPARATIVE ANALYSIS OF DIFFERENT TECHNOLOGY

6.1 Pyrolysis

Pyrolysis is a thermal degradation that occurs in the absence of or with a limited supply of an oxidising agent (i.e. partial gasification) to provide the thermal energy required for pyrolysis. The procedure is carried out at a temperature between 400 and 900°C, although often less than 700°C. Pyrolysis is an endothermic process with a heat output of 100 KJ/kg(Khiari et al., 2004). The pyrolysis process can reduce the waste volume by 50 – 90% (Nixon et al., 2013). Pyrolysis units for the treatment of waste usually include preparation and grinding, drying (depending on the process), pyrolysis reactor and secondary treatment setup for pyrolysis coke and pyrolysis gas (Bosemans et al., 2013). The pyrolysis process converts 80 percent of the energy stored in carbonaceous waste into liquid fuel and char (ouda et al., 2016).

Typical setups for conventional pyrolysis reactors include the following: Fixed bed, fluidized bed, moving bed, entrained flow, rotary kiln, ablative reactor, etc., and typically required waste pre-treatment. The interaction of a large number of thermo-chemical reactions produces distinct products that enhance the process complexity; several hundred different compounds are generated during waste pyrolysis, many of which have yet to be identified. It is critical to have a complete grasp of the properties and composition of the waste to be treated, especially if the waste is hazardous. (Helsen and van den Bulck, 2001). Three types of products are produced from pyrolysis process: pyrolysis gas, pyrolysis oil and char, the production of products depends on pyrolysis process and waste composition (Bosmans et al., 2013). Slow, moderate, fast, and flash pyrolysis are the four types of pyrolysis technology (Ahmad et al., 2014; Homagian et al., 2014). However, the slow and fast pyrolysis processes are the most commonly used. The main product of the slow pyrolysis process, which occurs at a moderate temperature, a low heating rate, and a longer residence time, is bio char/char. Pyro-oil, on the other hand, is the main product of fast pyrolysis, which is carried out at a high heating rate and a short residence time. Fast pyrolysis yields more and higher-quality bio oil than slow pyrolysis. (Brown et al., 201 l; Jahirul et al., 2012). The bio-oil can be blended with standard liquid fuels to create an alternative fuel because it contains low alkali metal (Hossain and Davies, 2013). Because the yield and qualities of pyrolysis products vary depending on the operating conditions and process type, each method has a wide variety of applications. If a higher bio char yield is required, a gradual or intermediate pyrolysis technique can be utilised; if pyro-oil is desired, a fast/flash pyrolysis process is used. By adjusting the operating parameters, specifically the reaction temperature and heating rate, the quality and amount of pyro-oil and bio-char produced from a certain feedstock may be optimised. (Roy and Dias, 2017).

Because of the presence of nitrogen and carbon dioxide, pyrolysis gas has a lower calorific value than conventional fuels, whereas bio-char can operate as a carbon sequestration material and can be utilised for soil amendment (Parket al., 2004; Pütün et al., 2004; Tsai et al., 2006). The procedure is less harmful due to lower operating temperatures and the absence of oxygen, as oxygen and temperature are the main precursors for the synthesis of furans and dioxins (Conesa et al., 2009). The low working temperature also aids in the removal of heavy metals from the pyrolysis gas, which remains trapped in the solid carbonaceous char produced (Menendez et al., 2002). Though pyrolysis has sparked considerable interest in the field of energy recovery due to the economic possibilities of alternate products, there are no installed commercial facilities in India, and research into these sorts of systems is limited to lab scale (Singh and Gu, 2010) and due to lack of economic viability the technology is not established (Samolada and Zabaniotou, 2014) although several cases suggest economical viability on a larger scale.

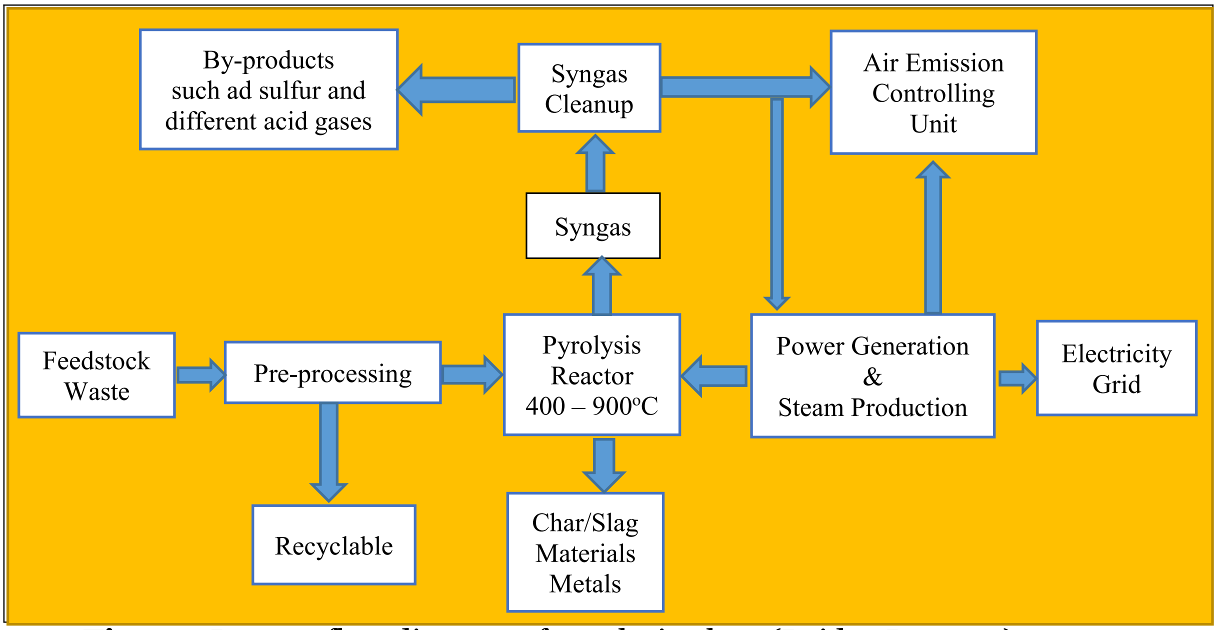

Fig. 47: Process flow diagram of pyrolysis plant (Baidya R., 2019)

6.2 Incineration

In many nations throughout the world, waste incineration is an essential aspect of waste management (Arena, 2012); approximately 65-80% of the energy trapped in waste material can be recovered (chakrborty et al., 2013). Incineration has a process efficiency of 25 to 30%. (Kirby and Rimstidt, 1993). Incineration produces hot combustion gases that contain nitrogen (N2), carbon dioxide (CO2), flue gas, oxygen (O2), and non-combustible material (Tan et al., 2015). Incineration is the most widely utilised thermo-chemical treatment for many forms of waste, including MSW, intended unsorted residual waste (i.e. waste remaining after separate collection), solid refused fuels (SRF), industrial waste (IW), and industrial hazardous waste (IHW). Waste incineration is commonly connected with energy recovery in the form of electricity and/or heat production; however, IHW is disposed of without energy recovery due to the presence of various pollutants in the generated flue gas (Lombardi et al., 2015). Incineration is utilised as a waste treatment technique for a wide spectrum of waste, and the process can reduce volume by up to 90%. (Di Marial et al., 2016). While MSW incineration/combustion is quite an old practice, its adoption as a sustainable waste management approach has grown in recent years (Grosso et al., 2010).

Drying and degassing, pyrolysis, gasification, and finally oxidation are the primary steps of the incineration process. These distinct stages usually overlap, implying that spatial and temporal separation of these stages may be limited. Although these processes can be influenced in order to limit pollutant emissions (Bosmans et al., 2013). Incineration is usually considered as a recovery treatment rather than a disposal strategy, and it also meets certain energy efficiency standards (Consonni et al., 2011). Because the primary goal of an incineration facility is to reduce the amount of MSW that goes to landfill, it should not be compared to energy generation from fossil fuels. The amount of energy recovered is determined by the MSW ratio of biogenic to fossil carbon, as well as the energy transformation efficiency of the incineration technique used. Conventional mass burn systems required 40-100% excess air above the stoichiometric value, resulting in a significant amount of flue gas to be cleaned. Acidic gases (SO2, HCl, HF, NOx, etc.), volatile organic compounds (VOCs), heavy metals, and other toxic emissions are released during the incineration process. Additionally, the process residues left behind are also a significant issue (Liu and Liu, 2005). Particulate particles can potentially cause a variety of respiratory issues. Dioxins, furans, and PCBs are carcinogenic. And mercury, like other heavy metals, is toxic. GHG emissions from incinerators are high, with estimates for CO2 in the region of 0.5 kg CO2/kwh. Although the quality of CO2 and other pollutants released during incineration is largely dependent on the operating conditions and waste qualities (Nixon Wright et al., 2013). Most modern waste incinerators utilize a lot of pollutants and emissions to reduce and address air pollution, and as a result, the risk of pollution from these facilities is now considered to be quite low (Yap and Nixon, 2015). The quantities of solid residue (fly and bottom ash, slag, filter dust, and other flue gas cleaning residues) vary substantially depending on the process design, waste composition, and waste type.

Bottom ash accounts for approximately 25 to 30% of the input garbage in MSW incinerators, whereas fly ash accounts for 1 to 5%. Based on its properties, bottom ash can be used in concrete aggregates and other construction materials (Bosmans et al., 2013). Similarly, slag and fly ash can be utilized into cement or other similar building materials, or designated for landfill provided the properties meet the standards (Arena, 2012). The capital cost of incineration facilities in India for 100-200 ktpa has been quoted to be between 136 and 295 $/tpa (Salvatore, 2013; Yap and Nixon, 2015). In India, the operational cost of incineration is projected to be roughly 85$/tonne (Chakraborty et al., 2013). However, waste incineration can be an environmentally acceptable process if linked with energy recovery, emission control, and a proper disposal mechanism (Nixon, Write, et al., 2013: Yap and Nixon, 2015). Although incineration has a cheaper initial cost than other energy recovery technologies, this does not directly correspond to its economic feasibility. Pollution control systems, feedstock handling units, building requirements, and other supporting elements for incinerators can account for 40-70 percent of overall project costs (Ouda et al., 2016).

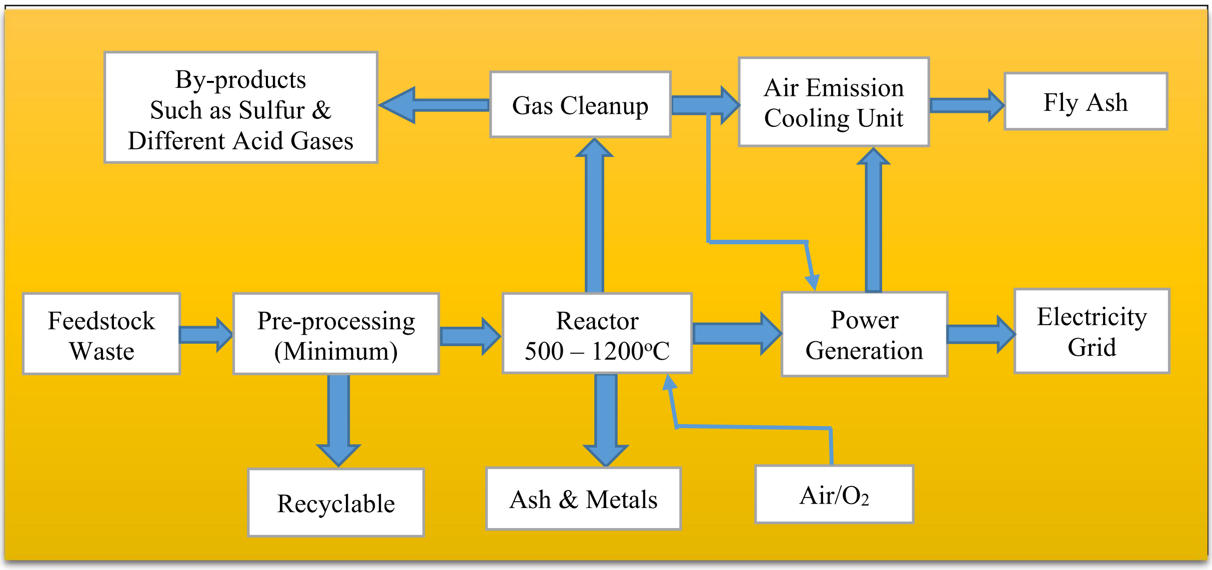

Fig. 48: Process flow diagram of Incineration plant (Baidya R., 2019)

6.3 Co-processing

Co-processing is the use of waste as either a raw material or a source of energy, or both, to substitute natural mineral resources and fossil fuels in industrial processes such as cement manufacturing. Waste used in co-processing is commonly referred to as alternative fuel and raw material (AFR) (Baidya et al., 2017). Waste co-processing in cement kilns is a waste treatment strategy that provides the benefits of simultaneously energy and resource recovery while also producing cement. Waste co-processing in cement kilns has economic, technical, and environmental advantages, making it an appealing and viable waste treatment approach (Jin et al., 2016). Co-processing, when combined with resource conservation and reduced carbon emissions, is a preferred alternative for sound and environmentally sustainable waste treatment methodology over traditional incinerator and non-scientific procedures. It not only solves the waste disposal problem, but it also lessens the pressure on secure landfills (Tiwari et al., 2014). The cement industry has enormous potential for offering better waste management solutions. Energy recovery from waste is also critical for lowering CO2 emissions (Kara et al., 2009). With the proper equipment and fixtures, various types of AFRs

can be employed in a cement kiln. The use of AFRs in cement kilns also reduces landfill emissions (Benhelal et al., 2013). Due to the long residence time of about 14 seconds at high temperatures of about l450°C, inherent ability of clinker to absorb and lock contaminants, such as heavy metals into the clinker, and also the alkaline environment of the kiln acting as a natural scrubber, cement rotary kiln are able to burn a wide range of materials (Baidya et al., 2017) aids the co-processing methodology.
The clinker firing process is well-suited to various alternative fuels and raw materials; the goal is to optimise the process and AFRs feeding rate so that clinker quality is maintained. The use of AFRs by cement manufacturers is both ecologically and economically justified, according to industrial experience (Chatziaras et al., 2014) and has no impact on emissions or the quality of the clinker produced (Garcia et al., 2014). Wide variety of waste products, including rubber residue, pulp sludge, used tyres, ELV plastic residues, wood waste, etc., are being co-processed. Tar, chemical waste, distillation residues, waste solvents, spent oils, wax suspension, and oil sludge, among other industrial hazardous waste, are co-processed as well (Kantee et al., 2004). Waste from the combustion of fossil fuels Solvent, plastics, and old tyres are not considered carbon neutral, although it is important to note that shifting waste from incineration plants to cement kilns results in a considerable net CO2 reduction due to cement kilns' higher efficiency. Another advantage is that no residue is produced as ash is converted in to clinker (Baidya et al., 2017; Karstensen, 2008). Co-processing of AFRs, in particular, has played a critical role in lowering CO2 emissions, saving natural resources and fossil fuels, and improving waste management operations (Supino et al., 2016), hence providing an effective waste management methodology.

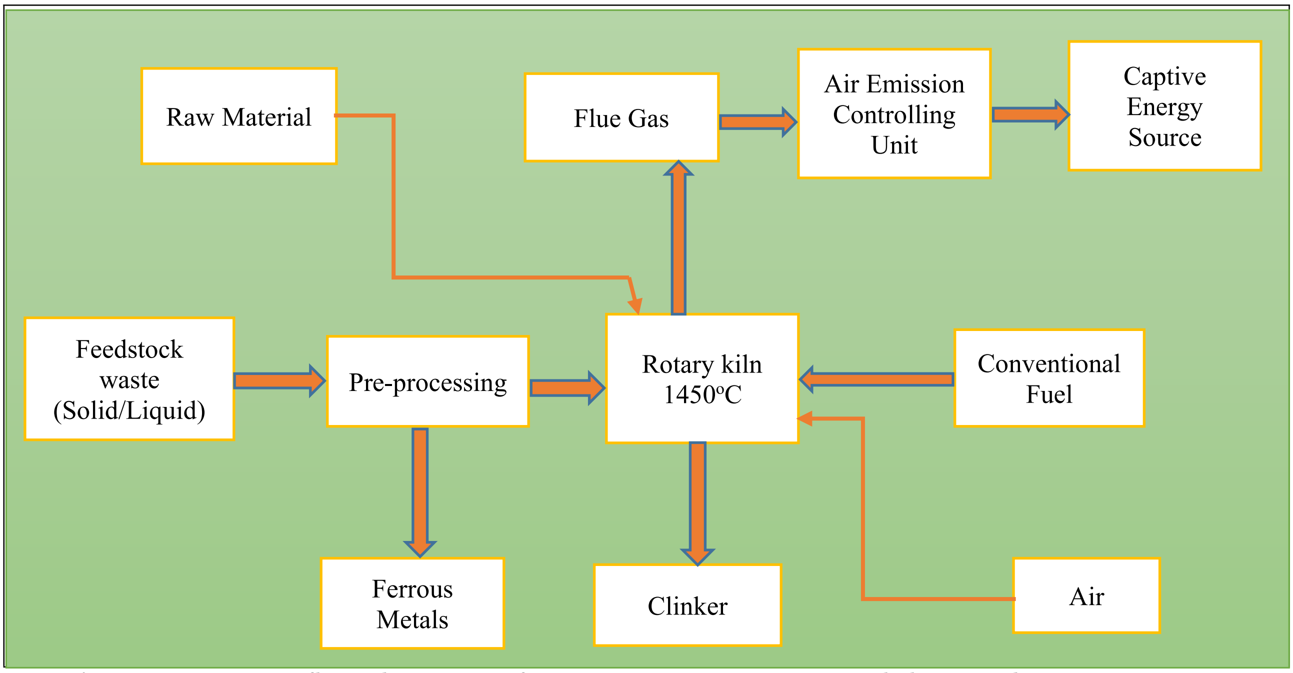

Fig. 49: Process flow diagram of co-processing in cement kiln (Baidya R., 2019)

Table 22: Comparative analysis of different technology

	Co-processing in cement kiln	Incinerators with Energy recovery	Pyrolysis-Plastic to fuel
Purpose	Industrial production of cement clinker	Reduce the volume of organic waste by burning	Produce liquid fuels from plastic wastes
Circular economy?	Yes; co-processing of wastes replaces coal and raw materials	No, only disposal of wastes	Yes; produced fuels can replace boiler oil and automobile fuels
Temperature ranges	1500-2000 °C. Inherent features, e.g. time, temperatures and oxidising conditions are excellent for waste destruction.	800-1100 °C	460-600 °C (~ 500 oC)
Investment cost	Kiln systems are already in place and operates at all time. The industry bears the investment and	Expensive to build, operate and maintain. Electricity production will not recover the Construction costs.	Expensive to build, operate (high cost of auxilliary fuels and catalysts) and maintain. Low scale

	operation costs for waste pre and co-processing. Facilities usually constructed within existing plant premises.	Land requirement: 0.8 ha for 300 t/d plant	tech at present. Land requirement: 0.8 ha for 300 t/d plant
Capital Cost for 100- 200 ktpa	80- 100 USD/t	135- 295 USD/t	925 USD/t
Operations and Maintenance Cost for 100-200 ktpa	15-20 USD/t	85- 100 USD/t	185 USD/t
Cost for waste disposal	Usually cost-efficient	Varies widely; 100-200 USD/t	Expected to be cost-efficient with low payback period (2-4 years) because of high cost of Diesel and Fuel Oil substituted (~1000 USD/t).
Energy utilization efficiency	Approaches 100%.	Low energy efficiency, range 15 ~ 25% for electricity production (for steam 80-90% efficiency)	Low energy efficiency, range 18 ~ 25%.
Waste types versatility	Certain limitations: pre-treatment of the wastes is usually needed such as segregation and shredding	More versatile than Cement kilns, but wet wastes in rainy season makes efficient operation difficult and will lead to emissions	Only LDPE and PP are suitable feedstocks, limitations on using PVC. Pre-treatment such as shredding and drying required.
Production of residues	Usually, no residues to dispose of	~ 30% of the incinerated waste ends up as residues and need to be disposed of in landfills	~ 5-10% end up as solid residues (rich in Carbon). 10-15% gas produced can be used as fuel in Pyrolysis process.
Emissions	Will normally be unaffected if properly operated. BAT cement plants have state of art	Exit gas from WtE-incinerators have often high concentrations of	Will ideally be very low, however, long term studies required for assessing

	dust and NOx controls and equipped with continuous emission monitoring system.	dioxins and other air-pollutants such as SOx, NOx and HCl (Luke Makarachi et al, 2018)	environmental performance and standards.
Green house gases	Reduces CO_2 emissions compared to landfilling and incineration.	Building WtE-incinerators will add the number of emission points in a country.	

6.4 Discussion & Conclusion

The comparative analysis of selected energy recovery processes, namely, co-processing, Incineration, Pyrolysis, have been carried out through literature review, experts' opinion and some real life experience from field study in the OPTOCE Research Project at Jadavpur University, India funded by SINTEF, Norway; It has been observed from the literature review that co-processing of plastics waste and NRPW is the most effective process with respect to investment, emission control, utilisation efficiency, Overall system efficiency, volume reduction, Public Acceptance/ Related issues etc.

CHAPTER 7 CONCLUSION AND FUTURE SCOPE

CONCLUSION

According to Central Pollution Control Board (CPCB) India generates more than 9.5 million tons plastic waste per annum which works out to be 26000 tons per day. As per study conducted in various city of West Bengal and Odisha it is found that 10.96% Non-recyclable Plastic Waste (NRPW) in municipal solid waste (MSW) that means in total 16 dumpsite 6552 tons of MSW dumped every day as a result 718 tons of NRPW goes to land fill which which can be converted in RDF. As a test result of RDF it is found that the calorific value of RDF is 2892 Kcal/kg which is in range of CPCB limit to be used for co-processing. From this study it can be understand that there is huge potential for co-processing of RDF as AFR in cement kiln.

In second part of this study has found the importance of reverse logistics implementation for End-of-Life vehicle (ELV) in automotive industry. The empirical finding indicates the importance of reverse logistics, generally presented by it helps automotive enterprises improve logistics service level, enhance operational efficiency, and reduce production costs. As in a vehicle around 20-25% of plastic waste which in mainly disposed of in land. We proposed a model for ELV recycling and combustible fraction of ELV waste to be used in co-processing by utilizing reverse logistics system to reduce environmental impact and enhance circular economy through resource circulation.

FUTURE SCOPE

- Select more cities for further study to identify and quantify the Non recyclable plastic waste dumped in landfill to know the exact quantity that will strengthen and clear the picture of potential of NRPW to be co-processed in cement kiln.

- Conduct interview with reverse logistic manager in automotive industries to know the challenges and problem face during implication of reverse logistic system system for End-of-Life vehicle in automotive industries.

- Explore more recycling and recovery technology to utilize plastic waste in a sustainable way to reduce environmental impact and improve circular economy.

- Conduct survey with more scavenger to know the social economical environmental and health impact by involving in waste picking and processing to strengthen the study.

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