Converting Waste Plastics into A Resource

Assessment Guidelines

UNEP

United Nations Environment Programme

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(revised version)

Compiled by

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Preface

Economic growth and changing consumption and production patterns are resulting into rapid increase in generation of waste plastics in the world. The world's annual consumption of plastic materials has increased from around 5 million tonnes in the 1950s to nearly 100 million tonnes; thus, 20 times more plastic is produced today than 50 years ago. This implies that on one hand, more resources are being used to meet the increased demand of plastic, and on the other hand, more plastic waste is being generated. In Asia and the Pacific, as well as many other developing regions, plastic consumption has increased much more than the world average due to rapid urbanization and economic development.

Due to the increase in generation, waste plastics are becoming a major stream in solid waste. After food waste and paper waste, plastic waste is the third major constitute at municipal and industrial waste in cities. Even the cities with low economic growth have started producing more plastic waste due to increased use of plastic packaging, plastic shopping bags, PET bottles and other goods/appliances using plastic as the major component.

This increase has turned into a major challenge for local authorities, responsible for solid waste management and sanitation. Due to lack of integrated solid waste management, most of the plastic waste is neither collected properly nor disposed of in appropriate manner to avoid its negative impacts on environment and public health and waste plastics are causing littering and choking of sewerage system. Due to extremely long periods required for natural decomposition, waste plastic is often the most visible component in waste dumps and open landfills.

Plastic waste recycling can provide an opportunity to collect and dispose of plastic waste in the most environmental friendly way and it can be converted into a resource. In most of the situations, plastic waste recycling could also be economically viable, as it generates resources, which are in high demand. Plastic waste recycling also has a great potential for resource conservation and GHG emissions reduction, such as producing fuel from plastic waste. This resource conservation goal is very important for most of the national and local governments, where rapid industrialization and economic development is putting a lot of pressure on natural resources. Some of the developed countries have already established commercial level resource recovery from waste plastics. Therefore, having a "latecomer's advantage," developing countries can learn from these experiences and technologies available to them.

UNEP has developed a programme on integrated solid waste management to support capacity building and technology transfer and under which a set of guidelines on development of ISWM Plan (four volumes available on line: http://www.unep.or.jp/ietc/spc/activities/activity_capacity-bldg.asp) have been prepared.

Recognizing the importance of particular waste streams and to build the capacity for the design and implementation of projects on the conversion of waste into material/resource source, UNEP has also developed guidelines for the characterization and quantification of specific types of waste, the assessment of waste management systems and compendiums of technologies for various types of wastes.

This document pertains to the methodology for waste plastics characterization and quantification (mainly for conversion into resource/fuel) and the assessment of current waste management system including the identification of gaps therein. It is aimed to raise awareness and assist policy – makers and managers on the collection and analysis of data to generate a baseline on waste plastics to further develop viable business propositions for converting waste plastics into fuels and to identify, assess and select Environmental Sound Technologies (EST) suitable for local conditions.

This document can also be of interest to other interested parties/organizations that aim at supporting decision-makers. They may be:

- consultants working on urban services, recycling, or waste management;
- representatives or staff of other local stakeholders including community groups, NGOs, and the private sector;
- entrepreneurs wishing to expand or strengthen their solid waste portfolios;
- academicians and scholars in urban environmental management;
- the press, especially when seeking background materials;
- donors interested in supporting future waste management activities; and
- local experts interested in using or replicating the results.

Table of Contents

Part II: Assessment of Current Waste Plastics Management Systems

8. Waste Plastics Management System / Practices

Annexure

Acronyms

ABS	Acrylonitrile Butadiene Styrene
BOT	Build-Operate-Transfer
BFR	Brominated Flame Retardants
C&D	Construction & Demolition
CIWMB	Californian Integrated Waste Management Board
CL	Confidence Level
CV	Calorific Value
CRV	Californian Redemption Value
DTIE	Division of Technology, Industry and Economics
ESTs	Environmentally Sound Technologies
E-Waste	Electronic Waste
HDPE	High Density Polyethylene
HIPS	High Impact Polystyrene
IETC	International Environmental Technology Centre
ISWM	Integrated Solid Waste Management
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
MC	Moisture Content
MSDS	Material Safety Data Sheet
MSW	Municipal Solid Waste
NGOs	Non-governmental Organizations
OECD	Organisation for Economic Co-operation and Development
PA	Polyamides
PC	Polycarbonates
PE	Polyethylene
PES	Polyester
PET	Polyethylene Terephthalate
PP	Polypropylene
PPVC	Plasticized Polyvinyl-Chloride
PRC	People's Republic of China
PS	Polystyrene
PSP	Private Sector Participation
PU	Polyurethanes
PVC	Polyvinyl-Chloride
3R	Reduce, Reuse and Recycle
RPPCS	Rigid Plastic Packaging Containers
SAN	Styrene AcryloNitrile
SPI	Society of the Plastics Industries
StEP	Solving the E-waste Programme
TPE	Tons Per Employee
UNEP	United Nations Environment Programme
WEEE	Waste Electrical and Electronic Equipment
WGF	Waste Generation Factors

PART I

Waste Plastics Quantification

and Characterization.

Projections for the Future

1. Introduction

1.1 Overview

The aim of these guidelines is to provide a methodology for the collection of baseline data for a potential project on converting waste plastics into a resource/fuel. The guidelines have been prepared to facilitate the collection of information on waste plastics, which could be recovered either from mixed waste or directly at source from different waste generating sectors, viz.: domestic, commercial, industrial, construction and demolition, and WEEE/E-waste. These guidelines are also expected to help in estimating the trend of waste plastics generation by each generator type or sector as per demographic and socioeconomic trends of solid waste generation rates.

It is important to put into context the waste plastics generation in relation with the overall solid waste generated. Quantification and characterization of the solid waste stream as a whole is recommended prior to focusing on waste plastics. Further, plastics to fuel conversion technologies may require the mixing of waste plastics with organic waste, including paper and wood, as additional feedstock; hence the quantification of these streams of waste will also be useful to be known (Please refer to the following guideline "Developing Integrated Solid Waste Management Plan – Training Manual Vol. 1: Waste Characterization and Quantification with Projections for Future" http://www.unep.or.jp/ietc/SPC/publications.asp).

These guidelines for waste plastics could be used as stand alone set of guidelines, if the target is to characterize and quantify only waste plastics, or could be used as an additional set of guidelines to narrow down the characterization and quantification of solid waste with reference to waste plastics.

1.2 Importance of data collection

The data on current and future trends of waste plastics is the basic requirement to develop a viable system for converting waste plastics into a resource (energy or useful material). Information on quantities, types and quality of the waste plastics is necessary to determine the technology to be used, its size, specification of equipment and additional aspects of the system such as the vehicles for collection, buildings and stockyards. The data will also ultimately help in working out the economic feasibility of the planned business.

1.3 Roadmap

As a starting point for the baseline data compilation it is very important to set the boundaries and plan the data collection and analysis procedures before hand. Figure 1.1 presents the roadmap to follow for the data collection and its analysis. This roadmap is divided into the following steps:

1. **Setting the boundaries:** Clear definition and demarcation of geo-political and administrative boundaries based on the sectors and/or waste generators (Chapter 3); and

2. **Setting the procedures for data collection, analysis and presentation: D**etermining the number of samples for primary data collection, identifying the sites and timing for sample collection, selecting the methods for the analysis of the samples, and choosing the methodology for analysis and presentation of the data (Chapter 4).

The procedure for the data collection might differ according to the waste generator sector that is targeted, as well as the specific waste stream such as Waste Electrical and Electronic Equipment (WEEE) or Construction and Demolition (C&D) waste. Guidance on this regard will be provided in the following chapters:

- **Municipal solid waste (residential and commercial):** (Chapter 5)
- **Industrial solid waste (non-hazardous):** (Chapter 6)
- **WEEE/E-waste:** (Chapter 7)

Construction and Demolition (C&D) Waste

In developing countries, C&D waste may not contain substantial portion of waste plastics, however it might be present in the form of packaging materials or parts of equipment or materials itself (e.g. pipes). Segregation of the plastics from other streams of waste is recommended. In addition to it PVC should also be segregated from other plastics as a separate stream.

Hazardous Waste

It is recommended that wherever waste plastics are mixed or contaminated with hazardous waste, then that portion of the waste (which includes the waste plastics), is treated as hazardous waste. Please refer to the *Guidelines for Integrated Solid Waste Management (ISWM),* which are available separately.

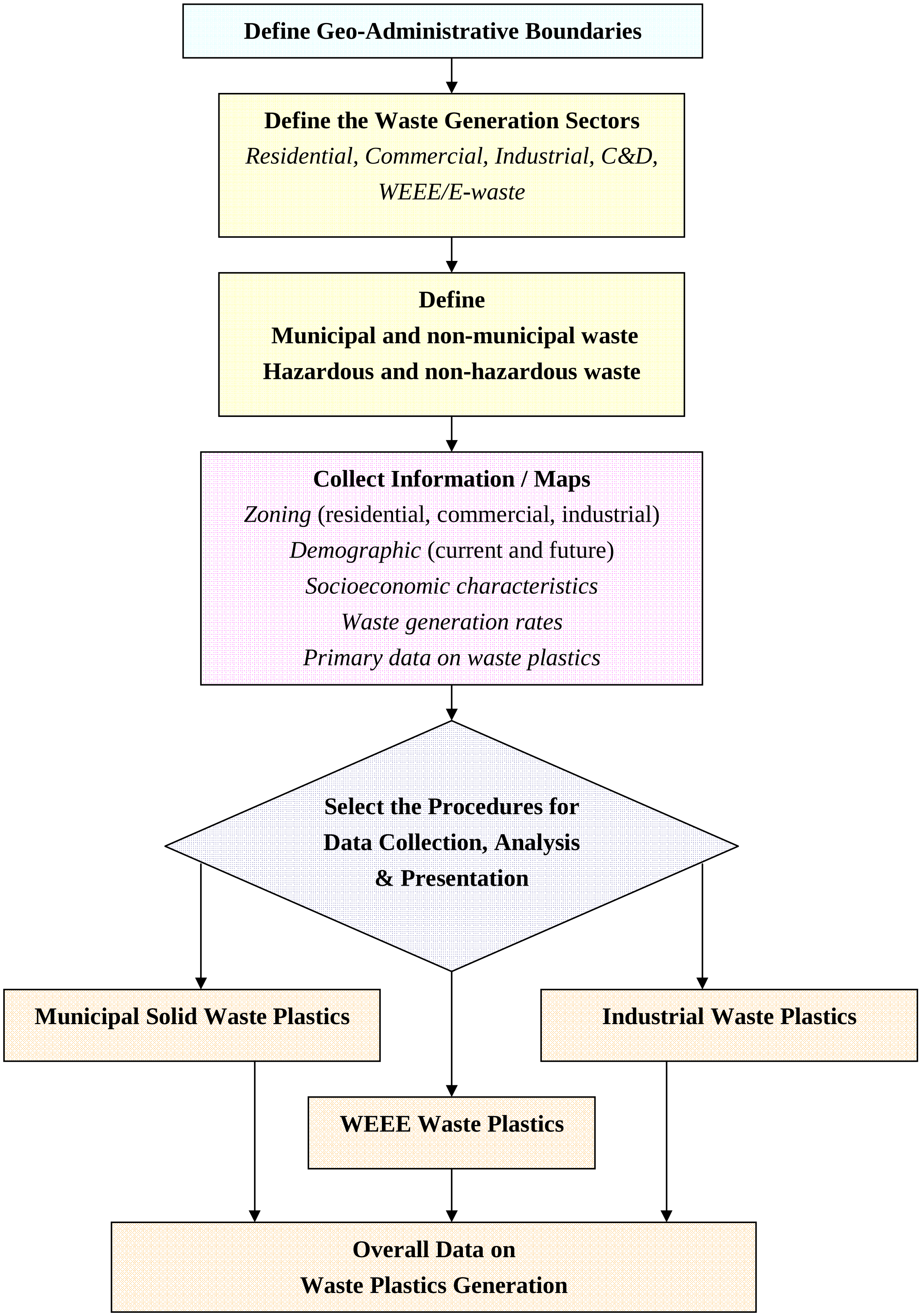

Figure.1.1: Flowchart for Data Collection & Analysis

2. Plastics

2.1 Overview

Plastics are polymers, a very large molecule made up of smaller units called monomers which are joined together in a chain by a process called polymerization. The polymers generally contain carbon and hydrogen with, sometimes, other elements such as oxygen, nitrogen, chlorine or fluorine.

There exist natural plastics such as shellac, tortoiseshell, horns and many resinous tree saps but the term “plastic” is commonly used to refer to synthetically (synthetic or semi-synthetic) created materials that we constantly use in our daily lives: in our clothing, housing, automobiles, aircraft, packaging, electronics, signs, recreation items, and medical implants to name but a few of their many applications.

These plastics are not just polymers which can be molded or extruded into desired shapes but often contain additives that improve their performance. According to the polymer used, the synthetic and semi-synthetic plastics can be designed with a broad variation in properties that can be modified by the addition of such additives. Some additives include the following:

- Antioxidants – added to reduce the effects of oxygen on the plastics during the ageing process and at elevated temperatures.
- Stabilizers – in many cases used to reduce the rate of degradation of polyvinyl chloride (PVC).
- Plasticizers or softeners- used to make some polymers more flexible, such as PVC.
- Blowing agents –used to make cellular plastics such as foam.
- Flame retardant –added to reduce the flammability of plastics.
- Pigments –used to add color to plastic materials.

2.2 Thermoplastics and Thermosets

Synthetic and semi-synthetic plastics can be divided into two broad categories: thermoplastics and thermosets.

Thermoplastics are plastics that can be repeatedly soften and melt when heat is applied and they solidify into new shapes or new plastics products when cooled. Thermoplastics include Polyethylene Terephthalate (PET), Low Density Poly Ethylene (LDPE), Poly Vinyl Chloride (PVC), High Density Poly Ethylene (HDPE), Polypropylene (PP) and Polystyrene (PS) among others.

Thermosets or thermosettings are plastics that can soften and melt but take shape only once. They are not suitable for repeated heat treatments; therefore if heat is reapplied they will not soften again but they stay permanently in the shape that they solidified into. Thermosets are widely used in electronics and automotive products. Thermoset plastics contain alkyd, epoxy, ester, melamine formaldehyde, phenolic formaldehyde, silicon, urea formaldehyde, polyurethane, metalised and multilayer plastics etc.

Of the total post-consumer plastics waste in India, thermoplastics constitute 80% and the remaining 20% correspond to thermosets. Similar percentages are also representative in the rest of the world.

2.3 Most Common Plastic Types

Plastics are classified on the basis of the polymer from which they are made, therefore the variety of plastics it is very extensive.

The types of plastics that are most commonly reprocessed are polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl chloride (PVC).

- **Polyethylene (PE)** - The two main types of polyethylene are low-density polyethylene (**LDPE**) and high density polyethylene (**HDPE**). LDPE is soft, flexible and easy to cut, with the feel of candle wax. When it is very thin it is transparent; when thick it is milky white, unless a pigment is added. LDPE is used in the manufacture of film bags, sacks and sheeting, blow-moulded bottles, food boxes, flexible piping and hosepipes, household articles such as buckets and bowls, toys, telephone cable sheaths, etc. HDPE is tougher and stiffer than LDPE, and is always milky white in color, even when very thin. It is used for bags and industrial wrappings, soft drinks bottles, detergents and cosmetics containers, toys, crates, jerry cans, dustbins and other household articles.

- **Polypropylene (PP)** - Polypropylene is more rigid than PE, and can be bent sharply without breaking. It is used for stools and chairs, high-quality home ware, strong moldings such as car battery housings and other parts, domestic appliances, suitcases, wine barrels, crates, pipes, fittings, rope, woven sacking, carpet backing, netting, surgical instruments, nursing bottles, food containers, etc.

- **Polystyrene (PS)** - In its unprocessed form, polystyrene is brittle and usually transparent. It is often blended (copolymerized) with other materials to obtain the desired properties. High impact polystyrene (HIPS) is made by adding rubber. Polystyrene foam is often produced by incorporating a blowing agent during the polymerization process. PS is used for cheap, transparent kitchen ware, light fittings, bottles, toys, food containers, etc.

- **Polyethylene Terephthalate (PET)** – PET exists as an amorphous (transparent) and as a semi-crystalline (opaque and white) thermoplastic material. Generally, it has good resistance to mineral oils, solvents and acids but not to bases. The semi-crystalline PET has good strength, ductility, stiffness and hardness while the amorphous type has better ductility but less stiffness and hardness. PET has good barrier properties against oxygen and carbon dioxide. Therefore, it is utilized in bottles for mineral water. Other applications include food trays for oven use, roasting bags, audio/video tapes as well as mechanical components and synthetic fibers.

- **Polyvinyl chloride (PVC) -** Polyvinyl chloride is a hard, rigid material, unless plasticizers are added. Common applications for PVC include bottles, thin sheeting, transparent packaging materials, water and irrigation pipes, gutters, window frames, building panels, etc. If plasticizers are added, the product is known as plasticized polyvinyl chloride (PPVC), which is soft, flexible and rather weak, and is used to make inflatable articles such as footballs, as well as hosepipes and cable coverings, shoes, flooring, raincoats, shower curtains, furniture coverings, automobile linings, bottles, etc.

Other plastics extensively used in our daily lives are as follow:

- **High Impact Polystyrene (HIPS) –** used in fridge liners, food packaging, vending cups**.**
- **Acrylonitrile butadiene styrene (ABS) –** used in electronic equipment cases (e.g., computer monitors, printers, keyboards), drainage pipe.
- **Polyester (PES) –** used in fibers, textiles.
- **Polyamides (PA) (Nylons) -** used in fibers, toothbrush bristles, fishing line, under-the-hood car engine mouldings.
- **Polyurethanes (PU) -** used in cushioning foams, thermal insulation foams, surface coatings, printing rollers.
- **Polycarbonates (PC) -** used in CDs, eyeglasses, riot shields, security windows, traffic lights, lenses.
- **Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) -** A blend of PC and ABS that creates a stronger plastic. Used in car interior and exterior parts and mobile phone bodies.

2.4 Film/Soft – Rigid/Hard Plastics

One common classification with regards to waste plastics is rigid/hard and film/soft plastics. Plastic films are technically defined as plastic sold in thicknesses of up to 0.0254 mm, or 25.4 μm. However it is usually referred to plastics which are typically thin items, pliable sheets or collapsible tubes (e.g. shopping bags, trash bags and packaging materials for many different products).

On the other hand rigid plastics have the properties to be sturdy and self-supporting (e.g. cosmetic and toiletry bottles, soft drink and water bottles, basins, pails, trays, various containers and many others).

The most common polymer used in film plastics is low density polyethylene (LDPE) and shrink wrap, which is a linear low density polyethylene (LLDPE) designed to stretch. HDPE is also extensively used. PP film is commonly used to package cigarettes, candy, snack food and sanitary goods. PVC film is used in some bags and liners, labels, adhesive tape and to package fresh red meats. PET films is found in nonfood, non-packaging applications such as magnetic audio, photographic film and video recording film.

Similarly, rigid plastics are composed of a broad variety of polymers (e.g. In agriculture the most used resin types are mainly HDPE, PP and PS. Common products are nursery pots, trays, flats, tray inserts, baskets and hangers, pails and barrels).

This classification (film-rigid plastics) is based on common properties/features of the plastics but does not refer to the composition of the material.

Please refer to Annexure 1 for a classification on rigid and non rigid packaging plastics. Furthermore, definitions of various types of waste plastics are shown in Annexure 2.

2.5 Plastic/Resin Identification Code

The Society of the Plastics Industries (SPI) developed in 1988 the resin identification code to facilitate the recycling of post-consumer plastics by providing manufacturers a consistent and uniform system to identify the resin content of plastic bottles and containers. The SPI coding, by which a number is recorded within the plastic item to specify the type of polymer used in its manufacture process, focused on the plastic packaging commonly found in the residential waste stream. The majority of plastic packaging is made of six type of polymers such as polyethylene terephthalate (PET or PETE); high density polyethylene (HDPE); polyvinyl chloride (PVC or vinyl); low density polyethylene (LDPE); polypropylene (PP); or polystyrene (PS). Therefore SPI resin identification code assigned each of these resins a number from 1 to 6. Additionally this system included a seventh code, identified as "other" indicating that the product in question is made with a resin other than the six listed above, or is made of more than one resin used in combination.

Figure 2.1: Plastic Identification Code

Unfortunately the Plastic/Resin Identification Code is not world wide used and this classification is not followed in most of developing countries where usually the waste plastics are either covered under one category, “plastics” or two categories, “rigid and soft/film plastics”.

References:

- http://www.plasticsindustry.org/
- http://plasticulture.psu.edu
- Understanding Plastic Films: Its uses, benefits and Waste Management Options. Prepared for the American Plastics Council by Headley Pratt Consulting. Dec 1996.
- http://www.sdplastics.com/plastics.html
- http://www.ciwmb.ca

3. Plastic Waste Quantification and Characterization – Preparation for Data Collection

3.1 Setting the Boundaries

The first step for data collection is to clearly set the boundaries in terms of geographical and administrative coverage, waste generation sectors to be covered and identification of the waste plastic generators.

3.1.1 Setting Geographical Size of the Area and Zoning

A map is required from local authorities which identifies the geographical and administrative boundaries with geographical area and land zone planning.

- **Population Size and Growth**

Time series data of the population and future projections along with the distribution of the population among various zones is required.

- **Socio-Economic Patterns**

The information on socioeconomic patterns is required to assess their influence over the current and future waste plastics generation levels and trends. There is a strong correlation between the economic growth, or the rate of urbanization and industrialization, and the generation of waste plastics in developing countries. Currently there is an increase in goods predominately made of plastic instead of other materials: an increase on plastic packaging, refrigeration of foods wrapped in plastics, take away foods, plastic bags provided by shopping malls, etc.

- **Size and Number of Industries and Commercial Undertakings**

The information on the size and number of industries and other commercial undertakings, according to their type or clusters as per industrial classification (an example of industrial classification is shown in chapter 6), is required to formulate the data collection strategies, as various types of clusters may generate specific types and specific quantities of waste plastics.

- **Administrative Boundaries and Responsibilities**

The information on the administrative roles of various departments and their jurisdiction will be required as baseline information on the institutional arrangements and institutional gaps that need to be filled in to effectively manage waste plastics. This information will also cover the responsibilities of various actors (government, industry, service providers and community) in the collection, transportation, treatment, recycling, and disposal of the waste plastics. This would further help to estimate the types and quantities of waste plastics generated at its origin, transported to the disposal site, and/or recycled.

3.1.2 Defining Waste Generating Sectors

- **Municipal Waste**

Depending on the administrative boundaries, municipal waste may only cover residential and commercial waste or it may also include urban agricultural waste and/or industrial waste from canteens/restaurants, residences and offices within the industries (non-hazardous waste). Therefore, the term "municipal waste" has to be defined based on the existing regulations and practices within the specified geographic location.

Usually in most developing countries, municipalities are responsible for the collection and disposal of municipal waste from residential areas while other sectors (commercial, industrial, and agriculture) make their own arrangements to transport their waste to the municipal disposal sites (landfill and incineration plants), if they are allowed to dispose their waste at municipal facilities, and pay the subsequent disposal charges.

If within the municipal waste there are separate categories for residential and commercial waste, and they are collected separately, then it is recommended that the collection of the data is done under separate categories and not as municipal waste as a whole.

- **Residential Waste**

Residential waste generated by households, such as single-family houses or multi-family buildings, is comprised of different streams of waste in which waste plastics is included.

Usually the municipality is responsible for the collection and transportation of the residential waste, thus it is treated as municipal waste; however in some countries, the collection and transportation of waste from multi-family buildings could be the responsibility of the residents. In some countries there are regulations on segregation at source for the recyclable waste or in other cases without any regulation informal recycling occurs. Information on this type of regulation or information is vital to estimate the overall quantity and quality of waste plastics for designing a recycling facility.

- **Commercial Waste**

In many places, waste plastics, as part of the non-hazardous commercial waste generated by the commercial entities (shopping malls, markets, offices etc.) is considered as municipal waste and therefore collected by the local government or municipality. However in many cases waste generators arrange its collection through the private sector. Either way, businesses might segregate the waste plastics and sell them to recycling companies. This information would help to estimate the overall quantity and quality of waste plastics and final disposal.

- **Industrial Waste**

Industrial waste can be both, hazardous and non-hazardous. Usually, industrial waste is not considered as municipal waste; however, in some places, the non-hazardous portion of the waste (where waste plastics is included), is disposed of at municipal disposal facilities. In this case, the industries make arrangements for the transportation of the waste to the disposal facility and they may pay disposal charges. Some or all of the waste plastics generated by industries may be directly sold to recyclers. Hence this information would be useful for designing a recycling activity in the city.

- **Construction and Demolition (C&D) Waste**

In developing countries, C&D waste may not contain substantial portion of waste plastics. However, this should be confirmed locally as well as the arrangement for collection, transportation and disposal (recycled or disposed at landfill).

Segregation of the plastics from other streams of waste is recommended. Additionally PVC should also be segregated from other plastics, as a separate stream.

- **WEEE/E-Waste**

Waste Electrical and Electronic Equipment (WEEE) or E-waste is one of the fastest growing waste streams in the world. In developing countries like China and India, though annual generation per capita is less than 1 kg, it is growing at an exponential pace. Composition of WEEE/ E-waste is very diverse and differs in products across different categories. It contains more than 1000 different substances, which fall under “hazardous” and “non-hazardous” categories. Broadly, it consists of ferrous (50%) and non-ferrous metals (13%), plastics (21%) and other constitutes like glass, wood & plywood, concrete and ceramics, rubber etc. Usually, most of the plastic components from E-waste are dismantled and sold to recyclers. This information would be vital to assess the overall quantity and quality of waste plastics available within a city.

3.2 Collecting the Information Required

In addition to setting the boundaries and specifying the sectors it is important to collect the information related to policies, national classifications of materials (and industries) and any other information locally available regarding to waste in general and waste plastics in particular. Therefore, for a particular city or region, the information to be collected prior the preparation of the field data collection is as follows:

I. Maps from local authorities identifying the geographical and administrative boundaries.
II. Maps for land-use/zoning plans.
III. Population size and growth: Time-series data with future projections, distribution of population among various zones, number of single-family and multi-family buildings and average size of inhabitants.

IV. Size and number of industries and commercial undertakings, which generate waste plastics, as per national or local classification.
V. Regulations on solid waste in general and waste plastics in particular.
VI. List of plastic types. Identify local classification of the plastics if exist. Usually waste plastics are classified as soft/film plastic and rigid plastic, and within this classification the specific types such as PP, PE, PS, PVC etc should be detailed. Some countries, as it is the case of Thailand, have developed methodologies to assess waste plastics. Identification of those guides is recommended.
VII. Primary data on waste plastics and its proportion in the overall waste (if such data is available).

References:

- CASCADIA Consulting Group (2004), *Statewide Waste Characterization Study*. California Integrated Waste Management Board (CIWMB)

http://www.ciwmb.ca.gov/Publications/LocalAsst/34004005.pdf (6 April 2006)

- Sky Valley Associates (2003), *2002 Oregon Solid Waste Characterization and Composition*. Department of Environmental Quality, Oregon, USA.

http://www.deq.state.or.us/wmc/solwaste/wcrep/ReportWC02Full.pdf (6 April 2006)

- CASCADIA Consulting Group (2003), *Guidelines for Waste Characterization Studies in the State of Washington*. Washington State Department of Ecology
- CASCADIA Consulting Group (2005), *Provincial Waste Characterization Framework*. Government of Canada.
- http://www.recycle.ab.ca/Download/WasteCharFinalReport.pdf (6 April 2006)

4. Plastic Waste Quantification and Characterization – Data Collection, Analysis and Presentation

4.1 Overall Solid Waste Data Collection

Prior to the characterization of waste plastics it is important to put into context the waste plastics generation in relation with the overall solid waste. Quantification and characterization of the solid waste stream as a whole is desirable so that each stream of waste is segregated, weighted and their data is recorded (Please refer to "Developing Integrated Solid Waste Management Plan – Training Manual Vol. 1: Waste Characterization and Quantification with Projections for Future" http://www.unep.or.jp/ietc/SPC/publications.asp). For the purpose of this guideline we will focus on data collection for plastics as a segregated stream.

4.2 Waste Plastics Data collection

The assessment of a potential project on the conversion of waste plastics into a resource requires a detailed study of the composition of the waste plastics being generated. However extensive studies on waste quantification and characterization, including measurement and sample analysis, could be costly, time consuming and complicated. Thus the design of the study should be in line with available time, funds and skills; and to the level, where sufficient data could be made available to take appropriate decisions to identify technologies and make techno-economic feasibility studies leading to implementation of these technologies.

The required information from the data collection to be analyzed is as follows:

1) Amount of plastics being generated within the geographical boundaries delimited for the project.
2) Amount of plastics reaching the transfer station and the disposal site as well as the plastics being diverted for recycling.
3) Amount of rigid and soft/film plastics (if required).
4) Further classification of plastic types to be able to assess the technology suitable to the plastics available and
5) Quality of the plastics (how clean/dirty they are).

It should be highlighted that this process for collecting the information will also depend and differ according to the location where the data collection is taking place.

Once the details of what type of data collection is required, the next step would be the identification of the number of samples, timing of samples, methods to cover seasonal variations, sites for collection of samples and methodologies for sample analysis and data generation. For data analysis, the important considerations would be to produce results, which are representative with high confidence levels with minimum costs, and the future projections incorporating population and socioeconomic growth, and technological development. For data presentation (graphically and in tables), the useful aspects would be to provide overall current and future picture of the plastic waste generation including the percentage of such stream within the overall solid waste stream as well as its sub-categorization with respect to various types of plastics.

4.2.1 List of Plastic Types

The list of waste plastics types to be identified must be in accordance with the possible identification of such types of plastics and/or in accordance with any methodology proposed by the country or local/national regulations or practices.

The classification could be based on different criteria such as:

a) Rigid and film plastics, if the level of information obtained through this classification would be enough (which it is not usually the case).
b) Types of polymers used (PET, PP, PE, PS, etc)
c) Others, as containers, packaging etc. Example presented below.

1 **PET Containers**
2 **HDPE Containers**
3 **Miscellaneous Plastic Containers**
Film Plastic*
4 **Trash Bags**
5 **Grocery and Other Merchandise Bags**
6 **Non-Bag Commercial and Industrial Packaging Film**
7 **Film Products**
8 **Other Film**
9 **Durable Plastic Items**
10 **Remainder/Composite Plastic**

The most recommended categorization is based on the typology of polymers used in the manufacture process since each technology is best suited for a plastic type and therefore this information will be needed for the assessment of technologies.

Identification of plastic typology

Experienced and skilled persons can sometimes identify various types of plastics by visual observation, feel and texture. However, due to the similar appearance or properties of some types of plastics, in many cases it is difficult to identify the various types at a glance. A laboratory test will definitively characterize the typology however it can be very costly.

Identification methodologies are to be applied according to the local situation in which the data collection is taking place. Potential identification methods are as follow:

i) *According to the Plastic Identification Code* - Just possible if this code is used in the area where the characterization is taking place.

ii) *By the properties of the materials* - Previous identification of main plastics materials within the municipal waste by its properties and product applications (Please refer to Annexure 3: "Common types of plastics, properties and product applications").

iii) *Including waste pickers in the field team* – They are experts on the characterization of the plastics since each type of plastic has a market value.

iv) *Going back to the manufacturers* - Previous identification of main plastics materials within the municipal waste by contacting the manufacturers. This is very time consuming and the results are not very satisfactory since it is very difficult to identify and classify all the plastics.

4.2.2 Number of Samples

The number of samples depends primarily on the cost versus its utility. For higher statistical accuracy and confidence level, the number of the samples will be more. There are statistical procedures to calculate the number of samples at each confidence level. Table 4.1 is an example of the variation of materials in mixed solid waste and the number of samples required to achieve confidence levels of 95%, 90%, 80% and 70% respectively (RecycleWorlds 1994).

Usually, for solid waste data, it is recommended to set the number of samples according to a confidence level (C.L) of approximately 80% (Cascadia 2003).

Table 4.1: Number of Samples for Waste Composition

Materials	C.L 95%		C.L 90%		C.L 80%		C.L 70%	
	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial
Newsprint	224-2397	698-3563	58-600	170-991	16-150	48-223	9-58	21-101
Cardboard	899-1955	533-997	225-499	134-250	58-123	35-64	27-66	17-30
Aluminum	275-1437	754-4399	70-350	191-1100	19-92	60-275	10-42	23-123
Ferrous	194-554	552-3411	50-139	138-953	14-37	36-214	8-18	17-97
Glass	145-619	596-2002	39-155	149-501	19-61	39-126	6-19	19-58
Plastic	261-1100	422-783	67-275	107-195	18-70	28-61	10-32	14-24
Organic	12-47	26-92	5-14	8-25	3-5	4-8	3-4	3-5

The difference in number of samples for residential and commercial waste is due to the level of variation in waste between these two sectors. For residential waste the variation of material types across the samples is usually low; therefore, fewer samples would be required to establish the same confidence level in comparison with assessment of commercial waste (e.g. California Integrated Waste Management Board (CIWB) asks for 40 samples for residential waste, 50 samples for nonresidential wastes, 25 samples for subpopulation with similar businesses and 40 samples for subpopulation with different businesses per year).

In the case of the waste plastics, the number of samples will depend on the proportion of different types of waste plastics (which may vary depending on the local situation). If a certain type of plastic contained in the sample is in lower percentages with respect to other materials (e.g. durable plastic items, such as plates) higher number of samples will be required to confirm the quantity of that material in comparison with the higher percentage material (e.g. PET bottles).

The number of samples also depends on the methodology for sample analysis, so that more samples would be required to achieve same confidence level if the samples are being analyzed through visualization, in comparison to analysis based on hand sorting.

Due to higher costs and efforts required to collect and analyze the samples, it is recommended to be careful in narrowing down the types of waste plastics.

4.2.3 Timing for Sample Collection

The timing of sample collection could be a vital factor for getting a representative data. Waste disposal patterns, with respect to types of materials, often vary according to the time of day or week. Therefore, based on the economic viability, the study should include plans either (1) to collect data that covers the *entire* period of disposal, or (2) to collect data that may be assembled later in a way that *represents* the entire period.

Nevertheless, the local knowledge can play an important role to identify suitable timings for data collection for various waste streams or for different types of materials. In some countries, there are regulations for disposing certain types of wastes at certain timings (e.g. residential waste early in the morning or late at night) and at certain days of the week (e.g. recyclables once a week). This information would help to plan for appropriate timings. In other case, a pilot survey can also help to determine the variations across the different timings of the day or across the different days of the week.

4.2.4 Seasonal Variations

To account for seasonal variations, the local knowledge may help to identify the possible seasonal changes in the waste plastics streams (e.g. the availability of certain type of agricultural or industrial products in a certain season may increase the waste plastics generation due to packaging of industrial and agricultural goods). Similarly, at some places the seasonal migration may affect overall solid waste and consequently waste plastics. This identification would be useful to plan the data collection activities, as it will be very costly and time consuming to collect data during all the seasons for all types of waste plastics.

4.2.5 Selection of the Sites

The samples may be taken directly from generators, at the primary collection point (piles/heaps), from waste collection vehicles or at the disposal facility. The decision in this regard depends on the tradeoff between efforts and the requirements for data. If data has to be very accurate with respect to waste generators, then samples should be collected at the primary stage of waste generation but be aware of areas or small towns where waste is not collected properly and therefore samples at specific points such as the disposal site do not represent the waste generated within the area (since open dumping, burning and other treatments of the waste are carried out). Furthermore, the timing of the sample collection would differ based on the decision for the site for sample collection. For selection of sites, it is important to ensure that samples are randomly selected across the different sites for unbiased statistical analysis. To facilitate random selection of samples, "random numbers table" may be generated based on the virtual numbering of the sites.

For analyzing source segregated waste plastics, the samples would be directly collected either at generation level or at transfer stations. This would be easier than analyzing samples of mixed waste, where some of the waste plastics become dirty or contaminated and may not be considered as "waste plastics" for recycling purposes.

4.3 Methods for Sample Analysis (quantification and characterization)

To analyze mixed waste samples or source-segregated waste plastics samples, an appropriate methodology would be required. There are a few common methods, which are adopted to analyze the samples at generation point, from the vehicles transporting the waste and at the disposal point. The data may slightly vary from one method to another. For example for higher confidence level extensive samples may be collected at generation point and could be analyzed by hand sorting. These methods also differ in terms of cost and efforts. Therefore, depending on the information requirements, one of the methods or a combination of the methods could be adopted to collect the information. These methods can be divided into two categories. First one is for measuring the amount of waste or quantification of waste. The second one is for characterization of waste. This could be further divided into characterization through visualization and characterization through hand sorting.

4.3.1 Quantification of Waste

There are several ways and methods to quantify the waste. One or more of the following methods could be used depending on local conditions:

- **Survey**

At Generation Point: This method of quantifying waste involves visiting or contacting waste generators (e.g., businesses, apartment buildings, etc.) and determining through measurement or observation the amount of waste plastics disposed during a given time period. Since waste generation is highly variable from place to place, or from one time to another, it is advisable to collect many data points in order to develop a reliable estimate of the *average* amount of plastics disposed by that class of waste generator. Typically, estimates of generation are correlated with another variable that describes the generator, such as number of residents, employees, area, etc. This correlation allows estimates of waste quantities to be "scaled up" to a level larger than the individual generator.

From the Vehicles at the Disposal Facility: This method quantifies the waste that arrives at a disposal facility according to the waste sector. Since disposal facilities often do not classify disposed waste according to the same *waste sectors* that are used in municipal solid waste planning or waste characterization studies, it is sometimes necessary to use statistically valid surveying techniques to determine the portion of a facility's disposed tonnage that corresponds to each sector. The portions that are revealed through the vehicle survey are then applied to a known total amount of waste that is disposed at the facility during a given time period.

To quantify the waste plastics from this type of information it would be necessary to know the percentage (by weight or volume) of the plastics within the overall waste stream.

- **Examination of Records**

At Generation Point: Some businesses and institutions maintain records that reflect the amount of waste disposed over time. This information can often be found in invoices from the waste hauler or from the log sheet. Typically, the amount of waste is expressed in terms of *volume* rather than weight, so a volume-to-weight conversion factor may be necessary in order to quantify the weight of waste.

To quantify the waste plastics from this type of information it would be necessary to know the percentage (by weight or volume) of the plastics within the overall waste stream.

At the Disposal Facility: Most disposal facilities keep transaction records that reflect the tonnage brought for disposal. In cases where the facility classifies waste according to the same sectors that are considered in the waste characterization study, facility records can provide thorough and reliable data to show the portion of a facility's disposed tonnage that corresponds to each sector. The portions that are revealed in the records would have to be related to the percentage of plastics within the overall waste specifically for that sector. These figures can be further correlated to a known total amount of waste that is disposed at the facility during a given time period.

4.3.2 Characterization of Waste

There are several ways and methods to characterize the waste. One or more of the following methods could be used depending on local conditions:

- **Hand sorting of Samples**

From Generators: This study method produces waste composition data that can be correlated to specific types of waste generators, such as specific categories of business or industry, multifamily buildings, or single-family residences in specific neighborhoods. Waste samples are obtained at the location where they were generated – e.g., from the dumpsters or disposal areas of the business or building in question.

At Disposal Facility: Generally, within this method an entire vehicle-load of waste is identified for sampling, but only a portion of the load is pulled out for actual sorting. This method is essential for characterization of waste plastic which is finally disposed of and has not been diverted for recycling purposes. However, because the method is employed at the disposal facility, it is of little use in correlating waste composition with specific types of waste generators, such as particular types of business, since it would not be possible to identify them.

- **Visual Characterization of Samples**

*From Generators***:** This method of waste characterization is ideal for wastes that are nearly homogeneous, such as waste plastics segregated at shopping malls, etc.

From Vehicles: This method is ideally suited for waste that is taken to a disposal facility and that arrives in loads that are fairly homogenous individually (even if loads are markedly different from one another). Waste plastics loads from various commercial entities and industries are often suitable for visual characterization, because an individual load often contains just a few materials. The usual approach in visual characterization is to estimate the composition of the entire load and to correlate the visual estimate with the net weight of the load.

4.4 Methods for Data Analysis

4.4.1 Waste Plastics Quantification

- **Quantifying based on Vehicle Surveys**

If the annual tonnage of all waste disposed at the facility is known as well as the percentage of waste plastics in the waste reaching the disposal site, then the analyst should use the vehicle survey to determine the portion of annual disposal corresponding to the waste sectors being studied. For a given waste sector, *S*, the sector overall tonnage can be calculated from the tonnage, *q*, found on individual vehicles.

$$\text{Sector (tons)} = \frac{\sum Q\text{, S, survey period}}{\sum Q\text{ all, survey period}} \times \sum Q\text{ all, annual}$$

To calculate the Sector plastic tonnage we would apply the percentage of the waste plastics within the overall stream to the sector tonnage:

$$\text{Sector (plastic tons)} = \text{Sector (tons)} \times \text{\% of plastics within the overall waste stream}$$

If the annual tonnage of all the waste disposed at the facility is not known, then the analyst should extrapolate sector tons directly from the corresponding tons that were counted during the vehicle survey.

$$\text{Sector (tons)} = \sum Q, S, \text{survey period} \times \frac{\text{Operating days in year}}{\text{Days in survey period}}$$

Appropriate adjustments should be made for the differences between weekdays and weekends and for any other known shifts in waste disposal patterns across days, weeks, or seasons.

In the same way as before:

$$\text{Sector (plastic tons)} = \text{Sector (tons)} \times \text{\% of plastics within the overall waste stream}$$

- **Quantifying a Waste Sector at the Point of Generation**

The process of quantifying waste plastic for a given sector involves several steps, starting with the individual measurements of waste plastic taken at the generators that were visited (this can be calculated by multiplying the total waste generated by the surveyed industry and the percentage of the waste corresponding to plastics). The general procedure, applicable in most instances, is described below. It should be followed separately for each *size group* that is being studied within a larger commercial group or industry group.

First, extrapolate the volume of waste disposed using each waste container (or pile or process, etc.) at each generator that was visited.

$$\text{Volume}_{\text{container, annual}} = \text{Volume}_{\text{container, measured}} \times \frac{\text{Generation time}_{\text{annual}}}{\text{Generation time}_{\text{measured}}}$$

Second, add together the extrapolated volume of waste disposed in all containers that handle waste belonging to the same waste stream at the location.

$$\text{Volume}_{\text{site, annual}} = \sum \text{Volume}_{\text{container, annual}}$$

Third, calculate the density of the mixture of waste plastics at the generator location, based on data from the waste sample.

$$\text{Density}_{\text{site}} = \frac{\text{Weight}_{\text{sample}}}{\text{Volume}_{\text{sample}}}$$

Fourth, apply the location-specific density figure to calculate the tons of waste plastics disposed annually by the generator.

$$\text{Tons}_{\text{site, annual}} = \text{Volume}_{\text{site, annual}} \times \text{Density}_{\text{site}}$$

Fifth, calculate a "scale-up factor" for waste generation by the given sector and size group. For many commercial sectors, the appropriate scale-up factor is according to the number of employees. For most industrial sectors, it is according to number and size (production output) the industry. The example shown below involves calculating *tons per employee*, or TPE for a given size group in the industry. It draws upon data reflecting the disposed tons of plastics and employment only at the locations that were visited as part of the study.

$$TPE_{\text{annual, size group}} = \frac{\sum_{\text{visited sites}} Tons_{\text{site, annual, size group}}}{\sum_{\text{visited sites}} Employees_{\text{site, annual, size group}}}$$

Sixth, calculate the tons disposed from the entire size group in the sector being studied. The example below draws upon data reflecting the total number of employees in the larger population (e.g. countywide, statewide, etc.) of industry members in the appropriate size group.

$$Q_{\text{site, annual}} = TPE_{\text{annual, size group}} \text{ X Industry - wide employment in size group}$$

Seventh, add the results for the size groups to calculate total tons disposed by the industry.

$$Q_{\text{industry}} = \sum Q_{\text{size group}}$$

- **Quantifying based on Waste Generation Factors**

For calculating and projecting waste plastics quantities, especially from **service and industrial sector**, waste generation factors (WGF) could be determined. Then it will be easy to extrapolate the waste generation rates for the industries and services. WGF depends on the size of the operation, the waste management practices and the process technology. Therefore, the information for this sector should not only have a number according to the industrial classification, but also the size of production and process technology. WGF can be defined as:

$$WGF = \frac{\text{Quantity of waste plastics generated (tons per year)}}{\text{Quantity of product produced (tons per year)}}$$

4.4.2 Waste Plastics Characterization

Waste characterization or composition of the waste plastics is not as difficult as characterization of mixed waste, if the waste plastics are segregated at least in one type "plastics." However, if one has to start with mixed waste then it should be calculated the percentage of plastics within the mixed waste for each of the waste sector being studied and to each size group within an industry group. Once waste plastics are identified from the mixed waste or at waste generation point, then the next step would be to further categorize waste plastics and quantify the proportion of each category within the total waste plastics. The next section of this chapter describes how results for individual sectors or size groups can be combined to describe the composition of larger segments of the waste plastics.

- **Calculating the Average Values**

For a given material, *j*, in all of the relevant samples, *i*, calculate the ratio, *r*, of the material weight, *m*, to the total sample weight, *w*.

$$r_j = \frac{\sum_i m_{i,j}}{\sum_i w_{i,j}}$$

The calculation should be repeated for each type of waste plastics.

- **Calculating the Error Range**

For each mean estimate, r_j, calculated as described above, the confidence interval (error range) surrounding the mean estimate is calculated as follows. First, calculate the variance, Vr_j, of the mean estimate.

$$Vr_j = \frac{1}{n} \times \frac{1}{\bar{w}^2} \times \frac{\sum_i (m_{i,j} - r_j w_i)^2}{n-1}$$

Where *n* is the number of samples, and $\bar{w}$ mean sample weight $\bar{w} = \frac{\sum_i w_i}{n}$

Confidence level is $\pm$ (t X $\sqrt{V_{i,j}}$), where t depends on the number of samples, n, and the desired confidence level. The value of t can be estimated from t-static

- **Volume to Weight Conversion Factors & Net Weight of Waste**

Combining the composition estimates for two or more segments of the waste stream require the use of a *weighted averages* method. The result for each segment of the waste stream is weighted according to the relative size of that segment in the larger waste stream that is being studied. It is important to note that the density figures based on estimates are intended for use as “rules of thumb.” Following are the volume-to-weight conversion factors for waste plastics from Guidelines for Waste Characterization Studies in the State of Washington. However, situations often exist where the actual density of each material differs from the table presented below.

Table 4.2: Density of Waste Plastics

Material	Density (lbs per cubic yard)	Source
PET Bottles	35	EPA Government Guide
HDPE Bottles, CLEAR	24	EPA Government Guide
HDPE Bottles, COLORED	24	EPA Government Guide
Film and Bags	23	Tellus
Bottles Types 3 - 7		
Expanded Polystyrene	22	Tellus
Other Rigid Plastic Packaging	50	EPA Government Guide
Other Plastic Products		
Remainder/Composite Plastic	50	EPA Government Guide

Source: CASCADIA Consulting Group (2003), *Guidelines for Waste Characterization Studies in the State of Washington*. Washington State Department of Ecology

- **Calculating the Weighting Factors when Combining Waste Sectors**

A specific weighting factor should be calculated for each sector or segment of the waste stream being studied. The weighting factor, P_G, for each segment or size group, G, within the waste stream is calculated as follows:

$$P_G = \frac{t_{G,\ annual}}{T_{allsectors,\ annual}}$$

A weighting factor should be calculated for every waste sector, and thus the sum of all the values of P_G should equal one.

- **Calculating the Average Values for Combined Waste Sectors**

The mean estimate for a given material, *j*, in a combination of segments (1, 2, 3...) of the waste stream is found as follows.

$$r_{j,\ combined} = (p_1^2 \text{ X } V_{rj1}) + (p_2^2 \text{ X } V_{rj2}) + (p_3^2 \text{ X } V_{rj3}) + \ldots.$$

Confidence level is $\pm$ (t X $\sqrt{V_{j,\ combined}}$), where t depends on the number of samples, n, and the desired confidence level. The value of t can be estimated from t-static.

Variables:

S	tonnage associated with a sector during a particular time period
Q	quantity of waste encountered in the study
TPE	tons per employee
j	designation of a particular material

i	designation of a particular sample
r	ratio of material weight to total sample weight, for an individual sample
m	weight of a material in an individual sample
w	total weight of an individual sample
V	the variance associated with the estimate for a material's percent in a group of samples
n	number of samples in the group
p	a weighting factor given to a segment of the waste stream, where the sum of all the values of p is 1
G	designation of a size subgroup within a segment of the waste stream – usually used for generator samples

4.4.3 Determining Waste Characteristics

The components and properties of waste plastics influence the processing of fuel production and the qualities of the resulting fuel products.

- **Moisture Content**

Moisture content is very important factor that influences the decisions for collection, transportation, recycling, treatment and disposal of most of the waste streams including waste plastics. The moisture content shall be measured by heating the sample at 105 ^{o}C in an oven until the weight loss stabilizes. The weight of the sample before and after gives the moisture content. The different fractions of the waste stream shall have their moisture content measured separately and the moisture content measurement has to be carried out on the same day as the sample collection to avoid drying out.

Bottles or liquid containers need to be emptied before weighing.

- **Clean versus Unclean Waste Plastics**

Keeping in view the aim of these guidelines to collect data on waste plastics for designing recycling system, it is important to know the difference between clean and unclean plastics as the economic viability of recycling system will depend on the amount of clean plastic. Sometimes, especially if the waste plastics are part of the mixed waste, the unclean plastics may be double in weight than the clean plastics. Therefore, once quantification and characterization of unclean waste plastics is done, then few samples must be cleaned, dried and measured (weighted). The difference between unclean and clean weight would provide a factor to estimate the amount of clean waste plastics.

- **Calorific Value**

Calorific values can usually be taken as standard for waste plastics unlike other waste types such as kitchen and yard waste where calorific values are also calculated based on laboratory results.

- **Bulk Density**

It affects possible loading weights of waste. Bulky waste requires more transportation capacity or larger vehicles to be used for their collection. In many cases suitable shredding or crushing is required to increase the bulk density for cost reduction of the transportation and the effective input to processing equipment.

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\text{Weight (kg)}}{\text{Volume (m}^3\text{)}}$$

4.5 Data Presentation

Based on the target audience and their requirement, data on the waste plastics can be represented in relation to other streams or just in relation to the types of waste plastics. Furthermore, the data can be presented in different formats (tables and graphs), which are more suitable depending on the scope of the data.

4.5.1 Tabular Presentations

Tables will represent and correlate different waste streams, quantities, types of waste or times series and future projections.

Table 4.3: Solid Waste Generation

Sector	Waste Plastics Estimated percentage (%)	Waste Plastics Estimated tonnage per day
Residential	10.6	1.3
Commercial	14.4	1.1
Construction & Demolition	9.0	0.2
Healthcare	0.5	1.0
Industrial	7.9	1.4

Similar tables may be produced for different types of plastics or for available amounts of certain plastics for recycling or for final disposal.

These data tables can also be produced for time-series data showing overall trends or trends in each sector or for each type of material. Based on that data, future projections can be provided with a few different possible scenarios. For example, the following table shows hypothetical time series data.

Table 4.4: Time Series Data (2000-09) and Projections (2010-19) based on Linear Growth

Year	MSW			Year	MSW		
	Others (tons)	Plastic (tons)	Total (tons)		Others (tons)	Plastic (tons)	Total (tons)
2000	22.0	4.0	26.0	**2010**	33.3	7.3	40.6
2001	22.0	4.0	26.0	**2011**	34.1	7.7	41.8
2002	23.0	4.5	27.5	**2012**	34.9	8.0	42.9
2003	23.0	4.5	27.5	**2013**	35.6	8.4	44.0
2004	24.0	5.0	29.0	**2014**	36.4	8.8	45.2
2005	24.0	5.5	29.5	**2015**	37.2	9.1	46.3
2006	24.5	5.5	30.0	**2016**	38.0	9.5	47.4
2007	25.0	6.0	31.0	**2017**	38.7	9.8	48.6
2008	25.0	6.5	31.5	**2018**	39.5	10.2	49.7
2009	25.5	7.5	33.0	**2019**	40.3	10.6	50.8

4.5.2 Graphical Presentation

It is important to produce graphs, based on the tabulated data, as they provide quick and better understanding. For example, a pie chart can provide a quick glimpse of the share of each sector in overall plastic waste. Similarly, pie charts are also good to show the proportion of a type of waste (e.g. waste plastics) from each sector (Figure 4.1). Time-series data helps to provide a clear view of the historical trend and its future projections (Figure 4.2 and 4.3).

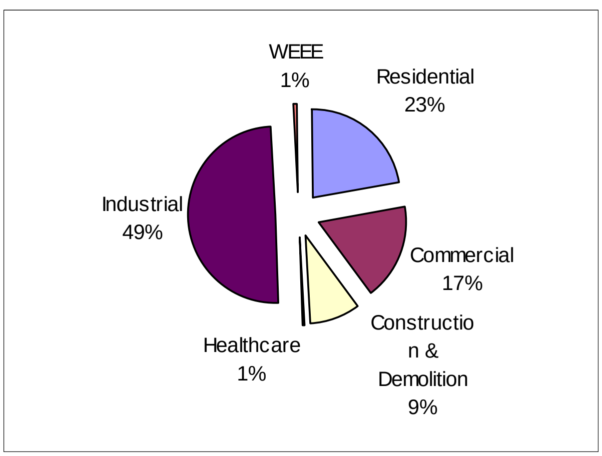

Figure 4.1: Waste Plastics from Different Sectors

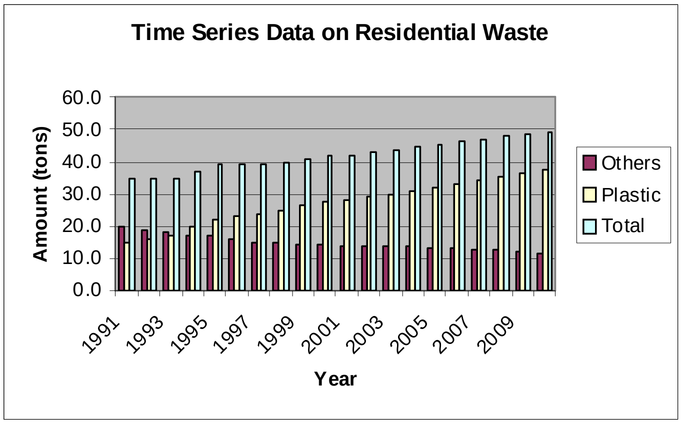

Figure 4.2: Time Series Data on Residential Waste

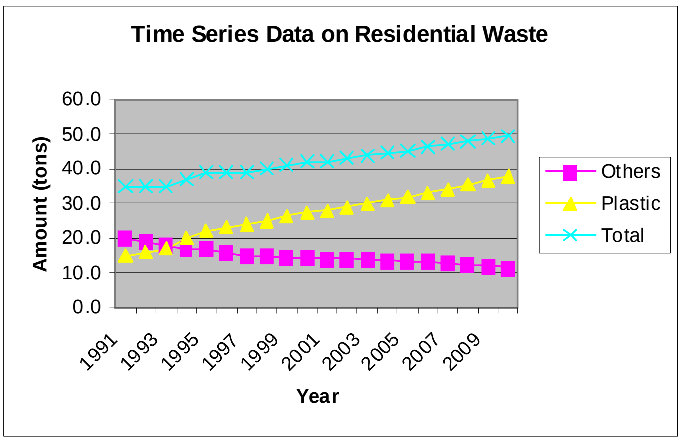

Figure 4.3: Time Series Data on Residential Waste

4.6 Working Example

Let us take an example of a small City X. The data collection and analysis has to be done to quantify and characterize waste plastics from municipal waste from residential and commercial sectors to assess the potential of a plastic to fuel facility.

It is assumed that waste plastics are part of the mixed waste as no segregation system is in place. Based on the historical data or pilot surveys, the major waste components of municipal waste have been identified as food wastes, paper, cardboard, plastics, textiles, rubber, leather, yard wastes, wood, glass, metals, dirt, and ash.

We should start our exercise with a quantification and characterization of the main components of the solid waste stream or since we are assessing the potential of a plastic to fuel facility we should at least quantify wood and paper in addition to plastics.

Since our main focus is the plastics we take the decisions on site selection, number of samples and methodology of the characterization based on plastic data. It has been decided that the collection of the samples is going to take place from the vehicles arriving at the disposal site and the characterization will be done through hand sorting.

The number of samples is to be determined based on the confidence level and the chosen methodology for the analysis of the samples.

The confidence level required will depend on the utility of the data. In our case, to assess plastic to be converted into fuel we can use a low confidence level since we are looking for all the plastics within the municipal waste (and we are not looking for a specific type that might be more difficult to be present in the samples. For example if we were assessing the recycling of rigid plastic (PET bottles, toys, plates, containers, etc.) back into plastic and recycling of soft plastic (shopping bags etc) as a mixture of combustible wastes for a boiler we would need to have higher confidence level, since we are specifically looking for rigid plastics (which might be in a small proportion).

Secondly, the chosen methodology for the analysis of the samples which has been agreed as hand sorting at the disposal facility so that samples will be taken directly from the vehicles arriving at the disposal facility and during different timings of the day.

We assume that there are no seasonal variations in municipal solid waste as well as in waste plastics. From Table 4.1, for 70% confidence level, the sample number for waste plastics ranges between 10-32 for residential sector and 14-24 for commercial sector. Thus we set the number of samples as 14 for municipal waste (which will be used as well as the samples for the quantification and characterization of the mixed well). We distribute the 14 samples over the 7 days with 2 samples per day, one for residential and one for commercial waste. There are 10 trips per day for residential waste as well as commercial waste and we select 1 vehicle for each waste sector based on a random numbering system. We can now start collecting the samples from the vehicles arriving at the disposal facility.

A. Quantification and Characterization of the Mixed Waste

We measure the tonnage of all the vehicles before and after unloading the waste to know the total Municipal Solid Waste (MSW) to be disposed. Since we are assessing the potential of a plastic to fuel facility information on wood, paper and cardboard are also required. Therefore we segregate the sample into five material types: plastics, wood, paper, cardboard and other wastes.

Each type of material will be measured individually either by weight, by volume or by both so that the sample bulk density can be determined (If the weight can not be measured, the volume will be recorded and volume-to-weight conversion factors (density) from literature will be applied).

After measuring all the materials, we can calculate the ratio of each component with respect to the total weight of the sample as shown, for the case of plastics, in Table A.1.

Table A.1: Quantity of Municipal Waste and Waste Plastics for City X

Daily Samples				Aggregated Data		
Day	**Samples**	**MSW (tons)**	**Waste Plastic (tons)**	**Day**	**MSW (tons)**	**Waste Plastics (tons / %age)**
1	1 (residential)	2	0.4	**1**	4	0.7 / 17
1	2 (commercial)	2	0.3	**2**	7	1.2 / 17
2	3 (residential)	3	0.5	**3**	3	0.4 / 13
2	4 (commercial)	4	0.7	**4**	4	0.6 / 15
3	5 (residential)	2	0.3	**5**	5	0.8 / 16
3	6 (commercial)	1	0.1	**6**	4	0.5 / 13
4	7 (residential)	2	0.3	**7**	6	1.1 / 18
4	8 (commercial)	2	0.3	**Total**	**33**	**5.3 / 16**
5	9 (residential)	3	0.6	**Av.**	**4.7**	**0.8 / 16**
5	10 (commercial)	2	0.2			
6	11 (residential)	3	0.4			
6	12 (commercial)	1	0.1			
7	13 (residential)	2	0.4			
7	14 (commercial)	4	0.7			

We should also check the records at the disposal facility of the annual tonnage disposed there as a comparison with our data. If the annual tonnage is not available, then we can extrapolate the annual tonnage, based on the vehicles surveyed.

The different components of the waste are to be analyzed. Since availability of funds is limited we will limit the analysis to moisture content. Calorific values will be obtained through bibliography sources.

We prepare Table A.2 on moisture content based on the laboratory tests or based on moisture meter readings. The bulky density could also be measured.

Table A.2: Raw Weight and Moisture Content of collected MSW in City X

Component	Raw Weight (tons)	Moisture Content MC (%)	Dry Weight (tons)
Plastics	5.3	1.4	5.2
Paper	6.3	5.9	5.9
Cardboard	2.7	5.0	2.6
Wood	0.9	20.0	0.7
Other waste	17.8	60.0	7.1
Total	**33**	**-**	**27.26**

B. Quantification and Characterization of Waste Plastics

We now know the amount of plastics within the waste stream however we need further information on the typology of the plastics.

At this example we segregate the waste plastics into the main plastics used for packaging as shown in Table B.1. The measurement of each type of available plastic could be done either by weighing it or by volume and then volume-to-weight conversion factors are applied. (An example of these conversion factors has been given in Table 4.2 however there should be locally established factors).

After measuring all the types of plastics, we can calculate the ratio of each component with respect to total weight of the plastics sample. Based on the average ratios from all the samples, these ratios could be used to calculate the distribution of major plastic types in the overall MSW.

Table B.1: Characterization of Waste Plastic

Component	Weight (kg)	Percentage (%)
PE	2168	40.9
PS	323	6.1
PP	101	1.9
PET	1129	21.3
PVC	148	2.8
Composite	90	1.7
Other plastics	1341	25.3
Total	**5300**	**100**

Furthermore, the difference between unclean and clean waste plastics should also be calculated. (This exercise can be undertaken with a smaller sample).

Table B.2: Clean and Unclean Waste Plastics in City X

Component	Unclean Plastic Weight (kg)	Clean Plastic Weight (kg)
PE	1237	931
PS	157	166
PP	61	40
PET	451	678
PVC	73	75
Composite	42	48
Other plastics	704	637
Total	2725	2575

The unclean plastics can be further clean and the amount of dirt and contaminants can be calculated.

Calorific values are taken as standard for waste plastics unlike other waste types such as kitchen and yard waste where calorific values are also calculated based on laboratory results.

NOTE: The same treatment of the data could have been done independently for the residential and commercial sector, so that we would get a more detailed data sector related. The example has considered MSW as a general stream.

Some of the obtained information can be presented as follows. (Sector related representations can also be included).

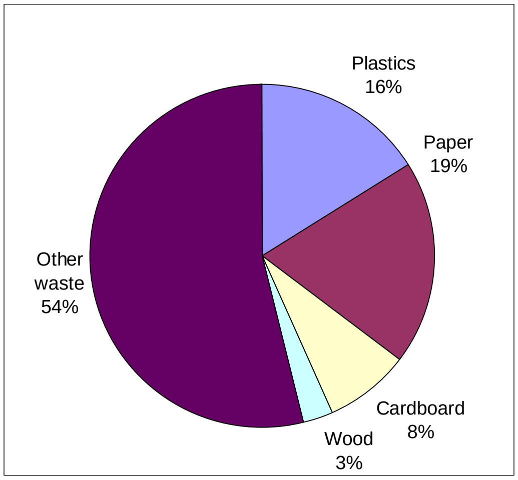

Figure A: MSW Composition in City X

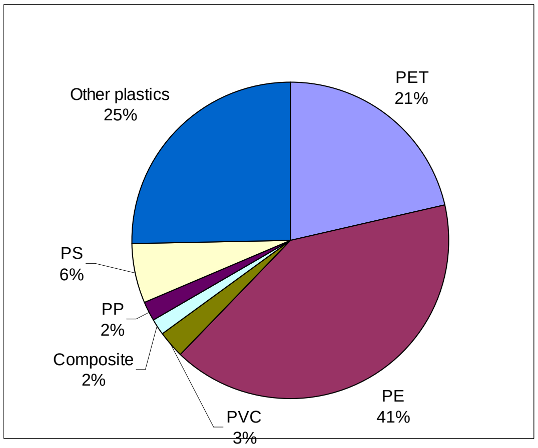

Figure B: Waste Plastics Composition in the MSW of City X

4.7 Collection of Additional Information

In order to assess the plastics for conversion into a resource including the set up of a facility on the conversion of plastics to fuel, it is necessary to know not only the amount of plastics that are generated but the actual management of that waste and the final treatment or disposal (e.g. plastics or types of plastics being recycled)

The quantification and characterization of the waste might not give a direct indication of the amount of plastics recycled (and therefore to be diverted from the final disposal or to not be available for a different treatment). This can be calculated by the difference in amount of the waste plastics generated at source and the waste plastics disposed at the transfer station and/or at the disposal site; though this would require the assessment in both locations and it might be very costly.

This information with regards to recycling could then be collected thorough **Source-based Surveys and Community-based Surveys**.

These types of surveys can also be used to collect additional information related to the quantification and characterization of the waste, however usually as a first step of the survey it is needed awareness raising within the communities on the different streams of solid waste in general and specifically on the different types of waste plastics.

After the awareness-raising, two methods could be applied to get more reliable information from communities. The first method is to have interviews with a representative population sample with respect to the different aspects of residential waste plastics, commercial waste plastics and industrial/agricultural waste plastics such as source segregation and primary collection. Simultaneously, as the second method, a similar population sample may be asked to develop a pizza (pie chart) of their weekly waste plastics.

References:

- CASCADIA Consulting Group (2004), *Statewide Waste Characterization Study*. California Integrated Waste Management Board (CIWMB)

  http://www.ciwmb.ca.gov/Publications/LocalAsst/34004005.pdf (6 April 2006)
- Sky Valley Associates (2003), *2002 Oregon Solid Waste Characterization and Composition*. Department of Environmental Quality, Oregon, USA

  http://www.deq.state.or.us/wmc/solwaste/wcrep/ReportWC02Full.pdf (6 April 2006)
- CASCADIA Consulting Group (2003), *Guidelines for Waste Characterization Studies in the State of Washington*. Washington State Department of Ecology
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- http://www.recycle.ab.ca/Download/WasteCharFinalReport.pdf (6 April 2006)

5. Municipal Waste

Waste plastics are becoming one of the major components in municipal solid waste. In developed countries, waste plastics are becoming the largest or second largest component in municipal solid waste, while in developing countries it is third largest component, after food and paper. To characterize and quantify waste plastics from municipal waste, it is important to either have information on characterization and quantification of municipal solid waste or to start with the analysis of municipal waste, before moving to analyze waste plastics.

Prior to carrying out data collection and analysis for municipal solid waste, the following information is should be available based on the previous steps discussed in Chapters 1 to 4:

1. Geographic and administration boundaries are defined and land use maps are ready with information on residential, commercial, industrial and other zones.
2. The decisions on geographical coverage and type of waste that is considered as municipal solid waste. Usually, residential and non-hazardous commercial waste is considered as municipal waste. However, if there are other sectors or types of wastes, to be considered as municipal solid waste, then those should be included in the survey.
3. The primary information on the waste transfer stations, transportation, and final disposal would be required to design the survey and to identify the sites for the collection of samples.

5.1 Survey for Municipal Solid Waste

The survey for municipal solid waste should be aimed to gather accurate data with minimum efforts, time, and money. The survey may be designed through the following process:

1. Based on the geographical and administrative map, prepare a list of districts/counties with basic information. Districts of similar characteristics (zoning, population distribution, socio-economic patterns, etc.) should be identified and grouped to assure that the survey covers all districts under the different conditions.

District / County	A	B	C	D
Zoning	Residential	Residential & Commercial	Industrial	Residential
Counties / Streets	A1, A2, A3…	B1, B2, B3…	C1, C2, C3…	D1, D2, D3…

Note: A, B, C, D will be replaced with the real district/county names and subsequently A1, A2...will be replaced with the street names within each district or county

2. A separate list of the primary waste collection and final disposal facilities for each county/district should be prepared and allocate a number to each waste collection site and waste disposal facility. In case the data has to be collected at a disposal facility, then identify the number of trips by each waste collection vehicle and check if they bring waste from a

single sector (e.g. residential) or from all the sectors under municipal waste. Additionally, identify if they transport waste from a single county/district. There should be a separate numbering for the vehicles transporting waste from a single sector. Furthermore, if the same vehicle makes more than one trip per day, then that vehicle will be allocated numbers equal to the number of trips.

District/County	A (A1)	A (A3)	B (B2)	B (B4)	C (C1)	C (C3)	D (D2)
Collection site	1, 2, 3	4, 5, 6, 7	8, 9	10, 11	12, 13	14, 15	16, 17, 18
Disposal site & vehicles	I 1, 2, 3,4	5, 6, 7, 8	9, 10	II 11, 12	13, 14	III 15, 16	17, 18, 19, 20

Note: A, B, C, D will be replaced with the real district/county names and subsequently A1, A2,…will be replaced with the street names within each district or county, and each primary collection site at generation or each collection vehicle at disposal site will be allocated one number (1,2,3..) for random selection of sites for collection of samples.

3. Calculate the number of samples, based on the information provided in chapter 4. Thereafter, randomly select the numbers corresponding to waste sites or vehicles. For example if the number of samples is decided as 20 and it is also decided to collect the samples from generators or collection points as well as from the vehicles arriving at the disposal facility, then, there may be a balance between samples collected at the generation point and the samples collected at the disposal point. In this case, 10 samples may be collected at generation point and 10 samples at disposal site. The selection of sites may look like this:

Sample No.	1	2	3	4	5	6	7	8	9	10
Collection site	2	3	5	7	8	11	12	15	17	18
Disposal site	1	2	6	8	12	13	15	17	18	20

4. The details should be chalked out for sample collection and sorting, including timetable, team members, and sample sorting procedures: hand sorting or visualization and weighing

Sample No.	1	2	3	4	5	6	7	8	9	10
Collection site **Date/Time** **Team** **Equipment** **Method**										
Disposal site **Time** **Team** **Equipment** **Method**										

5. The data should be recorded for each sample. The following table is for reference purposes and the list of materials could be modified (as mentioned earlier, paper, cardboard and wood

can also be included since plastics to fuel conversion technologies might require the mixing of waste plastics with these streams of waste as additional feedstock). Similarly the composition indicators may also be reduced or increased.

Sample No. 1 Location: Street A1, District A

Sample Type: Waste Container for primary collection

Sample Type: Mixed / Segregated (Recyclable, organic/food, non-recyclable)

Volume: 2 m3 Weight: 45.1 Kg

Component	Wet Weight	Dry Weight	Composition							
	(kg)	(kg)	MC	CV	C	H	O	N	S	Ash
Plastics										
Wood										
Paper										
Cardboard										
Other Waste										
Total										

Note: MC, CV, C, H, O, N, S are moisture content, calorific value, carbon, hydrogen, oxygen, nitrogen and sulfur respectively

6. Simultaneously information should be collected from the generators on their direct reuse, recycling and disposal of waste other than dumping at the waste collection points or waste disposal facilities

District A County / Street	A1	A2	A3	A4	A5	A6
Population, No. of houses Single family & Multi-family	2000 100 30	1000 20				
Number & type of commercial undertakings	Fruit Mart 5 shops	Services 5 Banks 4 Office				

Note: A1, A2, will be replaced with names of streets or areas within a district

Street A1	SF	SF	SF	MF	MF	Shop
Type and amount of waste for reuse and recycling	2 Plastic jar 1 newspaper	2 newspapers				
Ballpark estimates for %age of waste being reused or recycled at source	5%	4%				

Note: SF is single family residence and MF is multi family residence (e.g. apartment buildings)

7. Similar type of sample collection and analysis would be done at the disposal sites, where the waste collection vehicles would be analyzed (as samples) in the similar fashion. The total weight of samples (vehicles) could be measured at weighing bridges at disposal facility for loaded and empty vehicle.
8. Based on the data from all the samples, the municipal waste could be quantified and characterized as per the guidelines provided in Chapter 4.

NOTE: If the samples are to be collected from generators it is highly recommended to require the segregation of the plastics from the other streams of waste.

Source based intensive surveys and community-based surveys, as discussed in Chapter 4, should be conducted, if collection/transportation is not 100% for reliable assessment at the transfer station and disposal sites. These surveys could also be additionally required, if the waste at transfer stations and disposal sites is mixed from all sectors and sector-based assessment is required.

6. Industrial Solid Waste

Waste plastics are one of the major components of non-hazardous industrial waste. Industries generate two waste streams from two different activities. One stream is due to the production process, where hazardous and non-hazardous waste is generated. This production process also includes the laboratories and sludge from effluent treatment plants. The other solid waste stream is due to maintenance of the buildings and activities of the staff. This stream includes office wastes, construction and demolition waste, and wastes from staff canteens or restaurants.

The first part of this chapter discusses the guidelines to collect and analyze the data for the waste stream related with the production process. The second part discusses the guidelines for the waste stream related with daily activities of staff and maintenance of the premises.

6.1 Plastic Waste due to Production Process

The production process depends on the product and the production technology. Therefore characterization of waste is mainly dependent on these two factors, while quantification depends on the size of production and efficiency of the technology. Based on this information, waste generation factors (WGF), as defined in Chapter 4, may be developed to extrapolate the data for similar industries or to estimate future trends. WGF may already be available at national or regional basis and some pilot surveys could confirm their validity within the required confidence level for data. However, if either WGF are not available or they do not provide representative results, then based on the new survey for industrial solid waste, these factors could be developed for their future use.

Here, it is considered that WGF are not available and consequently surveys are to be undertaken to collect and analyze the data. The first step would be to prepare the list of the industries which are related to the plastic manufacturing or which production process generates substantial waste plastics (e.g. electronics).. The next step would be the collection of data from records and reports produced by these industries. If this data is available, then this would be a good benchmark and fewer samples would be required to only confirm the applicability of this data. If records are not available, then a detailed survey would be designed.

6.1.1 Identification of Industries

As our interest is in waste plastics and most of the times the budget and time is limited, we can only focus on the industries which generate waste plastics from their production line.

Therefore, as above mentioned, the industries which are related to the plastic manufacture or which production process generates substantial waste plastics are to be identified within the geographical area where the survey is taking place. They will be categorized according to their type, size and technology (information on the efficiency of the technology, especially with reference to input-output ratio is very useful).

Based on the information and local classification the formats could be developed in the following manner:

Table 6.1: Clustering the Industries

Type of Industry	Large		Medium		Small	
	Modern	Traditional	Modern	Traditional	Modern	Traditional
Electronics (TV, Computer)	3	1	-	-	-	5
Medical (Surgical Equipment)	1	-	1	-	1	-
Plastic manufacturing	-	-	2	-	-	-

Note: Large, medium and small shows the size of the industry based on ranges provided in national classification (if available, otherwise setup the virtual ranges). Modern and traditional either depends on the age of the industry or on the efficiency of the industry with respect to output-input ratio

6.1.2 Survey Design

The identification of those industries which generate substantial waste plastics would provide a clear picture of the number of industries with respect to size and technology. This information would also help to decide the appropriate number of samples in accordance with the number of the industries under each typology. If there are many different types of industries with different sizes and technologies, then more efforts will be required to collect the data for higher confidence levels. However, if there are fewer types of industries with little variation in size and technology, then fewer samples may provide data with acceptable confidence levels. As discussed in Chapter 4, the number of samples depends on the tradeoff between the requirement for the confidence level and the budget.

To prepare the list of the different types of waste plastics from different types of industries, the best approach would be to go through the industries' reports and records on solid waste generation. The other approach would be to consult the government departments responsible for the industries. The third approach would be to consult the literature on various types of the industries to finalize the list of the materials present in their waste stream.

In addition to the typology of plastics, it is important to get full information on the management and final disposal. Some types of plastics might be reused or recycled or used as a source of energy (waste exchange) within the same industry or within different industries.

Table 6.2: Plastic Waste Management (Production related Waste)

Type of Industry	Generation			Recycling/Reused			Final Discarded		
	PS	PP	PVC	PS	PP	PVC	PS	PP	PVC
Electronics (TV, Computer) - Large									
Electronics (TV, Computer) - Small									

Note: PP, PS, PVC …are examples of types of solid waste plastics. They can be substitute/amended according to the waste plastic generated at each type of industry

From all this information WGF should be developed for each type of industry of similar size and technology.

Time series data for each type of industry would be helpful to follow the trends for waste plastics generation in the future. This data may also reflect the relationship between the variation in waste plastics generation with respect to changes in technology and scale of the production.

Table 6.3: Time Series Data and Projections (1991-2010) for Industrial Waste Plastics

Year	Electronics			Year	Electronics		
	PS	PP	Total		PS	PP	Total
1991				2001			
1992				2002			
1993				2003			
1994				2004			
1995				2005			
1996				2006			
1997				2007			
1998				2008			
1999				2009			
2000				2010			

Note: PP, PS are examples of types of plastic waste encountered in a specific industry

There may be similar waste plastics from different types of industries. This would be clearly revealed in an overall dataset that could be developed based on the aggregated data. This data could be analyzed to provide current and future trends.

Table 6.4: Aggregated Data on Waste Components

Waste Plastic Type	Type of Industry					
	Electronics	Manufacturing	Medical	Automobile		Total
PE						
PP						
PS						
PET						
PVC						
Composite						
Others						
Total						

If required, the time series data tables and graphs may also be developed for all of the materials to take the decisions for each of the waste plastics material. This would be helpful for planning recycling and reuse activities for certain components and for planning proper disposal facilities for other components. The future forecast are very important as the investments in recycling plants and disposal facilities are bulky and require good assessment of each of the waste plastics materials. Furthermore, based on Chapter 4, the graphical presentation for industrial waste should be developed.

6.2 Plastic Waste due to Other Activities

Apart from the waste plastics generation due to the production activities, waste plastics are also generated due to maintenance of buildings, office work, and daily lives of staff working and living at industries. For staff, the major waste plastics are generated from consumption of packed goods, PET bottles and shopping bags. The office wastes may also include packaging materials and the building maintenance may generate plastic sheets, pipes and so on.

All these waste plastics components may be similar across the different types of industries; however, the amount of waste plastics may vary in accordance with the size and age of the industry.

Survey Design and Data Presentation

The survey for this type of waste from industries may be conducted together with the survey targeted to assess the waste plastics due to production activities. However, the data could be presented separately. The data can be categorized under different types of waste plastics. The list of the components should be prepared based on the local information or data from the industries records and reports.

Table 6.5: Solid Waste from Industries (Non-Production related waste)

Component	Unclean (tons)	Clean (tons)	Re-used on site (tons)	Discarded & sent to landfill (tons)
Staff activities				
Rigid waste Plastics				
Soft Plastics				
Office Activities				
Rigid waste Plastics				
Soft Plastics				
Maintenance				
Rigid waste Plastics				
Soft Plastics				
TOTAL				

NOTE: The categorization of the plastic types does not have to follow this one (rigid/soft) but a more exhausted classification can be included specifying types such as PE, PP, PS, PET, PVC etc)

The graphs and tables may be prepared in similar fashion, as discussed in Chapter 4, to provide information on current and future trends for this waste stream from industries.

7. WEEE / E-Waste

Globally, WEEE/ E-waste are most commonly used terms for electronic waste. At UNEP web site, it is cited that "E-waste is a generic term encompassing various forms of electrical and electronic equipment (EEE) that are old, end-of-life electronic appliances and have ceased to be of any value to their owners". There is no standard definition of WEEE/ E-waste. A number of countries have come out with their own definition, interpretation and usage of the term "E-waste/WEEE". WEEE/E-waste definitions under different initiatives/ conventions/ agencies/ NGOs ex. StEP, Basel Convention, OECD and Basel Action Network may also differ. However, for assessment of waste plastics from WEEE / E-waste, it is recommended to use local/national standards/practices. Furthermore, if some items are not covered under WEEE / E-waste, then these may be covered under municipal or industrial waste; thus waste plastics from these items will be covered under either WEEE / E-waste or under municipal or industrial waste. For detailed analysis of WEEE / E-waste coverage and inventory and management, separate guidelines are available. However, for our focus, to characterize and quantify waste plastics, this chapter might be sufficient.

7.1 Plastic Substances in WEEE / E-Waste

Composition of WEEE/ E-waste components is very diverse and may contain more than 1000 different substances, many of which fall under "hazardous" category. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood & plywood, printed circuit boards, concrete and ceramics, rubber and other items. Iron and steel constitutes about 50% of the WEEE/ E-waste followed by plastics (21%), non ferrous metals (13%) and other constituents (Table 7.1).

Table 7.1: Average Weight and Composition of Selected Electrical and Electronic Appliances

Appliances	Average weight (kg)	Fe % weight	Non Fe-metal % weight	Glass % weight	Plastic % weight	Electronic components % weight	Others % weight
Refrigerators and freezers	48	64.4	6	1.4	13	-	15.1
Washing Machine	40 to 47	59.8	4.6	2.6	1.5	-	31.5
Personal computer	29.6	53.3	8.4	15	23.3	17.3	0.7
TV sets	36.2	5.3	5.4	62	22.9	0.9	3.5
Cellular Telephones	0.080 to 0.100	8	20	10.6	59.6	-	1.8

Source: (1) Data compiled from Waste from electrical and electronic equipment (WEEE) – quantities, dangerous substances and treatment methods, EEA Copenhagen, 2003; (2) QWERTY and Eco-Efficiency analysis on cellular phone treatment in Sweden. TU Delft, the Netherlands, 2004

Non-ferrous metals consist of metals like copper, aluminium and precious metals ex. silver, gold, platinum, palladium etc. The presence of elements like lead, mercury, arsenic, cadmium, selenium, hexavalent chromium and flame retardants in WEEE/ E-waste beyond threshold quantities as mentioned in Material Safety Data Sheet (MSDS) and regulations related to hazardous waste of different countries, classifies them as hazardous waste. Some of the plastic components in WEEE / E-waste could be hazardous. These include phthalate plasticize, brominated flame retardants (BFR). BFR can give rise to dioxins and furans during incineration. Therefore, even though plastic recovery potential from PC, TV and Refrigerators might be quantified, as described in table 7.2, the presence of these components in the plastic might limit their recycling efficiency.

Table 7.2: Recoverable Quantity of Plastics

Appliance	Plastic recovery potential (%)
TV(1)	26
Refrigerator (2)	13.84
PC (3)	23

Source: (1) Compiled from data presented in "Mechanical Recycling of Consumer Electronic Scrap. Licentiate Thesis 2005:36, Luleå University of Technology, Luleå, Sweden",Cui.j, 2005 (2) Compiled from data presented in "Waste Electrical and Electronic Equipment (WEEE), Pilot Scheme Report, Producer Responsibility Unit Environment and Heritage Service, Government of U.K., 2005 (3) Compiled from data presented in (1) Exporting Harm – High-Tech Trashing of Asia. Basel Action Network and Silicon Valley Toxics Coalition, US, 2005; (2) Management of Waste Electrical & Electronic Equipment, ACRR 2003

For detailed assessment of E-waste, a separate manual for E-waste Inventory is available at www.unep.or.jp

PART II

Assessment of Current Waste Plastics Management Systems

8. Waste Plastics Management System / Practices

8.1 Introduction

This part provides basic understanding and formats for collection of the information on current solid waste management system.

The assessment of current solid waste management systems, covering also waste plastics, is an important part of the baseline study since it would help to:

- Analyze the availability, enforcement and impact of regulations and economic tools;
- Assess the institutional framework, resources and jurisdictions for current institutions;
- Analyze the efficiency and effectiveness of collection, treatment and disposal system including technologies;
- Understand the role of different stakeholders at different levels of the waste management chain; and
- Identify the challenges and opportunities to improve waste/waste plastics management based on 3R (reduce, reuse and recycling) approach.

Therefore as we have seen a solid waste management system is usually comprised of:

- ➢ Policies, laws and regulations
- ➢ Institutions
- ➢ Financing mechanisms (economic instruments)
- ➢ Technology and infrastructure,
- ➢ Stakeholder participation

It is important to highlight that the current system in a given city may cover upstream measures such as source reduction at production and consumption level, and downstream measures such as collection, transportation, treatment and disposal, and recycling and recovery.

In most of countries, specific information on waste plastics might be limited and the waste plastics management system might fall within the overall solid waste management so that no specific regulations, economic tools, institutions or services are developed as a separate management system for this specific waste stream. Hence, all the information regarding solid waste management such as policies/laws, institutions, financing mechanism and technologies for all the waste generating sources (domestic, commercial, industrial, agriculture, healthcare facilities, E-waste, etc.) should be collected, analyzed and any direct or indirect implications on waste plastics should be identified.

This information will provide the basis for finding out the gaps in the management system and practices pertaining to solid waste management in general and waste plastics in particular.

Some local issues may also be of interest such as to confirm the existence of pollution related regulations which may, directly or indirectly, have an impact on waste plastics or its treatment. For example pollution due to plastic bags, and related laws if any, would be of interest for developing this information. Another example could be of air pollution act to address incineration of waste containing waste plastics and its emissions.

Additionally, as a local issue it is important to identify the informal sector involved in the management of the waste/plastic waste since they have a big impact on the waste plastics pathways.

8.2 Waste Plastics Pathways

Prior to assessing the solid waste/waste plastics management system it is important to understand the waste plastics pathways, as shown in Figure 8.1. Discarded plastics can follow different routes according to many different factors such as the behaviour of the generators (waste plastic to be reused for alternative purposes, segregation of the plastic waste from other streams of waste or plastics to be disposed for landfilling, burning or open dumping), the local system in place (primary collection points for plastics, secondary collection points for recovery of plastics, coverage of collection etc), national or local policies (segregation at source by law), existence of plastic recycling market, or the presence of the informal sector engaged in recovery activities, etc.

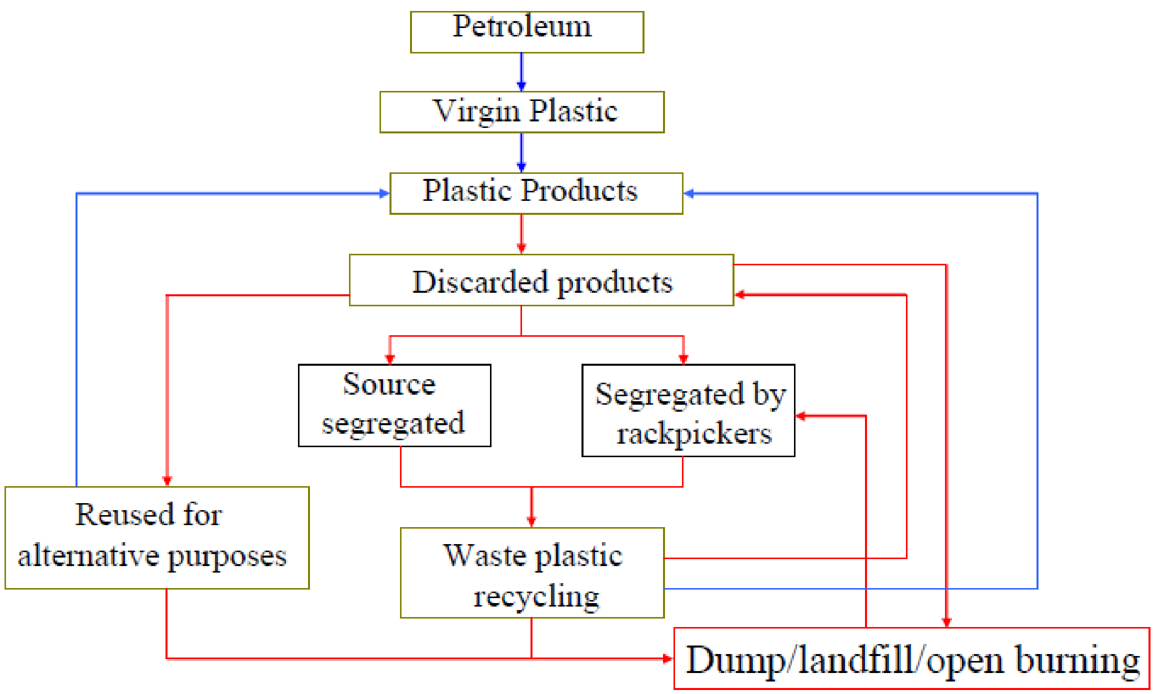

Figure 8.1: Waste Plastics Pathways

When carrying out the assessment of the system, the different routes and all the factors affecting such routes are to be identified; therefore the related information must be gathered or identified as a gap within the whole system including policies, institutions, financing mechanisms, technology and stakeholders.

8.1.1 Information Collection

The information required for the assessment of solid waste management systems in general and waste plastic management systems in particular, may follow the following roadmap:

- **Coverage:** Before starting to assess the management system, it is important to define the management system for solid waste management that usually covers waste plastics. There may be more than one management systems to address solid waste from different sources and/or different types of solid wastes including waste plastics.
- **Assessment of Individual Management Systems:** If there are more than one management systems to handle solid waste in general and waste plastics in particular, from different generators, then individual systems should be analyzed separately and then these could be compared to see the similarities and differences in each of these systems. However, this categorization should be adjusted based on local/national institutional arrangements and regulations.

8.3 Assessment of Waste Plastics Management System

As afore mentioned, most of the countries do not have a separate system for waste plastics management and it is usually managed under an umbrella system for solid waste management. Hence it is recommended to assess the current solid waste management system and find the gaps with reference to waste plastics management for making recommendations to make improvements in the solid waste management covering waste plastics.

Solid waste management may vary from country to country and from city to city. In most of the countries, the local governments are responsible for municipal solid waste management; however industrial solid waste and hazardous waste is the responsibility of national governments. In some places, the local governments are responsible for all types of waste; however, there may be different departments to manage municipal waste, industrial waste and hazardous waste. There could be fewer or more systems. The systems may be classified with respect to the responsible institution. If there is only one institution or department that is responsible for all types of solid waste management, then it may be considered that there is a single management system. However, if there is more than one institution responsible for different types of solid waste or waste generated by different sources then it is considered as a separate management systems. Therefore, it is recommended to collect the data and information separately for different types of systems even if there is some overlapping in terms of regulations and laws, financial mechanisms, technology and infrastructure and stakeholder participation (Fig 8.2).

Capacity / Challenges	Regulations & Laws	Institutions	Financial Mechanisms	Technology	Stakeholders' Participation
Municipal Solid Waste					
Industrial Solid waste					
Hazardous Solid Waste					
	Integrated Solid Waste Management				

Figure 8.2: Solid Waste Management System

It may also be noted that management systems may evolve over time depending on the variations in solid waste, political and administrative systems, socioeconomic situation and geo-climatic conditions. Hence, it is useful to capture the evolving process with respect to laws, institutions, financial mechanisms, technologies and stakeholder participation.

8.3.1 Flowchart for Data Collection and Analysis

It may be helpful to create a flowchart for data collection and analysis to avoid duplication of efforts and to assign a clear role to the team members who are responsible for data collection and analysis. The flowchart indicates that data / information which should be collected, or identified as a gap, for all the stages of solid waste management including source reduction, primary disposal, collection and transportation, treatment and disposal, and recycling and recovery:

It is important not only to collect the information but to specifically identify the data related to plastics or with a direct or indirect impact into the management of waste plastics.

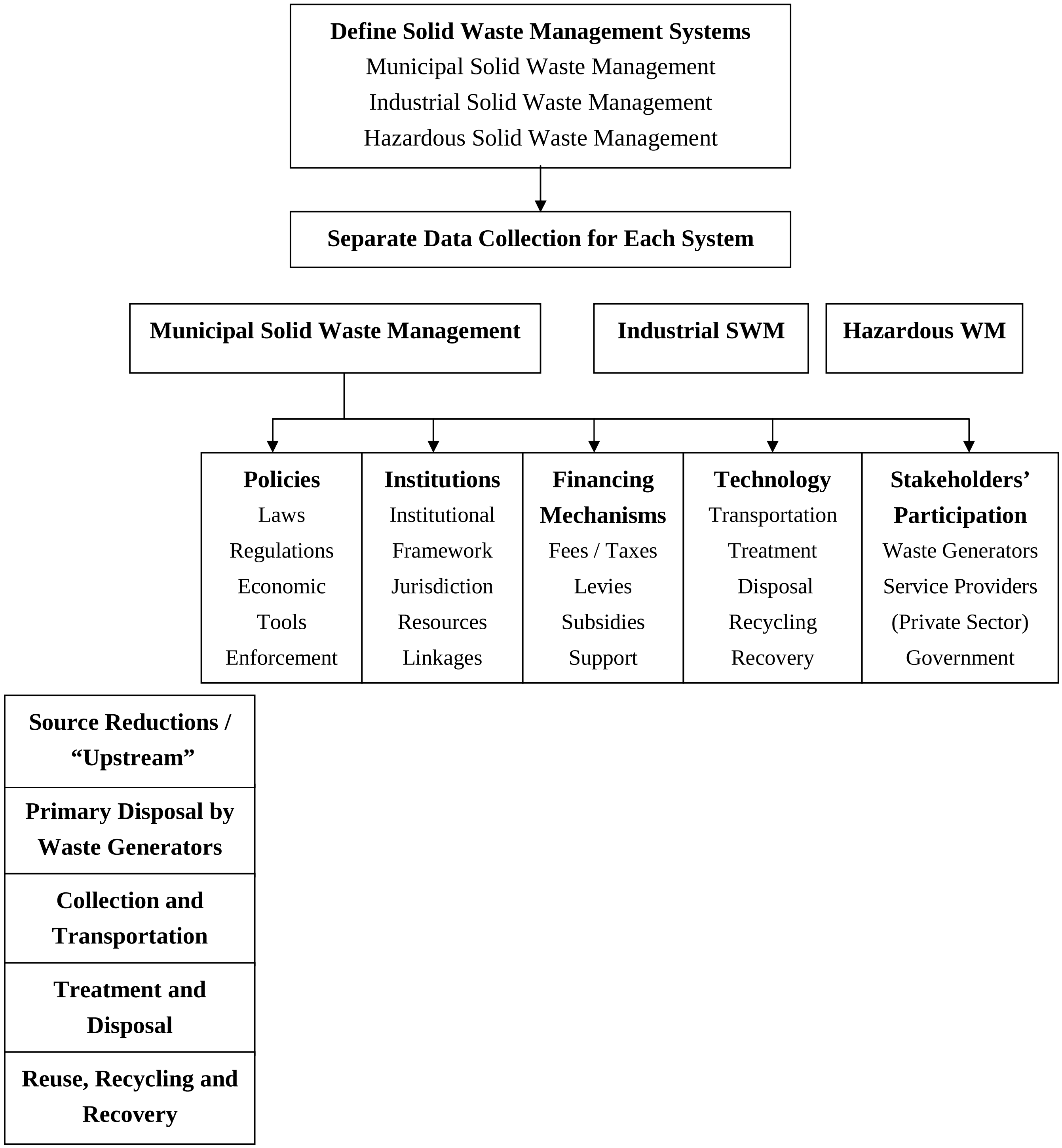

Figure 8.3: Flowchart for Data Collection & Analysis

8.4 Policies

The aim is to collect existing national and local policies. Policies are translated into regulatory and economic instruments for their implementation. Regulatory instruments, which are also known as command and control, specify the standards or limits to be followed. Economic instruments, which are also known as market-based instruments, provide incentives and disincentives. There may be some voluntary instruments agreed by the stakeholders.

Regulatory, economic and voluntary instruments may be available in general or may be available for each part of solid waste management chain including waste minimization (source reduction), segregation at source, storage and collection, transportation, treatment, disposal, and recycling and recovery.

8.4.1 Laws and Acts

Firstly, the laws and acts pertaining to solid waste management should be collected with special attention to plastics. There could be direct laws or acts addressing either overall solid/plastic waste management or a particular aspect of solid waste management chain, for example recycling and recovery. Environmental protection laws and acts usually cover solid waste management at national and local level. There may be a possibility that other laws, such as provision of public services, may also cover all or some aspects of solid waste management. The policies addressing various economic sectors, such as industries and agriculture, may also directly or indirectly address solid waste management/plastic waste. The specific laws for healthcare facilities, construction and demolition activities, and so on may also contain specific clauses on solid waste management. Laws or acts on solid waste management may cover hazardous waste management or there may be separate laws and acts addressing hazardous waste management. Some examples of the laws or acts could be as under: important relevant

I. Environmental Protection Law / Act
II. Recycling or Resource Recovery Law /Act
III. Public Services Act – Solid Waste Management
IV. Hazardous Waste Management Law / Act
V. Clean Air Act – Incineration, Landfill gases

Even thought some of the laws might not appear to be related to plastics, depending on the further use of the information they might become relevant. As an example, the Clean Air Act might not seem to be significant for plastic; however as the case of Philippines, the Clean Air Act bans incineration of municipal, biomedical and hazardous waste. If the conversion of waste plastics into a resource is being assessed, then it will be important to be aware of this act since automatically incineration would not be an option to be considered for the plastic conversion technology.

In the same way, the Hazardous Waste Law can specify components used as additives in some plastics which can be considered as hazardous, as it is the case of bromine flame retardants and therefore some countries might call for a separate treatment of such plastics.

8.4.2 Regulations

Secondly, information on all the relevant regulations should be collected. This may include various standards covering production and consumption for source reduction, segregation at source, storage and collection of various types of solid wastes, transportation, treatment, final disposal, and recycling and recovery. The standards may also be available for technology and infrastructure, for example construction and operation of landfills and incinerators. Some examples of regulations or standards could be as under:

I. Regulations on production and consumption – upstream measures
II. Regulations on segregation of recyclable and non-recyclable waste
III. Regulations on electronics waste
IV. Regulations pertaining to extended producer's responsibility
V. Regulations on handling of hazardous waste
VI. Regulations on collection and transportation of industrial waste
VII. Regulations on construction and operation of landfills
VIII. Regulations on construction and operation of incinerators
IX. Regulations on waste plastics or related to plastic

8.4.3 Economic Instruments

Thirdly, the information should be collected on all the relevant economic instruments addressing one or more aspects of solid waste management chain. Financial disincentives in the form of charges, levy, fine and penalty for waste generators could be a common economic instrument. Economic incentives, such as subsidies or payback, for recycling could be another common economic instrument. Some examples of economic instruments could be as under:

I. Levy on use of fresh resources in industrial production
II. Subsidies for recycling in industrial production
III. Volume-based solid waste fee on non-recyclable waste
IV. Penalties on hazardous waste
V. Subsidies for resource recovery, including power-generation at landfill

8.4.4 Enforcement

The most crucial aspect of policies for solid waste management would be their enforcement. Regulatory and economic instruments could only make a difference if these are properly enforced at all the levels. Therefore, an assessment of the level of enforcement is vital to make an overall assessment of the policies. However, it would be a challenge to assess the level of enforcement, as the criteria or benchmarks may not be available to ascertain the level of enforcement. The opinion on the enforcement levels may differ within different stakeholders, such as government, waste generators or handlers, and community. Hence, to get a comparatively appropriate assessment, opinions from all the major stakeholders should be sought.

8.4.5 Datasheet

Based on the collected information on laws, regulations, economic instruments and enforcement, a data sheet should be prepared as shown in Table 8.1. It would be helpful to have a table for overall solid waste and an additional one for waste plastics, so that policies specifically referring to plastics or impacting plastic waste, or gaps within the policy, can be easily identified. The relevant laws, standards or regulations and economic instruments should be annexed with Table 8.1. This table can be modified in accordance with the availability of data. If there is more information available in the specific aspects, then new columns and rows can be added accordingly.

Table 8.1: Policies for Overall Solid Waste/ Waste Plastics

	Laws / Acts	**Regulations / Standards**	**Economic Instruments**	**Enforcement**
Overall (General)				
Source Reduction				
Segregation of Waste (at source)				
Primary Storage & Collection				
Transportation & Transfer Stations				
Treatment				
Landfills				
Incinerators				
Recycling				
Resource Recovery				

8.5 Institutions

Plastic waste as one of the streams of the overall solid waste is managed by the institution/s responsible for solid waste management and not by any specific institution. Traditionally solid waste management was the responsibility of local governments. However, with increasing rate of solid waste from diversified sources, including industries and unconventional sources such as laboratories, various institutions got involved into one or more aspects of solid waste management chain. Furthermore more institutions became responsible due to the increasing awareness and regulations for recycling and recovery, hazardous waste management and source reduction by intervening at production and consumption level. There is also a transition from public institutions to private institutions for undertaking various public utilities and services including solid waste management. This requires governments to establish strong regulatory institutions to make sure that service providers are effectively and efficiently delivering their services. There may be more than one institutions involved at same level or for same type of activity, for example informal and formal sector recycling or public and private sector for collection and transportation of municipal waste.

We need to collect information on all the institutions, currently responsible at any level of solid waste management. The information should be as detailed as possible to identify their role or mandate, institutional framework, and human resources and sources for financing their activities. The collected data may be tabulated in two levels. At first, the name of the institutions may be provided as per Table 8.2. This table can be modified in accordance with the length and breath of the available information. Thereafter, a separate sheet, containing the following information regarding each institution, should be attached with this table:

1. Role or mandate of the institution
2. Institutional Framework
3. Human Resources
4. Sources of funding

Table 8.2: List of Institutions involved in Solid Waste Management Chain

Type of Service	Regulator	Service Provider		
		National Government	Local Government	Private Sector
Municipal Solid Waste Management				
1. Collection				
2. Transportation				
3. Treatment				
4. Disposal				
5. Recycling				
Industrial Solid Waste Management				

8.6 Financing Mechanisms

In many countries, solid waste management is the responsibility of the local government. Local governments used to finance all the activities within solid waste management chain (collection, transportation, treatment and disposal) from its annual budget, subsidies from national government and through international cooperation. However, with a rapid increase in solid waste generation rates and awareness for effective and efficient solid waste management to protect public health and environment, huge investments are required to bring improvements in collection and transportation, treatment and disposal, and recycling and recovery. This is resulting into a transition of solid waste management. The governments are adopting various financing modes and some of the widely practiced modes are as follows:

1. **User Charges:** In many countries, user charges are being introduced. For commercial and industrial sector, the charges can be as high to meet the costs in accordance with the polluter's pay principle. For municipal sector, the charges are still low; however, these user charges motivate waste generators to reduce the waste. Volume-based charges for municipal waste are quite common in some countries.

2. **Penalty, Fine and Levy:** The terminology and rate of the penalty/fine/levy may vary from country to country. This form of direct income is also becoming an important financing tool for government to finance solid waste management.

3. **Environmental Bonds:** In some countries, local governments float various bonds to arrange funds to finance development activities. Environmental bonds, a commonly used term in some countries, are a major source to arrange funds for environmental infrastructure and services including solid waste management

4. **Environmental Fund:** Some countries set a revolving fund to assist local governments in meeting their financing needs for environmental infrastructure and services. This fund is financed through various modes including national bonds, annual budget, loans from international financing institutions and international cooperation.

5. **Direct Loans:** Local governments may take direct loans either from domestic or international financing institutions.

6. **International Cooperation:** There is an increasing trend of a direct multilateral and bilateral cooperation with local governments. International agencies are providing support to local governments to improve the local environment. Various bilateral initiatives, including sister cities, are also helping local governments to seek assistance for financing their development projects including solid waste management.

7. **National Subsidies:** This is still a major source for many local governments to finance environmental infrastructure and services.

8. **Annual Budget:** Local governments allocate substantial portion of their development budget to finance solid waste management. This is usually cross-subsidized from the profit-making avenues of local governments.

9. **Private Sector Participation (PSP):** There is an increasing trend of private sector participation in waste plastics collection and recycling. This private sector participation is visible in collection, transportation, treatment, disposal, and recycling of waste plastics. Private companies are taking up major projects such as converting waste plastics into energy or material source under various arrangements such as BOT (build-operate-transfer) basis. Franchise is another common way for private sector participation, where private sector has the right to collect waste plastics within the agreed location and sell recyclable waste.

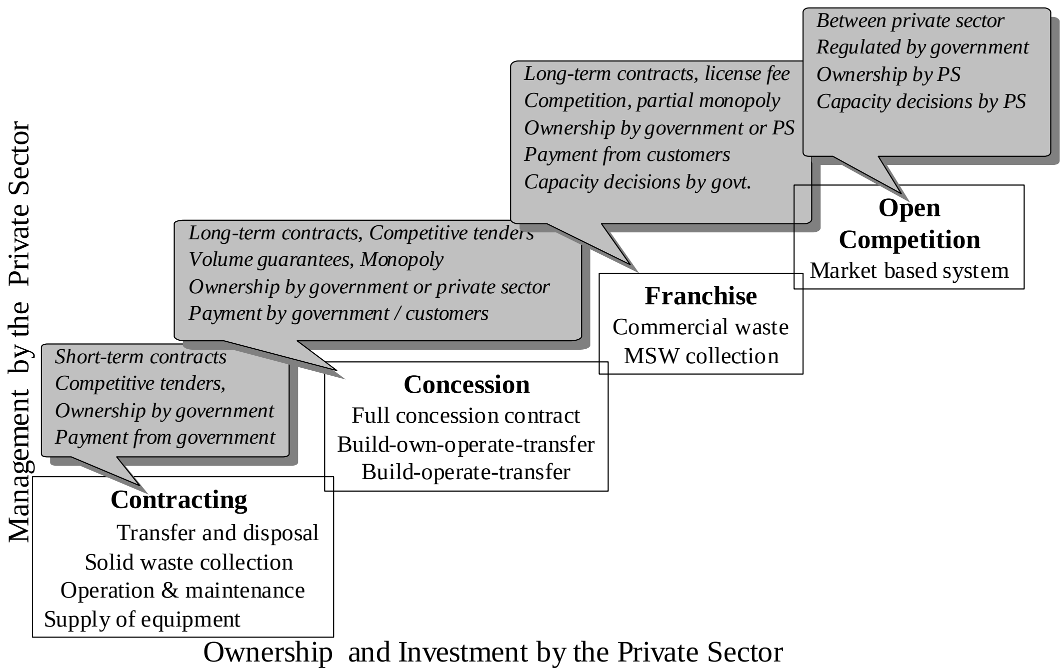

Figure 8.4: Management and Ownerships in Various Forms of Private Sector Participation

Datasheet:

The information should be collected on the financing mechanisms for all the activities under solid waste management chain (Table 8.3). There may be more than one organization involved for one activity and there may be more than one financing mechanism to finance one activity. Therefore, Table 3 can be modified in accordance with the available information.

Table 8.3: Financial Mechanisms for Solid Waste Management Chain

Type of Service	Organization	Financing Mode		
		Direct Revenue	Local Government/ National Government/ International Cooperation	Private Sector (Mention Type of PSP)
Waste Plastics from Residential and Commercial Sector				
1. Collection				
2. Transportation				
3. Treatment				
4. Disposal				
5. Recycling				
Waste Plastics from Industrial Sector				

8.7 Technology

Solid waste management chain requires intensive use of environmentally sound technology (ESTs) for collection, transportation, treatment, disposal, and recycle and recovery. The technology could be as simple as containers for primary collection to as complicated as incinerators for disposal of hazardous waste. The possible technological interventions within solid waste management chain, which might also apply or are specific to plastic waste, are as follows:

1. **Primary Collection and Transfer Stations:** This may include the waste collection bins for segregated municipal waste and special containers for hazardous waste. Material, construction, labeling and storage of the collection containers are also important. Construction and location of transfer station is quite crucial to avoid adverse effects due to odour, breeding of vectors such as flies and mosquitoes, and entry of birds or cats and dogs. The transfer stations should be located and constructed in such a way that it is convenient for small carts to unload solid waste and for bigger vehicles to collect and transport that waste.

2. **Transportation:** This covers all types of vehicles under operation to transport solid waste from waste generation point to transfer station; and from transfer station to treatment and disposal site. All the vehicles in operation should be listed out including manually driven small carts, mechanically driven sophisticated transportation vehicles and special vehicles for special waste such as hazardous waste, bulky waste and recyclable wastes.

3. **Treatment:** This includes separation of different types of waste for materials recovery and recycling as well as for different types of treatment before final disposal. Hence at this level of solid waste, technology may cover equipment for separation of various types of materials, equipment for shredding of final disposable waste and technology for the treatment of final

disposal waste. In some countries, incineration is covered at this level and ash from incinerator is sent to landfill for final disposal. Incineration is a high-tech process and negative impacts of incineration could be worse for public health as well as for environment.

4. **Final Disposal:** Sanitary landfill is the most common technology around the world. The conventional and environmentally unfriendly methods may still be in use. These include open-burning, open-dumping and non-sanitary landfill. However, in most of the countries these are officially banned and only sanitary landfill is recommended for final disposal. Various types or technologies of sanitary landfills are available including fully aerobic, semi-aerobic and anaerobic. The technologies may also vary in accordance with the type of final disposable waste, for example some landfills may be used for co-disposal of special wastes. The landfills for hazardous wastes could be more complicated and known as "secure landfill." The location of landfill is an important factor towards transportation costs as well as for its impacts on the urban environment.

5. **Recycling and Recovery:** This includes various types of activities including recycling of reusable materials such as plastic and glass containers, recycling of materials to into industrial production such as paper and iron, converting waste into a energy such as burning tires in cement kiln to produce heat, and converting waste into a resource such composting and landfill gas. Hence technology can determine the level and sophistication of recycling and recovery activities.

Table 8.4: Technology for Solid Waste Management

Type of Service	Technology		
	Type	**Number**	**Important Features**
Waste Plastics from Residential and Commercial Sector			
1. Collection			
2. Transportation			
3. Treatment			
4. Disposal			
5. Recycling			
Industrial Solid Waste Management			
Waste Plastics from Industrial Sector			

Datasheet: The information on the technology is required for all the activities within solid waste management chain. First of all, an overview of current technologies could be provided as per Table 8.4. Thereafter, separate sheets may be attached with this table on the details of each of the technology including transportation vehicles, landfill, and recycling and recovery processes. Table 8.4 can be modified in accordance with the available technology/equipment.

8.8 Stakeholder's Participation

Stakeholder participation is becoming an essential part of solid waste management. Major stakeholders include waste generators, regulators, service providers (including the informal sector) such as organizations involved in waste collection and waste disposal, and organizations involved in recycling and recovery. These stakeholders can improve the efficacy and efficiency of solid waste management by continuous interaction to bring improvements in the system, and by active participation as each stakeholder may have a clear role to play. Waste generators, which are traditionally considered as passive partners, have a major responsibility to reduce the waste, segregate the waste and properly throw the waste as per the regulations. A close cooperation would be required between waste generators and waste collectors to increase the coverage and effectiveness of waste collection system. Similar cooperation is vital for disposal of waste. Recycling and recovery of materials also depend on the cooperation of waste generators and waste collectors. Furthermore, with rapid changes in quantity and composition of solid waste, regulatory organizations or governments have to be in continuous dialogue with the stakeholders to introduce appropriate regulations which can bring the required improvements in solid waste management system.

The identification of the stakeholders within waste plastics can be narrowed down from the stakeholders of the general waste to specific stakeholders of waste plastics (e.g. specific organizations or groups within the informal sector might limit their activities to waste plastic collection or recycling).

Datasheet: The information on stakeholder participation would be required at two levels. On the one hand, the information would be required on the process to increase stakeholder participation. This may cover the materials, campaigns, meetings, and other political and social interactions to motivate stakeholders to participate in solid waste management. On the other hand, the information would be required on the ways and means for stakeholder participation, for example, stakeholder representation in decision-making bodies such as regulatory body and monitoring committee. Stakeholder participation in the decisions to set the level and type of service, such as door-to-door collection or location of transfer station, could also indicate the level of participation. Table 8.5 may be helpful in obtaining and filling in this information.

Table 8.5: Process and Level of Stakeholder Participation in SWM

Type of Service	Major Stakeholders	Measures to Improve Stakeholder Participation*	Level of Stakeholder Participation**
Waste Plastics from Residential and Commercial Sector			
Waste Plastics from Industrial Sector			
Waste Plastics from Specific Wastes such as E-waste			

* Measures may include awareness raising materials and campaigns, meetings, etc.

** Level of participation may be indicated by the role of stakeholders in SWM chain

Annexure 1

Types of Waste Plastics

Many of the plastic types have been designed to collect information on Rigid Plastic Packaging Containers (RPPCs), a category that is subject to specific regulation. Please see the subsequent section for definitions and examples of RPPCs.

"PET Containers" means clear or colored PET containers. When marked for identification, it bears the number "1" in the center of the triangular recycling symbol and may also bear the letters "PETE" or "PET." The color is usually transparent green or clear. A PET container usually has a small dot left from the manufacturing process, not a seam. It does not turn white when bent.

1. **RPPC Small CRV PET Bottles** means clear or colored PET bottles designed to contain less than 24 ounces of material and meet the RPPC and CRV criteria.
2. **RPPC Large CRV PET Bottles** means clear or colored PET bottles designed to contain 24 ounces or more of material and meet the RPPC and CRV criteria.
3. **RPPC Non-CRV PET Bottles** means clear or colored PET bottles that meet the RPPC criteria but do not meet the CRV criteria.
4. **Other RPPC PET Containers** means non-bottle PET containers that meet the RPPC criteria. Includes clamshell containers.
5. **Non-RPPC Non-CRV PET Containers** means PET bottles and containers that do not meet the criteria for being either CRVs or RPPCs.

"HDPE Containers" means natural and colored HDPE containers. This plastic is usually either cloudy white, allowing light to pass through it (natural) or a solid color, preventing light from passing through it (colored). When marked for identification, it bears the number "2" in the triangular recycling symbol and may also bear the letters "HDPE."

6. **RPPC CRV Small HDPE Natural Bottles** means clear/translucent HDPE bottles designed to contain less than 24 ounces of material and meet the RPPC and CRV criteria.
7. **RPPC CRV Large HDPE Natural Bottles** means clear/translucent HDPE bottles designed to contain 24 ounces or more of material and meet the RPPC and CRV criteria.
8. **RPPC Non-CRV HDPE Natural Bottles** means clear/translucent HDPE bottles that meet the RPPC criteria but do not meet the CRV criteria.
9. **RPPC CRV Small HDPE Colored Bottles** means colored, non-translucent HDPE bottles designed to contain less than 24 ounces of material and meet the RPPC and CRV criteria.
10. **RPPC CRV Large HDPE Colored Bottles** means colored, non-translucent HDPE bottles designed to contain 24 ounces or more of material and meet the RPPC and CRV criteria.
11. **RPPC Non-CRV HDPE Colored Bottles** means colored, non-translucent HDPE bottles that meet the RPPC criteria but do not meet the CRV criteria.
12. **Other RPPC HDPE Containers** means non-bottle HDPE containers that meet the RPPC criteria.
13. **Non-RPPC Small CRV HDPE Containers** means HDPE bottles and containers that do not meet the RPPC criteria but that meet the criteria for CRV containers designed to contain less than 24 ounces of material.
14. **Non-RPPC Non-CRV HDPE Containers** means HDPE bottles and containers that do not meet the criteria for being either CRVs or RPPCs.

"Miscellaneous Plastic Containers" means plastic containers made of types of plastic other than HDPE or PET. Items may be made of PVC, PP, or PS. When marked for identification, these items may bear the number "3," "4," "5," "6," or "7" in the triangular recycling symbol. This subtype also includes unmarked plastic containers. This includes types below.

15. **RPPC Small CRV Bottles not HDPE or PET** means bottles made of types of plastic other than HDPE or PET (that is, made of types #3–7, or unmarked) that meet the RPPC criteria and that meet the CRV criteria for plastic items that contain less than 24 ounces of material.

16. **RPPC Large CRV Bottles not HDPE or PET** means bottles made of types of plastic other than HDPE or PET (that is, made of types #3–7, or unmarked) that meet the RPPC criteria and that meet the CRV criteria for plastic items that contain 24 ounces or more of material.

17. **RPPC non-CRV Bottles not HDPE or PET** means bottles made of types of plastic other than HDPE or PET (that is, made of types #3–7, or unmarked) that meet the RPPC criteria but do not meet the CRV criteria.

18. **RPPC Clamshells not HDPE or PET** means clamshell packaging that meets the RPPC criteria, made out of plastic types #3-7 or unmarked. This category includes polystyrene egg cartons.

19. **Other RPPC Containers not HDPE or PET** means other plastic containers of types #3-7, or unmarked, that meet the RPPC criteria.

20. **Non-RPPC Small CRV Miscellaneous Plastic Containers** means other containers made of types #3-7 that do not meet the RPPC criteria but do meet the CRV criteria for plastic items that contain less than 24 ounces of material.

21. **Non-RPPC non-CRV Miscellaneous Plastic Containers** means other containers made of types #3-7 that do not meet the RPPC criteria or the CRV criteria. This includes single-serving drink cups from take-away food stores and restaurants.

    "Film Plastic" means flexible plastic sheeting. It is made from a variety of plastic resins including HDPE and LDPE. It can be easily contoured around an object by hand pressure. This includes types. **NOTE**: These types were previously classified under the more general type "Film Plastic."

22. **Trash Bags** means plastic bags sold for use as trash bags, for both residential and commercial use. Does not include other plastic bags like shopping bags that might have been used to contain trash.

23. **Grocery and Other Merchandise Bags** means plastic shopping bags used to contain merchandise to transport from the place of purchase, given out by the store with the purchase. Includes dry-cleaning plastic bags intended for one-time use.

24. **Non-Bag Commercial and Industrial Packaging Film** means film plastic used for large-scale packaging or transport packaging. Examples include shrink-wrap, mattress bags, furniture wrap, and film bubble wrap.

25. **Film Products** means plastic film used for purposes other than packaging. Examples include agricultural film (films used in various farming and growing applications, such as silage greenhouse films, mulch films, and wrap for hay bales), plastic sheeting used as drop cloths, and building wrap.

26. **Other Film** means all other plastic film that does not fit into any other type. Examples include other types of plastic bags (sandwich bags, zipper-recloseable bags, newspaper bags, produce bags, frozen vegetable bags, bread bags), food wrappers such as candy-bar wrappers, mailing pouches, bank bags, X-ray film, metalized film (wine containers and balloons), and plastic food wrap.

    "Durable Plastic Items" means plastic objects other than disposable package items. These items are usually made to last for a few months up to many years. These include the plastics used in construction, communication, electrical and electronics, furniture, transportation, and recreation industries.

27. **RPPC HDPE Buckets** means colored and natural buckets and pails made of HDPE and designed to hold 5 gallons or less of material. This category includes buckets regardless of whether they are attached to metal handles. Examples include large paint buckets and commercial buckets used to contain food for commercial use (restaurants, etc.). These objects are packages containing material for sale, and are not sold as buckets themselves (such as mop buckets).

28. **Other Durable Plastic Items** means all other plastic objects other than containers, film plastic, or HDPE buckets. Examples include mop buckets, plastic outdoor furniture, plastic toys, CD's, plastic stay straps, and sporting goods, and plastic house wares such as dishes, cups, and cutlery. This type also includes building materials such as house siding, window sashes and frames, housings for electronics (such as computers, televisions and stereos), fan blades, impact-resistance cases (for example, tool boxes, first aid boxes, tackle boxes, sewing kits, etc.), and plastic pipes and fittings.

29. **Remainder/Composite Plastic** means plastic that cannot be put in any other type or subtype. They are usually recognized by their optical opacity. This type includes items made mostly of plastic but combined with other materials. Examples include auto parts made of plastic attached to metal, plastic drinking straws, foam drinking cups, produce trays, foam meat and pastry trays, foam packing blocks, packing peanuts, foam plates and bowls, plastic strapping, plastic lids, some kitchen ware, toys, new plastic laminate (for example, Formica), vinyl, linoleum, plastic lumber, insulating foams, imitation ceramics, handles and knobs, plastic string (such as is used for hay bales), and plastic rigid bubble/foil packaging (as for medications).

Source: CASCADIA Consulting Group (2004), *Statewide Waste Characterization Study*. California Integrated Waste Management Board (CIWMB). http://www.ciwmb.ca.gov/Publications/LocalAsst/34004005.pdf (6 April 2006)

Annexure 2

Types of RPPCs and CRV Containers

In coordination with classifying all materials according to the 98 material types, certain plastic materials were classified as RPPC (Rigid Plastic Packaging Containers) from each sample into the nine types listed below.

	RPPC Material	Description and Examples
1	RPPC PET (#1) Bottles	PET bottles containing beverages or other liquids. Examples include bottles for soda pop, some sports drinks, sparkling waters, cooking oil, shampoo, and some liquors.
2	RPPC PET (#1) Other Containers	PET containers and packages, other than bottles, that are recloseable. Examples include packages containing small toys or hardware items.
3	RPPC HDPE (#2) Natural Bottles	Primarily milk jugs and some juice bottles.
4	RPPC HDPE (#2) Colored Bottles	Any HDPE bottle that is not clear/translucent. Examples include some orange juice bottles, many laundry detergent bottles, and some shampoo bottles.
5	RPPC HDPE (#2) Other Containers	Examples include some margarine containers, some food jars, and some yogurt containers.
6	RPPC #3–#7 Bottles	All plastic bottles that are not PET or HDPE. Examples include some sports drink bottles, many shampoo bottles, and some detergent bottles.
7	RPPC #3–#7 Clamshells	Food clamshell containers such as those often used by restaurants, delicatessens and fast food restaurants; and non-food clamshells used for packaging such as for hardware, electronics, automotive parts, sports gear, safety equipment, and personal care products.
8	RPPC #3–#7 Other Containers	Includes containers for some prepared foods, such as chip dip. Also includes some yogurt and margarine containers.
9	RPPC HDPE (#2) Buckets	HDPE buckets, often used as containers for paint and other household chemicals and building materials. These buckets are sometimes used for shipment of bulk foods.

A container must meet all of the following criteria to be considered an RPPC:

- It is made entirely of plastic, except that lids, caps, or labels may be made of some other material.
- It is capable of maintaining its shape while holding a product.
- It has an attached or unattached lid or cap.
- Contains at least 8 fluid ounces but no more than 5 gallons, or the equivalent volumes.

Also, certain glass, plastic, and metal containers were classified as CRV (California Redemption Value) containers. CRV containers were defined for sorting as beverage containers that display the CRV notification. Generally, CRV containers include carbonated soft drinks, beer, bottled water, and juice and sports drinks. For more details, see the Department of Conservation, Division of Recycling websites at www.bottlesandcans.com/what_main.html and www.consrv.ca.gov/dor/crcp/recyclers/Images/Act-2004.pdf.

Source: CASCADIA Consulting Group (2004), *Statewide Waste Characterization Study*. California Integrated Waste Management Board (CIWMB). http://www.ciwmb.ca.gov/Publications/LocalAsst/34004005.pdf (6 April 2006)

Annexure 3

Common Types of Plastics, Properties and Product Applications

Name	Properties	Product Application
Polyethylene Terephthalate (PET or PETE)	Clear, strength / toughness, barrier to gas and moisture, resistance to heat. Excellent resistance to most solvents	Plastic soft drink and water bottles, beer bottles, mouthwash bottles, peanut butter and salad dressing containers, oven-able film, oven-able pre-prepared food trays.
High Density Polyethylene (HDPE)	Stiffness, strength / toughness, resistance to chemicals and moisture, permeability to gas, ease of processing, ease of forming. Un-pigmented bottles are translucent, have good barrier properties and stiffness	Bottles for milk, water, juice, cosmetic, shampoo, dish and laundry detergent; trash and retail bags, yogurt and margarine tubs, cereal box liners. In addition to packaging, HDPE's major uses are in injection molding applications, extruded pipe and conduit, plastic wood composites, and wire and cable covering.
Polyvinyl Chloride (V or Vinyl or PVC)	Versatility, ease of blending, strength / toughness, resistance to grease/oil, resistance to chemicals, clarity	Toys, clear food and nonfood packaging, shampoo bottles, medical tubing, wire and cable insulation, film and sheet; construction products such as pipes, fittings, siding, flooring, carpet backing, window frames.
Low Density Polyethylene (LDPE)	Ease of processing, barrier to moisture, strength / toughness, flexibility, relative transparency and ease of sealing. Excellent resistance to acids, bases and vegetable oils	Dry cleaning, bread, and frozen food bags; squeezable bottles (i.e., honey, mustard).
Polypropylene (PP)	Strength / toughness, resistance to chemicals, resistance to heat (has a high melting point), barrier to moisture, versatility, resistance to grease/oil, inertness toward acids, alkalis and most solvents	Ketchup bottles, yogurt containers and margarine tubs, medicine bottles. Packaging, automotive, appliances and carpeting
Polystyrene (PS)	Versatility (can be rigid or foamed), Generally is clear, hard and brittle. It has relatively low melting point, Significant stiffness in both foamed and rigid forms Easily foamed ("styrofoam"). Low thermal conductivity and excellent insulation properties in foamed form.Low density and high stiffness in foamed applications	Compact disc cases, foodservice applications, grocery store meat trays, egg cartons, aspirin bottles, foam cups, plates, cutlery, protective packaging and building insulation.
Others (Products made with a resin other than the six listed above, or is made of more than one resin and used in a multi-layer combination).	Dependent on resin or combination of resins.	*Plastics with presence of polycarbonate*: a hard, clear plastic used to make baby bottles, water pitchers, three and five-gallon reusable water bottles, food containers, some citrus juice and ketchup bottles, compact discs, cell phones, automobile parts, computers. *Acrylonitrile styrene (AS) or styrene acrylonitrile (SAN), and acrylonitrile butadiene styrene (ABS):* Both AS/SAN and ABS are higher quality plastics with increased

		strength, rigidity, toughness and temperature and chemical resistance. AS/SAN is used in mixing bowls, thermos casing, dishes, cutlery, coffee filters, toothbrushes, outer covers (printers, calculators, lamps), battery housing. The incorporation of butadiene during the manufacture of AS/SAN, produces ABS, which makes it an even tougher plastic. ABS is used in LEGO toys, pipes, golf club heads, automotive parts, protective head gear.

American Chemistry Council
Society of the Plastics Industry (SPI) [www.plasticsindustry.org],
Canadian Plastics Industry Association (CPIA) [www.cpia.ca],
Environment and Plastics Industry Council (EPIC) [www.cpia.ca/epic/].

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

- **The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information, see **www.unep.fr**

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The world's annual consumption of plastic materials has increased from around 5 million tonnes in the 1950s to nearly 100 million tonnes; thus, 20 times more plastic is produced today than 50 years ago. Plastic waste recycling is one of the most established recycling activities in economically developed countries. In most of the situations, recycling of waste plastics is becoming viable in developing countries as well, as it generates resources and provides jobs, which are in high demand. The recycling of waste plastics also has a great potential for resource conservation and GHG emissions reduction, such as producing diesel fuel from plastic waste. As raw materials, wastes plastics have attractive potentials for large-scale industries and community-level enterprises. To develop and implement the projects for converting waste plastics into a resource, one of the most important factors is the information on quantity and characterization of waste plastics. This document is a compilation of the guidelines for collection and analysis of data on waste plastics. These guidelines are aimed to build the capacity of practitioners in developing countries on quantification and characterization of waste plastics with projections into future. This document contains relevant formats for data recording and presentation.

DTI/1231/JP