ICPE
INDIAN CENTRE FOR PLASTICS IN THE ENVIRONMENT

Envis ECO-Echoes

Management of Plastics, Polymer wastes and Biopolymers and impact of Plastics on the Eco-system

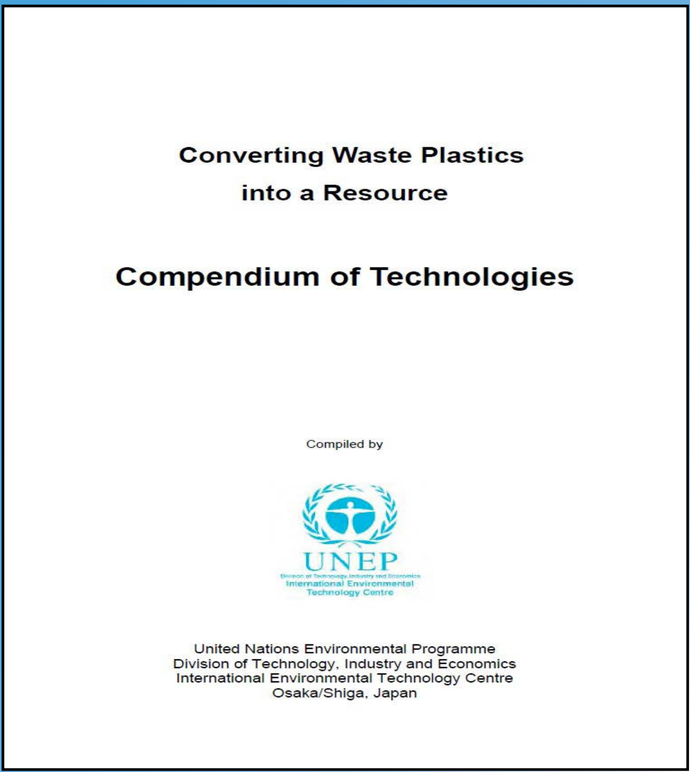
Environmental Information System

Sponsored by Ministry of Environment & Forests, Government of India

Quarterly Publication of Envis Center ICPE

Volume 16 | Issue 3 | July - Sept., 2015

IN THIS ISSUE



Converting Waste Plastics
into a Resource

Compendium of Technologies

Compiled by

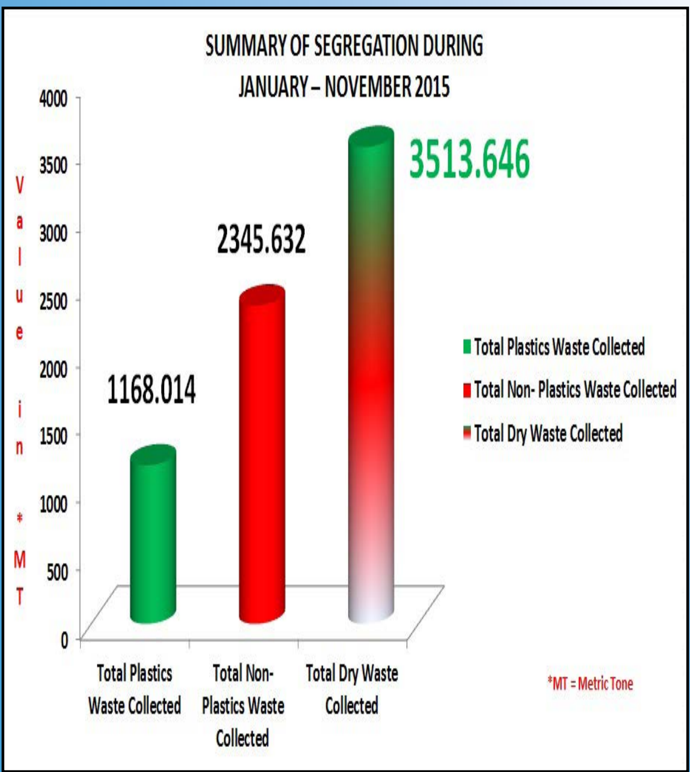
UNEP

United Nations Environmental Programme
Division of Technology, Industry and Economics
International Environmental Technology Centre
Osaka/Shiga, Japan

Page-1

CONVERTING WASTE PLASTICS INTO A RESOURCE

COMPENDIUM OF TECHNOLOGIES



Page-14

SEGREGATION OF WASTE AT SOURCE PROJECTS AT SELECT WARDS IN MUMBAI

ICPE INITIATIVE

Envis Eco-Echoes

Volume 16 • Issue 3 • July - Sept. , 2015

Editorial

NAME OF THE ENVIS CENTRE

INDIAN CENTRE FOR PLASTICS IN THE ENVIRONMENT

Olympus House, 2nd Floor, 25, Raghunath Dadaji Street, Fort, Mumbai - 400 001.
Tel.: +91 22 4002 2491, 2261 7137 / 7165
Fax: 2261 7168
E-mail: icpe@icpe.in, icpe@envis.nic.in

Web sites

www.icpeenvis.nic.in
www.icpe.in

• • •

1009, Vijaya Building, 10th Floor, 17 Barakhamba Road, New Delhi - 110 001.

Tel.: 011 4359 6329 • Telefax: 011 2332 6376
E-mail: icpedelhi@airtelmail.in

• • •

Area of Activity

Capacity Enhancement Programme on Management of Plastics, Polymer Waste and Bio-Polymers, Impact of Plastics on Eco-System

Plastics Waste is a Resource

Despite plastics materials' possessing various excellent all-round positive attributes like energy saving, lowest green house gas emission amongst the alternate materials, excellent chemical resistance properties suitable for its safe use in contact with food and non-food products supported by excellent processing characteristics, there are some issues which have been surrounding the material ever since its growth rate increased. These issues mostly relate to the management of waste created by plastics products after its use mostly in the packaging applications.

The important issue of waste management as fallout of improper disposal of plastics packaging and other waste has been addressed by plastics recovery / recycling system. Technologies have been developed for recycling all types of plastics waste and recovery of the latent energy. However, segregation of Dry and Wet Waste at source of waste generation is the most important step for achieving success in the implementation of any waste management activity including plastics waste management.

Although plastics are 100% recyclable, however, plastics materials of different types and of varying properties are difficult to be recycled through mechanical recycling process, the most adopted method world wide including in India. While rigid plastics waste can be segregated into individual groups / types more easily, waste generated out of flexible packaging in the form of mixed / co-mingled plastics and plastics materials made out of a combination of different plastic materials (multilayered plastics), being difficult for mechanical recycling, are mostly abandoned in the waste stream causing a serious environmental problem.

Feedstock Recycling Process of plastics waste can convert mixed plastics waste into hydrocarbon fuel (Light Diesel Oil - LDO). All types of plastics waste can also be Co processed in Cement Kilns as energy providing input.

In this edition, an article of United Nation Education Programme (UNEP) containing the success already achieved in converting such plastics waste in to industrial fuel in an environmental friendly technology in Japan and other countries have been published. This option has the benefit of using mixture of different types of plastics waste, mixed together, without segregation. Elaborate cleaning / washing is also not required. Industrial Fuel made out of the plastics waste is substitute of fossil fuel.

All plastics, rigid and flexible, made of one or multilayer, are 100% recyclable with one technology or the other. While in India about 100% rigid plastics waste is recycled, there is however a gap in the collection of flexible plastics packaging waste mainly due to economic reasons and lack of infrastructure. By assigning the responsibility of waste collection to the producer and user under the overall responsibility of civic bodies and creating mass awareness against littering, efficient plastics waste management could be achieved.

Editor
Mr. T. K. Bandopadhyay

Converting Waste Plastics into a Resource

Compendium of Technologies

Compiled by

Division of Technology, Industry and Economics
International Environmental Technology Centre

United Nations Environmental Programme
Division of Technology, Industry and Economics
International Environmental Technology Centre
Osaka/Shiga, Japan

Technologies for Converting Waste Plastics into Fuel

1. Introduction

1.1 Overview

This compendium of technologies aims to present an overview of the technologies available for converting waste plastics into a resource - solid, liquid and gaseous fuels as well as the direct combustion of waste plastics for specific applications. This compendium displays the plastics which are suitable for each type of fuel and the potential problems posed by contamination by undesirable materials. Flowcharts of typical production systems for solid, liquid and gaseous fuels are contained in this compendium. Other technologies used in the steel, cement and lime manufacturers have been discussed.

1.2 Plastics

As a brief introduction to plastics, it can be said that plastics are synthetic organic materials produced by polymerization. They are typically of high molecular mass, and may contain other substances besides polymers to improve performance and/or reduce costs. These polymers can be molded or extruded into desired shapes. There are two main types of plastics: **thermoplastics and thermosetting polymers.**

- **Thermoplastics** can repeatedly soften and melt if enough heat is applied and hardened on cooling, so that they can be made into new plastics products. Examples are polyethylene, polystyrene and polyvinyl chloride, among others.

- **Thermosets or thermosettings** can melt and take shape only once. They are not suitable for repeated heat treatments; therefore after they have solidified, they stay solid. Examples are phenol formaldehyde and urea formaldehyde.

2. Target Waste Plastics

Waste plastics are one of the most promising resources for fuel production because of its high heat of combustion and due to the increasing availability in local communities. Unlike paper and wood, plastics do not absorb much moisture and the water content of plastics is far lower than the water content of biomass such as crops and kitchen wastes. The conversion methods of waste plastics into fuel depend on the types of plastics to be targeted and the properties of other wastes that might be used in the process. Additionally the effective conversion requires appropriate technologies to be selected according to local economic, environmental, social and technical characteristics. In general, the conversion of waste plastic into fuel requires feedstocks which are non-hazardous and combustible. In particular each type of waste plastic conversion method has its own suitable feedstock. The composition of the plastics used as feedstock may be very different and some plastic articles might contain undesirable substances (e.g. additives such as flame-retardants containing bromine and antimony compounds or plastics containing nitrogen, halogens, sulfur or any other hazardous substances) which pose potential risks to humans and to the environment.

The types of plastics and their composition will condition the conversion process and will determine the pretreatment requirements, the combustion temperature for the conversion and therefore the energy consumption required, the fuel quality output, the flue gas composition (e.g. formation of hazardous flue gases such as NOx and HCl), the fly ash and bottom ash composition, and the potential of chemical corrosion of the equipment, Therefore the major quality concerns when converting waste plastics into fuel resources are as follows:

» ***Smooth feeding to conversion equipment:*** Prior to their conversion into fuel resources, waste plastics are subject to various methods of pretreatment to facilitate the smooth and efficient treatment during the subsequent conversion process. Depending on their structures (e.g. rigid, films, sheets or expanded (foamed) material) the pretreatment equipment used for each type of plastic (crushing or shredding) is often different.

» ***Effective conversion into fuel products:*** In solid fuel production, thermoplastics act as binders which form pellets or briquettes by melting and adhering to other non-melting substances such as paper, wood and thermosetting plastics. Although wooden materials are formed into pellets using a pelletizer, mixing plastics with wood or paper complicates the pellet preparation process. Suitable heating is required to produce pellets from thermoplastics and other combustible waste. In liquid fuel production, thermoplastics containing liquid hydrocarbon can be used as feedstock. The type of plastic being used determines the processing rate as well as the product yield. Contamination by undesirable substances and the presence of moisture increases energy consumption and promotes the formation of byproducts in the fuel production process.

» ***Well-controlled combustion and clean flue gas in fuel user facilities:*** It is important to match the fuel type and its quality to the burner in order to improve heat recovery efficiency. Contamination by nitrogen, chlorine, and inorganic species, for instance, can affect the flue gas composition and the amount of ash produced. When using fuel prepared from waste plastics, it must be assured that the flue gas composition complies with local air pollution regulations. In the same way, ash quality must also be in compliance with local regulations when disposed at the landfill. If there aren't any relevant regulations, both the producers and consumers of the recycled fuel should control the fuel quality and the emissions at combustion in order to minimize their environmental impact.

Table 2.1 classifies various plastics according to the types of fuel they can produce. It can be observed that thermoplastics consisting of carbon and hydrogen are the most important feedstock for fuel production either in solid or liquid form.

As shown in Table 2.2, PE, PP and PS thermoplastics are preferable as feedstock in the production of liquid hydrocarbons. The addition of thermosetting plastics, wood, and paper to the feedstock leads to the formation of carbonous substances and lowers the rate and yield of liquid products.

Table 2.1: Polymer as feedstock for fuel production

Types of Polymer	Descriptions	Examples
Polymer consisting of carbon and hydrogen	Typical feedstock for fuel production due to high heat value and clean exhaust gas.	Polythylene, polypropylene, polystyrene. Thermoplastics melt to form solid fuel mixed with other combustible wastes and decompose to produce liquid fuel.
Polymers containing oxygen	Lower heat value than above plastics	PET, phenolic resin, polyvinyl alcohol, polyoxymethylene
Polymers containing nitrogen or sulfur	Fuel from this type of plastic is a source of hazardous components such as NO_x or SO_x in flue gas. Flue gas cleaning is required to avoid emission of hazardous components in exhaust gas.	Nitrogen: polyamide, polyurethane Sulfur: polyphenylene sulfide
Polymers containing halogens of chlorine, bromine and fluorine.	Source of hazardous and corrosive flue gas upon thermal treatment and combustion.	Polyvinyl chloride, polyvinylidene chloride, bromine-containing flame retardants and fluorocarbon polymers.

Table 2.2: Product types of some plastics pyrolysis

Main Products	Type of Plastics	As a Feedstock of liquid fuel
Liquid hydrocarbons	Polyethylene (PE) Polypropylene (PP) Polystrene (PS) Polymethyl metacrylate (PMMA)	Allowed. Allowed. Allowed. Allowed.
Liquid hydrocarbons	Acrylonitrile-Butadiene-Styrene copolymer (ABS)	Allowed. But not suitable. Nitrogen-containing fuel is obtained. Special attention required to cyanide in oil.
No hydrocarbons suitable for fuel	Polvinyl alcohol (PVA) Polyoxymethylene (POM)	Not suitable. Formation of water and alcohol. Not suitable. Formation of formaldehyde.
Solid products	Polyethylene terephthalate (PET)	Not suitable. Formation of terephthalic acid and benzoic acid.
Carbonous products	Polyurethane (PUR) Phenol resin (PF)	Not suitable. Not suitable.
Hydrogen chloride and carbonous products	Polyvinyl chloride (PVC) Polyvinylidene chloride (PVDC)	Not allowed. Not allowed.

3. Solid Fuel Production

Figure 3.1: Example of RPF

3.1 Scope of solid fuel in this compendium

Solid fuel, as referred in this compendium, is prepared from both municipal and industrial non-hazardous waste. Additionally, the solid fuel outlined here excludes coal and coal-derived fuels as well as solid biofuels such as firewood and dried manure but it may contain biofuels as a component.

This compendium differentiates two types of solid fuel: refuse derived fuel (RDF), also called solid recovered fuel (SRF) and refuse-derived paper and plastic densified fuel (RPF). RDF is mainly produced from municipal kitchen waste, used paper, waste wood and waste plastics. Due to the presence of kitchen waste, prior to the conversion to a fuel, a drying process is required to remove the moisture from such waste to allow the solidification of the waste in suitable shapes and densities. This process is seen as a disadvantage due to the large amount of energy that the process requires. Solid recovered fuel (SRF) is defined in the European Committee for Standardization technical specification (CEN/TS 15359:2006).

On the other hand RPF (Figure 3.1) is prepared from used paper, waste plastics and other dry feedstocks. Within the plastics, the thermoplastics play a key role as a binder for the other components such as thermosetting plastics and other combustible wastes, which cannot form pellets or briquettes without a binding component. Approximately 15wt% of thermoplastics is the minimum required to be used as a binder to solidify the other components; however excessive amounts, higher than 50wt%, would cause a failure in the pellet preparation. The components of RPFs are mainly sorted from industrial wastes and are sometimes also obtained from well-separated municipal waste. This type of solid fuel is set to be standardized in the Japanese Industrial Standards (JIS).

In both cases, the plastic contents can be varied (within a range) to meet the needs of fuel users. The shape of the fuel will vary according to the production equipment (e.g. a screw extruder is often used to create cylindrical-shaped fuel with a variable diameter and length). The example of Figure 3.1 contains RPF samples 40 mm in diameter and 50 mm in length. In the production of solid fuel, the contamination of the targeted plastics with other plastics containing nitrogen, halogens (Cl, Br, F), sulfur and other hazardous substances may cause air and soil pollution by the flu gas emission and the incineration ash disposal (e.g. inorganic components such as aluminum in multilayer film of food packages produces fly ash and bottom ash). Other contaminants such as hydrogen chloride might cause serious damage to the boiler by corrosion.

3.2 Production method

The solid fuel production process usually involves two steps, pretreatment and pellet production:

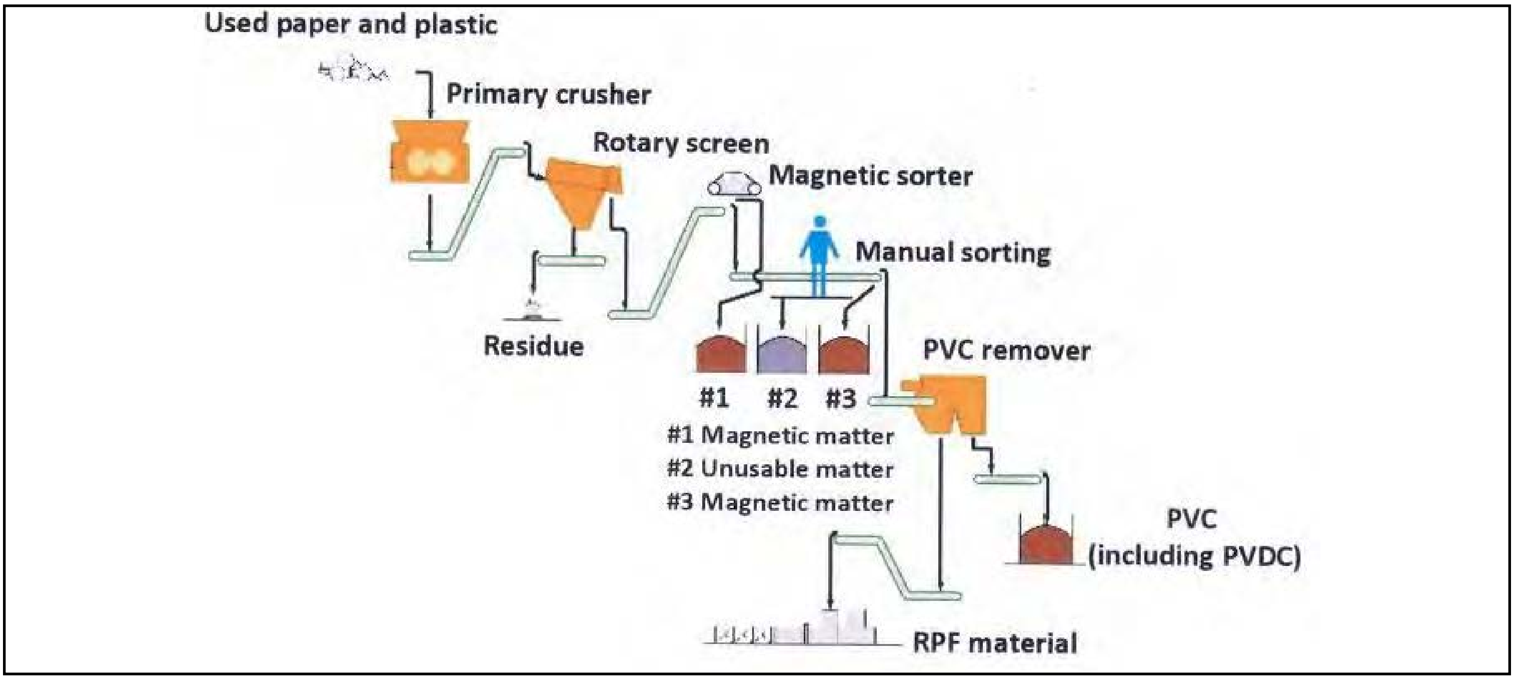
- Pretreatment includes coarse shredding and removal of non-combustible materials.
- Pellet production comprises secondary shredding and pelletization (<200°C).

However, pretreatment is not required if the solid fuel producer can collect waste with suitable properties. Two types of commercial production systems are described as follows. One is a large-scale model with pretreatment for the separation of undesirable contamination such as metals and plastics containing chlorine. The other is a small-scale model without pretreatment equipment.

3.2.1 Large-scale model (3 ton/hour)

Industrial waste plastics, which have been separated and collected in factories, are ideal to be used for solid fuel production.

A fuel production facility consists of a waste unloading area, stockyard, pretreatment equipment, pelletizing equipment and solid fuel storage. The pretreatment process includes crushing and sorting for the removal of unsuitable materials from incoming wastes. A schematic diagram of the pretreatment process is shown in Figure 3.2. Figure 3.3 presents a photograph of a pretreatment process.



(Copyright Japan RPF Association)

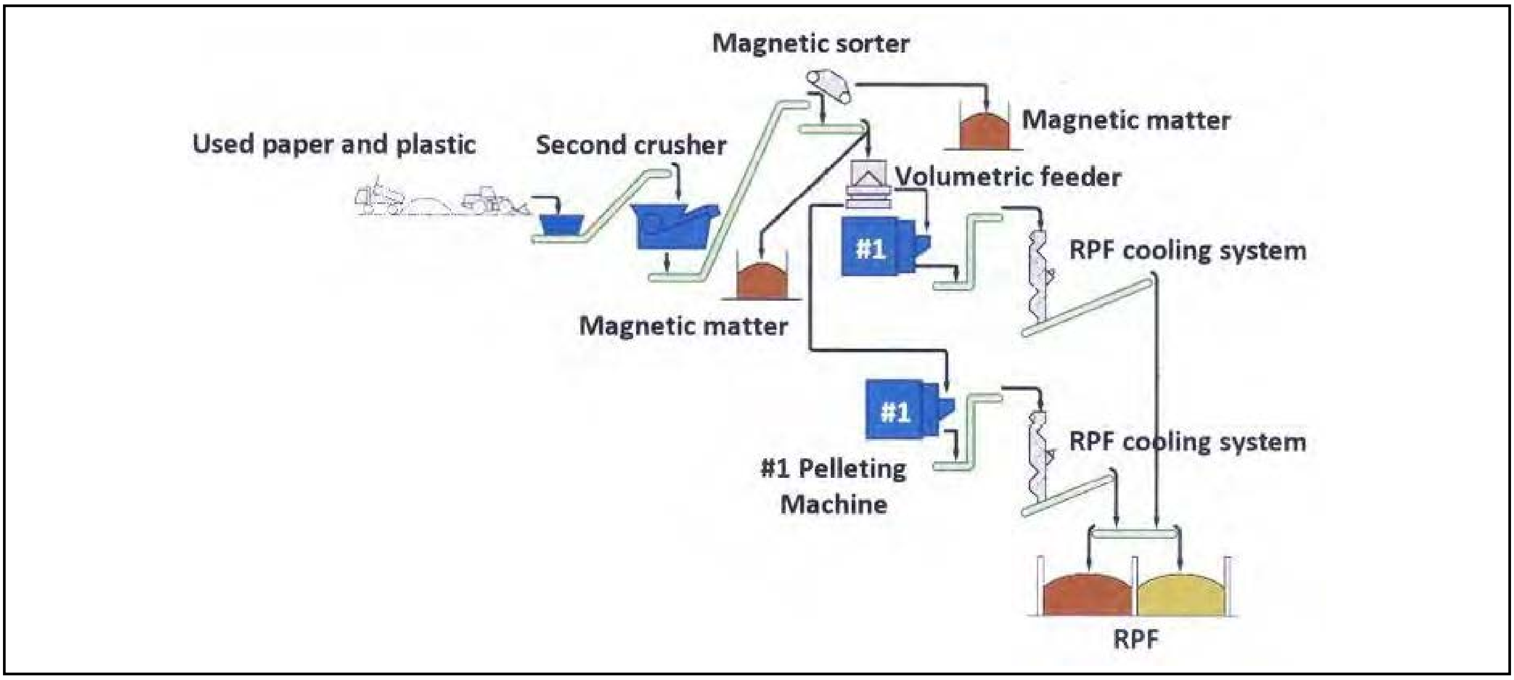
Figure 3.2: Schematic diagram of pretreatment process

(Copyright Japan RPF Association)

Figure 3.3: Example of pretreatment process (3 ton/h capacity)

After pretreatment, a suitable mixture of paper and plastics are further processed in a secondary crusher and sorting process (conveyor and magnetic separator) and the resulting mixture is pelletized to produce solid fuel. The resulting solid fuel is cooled in an air-cooling system to prevent natural ignition during storage and it is further stored for shipping. The output of the process is usually solid fuel pellets of dimensions between 6 to 60 mm in diameter and 10 to 100 mm in length. The heating value of the pellets will change depending on the content of the plastics. A mixture of paper and plastics of a 1:1 weight ratio gives a heating value of approximately 7,000 kcal/kg or higher. Figure 3.4 shows a pelletizing process and Figure 3.5 a typical pelletizing process facility with a 1 ton/h capacity

Continued......



Copyright Japan RPF Association)

Figure 3.4: Schematic diagram of a pelletizing process

(Copyright Japan RPF Association)

Figure 3.5: Typical pelletizing process facility (1 ton/h line

3.2.2 Small-scale model (150 kg/hour)

This small-scale model is a system for solid fuel production with a 150-kg/h capacity. In this case the facility does not have a pretreatment process, (as aforementioned, a sorting process is not required if properly segregated waste can be collected) so the combustible wood, paper and plastic waste is directly fed into the crusher of the facility. This is carried out by using a handling machine as shown in Figure 3.7 where the operator must control and feed into the crusher a suitable ratio of each type of waste in order to maintain the fuel qualities such as the heating value. After crushing the materials, they are transported through a pipe conveyor and are introduced into a twin-screw pelletizer.

Figure 3.6 shows the entire process (the crusher, the pipe conveyor and the pelletizer).

Figure 3.6: Smaller RPF production facility

Figure 3.7: Heavy duty machine to feed wastes (150 kg/h capacity)

3.3 Product and byproduct

Heating value is an important characteristic of solid fuels. Some examples of heating values of several types of waste and solid fuel are listed in Table 3.1.

Table 3.1: Heating values of various fuels and wastes

Fuel or Waste	Typical heating value (kcal/kg)
RDF	**4000 - 5000*1**
RDF	**6000 - 8000*2**
Coal	6000 - 8000*3
Heavy oil	9500
Wood/paper	4300
Plastics (polyethylene)	11000
Typical municipal wastes	1000 - 1500*1

*1 Depends on waste composition. *2 Can be controlled by plastic composition in fuel production process. *3 Depends on rank of coal

The heating values of solid RDFs and RPFs may vary depending on the composition of the materials they contain. Especially in RDF, fluctuations in the heating values are often observed due to changes in the composition of the municipal waste (which is difficult to control) and according to the degree of drying of the municipal waste used in the production process. RPF heating values can usually be controlled easily due to the use of dry and sorted plastics, paper and other combustible waste, which have been collected from companies. Other important features of the solid fuels are its content of ash, moisture and the content of potential hazardous substances like nitrogen, chlorine, sulfur and heavy metals. Fuel suppliers should have an agreement with fuel users regarding the solid fuel qualities. Special attention is required in order to avoid self-ignition and methane evolution during the RDF storage

4. Liquid Fuel Production

4.1 Scope of liquid fuel in this compendium

Liquid fuel within this compendium is defined as plastic-derived liquid hydrocarbons at a normal temperature and pressure. Only several types of thermoplastics undergo thermaldecomposition to yield liquid hydrocarbons used as liquid fuel. PE, PP, and PS, are preferred for the feedstock of the production of liquid hydrocarbons. The addition of thermosetting plastics, wood, and paper to feedstock leads to the formation of carbonous substance. It lowers the rate and yields of liquid products.

Depending on the components of the waste plastic being used as feedstock for fuel production, the resulting liquid fuel may contain other contaminants such as amines, alcohols, waxy hydrocarbons and some inorganic substances. Contamination of nitrogen, sulfur and halogens gives flu gas pollution. Unexpected contamination and high water contents may lower the product yields and shorten the lifetime of a reactor for pyrolysis

Liquid fuel users require petroleum substitutes such as gasoline, diesel fuel and heavy oil. In these fuels, various additives are often mixed with the liquid hydrocarbons to improve the burner or the engine performance. The fuel properties such as viscosity and ash content should conform to the specifications of the fuel user's burners or engines. No additives would be needed for fuel used in a boiler. A JIS technical specification was proposed for pyrolytic oil generated from waste plastic for use as boiler and diesel generator fuel (TS Z 0025:2004).

Skillful operators and a well-equipped facility are required due to the formation of highly flammable liquids and gases.

4.2 Production method

The production method for the conversion of plastics to liquid fuel is based on the pyrolysis of the plastics and the condensation of the resulting hydrocarbons. Pyrolysis refers to the thermal decomposition of the matter under an inert gas like nitrogen.

For the production process of liquid fuel, the plastics that are suitable for the conversion are introduced into a reactor where they will decompose at 450 to 550 ^{o}C. Depending on the Pyrolysis conditions and the type of plastic used, carbonous matter gradually develops as a deposit on the inner surface of the reactor. After pyrolysis, this deposit should be removed from the reactor in order to maintain the heat conduction efficiency of the reactor.

The resulting oil (mixture of liquid hydrocarbons) is continuously distilled once the waste plastics inside the reactor are decomposed enough to evaporate upon reaching the reaction temperature. The evaporated oil is further cracked with a catalyst. The boiling point of the produced oil is controlled by the operation conditions of the reactor, the cracker and the condenser. In some cases, distillation equipment is installed to perform fractional distillation to meet the user's requirements.After the resulting hydrocarbons are distilled from the reactor, some hydrocarbons with high boiling points such as diesel, kerosene and gasoline are condensed in a water-cooled condenser.

The liquid hydrocarbons are then collected in a storage tank through a receiver tank. Gaseous hydrocarbons such as methane, ethane, propylene and butanes cannot be condensed and are therefore incinerated in a flare stack. This flare stack is required when the volume of the exhaust gas emitted from the reactor is expected to be large.

Figure 4.1 presents a schematic diagram of a liquid fuel production plant.

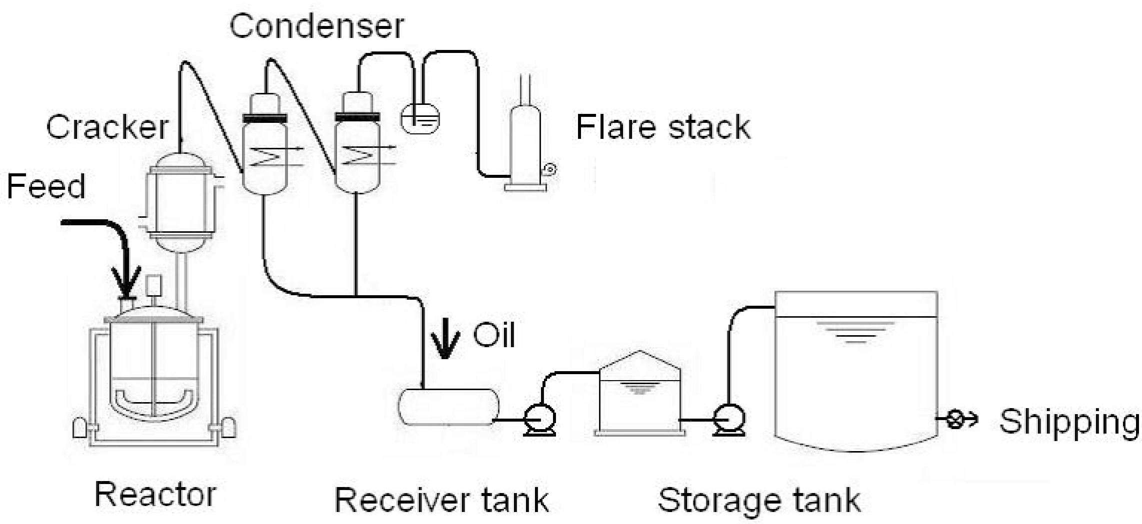


Figure 4.1: Schematic diagram of a production plant of plastics-derived fuel

There may be variations in the feeding methods used depending on the characteristics of the waste plastic. The easiest way is to simply introduce the waste plastics into the reactor without any pretreatment. Soft plastics such as films and bags are often treated with a shredder and a melter (hot melt extruder) in order to feed them into the reactor because otherwise they would occupy a large volume of the reactor.

There are also different types of reactors and heating equipment. Both kiln-type and screw-type reactors have been proposed, while induction heating by electric power has been developed as an alternative to using a burner.

Due to the formation of carbonous matter in the reactor, which acts as a heat insulator, in some tank reactors the stirrer is used to remove the carbonous matter rather than for stirring. After the liquid product of the pyrolysis is distilled, the carbonous matter is taken out either with a vacuum cleaner or in some cases reactors are equipped with a screw conveyor at the bottom of the tank reactor to remove the carbonous matter.

Operators should understand the relationship between the amount and composition of the waste plastics as well as the operating onditions. Energy consumption and plant costs relative to the plastic treatment capacity are the typical criteria for evaluating the plant performance. Operating skill and safety considerations are important in this type of chemical conversion due to the highly flammable liquid fuels which are formed.

4.3 Products and byproducts

Liquid fuel is used in burners or engines as a substitute for liquid petroleum. Table 4.1 presents the properties of waste plastic-derived fuel and petroleum fuels. Samples A and B are a whole distillate and middle distillate of waste plastic pyrolytic oil respectively. After considering the burner or engine operating stability, it is possible to mix plastics-derived oil with petroleum fuel.

Continued......

Table 4.1: Typical properties of waste plastics-derived fuel and petroleum fuels

Category	Sample A (whole distillate)	Sample B (Middle distillate)	Diesel Fuel	Heavy Oil
Specific gravity (15°C), g/cm^3	0.8306	0.8430	0.8284	0.8511
Flashing point (°C)	-18(PM)	68.0 (Tag)	69.0 (Tag)	64 (PM)
Kinetic viscosity (30 °C, mm^2/s)	1.041/-	-/1.73	3.822/-	-/2.29
Carbon residue on 10% bottoms; wt%	-	0.85	0.01	0.46
Ash Weight (%)	0.00	<0.001	-	0.006
Gross heating value (cal/g)	11294	10746	-	10708
Total chlorine (wt ppm)	47	10	<1	1.6
Nitrogen (wt%)	0.14	0.033	-	0.015
Sulfur (wt ppm)	100	910	310	0.41%
Cetane index	27.0	42.9	58.4	46.3
Distillation temperature (°C)				
Initial	47.0	180.0		164
10%	69.0	199.0		195
50%	148.0	233.0		276
90%	294.5	323.5	344.0	347
End	374.0	351.5		370<

Some plastics yield residual substances such as carbonous matter and other inorganic matter during pyrolysis. Carbonous matter can be used as a feedstock for solid fuel. Aluminum foil or other inorganic substances may be contained depending on the level of waste composition so suitable management is required.

5. Gaseous Fuel Production

5.1 Scope of gaseous fuel in this compendium

The gaseous fuel described in this report refers to the flammable gas obtained from the thermal treatment of waste plastics. There are two types of gaseous fuel:

- Gaseous hydrocarbon: hydrocarbons that are in a gaseous state under normal temperature and pressure (0 °C, 1 atm).
- Synthesis gas or syngas: mixture of hydrogen and carbon monoxide

In the conversion of plastics to gaseous fuel, the waste plastics undergo thermal decomposition in a tank reactor, resulting in the formation of liquid fuel as the main product and gaseous fuel up to about 20 wt%, as the minor product. Gaseous hydrocarbons become the main product after residing in the reactor for an extended time at a reaction temperature under controlled decomposition conditions and the use of a specific reactor. Under specific conditions, carbon and carbohydrates can be used as feedstocks for the production of gaseous fuel like methane and hydrogen.

Continued......

5.2 Production method

The gasification process includes a series of steps such as pretreatment, gasification, gas cleaning and storage.

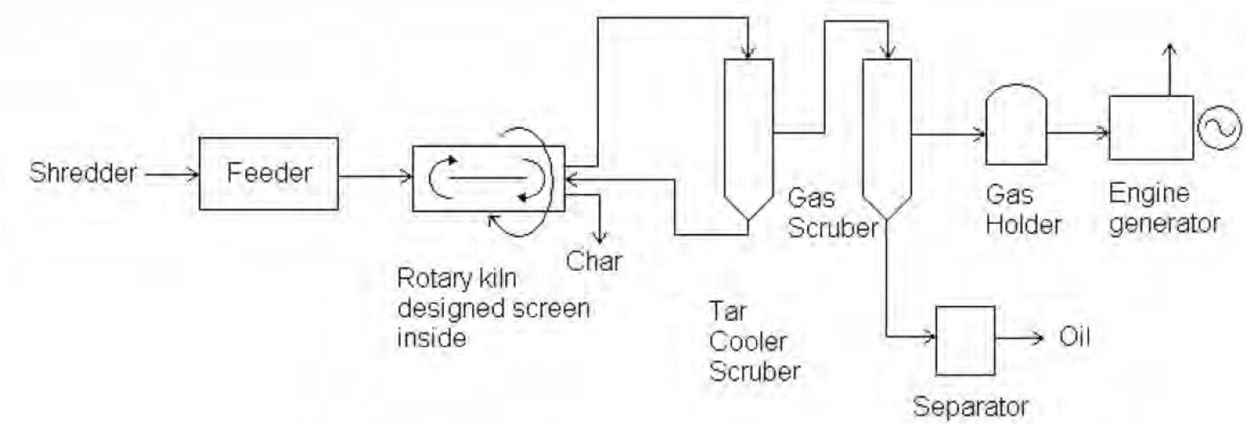


Figure 5.1: Schematic diagram of a production plant of plastics-derived gaseous fuel

Polyethylene and polypropylene thermally decompose at temperatures up to about 700 °C and under a inert atmosphere to form a mixture of gaseous hydrocarbons, methane, ethane, ethylene, propane, propylene, and various isomers of butane and butane[1]. On the other hand, most of the organic substances undergo gasification yielding syngas[2.]

Gasification proceeds at elevated temperatures, higher than 800 and practically 1000 °C. Depending on the types of reactors and reaction conditions, carbonous matter and carbon dioxide are formed, and nitrogen from the air is contained in the product gas. The gasification reactors to be used are moving-bed, fluidized-bed and entrain-bed reactors. If the product is to be stored, a large gas holder is to be required. The gasification technique is already used commercially for coal and there are several examples of commercial operations using biomass and waste plastics to produce low- and medium-BTU gas. Several manufacturers have proposed small-scale gasification systems. Careful cost analysis is important with respect to the amount of collected waste, the transportation distance and the commercial value of the resultant products such as electricity and gaseous fuel. In any case, this technology requires skillful operators and careful handling to avoid hydrogen explosion

Table 5.1 summarizes the gasification methods which yield flammable gas.

Type of gasification	Conditions	Typical products
Pyrolysis	>700 °C under inert atmosphere	Gaseous hydrocarbons from aliphatic hydrocarbons including polyethylene and polypropylene.
Partial oxidation	>1000 °C under oxygen or air	Carbon monoxide from carbon, hydrocarbons and carbohydrates including wood. Hydrogen alsoforms from hydrocarbons and carbohydrates.
Steam gasification	>800 °C under oxygen or air	Methane, carbon monoxide and hydrogen
Hydrogasification	Around 500 – 600 °C under hydrogen	Methane, carbon monoxide and water

Table 5.1: List of various gasification methods

1. *Kodera, Y., Ishihara, Y., Kuroki, T.; Energy Fuels, 20, 155-158, 2006.*
2. *Gebauer, M., Stannard, D.; Gasification of Plastics Wastes, In Recycling and Recovery of Plastics, Ed. by Brandrup, J., Bittner, M.,*

Continued......

5.3 Product

As afore mentioned, there are two types of pyrolysis products in the gasification process. One is a mixture of gaseous hydrocarbons such as methane and ethylene while the other is synthetic gas– a mixture of hydrogen and carbon monoxide. Table 5.2 shows the type of waste and its typical products.

Table 5.2: Wastes and typical products

Type of waste	Pyrolysis conditions	Typical products
Polyethylene, polypropylene	Inert atmosphere, 700 – 800 °C	High-BTU gas (e.g. 9000 kcal/Nm3); Hydrocarbon gas like Methane and ethylene. Liquid hydrocarbon like benzene and toluene.
Aromatic polymer, carbonous substances, carbohydrates like wood in addition to the polymers above.	Air, steam atmosphere, above 1000 °C	Low-BTU gas (e.g. 800-1800 kcal/Nm3); Hydrogen, carbon monoxide, carbon dioxide and nitrogen. Methane formation increases the heating value to give medium-BTU gas.

Cf. Higher heating value: hydrogen 3050 kcal/Nm3 (0°C, 1atm).

The heating values of the gaseous products will vary according to the type of waste used, the contamination of nitrogen from the air and/or other reasons. However it can be said that the calorific value of Syngas ranges between the calorific value of biogas and LNG/LPG.

Typical commercial plant for liquid and gaseous fuel production

Main features

	1. All plastics (thermoplastics, thermosetting, halogen-containing)
Feed	2. Plastics contained with biomass, metal, asbestos, bacteria etc.
	3. Biomass
Processes	Pyrolysis
Main equipment	Rotary kiln designed with screen solid circulation.
Special features	Continuous operation & rapid heating by internal circulating of solids.
	External or internal heating by heating medium.
Main product	Liquid and gaseous hydrocarbons

Partial Abstract

Environmental Issues of Packaging

Environmental concerns have led to governments throughout western Europe taking steps to deal with the issue of packaging waste and recycling. Recent packaging directives from the European Commission, for example, have led to the imposition of challenging targets for recycling, and national governments are also examining new ways to discourage packaging waste. Landfill is becoming a major political issue, with landfill taxes being introduced by governments – in some cases before the necessary infrastructure is in place to provide alternatives to disposal.

Recycling was though regarded as only the eighth most important driver to packaging growth out of the nine drivers. Views were distinctly mixed among industry respondents, with 36% of respondents regarding recycling as being of no importance to the market. In the case of consumers are less often concerned about the effect of their consumption habits on the environment – rather, they are more concerned about the effect of the external environment upon themselves. Consumers have begun to desire all things natural, unaffected by 'unnatural' processes, hence the suspicion of GM foods, etc. Nevertheless, the packaging industry has taken steps to address the environmental question, but this has been more of a function of cooperation with government rather than strictly a marketing issue, although some consumers will seek out environmentally-friendly packaging and products as a matter of course.

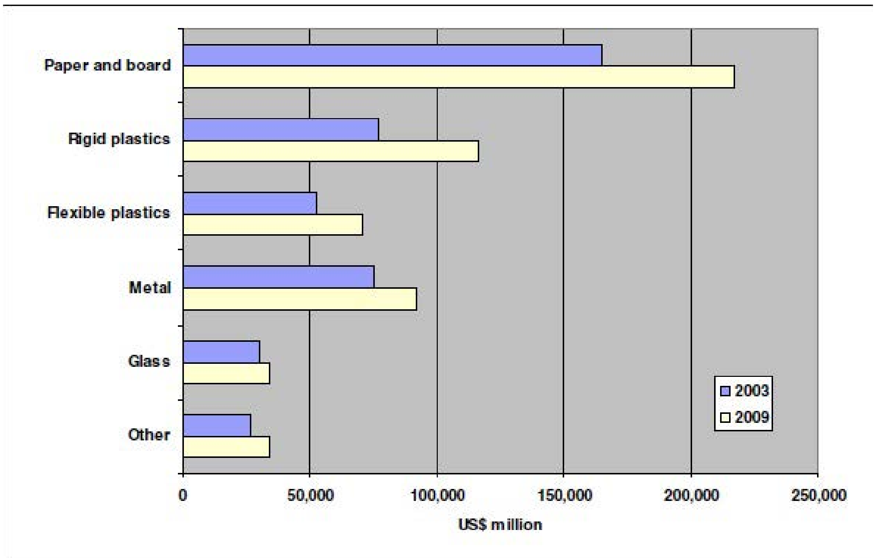
Materials

Packaging encompasses a wide range of material types across paper, board, plastic, metal, glass, wood and other materials. The largest share of global packaging is accounted for paper and board packaging with sales of $165 billion in 2003, equating to 38% of the market. Paper and board will remain the single largest element of the market into 2009, growing at an annual rate of around 4% in real terms, driven on the one hand by rising demand in fast-growth national markets as well as steady growth in secondary/ bulk packaging across the globe.

Plastic packaging accounted for 30% of sales, with rigid plastics alone taking an 18% share of the market. Rigid plastics was the fastest growing sector of the market during the period 1999-2003 at an annual rate of 6.2% to $77.2 billion. This was driven by several factors: rising demand for PET bottles in soft drink and bottled water markets; the consistent substitution of traditional metal, glass and sometimes paper-based materials in food and other markets; increasing incursions by packaging as a whole into food markets, particularly in the case of meat, fish and poultry products; and rising consumption of ready-meals and other convenience-oriented products. Rigid plastic packaging will continue to be the fastest growing sector of the market, with consumption forecast to progress at an annual average rate of 6.5% in the period to 2009 to reach $116 billion, with consumption of flexible plastic packaging also set to grow at an above-average rate, driven by rising demand in fast-growth markets in Asia and other emerging regions.

Across other sectors, metal packaging, accounting for 18% of the market in 2003, is set to grow steadily, but will lose further share to plastics in beverage markets with food cans also losing share. Glass packaging, meanwhile, accounting for 7% of the market, will see only steady growth as further share is lost to plastics across food, beverage, healthcare and other key end-use sectors.

FIGURE E.4 World packaging consumption by sector, 2003-09



Note: constant 2004 prices in 2009
Source: Pira International Ltd

SEGREGATION OF WASTE AT SOURCE PROJECTS AT SELECT WARDS IN THE CITY ICPE INITIATIVE

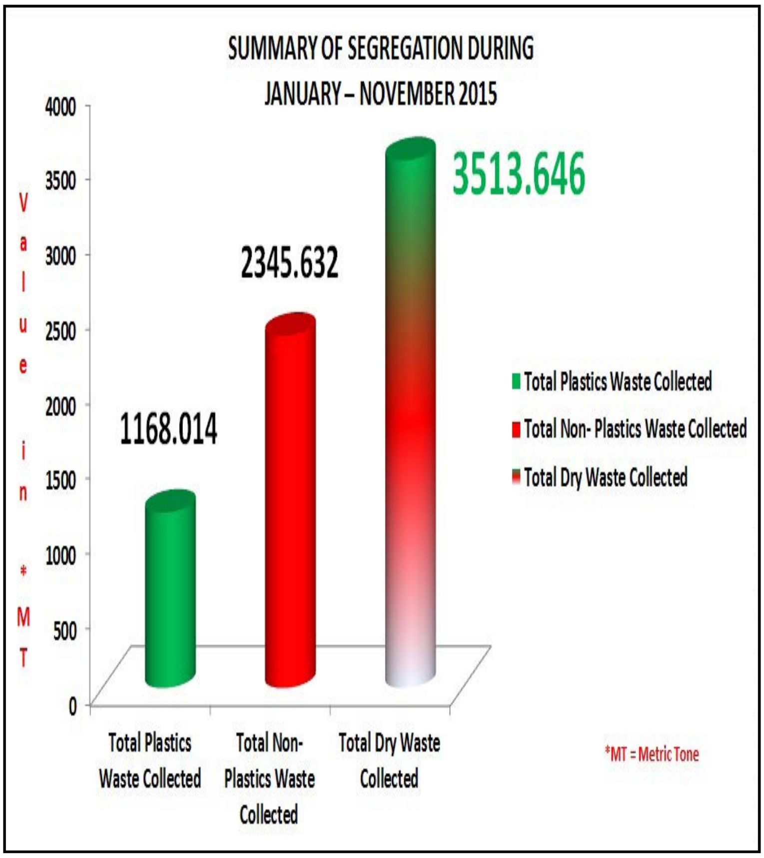
At the first place it is important to segregate Waste in to 'Dry' and 'Wet' at the source of waste generation itself. This is the action which is taken by the waste generator – households / occupiers. Once this is done, the next step is collection of the waste, specifically the Dry Waste, for further segregation in to different types. This action can be accomplished appropriately by engaging waste separators, who segregates plastics, papers, metals, glass etc wastes separately so that the same could be forwarded to respective recycling industries for their conversion in to suitable products for further use. Such practice of engaging manual workforce for segregating Dry Waste in to specific categories does exist in some parts of our country.

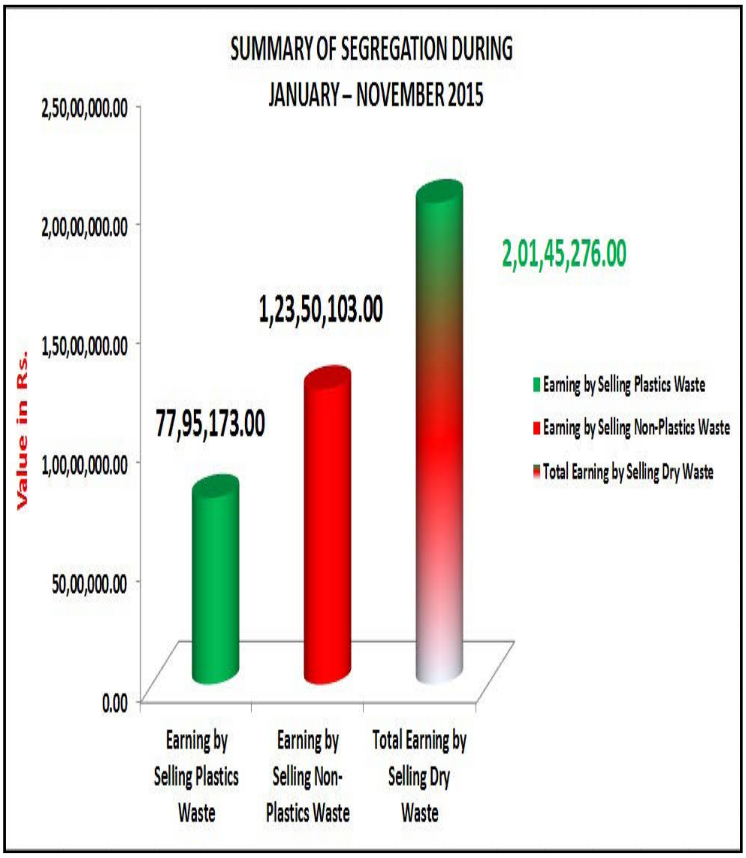
In Mumbai such model projects have been successfully carried out in select Wards with the initiatives of ICPE in association with some like minded NGOs and with the assistance of Brihanmumbai Municipal Corporation since 2002 – 03. There is an increasing activity among various Local Self Government Councils to treat the Wet Waste also through Vermiculture or similar process, to generate compost which can be used as fertilizers. In 2013 Total Dry Waste Collection under this project area was about 2000 MTs and Total Earning by sale of segregated Dry Waste was about Rs. 1.1 Crore. In 2014 Total Dry Waste Collection was more than 3000 MTs and Total Earning was about Rs. 1.8 Crore (by about 110 Waste Pickers). In 2015, the collection figure in 11 months has already surpassed the annual figure of 2014. This is indicative that the segregation at source is gaining mass support where awareness programmes were conducted.

SUMMARY OF SEGREGATION DURING JANUARY – NOVEMBER 2015

Total **Plastics Waste** Collected	**1168.014 MT**
Total **Non- Plastics Waste** Collected	**2345.632 MT**
Total Dry Waste Collected	**3513.646 MT**
Earning by Selling **Plastics Waste**	**Rs. 77,95,173.00**
Earning by Selling **Non-Plastics Waste**	**Rs. 1,23,50,103.00**
Total Earning by Selling Dry Waste	**Rs. 2,01,45,276.00**

Such activities across the country would help in safe recycling of all recyclable dry waste resulting in resource management as well as proper waste management.





ICPE STALL AT IPLEX-2015, BENGALURU

ICPE had participated in the 6th International Plastics Exposition 2015 Exhibition held during September 25 – 27, 2015 at Bangalore International Exhibition Centre, Karnataka. ICPE had focused its Awareness Programme on the Benefits of Plastics, Issues related to the handling of the waste generated after the use of plastics – mainly from the packaging sector and the scientific solutions thereof with the help of Case Studies, by way of Display Panels, Realities of Plastics were brought forth to the public view. It was observed that many of the facts about plastics – especially the fact that plastics emit least Green House Gas to the atmosphere compared to the alternate packaging materials like glass, aluminium, paper etc, are not known to general mass.

The fact that plastics consume least energy compared to alternative materials and thus saving the environment to a great extent is also not realised by the critics. Special Panels were displayed to show how all types of plastics waste, without any segregation could be Co-processed in Cement Kilns as a source of energy in partial replacement of Coal, which is conventional material of use, in a scientifically proven and approved method by Indian authority. While German Cement Kilns replace about 60% conventional coal, a 10% replacement of coal by plastics waste in India's 170 odd Cement Kilns could dispose of the entire quantity of un-recycled plastics waste of India in a scientific manner and providing a solution to the Plastics Waste Management issues.

Panels on other methods of plastics recycling also were on display. Throughout the exhibition period, ICPE Pavilion screened short Awareness Films on the benefits of plastics, various issues and solutions. Visitors, including students who visited ICPE Pavilion had said that they had learned the realities about plastics. Apart from Students many other delegates also visited ICPE pavilion.

Indian Waste Pickers get World's Recoginition

Plastics for Change launches mobile platform to reduce plastic pollution and poverty

Entrepreneurs use mobile technology to create dignified jobs, fight climate change and alleviate plastic pollution in developing countries.

Waste Pickers in India are starting to become recognized for the important work they do to increase recycling rates. By ensuring urban waste pickers receive fair market value for the plastic they collect, we can catalyze real change in communities that need it most.

LOS ANGELES, NEW YORK AND TORONTO (PRWEB) SEPTEMBER 10, 2015

Did you know that by 2025 there is expected to be one tonne of plastic for every three tonnes of fish in the sea? Plastics For Change is taking an innovative approach to address this problem. This organization has developed a process using mobile technology to alleviate plastic pollution while creating dignified jobs to reduce extreme poverty in developing regions. According to the United Nations, the root cause of plastic pollution stems from the fact that some 3.5 billion people, or half of the world's population, are without access to crucial waste management services. Imagine what your community would look like without a waste collection service.

Often the same developing regions that cannot afford waste management services also have chronic unemployment. Regardless, many people have found a way to make a living by collecting and selling discarded plastic waste. These urban waste pickers play a critical role in cleaning up cities and increasing recycling rates. However, they often receive very little monetary value for their collected plastic because the middlemen and exporters in the supply chain dictate the price. As a result, most developing countries have a dismal 2-8 percent recycling rate. The Plastics For Change system and mobile technology helps to increase the recycling rates by ensuring that urban waste pickers are paid a fair value for the plastic they collect. The open book trading platform builds trust and transparency through the supply chain and rewards the middlemen who pay waste pickers fair market prices. The organization partners with eco-friendly brands to recycle this ethically sourced plastic into recycled product lines with a triple bottom line impact. Plastics For Change recently launched a campaign to raise global awareness and generate funding to increase the rate at which the ethical sourcing methodology can be scaled through communities in India. The campaign is already over 50% funded with backers from over 10 countries. This ground-breaking platform has been tested with urban recyclers in Coimbatore, India. Plastics For Change plans on using the funds to implement the fair trade system in numerous developing communities in India and eventually expanding to regions around the world that have a high level of poverty. Check out the campaign video to learn more about the organization's approach for creating dignified jobs, fighting climate change and reducing plastic pollution in developing countries.

To request an interview or press kit with video and photos please email at ***impact@plasticsforchange.org***

Source: http://www.prweb.com/releases/2015/09/prweb12947840.htm

DATA SHEET

LIST OF TECHNOLOGY PROVIDERS

A List of Solid, liquid and gaseous fuel production system technology providers

A list of plant manufacturers and consultants is provided below. Note that some companies may have limited ability to communicate with overseas customers without the assistance of experienced trading companies and may have changed their products from those currently advertised on the internet or ceased to sell waste plastic conversion technologies for business reasons. Some companies supply smaller equipment for thermal decomposition of waste plastics with a capacity of less than 100kg/h. However, waste plastic conversion using these micro-reactors requires special business and economic feasibility considerations.

Technology	Company, URL and Contact
Solid fuel (RPF)	Earthtechnica Co., Ltd., Japan http://www.earthtechnica.co.jp/ http://www.earthtechnica.co.jp/english/ (website in Japanese and English)
Solid fuel (RPF)	Fujitex Co., Ltd., Japan http://www.fjtex.co.jp/profile/new_products.html (in English) http://www.fjtex.co.jp/kankyo/12other/rpf.html (in Japanese with access to video of solid fuel production)
Solid fuel (RPF)	Kyokuto Kaihatsu Kogyo Co.,Ltd. (Jpn) http://www.gec.jp/JSIM_DATA/WASTE/WASTE_2/html/Doc_397.html http://www.kyokuto.com/product/kankyo/sisetu/sisetu_05.shtml Contact http://www.kyokuto.com/cgi/form_en.cgi
Solid fuel (RDF)	O.Kay Engineering Services Limited (UK): - http://www.okay.co.uk/okay/index.htm Contact postbox@okay.co.uk : - http://www.okay.co.uk/okay/contact_main.htm
Solid fuel (RDF)	Mayo Vessels & Machines (India) :- http://www.mayovessels.com/technology.html Contact response@mayovessels.com :-- http://www.mayovessels.com/contact_us.html
Solid fuel (RDF)	eFACTOR3 (USA) :- http://www.efactor3.com/products.php Contact hbendfeldt@efactor3.com :- http://www.efactor3.com/contact.php
Solid fuel (RDF)	Visno (Netherland):- http://www.visno.nl/pages%20UK1.1/refuse_derived_fuel_uk_a.htm Contact info@visno.nl :- http://www.visno.nl/pages%20UK1.1/addresses_uk_a.htm
Liquid fuel	Kankyo Technology Co., Ltd., Japan :- http://www.kankyotec.com (website in Japanese; brochures in English, Korean, Chinese available for plants)
Liquid fuel	Dealer: Mogami-kiko Co., Ltd., Japan http://www.mogami-kiko.co.jp (website in Japanese) http://www.mitumine-kk.co.jp (website in Japanese)
Liquid fuel	Dealer: Shonan Trading Co., Ltd., Japan :- Manufacturer: Environment System Co.,Ltd., Japan* http://www.shonantrading.com/machine/?id=1227664212-334647 , (website in Japanese)
Liquid fuel	MCC Co., Ltd., Japan :- http://www.janis.or.jp/users/totalmcc/new1.htm , (website in Japanese)
Liquid fuel (Dry distillation of medical wastes)	Syo . A Co., Ltd., Japan : - http://www.cpri.co.jp/index.html (Web in Japanese) http://www.cpri.co.jp/English%20ver/E_Hospital%20waste_top.html (Web in English) http://www.cpri.co.jp/VIDEO_1E.html (Video presentation about the plant in English)
Liquid fuel (Dry distillation of medical wastes)	Altis Co., Ltd., Japan : - http://www.Altis.ne.jp (website in Japanese)
Liquid fuel	Splainex Ecosystems Ltd (Netherland) :- http://www.splainex.com/waste_recycling.htm Contact page http://www.splainex.com/contact_en.htm
Liquid fuel	Northern Technologies International Corporation (USA) : - http://www.polymerenergy.com/ Contact page http://www.polymerenergy.com/contact
Liquid fuel	Gossler Envitec GmbH (Germany) :- http://www.gossler-envitec.de/index.html http://www.gossler-envitec.de/GEN_Flyer_EN_03-11-2008-B.pdf : - Contact envitec@gossler.de
Liquid fuel	Alphakat GmbH (Germany) :- http://alphakat.de/index.php?option=com_content&task=blogcategory&id=37&Itemid=63 Contact mail@alphakat.de
Liquid fuel	Changing World Technologies, Inc. (USA) :- http://www.changingworldtech.com/
Liquid fuel	TA Technology (China) :- http://tyrerecyclemachine.com/ : - Contact jamesng2020@hotmail.com
Liquid and gaseous fuel	Toshiba Corporation, Social Infrastructure Systems Company, Japan http://www3.toshiba.co.jp/snis/ovs/index_e.htm (website in English)
Liquid and gaseous fuel	Ostrand Corporation, Japan :- http://www.ostrand.co.jp/index.html http://www.ostrand.co.jp/newtech_01.html(website in Japanese) :- Contact hatta@ostrand.co.jp

WORLD'S ICE DEPOSITORY IS MELTING DUE TO

GLOBAL WARMING

VANISHING GLACIERS GIVE AN ALARM NOTE FOR MOTHER EARTH.

Melting of Himalayan Glaciers

PLASTICS ARE AMONG THE HIGHEST GREEN HOUSE GAS SAVERS
&
DECREASE THE IMPACT OF GLOBAL WARMING

DON’T LITTER, USE PLASTICS RESPONSIBLY, KEEP THE MOUNTAINS CLEAN

Plastics, Metals, Paper ...
Can be recycled into useful products.

PLASTICS ARE 100% RECYCLABLE

ICPE
REUSE • RECYCLE • RECOVER