



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

ENERGY PRODUCTION FROM WASTE PLASTICS-2

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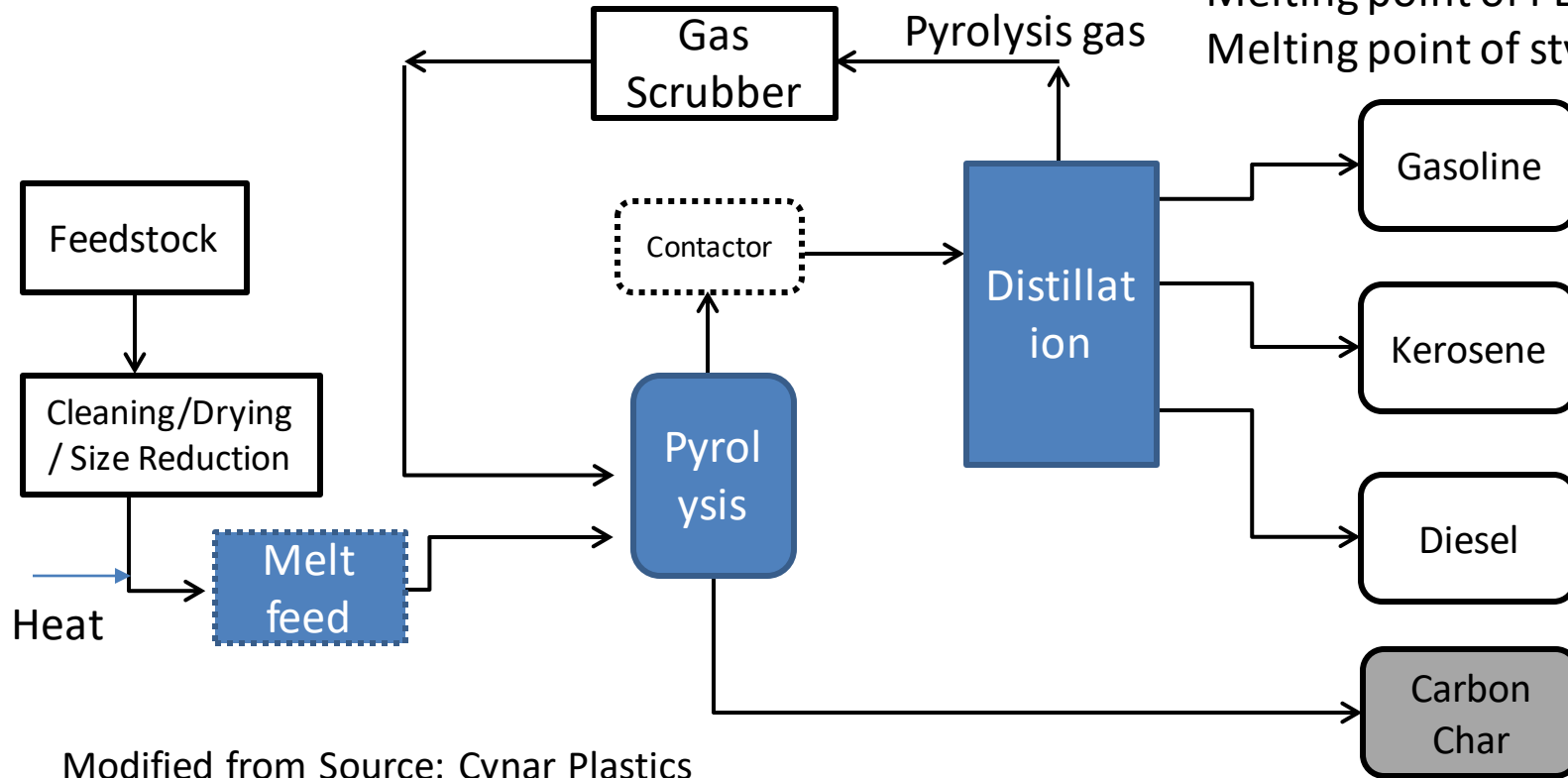


Contents

- Plastics, their classification and code for recyclable plastics
- Plastic types, their monomers and suitability for energy production
- Plastic wastes generation and its need for energy production
- Options for management of plastic wastes and recycling through pyrolysis
- Reaction mechanism
- Pyrolysis process types and their variables
- Catalytic pyrolysis
- Common steps for converting waste plastics to fuels
- Pyrolysis process flowsheet
- Reactors for pyrolysis
- International and national scenario on energy production from waste plastics
- Case study



Pyrolysis process flow



Melting point of PP 130-171 °C
Melting point of PE 115-135 °C
Melting point of styrene 240 °C

Modified from Source: Cynar Plastics
www.cynarplc.com

Melting point of PET 250-260 °C, boiling point > 350 °C

Reactors used for Pyrolysis

➤ Batch/semi-batch reactor

Temperature range 300-800 °C

- **Advantages:**

Easy to control process parameters.

Simple design.

- **Disadvantages:**

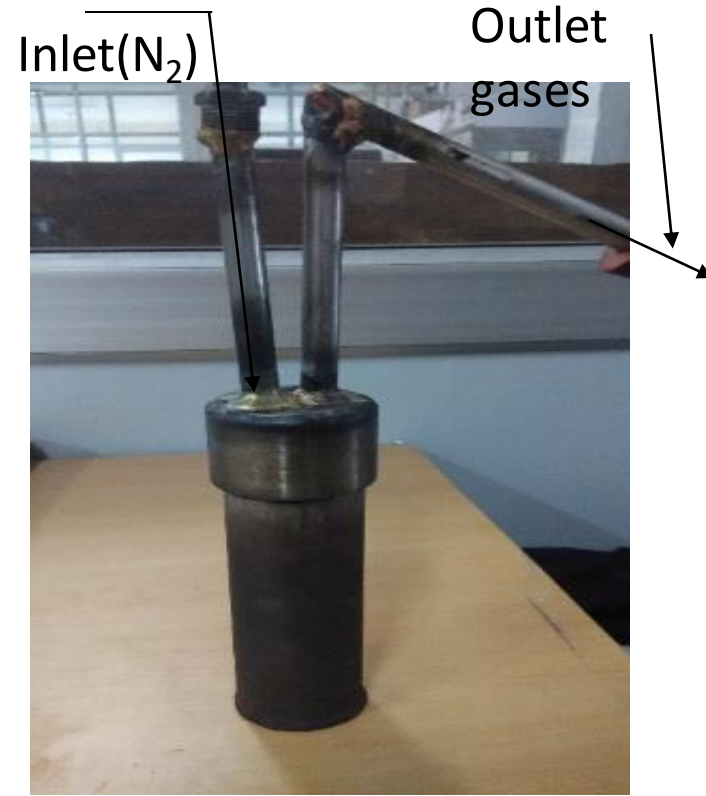
Variability of products from batch to batch.

More coke formation and catalyst deactivation

Difficulty in separation of catalyst

Higher labor cost per batch.

Difficulty of large scale operation.



Reactors used for Pyrolysis

Energy Conversion and Management 115 (2016)
308–326

➤ **Fixed bed Reactor:**

Catalyst is usually in palletized form and packed in a static bed.

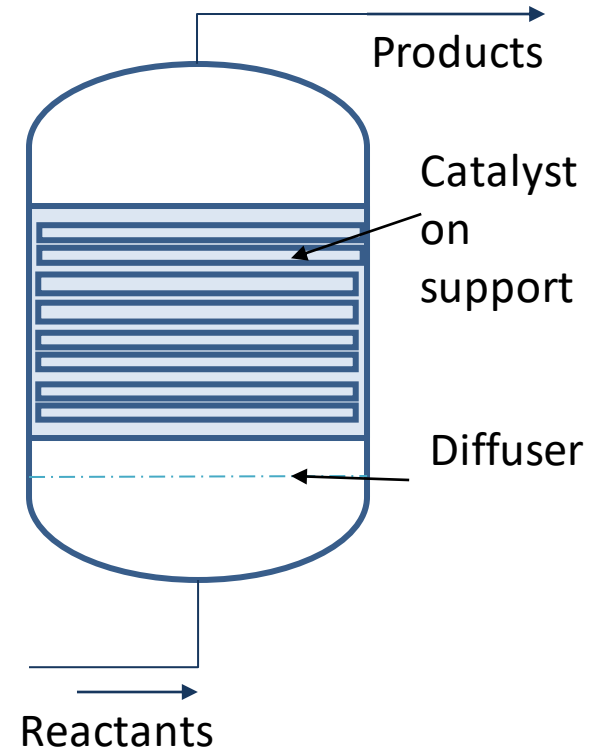
- **Advantages:**

- Continuous process.

- Less labor intensive.

- **Disadvantages:**

- The available surface area of the catalyst to be accessed by the reaction is also limited



➤ **Fluidized Bed Reactor:**

Catalyst sits on a distributor plate where the fluidizing gas carries these in a fluid state. Temperature 290-850°C

- **Advantages:**

Continuous process and less labor intensive

Improved heat transfer

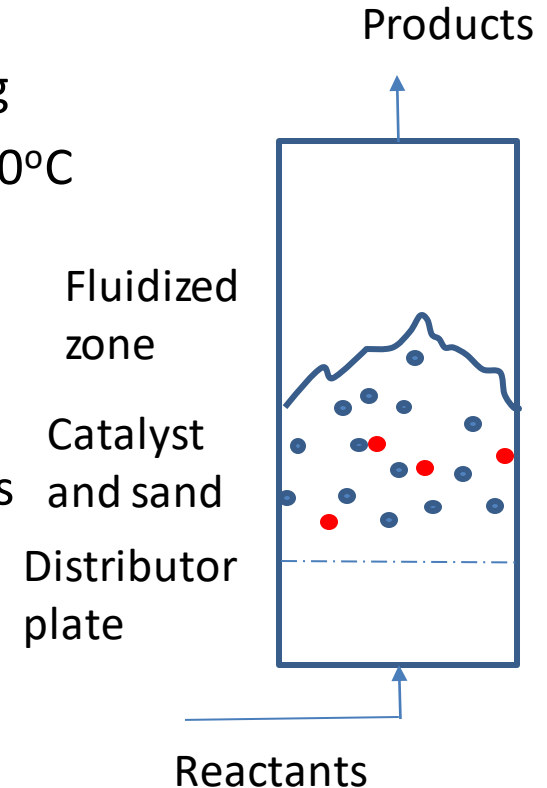
Narrower and more uniform spectrum of products

Better mixing of catalyst and reactants

Ease of scale up

- **Disadvantages:**

More controlled operation



Reactors used for Pyrolysis

➤ Screw Reactor :

- Advantages:

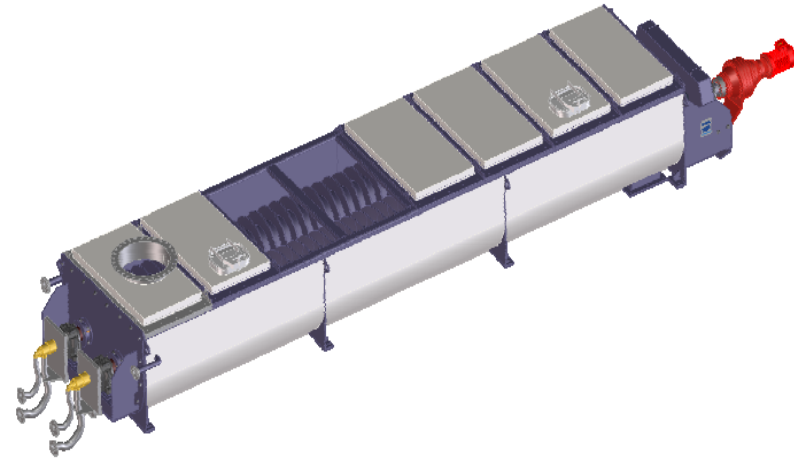
Continuous process.

Better mixing properties.

Removes the solid carbon residue from internal surface of reactor.

- Disadvantages:

Relatively low heat transfer co-efficient w.r.t fluidized bed.



http://www.celsiusprocessing.com/downloads/lezing_bulk_europe.php

Reactors used for Pyrolysis

➤ Conical Spouted Bed reactor:

- Advantages:

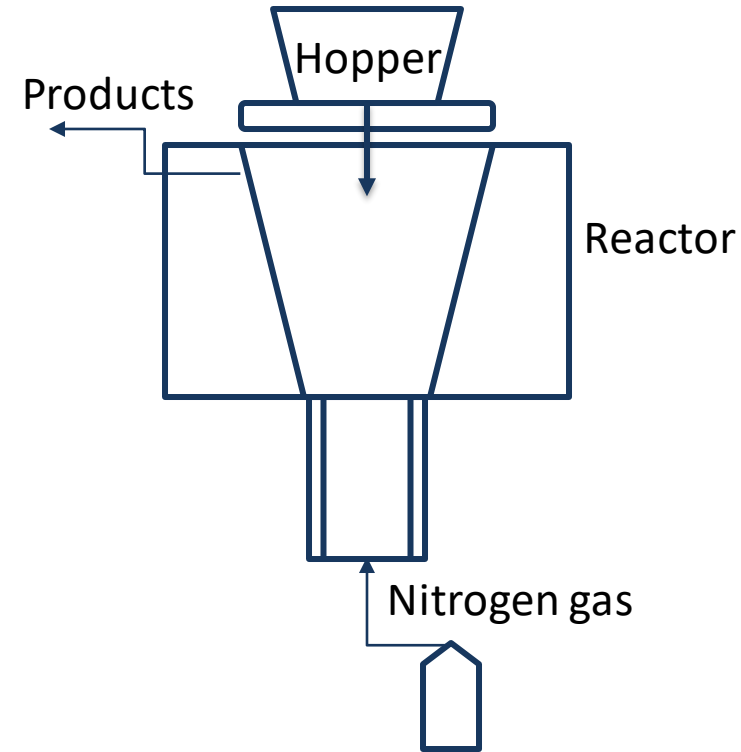
Provides good mixing with the ability to handle large particle size, and difference in particle densities.

Lower attrition and bed segregation than FBR.

- Disadvantages:

Complicated design.

Challenges during operation, catalyst feeding and entrainment.



International Scenario

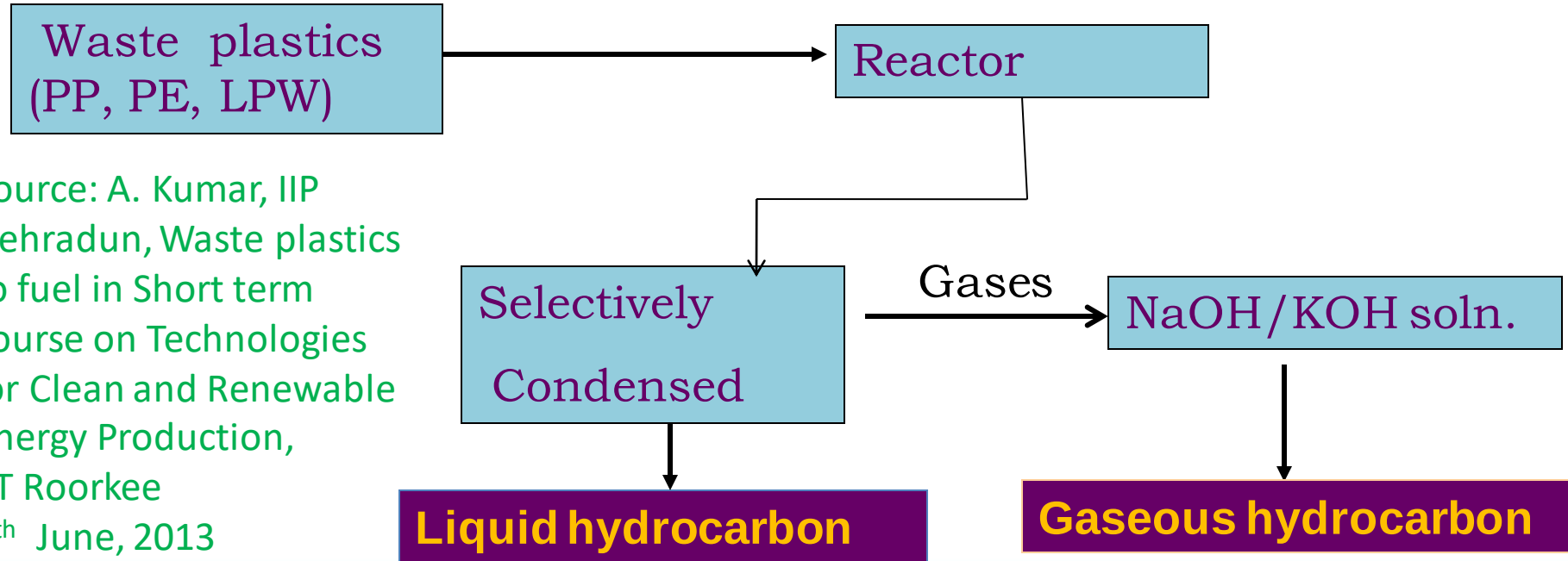
Company	Feed	Product	Remarks
Ozmotech Pty Ltd, Australia	Defined ratio of different plastics	High Grade diesel	
Polymer Energy LLC., USA	(PE+PP)	Pyrolysis oil	Yield: 0.78 Kg out of 1 Kg Plastic
Recycle Energy Company Ltd., Japan	Waste Plastics	Pyrolysis oil	Process: Catalytic cracking continuous process Processing Capacity: 200 kg/h

International Scenario

Company	Feed	Product	Remarks
Blest.co.Ltd., Japan	Waste Plastics	Gasoline, Kerosene, Diesel Oil and Heavy Oil	Process: continuous & Batch Plant Oil Yield: 80% Processing Capacity: 5-50 Kg/hr Processing time in batch: 150 min.
Enviro-Hub Holdings Limited, Singapore	Waste Plastics	Crude oil	Capacity: 30000 tones/annum
Pyrocrat Systems, Mumbai India	both plastic and tyres can be used	Pyrolysis oil comparable to industrial diesel	Capacity: 1MT to 10MT / day input capacity continuous type pyrolysis plants

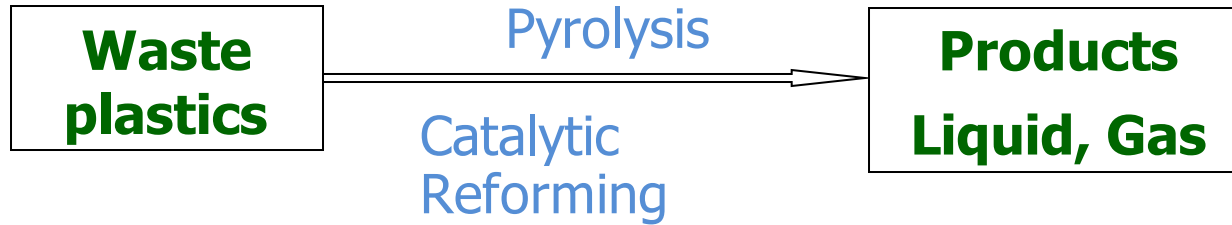
LPW: Low polymer wax
bag

Methodology



Source: A. Kumar, IIP
Dehradun, Waste plastics
to fuel in Short term
course on Technologies
for Clean and Renewable
Energy Production,
IIT Roorkee
5th June, 2013

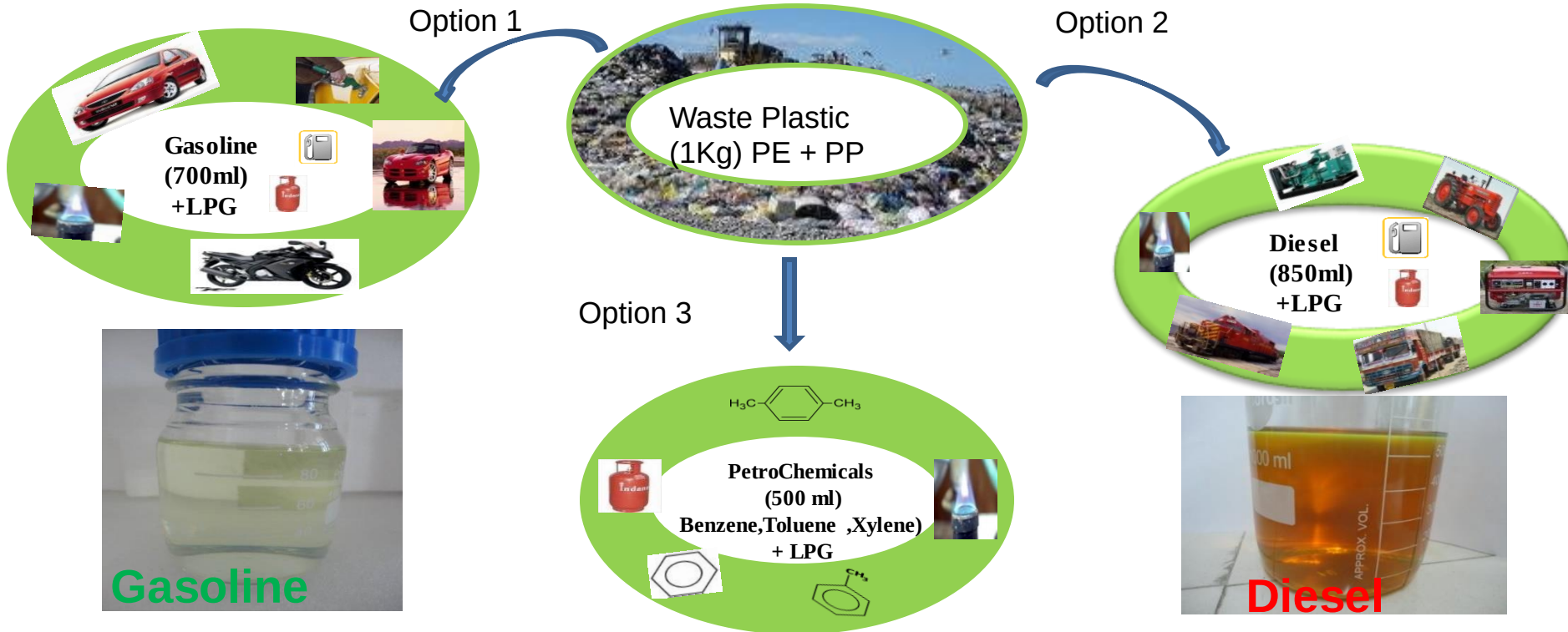
Catalytic pyrolysis



- Catalyst-Type 1: Catalyst for Aromatic rich liquid hydrocarbons
- Catalyst- Type 2: Catalyst for Gasoline rich liquid hydrocarbons
- Catalyst- Type 3: Catalyst for Diesel rich liquid hydrocarbons

Waste plastics to fuel and petrochemicals

IIP-GAIL Technology



Source: A. Kumar 2013



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Typical Gasoline Rich Hydrocarbon Yield

IIP-GAIL Technology

Weight of Liquid hydrocarbons (LHC)	56% of feed
Weight of Gasoline (IBP-212°C)	85% of LHC
Weight of high quality gasoline	48% of feed
Weight of LPG	44% of feed

Source: A. Kumar 2013



Properties of gasoline obtained from waste plastics

IIP-GAIL Technology

Properties	Indian Petrol Specifications required to meet Euro III norms	Gasoline obtained from waste plastics
Colour	Orange	Orange - red
Density, Kg/m ³	710 - 770	720
Recovery upto 70 °C, % vol	10-45	13-15
Recovery upto 100°C, % vol	40-70	42
Recovery upto 150°C, % vol	75, min	81
FBP, °C max	210	210
Residue, max; % vol	2	1
RON/MON	91 min / 81 min	85 /72
Aromatics content, % vol	42 max	42
Olefinic content, % vol	21 max	13



Typical diesel obtained from waste plastics

IIP-GAIL Technology

Properties	Indian Diesel Specifications to meet Euro III norms	Diesel obtained from waste plastics
Density @ 15 °C, Kg/m ³	820-845	825
Distillation 95 % vol at °C, max	360	360
Cetane index (calculated)	46	58
Viscosity @ 40 °C, cst	2.0 – 4.5	2.2
PAH, max; % mass	11	6

Source: A. Kumar 2013

PAH: Poly aromatic hydrocarbon



Typical aromatic rich liquid product yields and composition

IIP-GAIL Technology

Weight of Liquid	41% of feed
Total aromatics	85% of liquid
Total aromatics	35% of feed by weight

Weight of (C1-C5 gas)	59% of feed
Propane	40%
Propylene	25%
Iso-Butane	10%

Weight % of different components(basis feed)

Total aromatics (C6-C9)	= 27.3
Benzene	= 1.7
Toluene	= 14.5
Xylenes	= 9.8
C ₁ -C ₅ gases	= 59

Source: A.
Kumar 2013



Case Study : Cynar Plastic to Fuel

➤ Background:

- Cynar Plc. – a company to commercialize pyrolysis and distillation technology to convert waste plastics into liquid hydrocarbon fuels.
- Developing technology since 2004.
- First full scale plant in Ireland in 2008.
- Produces a synthetic fuel that is clean, low in sulphur and with better cetane number than generic diesel fuel.

Cynar Plc. – UK company

<http://www.zerowaste.sa.gov.au/>



Case Study : Cynar Plastic to Fuel

➤ Feedstock:

- Waste plastics such as packaging scrap, oil/detergent bottles, recovered from household wastes and agricultural plastic waste.

- Feedstock Challenges:

Some plastics such as PVC, PET and polyurethanes may cause difficulties.

PET contains oxygen atoms, which take part in oxidation reactions that can turn into sludge like substances.

PVC contains chlorine ions that produce unwanted chemical like HCl.

- The system has been designed to manage low levels of these materials, up to 10%.

Approximately 950ml of oil could be recovered from 1kg of plastics such as PE, PP and PS.



Case Study : Cynar Plastic to Fuel

➤ Technology:

- The feedstock is chipped to approx. 15mm, followed by washing and drying.
- The system consists of a stock in-feed system, pyrolysis chambers, contactors, distillation, oil recovery line and pyrolysis gas.
- The plastic is pyrolysed at 370-420°C, and the pyrolysis gases are condensed in a two-stage condenser to produce a low-sulphur distillate.
- The raw diesel is further refined in another distillation into road diesel, kerosene and light oil. A synthetic gas is produced as a by-product.

Case Study : Cynar Plastic to Fuel

➤ Outputs :

- Input capacity of 6,000 tpa of waste plastic and an output fuel capacity of about 5.7 million litres per year.
- Each tonne of plastic produces approx.
 - 700 litres of diesel
 - 200 litres of light oil
 - 100 litres of kerosene
 - Residual char (5% of output).



Case Study : Cynar Plastic to Fuel

➤ Benefits:

- Emissions from the production facility are of the order of 10 times lower per tonne of waste treated than a waste incineration treatment facility.
- Cynar claims that their diesel product is cleaner than conventional diesel and of a higher quality.
- Fuels produced from clean plastic feedstock will demonstrate low sulphur levels when compared to convention fuels.
- Sulphur levels can be under 10 ppm compared to sulphur levels of other fuels in the region of < 35 - 50 ppm.

Thanks...

