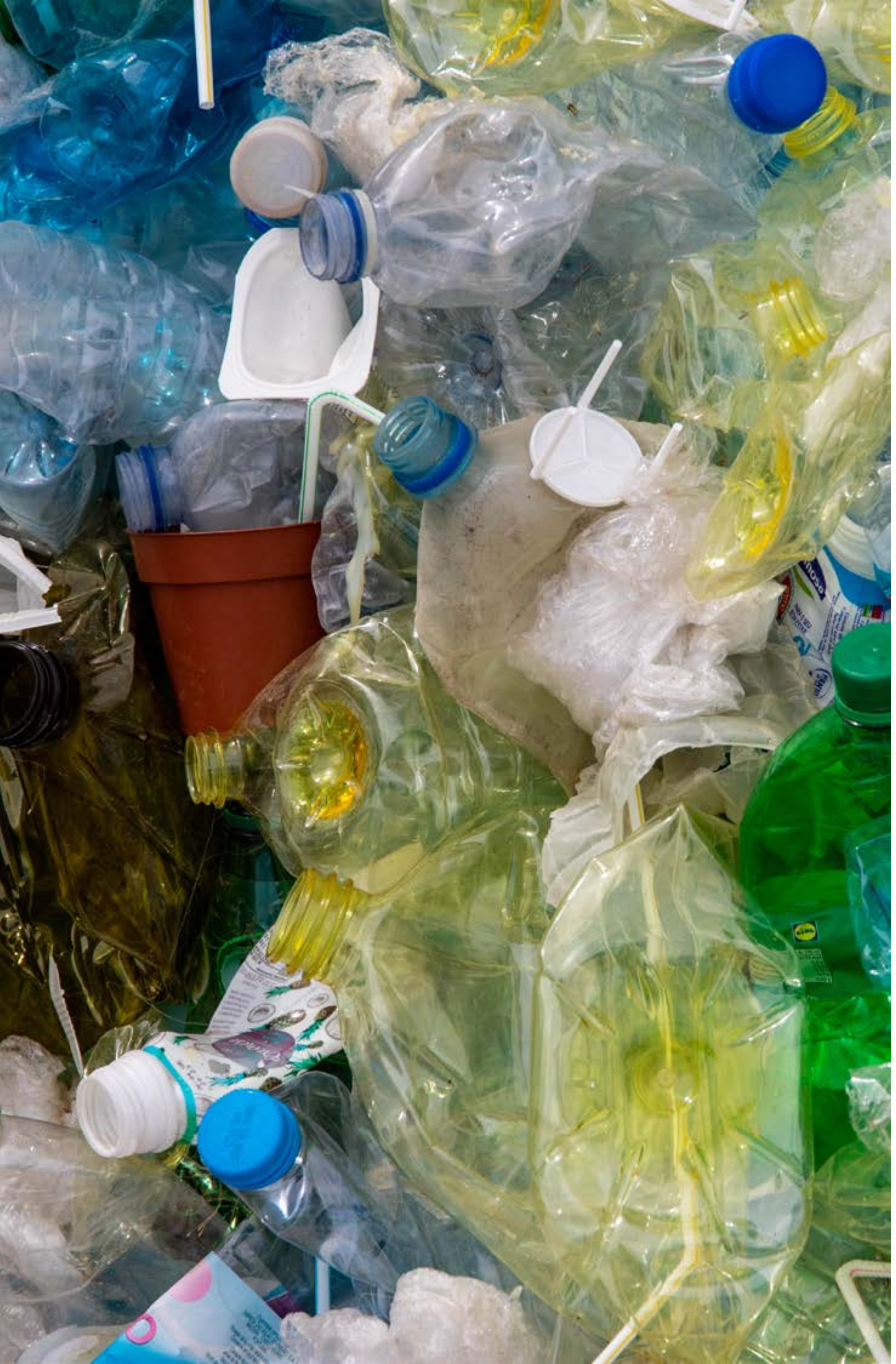

CHALLENGES AND OPPORTUNITIES IN THE CHEMICAL RECYCLING PROCESSES OF PLASTIC WASTE

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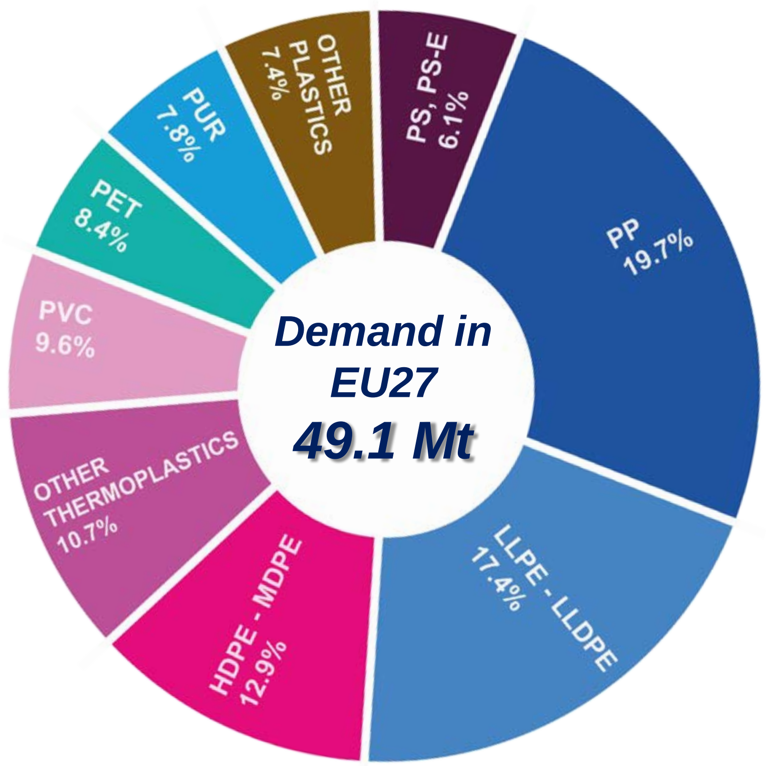
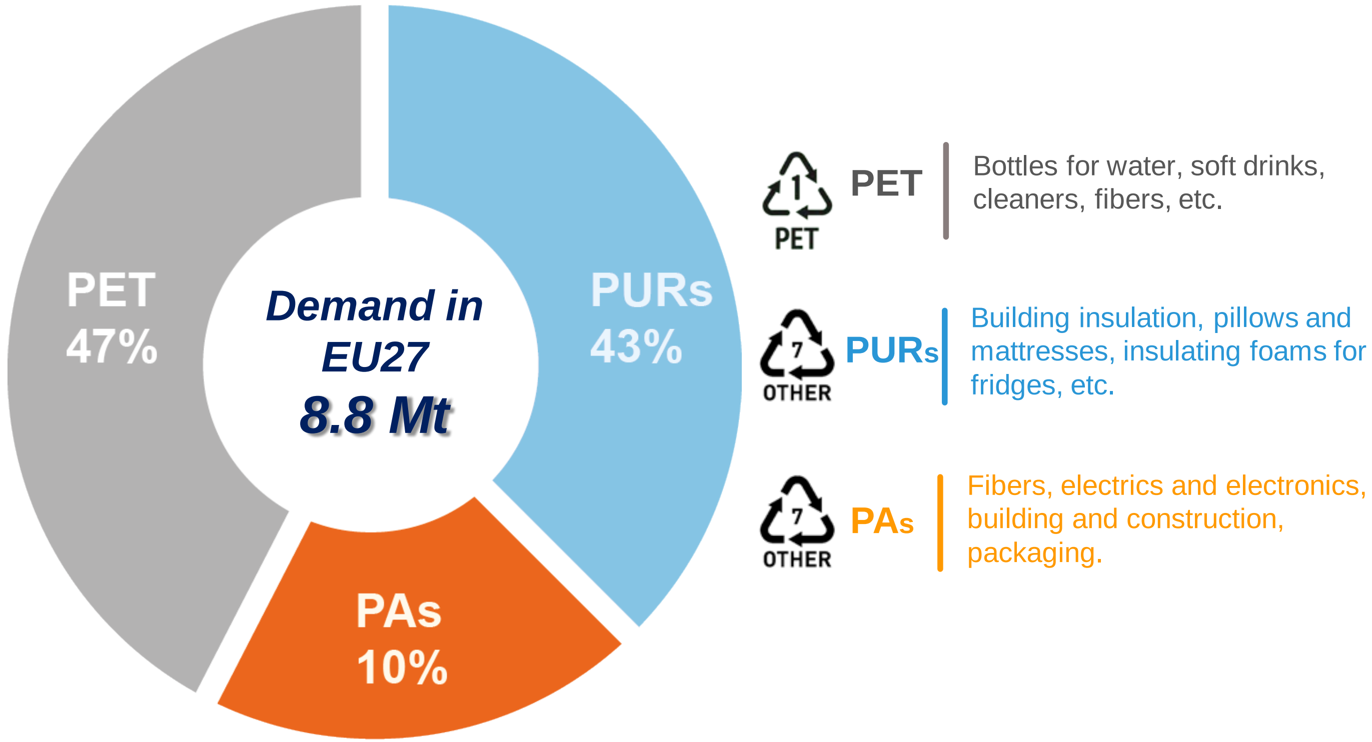
Introduction

- **Plastic Market Demand and Waste Treatment: *PET, PURs* and *PAs***



Distribution by polymer types in 2020



PET, PURs and PAs (PA 6 and PA 6.6) demand in EU27 - 2020

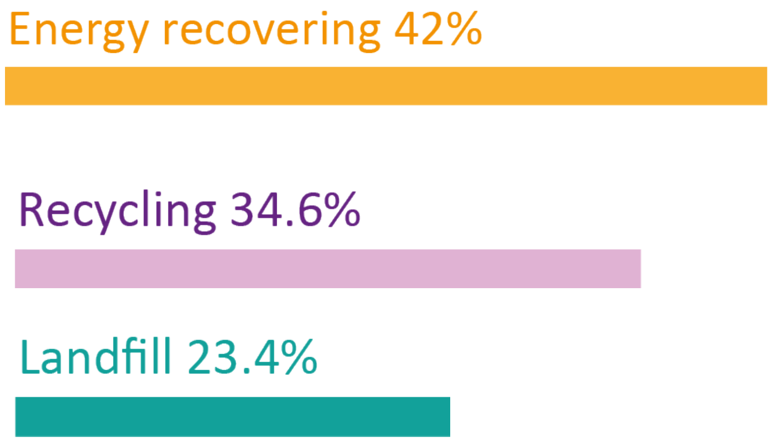
Adapted from *Plastics - the Facts* 2021.

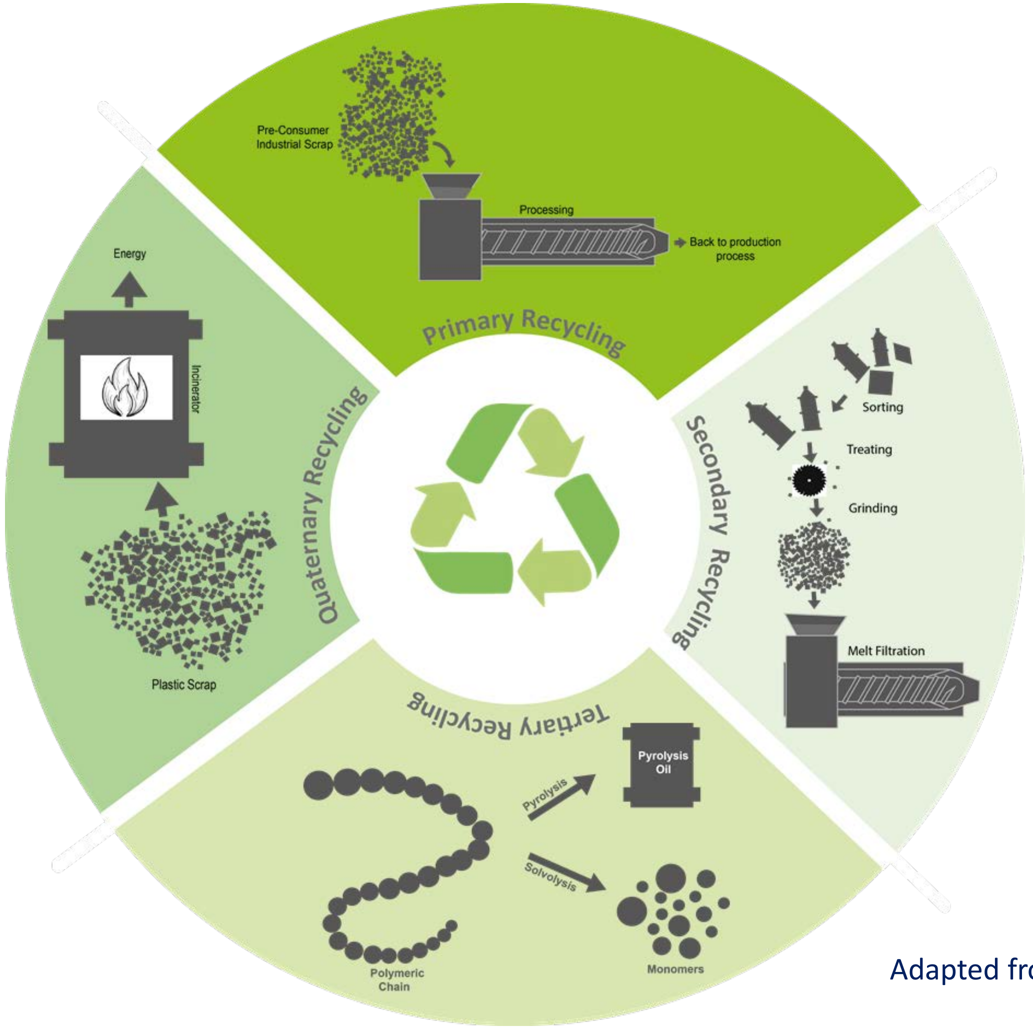
The demand of heteropolymers increases yearly along with the waste generation. Landfills can be avoided through mechanical recycling but this leads to downcycling. Moreover, not all heteropolymers can be physically recycled.

Introduction

- **Plastic Market Demand and Waste Treatment: *PET, PURs* and *PAs***

  - ***Plastic Waste Treatment in 2020***





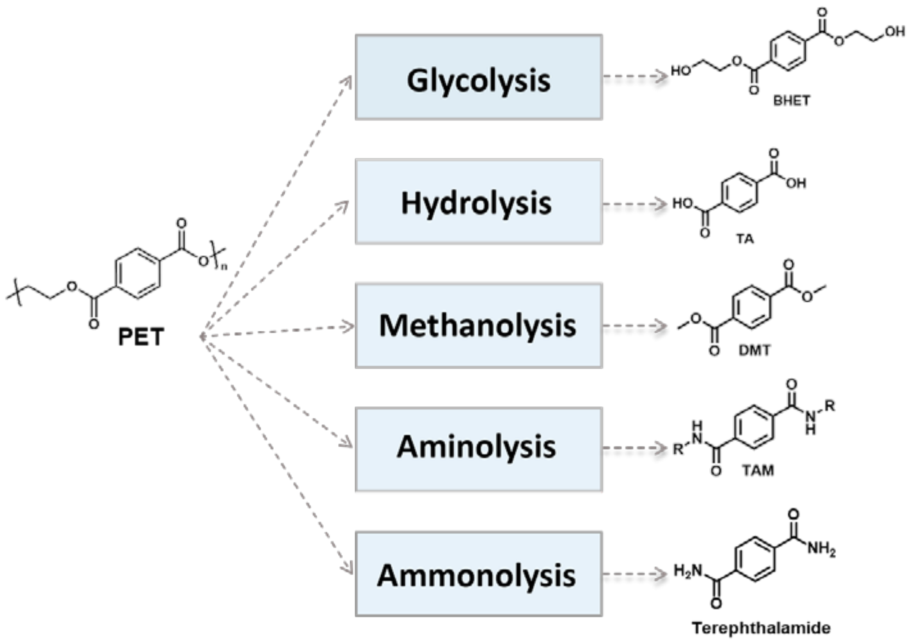
Adapted from *Plastics - the Facts* 2021.

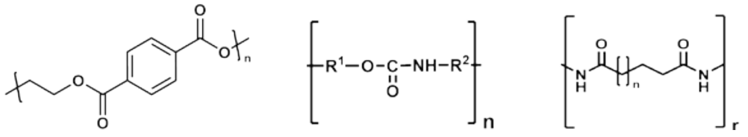
Chemical recycling of heteropolymers allows the recovery of the starting polymer or the synthesis of new chemicals. However, only the 0.2% of the recycled plastic is treated through this method.

Chemical Recycling – *Solvolysis*

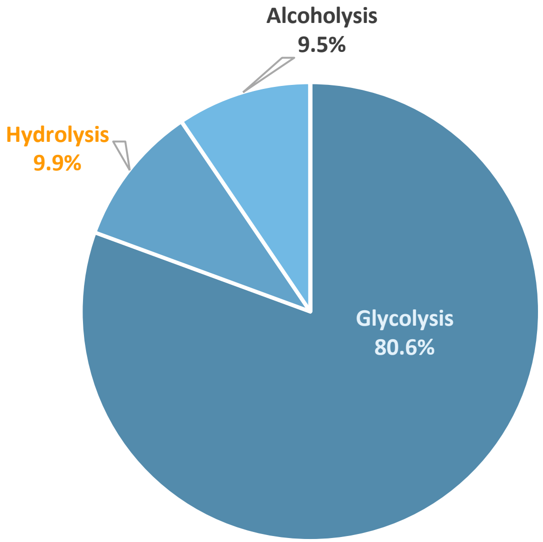
- **Solvolysis of PET, PURs and Pas: *Research outcomes consulted***

- ***Solvolysis of PET:***

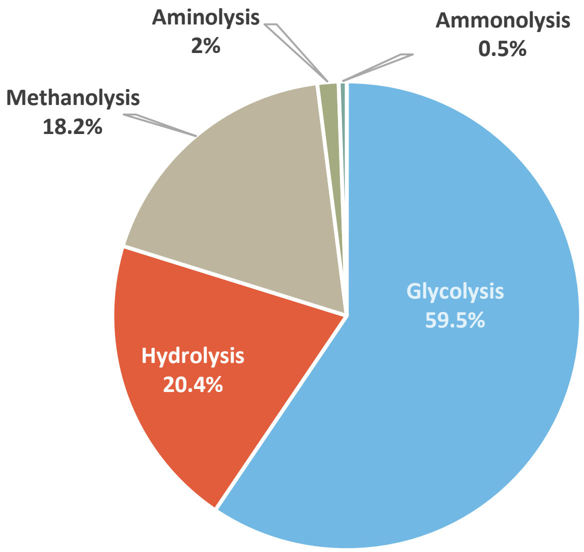




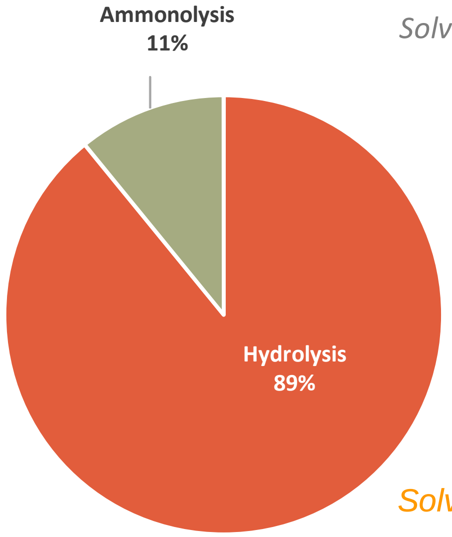
PET PURs PAs



*Solvolysis of **PURs***



*Solvolysis of **PET***



*Solvolysis of **PAs***

***Solvolysis** process allows to recover the original monomers or the synthesys of new chemicals. Glycolysis is the most explored technology to treat PET and (PUR)is not suitable to depolymerize Polyamides (PAs)*

Scale-Up Challenges Of Solvolysis Process

• Reaction Stage – Drawbacks

Catalyst Nature

- Activity and selectivity
- Toxicity
- Cost
- Catalyst Recover

Energy Demand

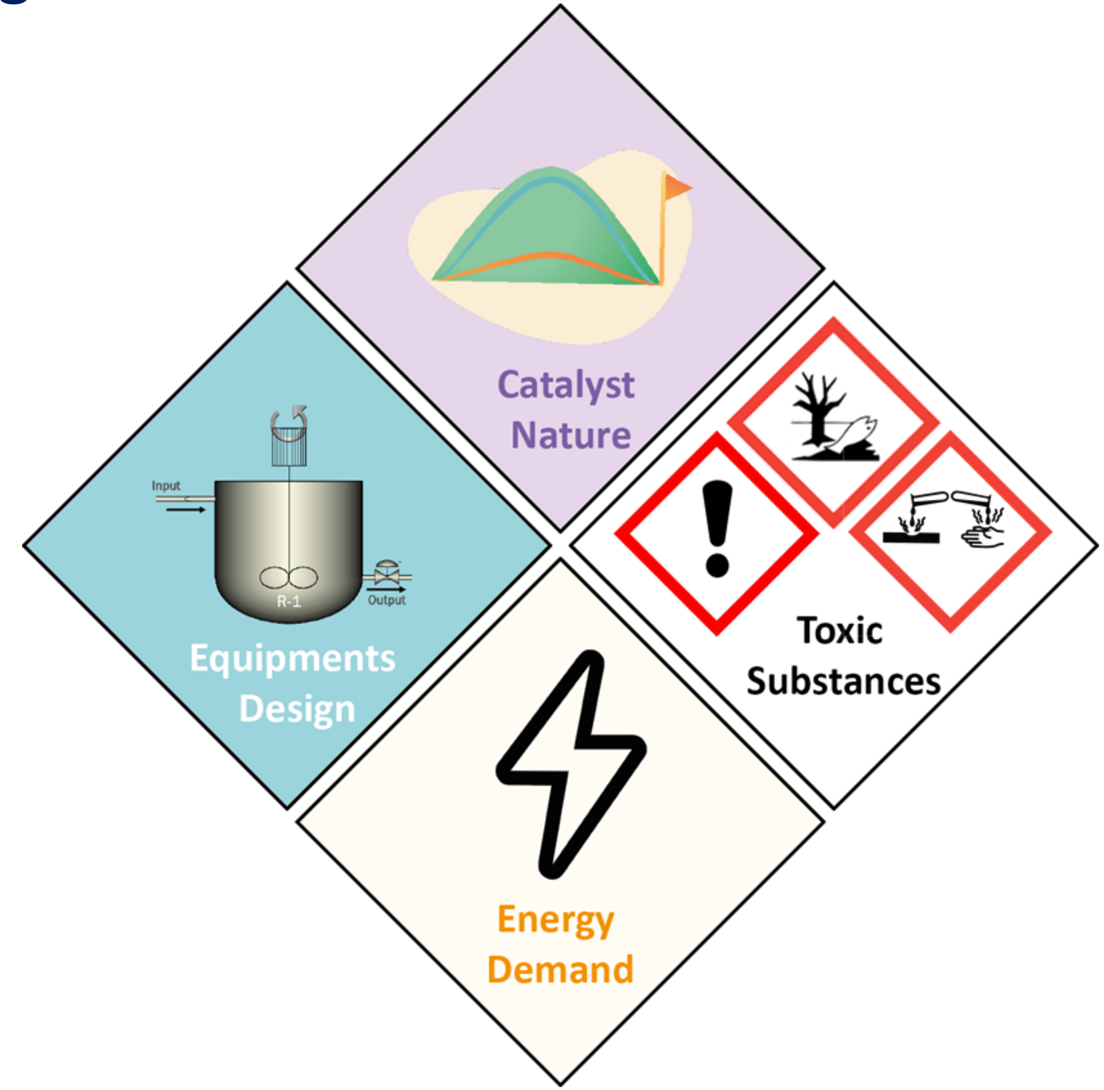
- Harsh reaction conditions for long reaction times

Toxic Reactants

- Toxic reactants, additives and side products
- Corrosive waste streams
- Several and/or complex purification stages

Equipment Design

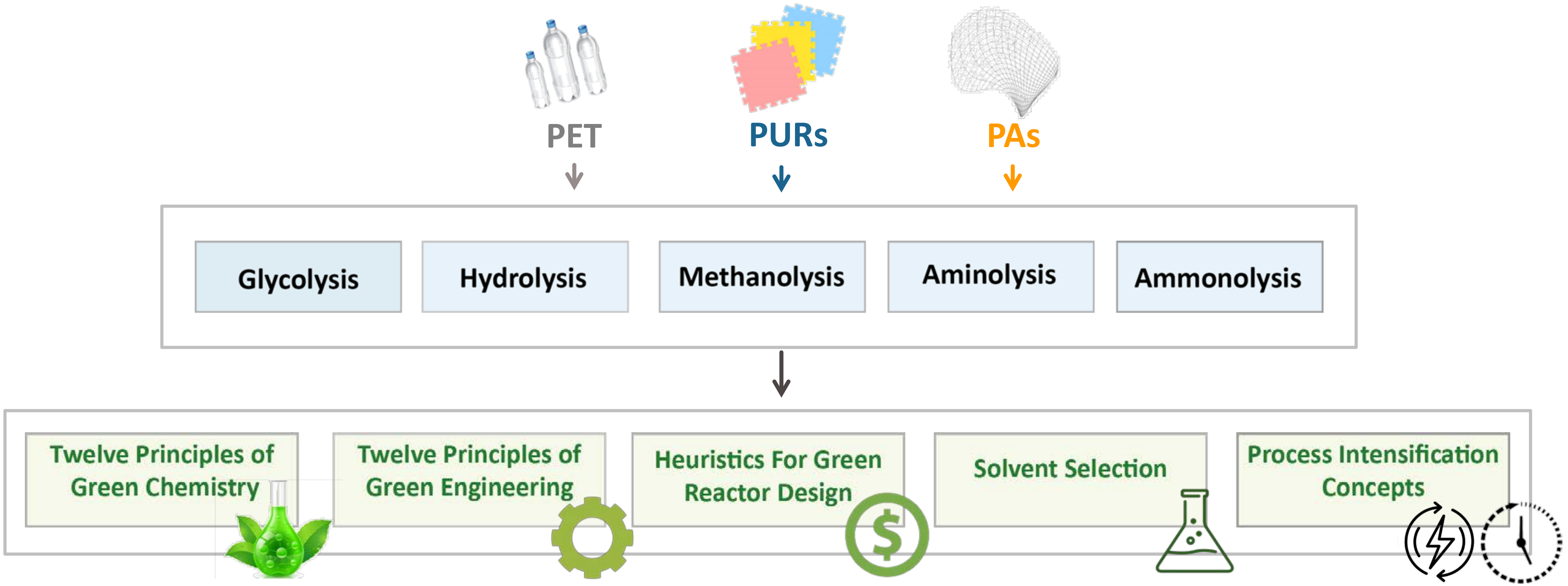
- Nature of feed stream
- High initial capital investment and maintenance costs
- Safety concerns



Most Solvolysis Processes have not achieved the industrial and commercial scale in part due to these drawbacks.

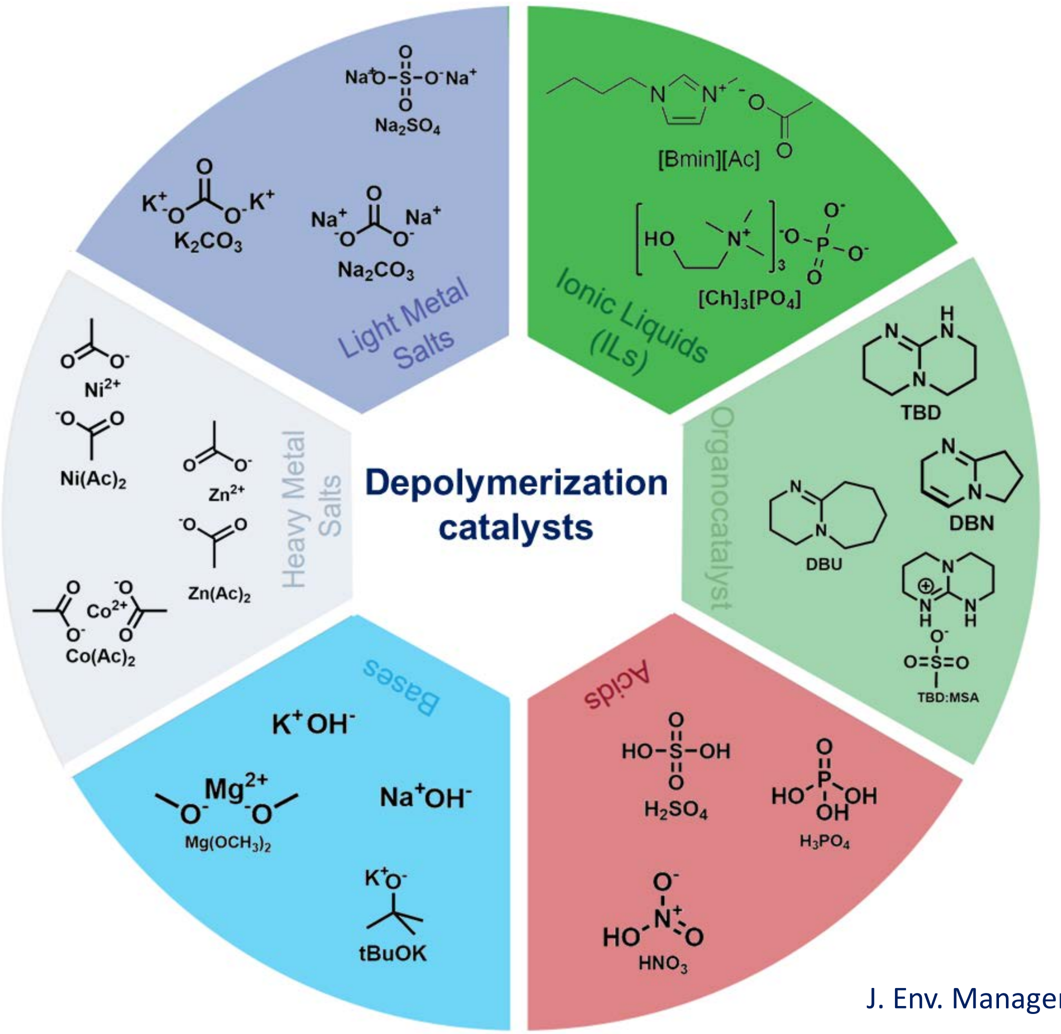
Objective – *Sustainable Process Design (SPD)*

- **SPD Principles applied to Solvolysis**



The application of the Sustainable Process Design principles to Solvolysis of Heteropolymers is a potential pathway to reach efficient, cost-effective processes.

SPD – *Catalysts/Product Separation*

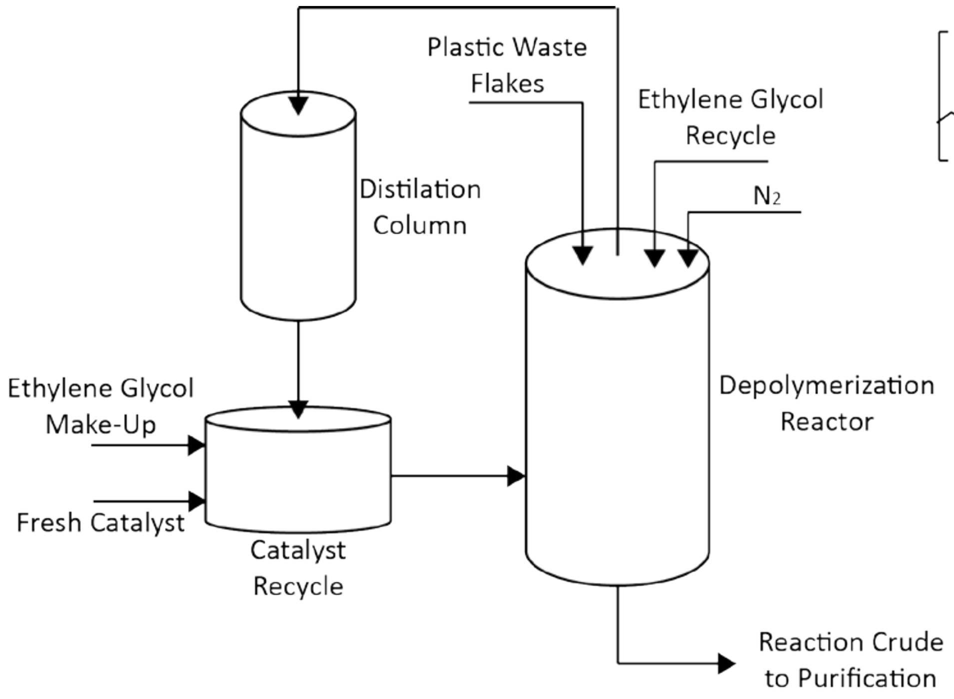


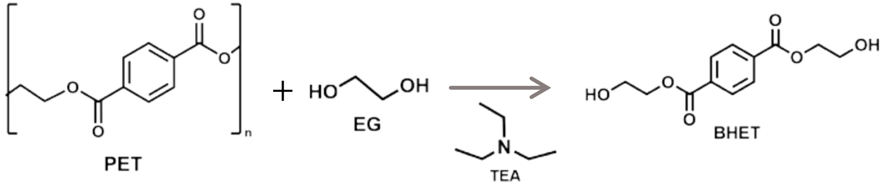
J. Env. Management, 296, 15 October 2021, 113267

*The **nature of the catalysts** is one of the most challenging factors and the source of most of the **problems** in the Solvolysis reaction stage.*

SPD – *Combining Reactors and Separators*

- ***VolCat* Process with Organocatalysts by IBM**

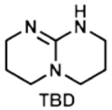


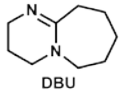


1 mol 15 mol 5% mol

Operating Conditions Reported	
T (°C)	220
Pressure (Barg)	~1.4
Stirring rate (rpm)	200
Reaction Time (min)	90
Batch Time (min)	120
Catalyst BP (°C)	89
Catalyst VP (Bar)	0.75

US 9914816 B2





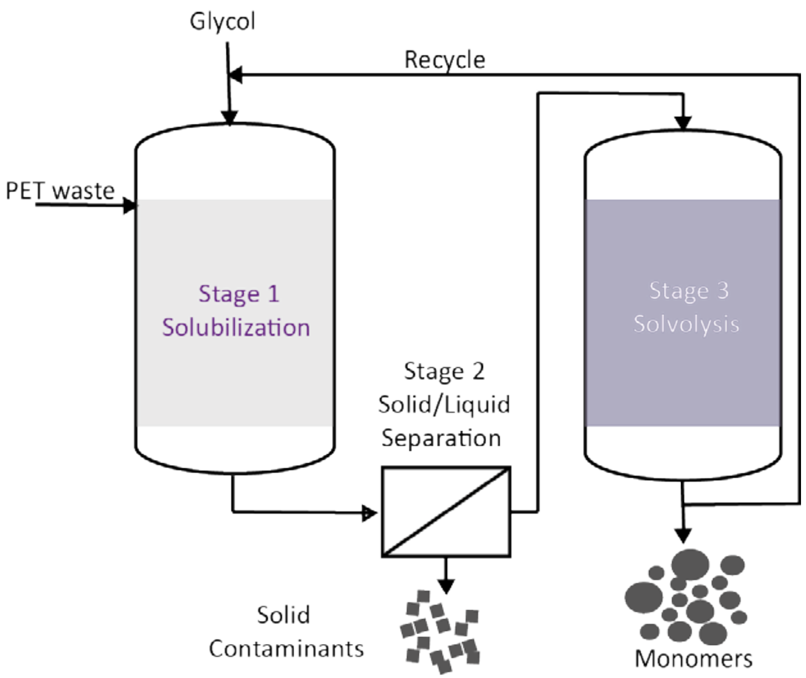
Other liquid Organocatalysts

US 2011004014 A1 → **US 20120223270 A1** → **US 9914816 B2 *VolCat***

*Homogeneous catalyst recovery issues as well as the reactor output purity can be improved through a **smart reactor design** and **catalyst selection**.*

SPD – *Supported Catalysts*

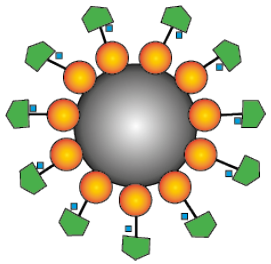
- **Rewind® PET by IFP Energies Nouvelles**



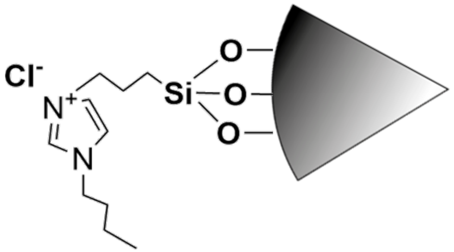
Reaction Conditions Reported	
T (°C)	210-280
Pressure (Barg)	~4
***X* (%)**	85

WO 2016096768 A1

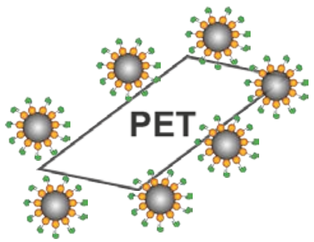
- **Magnetic Ionic Liquids by Ioniqa**



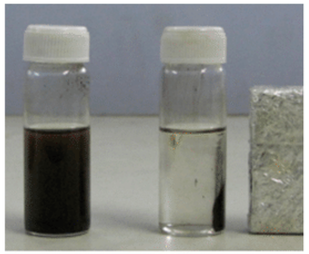
Catalyst supported on Magnetic particles



Ionic Liquid [Bmin][Cl] linked to Fe_3O_4 particle surface

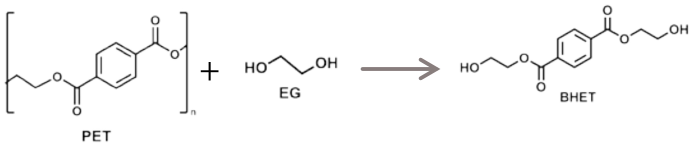


Nanoparticles allows more catalytic active sites accessible and high surface area



Recovering of Magnetic Catalyst by exposing the reaction crude to a magnetic field

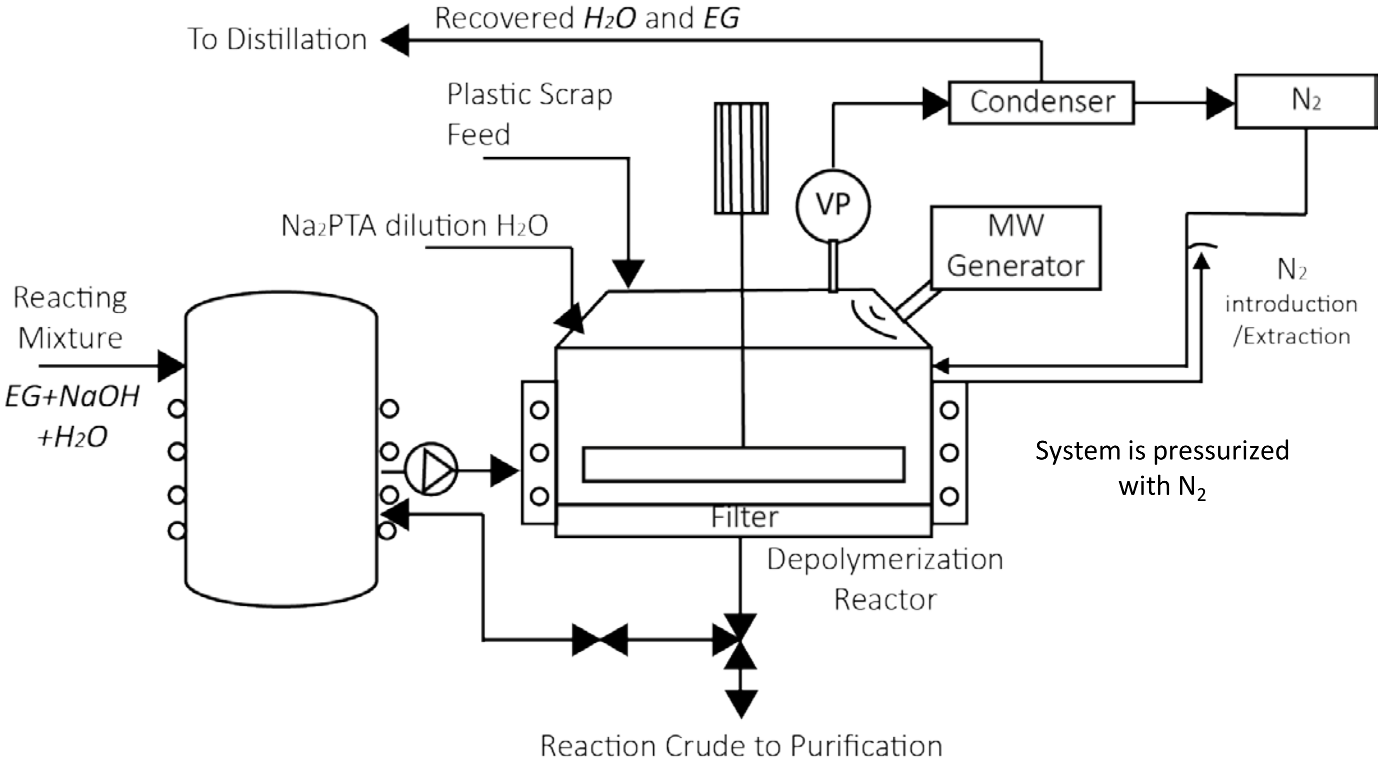
US 2020/0079927 A1



*Supporting catalytic species may reduce catalyst lost and also the number of Unit Operations required downstream. Still, the loss of **catalytic activity** and **waste pre-treatment** are drawbacks.*

- **Microwave – Assisted Alkaline Hydrolysis of *PET* and *PAs* by Gr3n**

Ethylene Glycol (EG) is used as co-solvent



System is pressurized with N_2

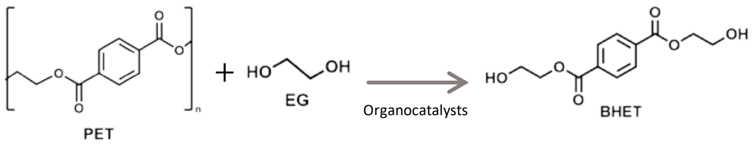
Operating Conditions Reported	
T (°C)	~180
Pressure (Barg)	~10
Frequency Range (GHz)	0.3-300

WO2021094949A1

*Microwave radiation used as **energy** source reduces the reaction **time** and the energy demand of solvolysis processes. However, it leads to **<u>complex reactor designs</u>**.*

SPD – Solvent Based Approach

- **Solvent Assisted Glycolysis of PET: *This Work***



Convertion of PET to BHET in the presence of different solvents at 60°C

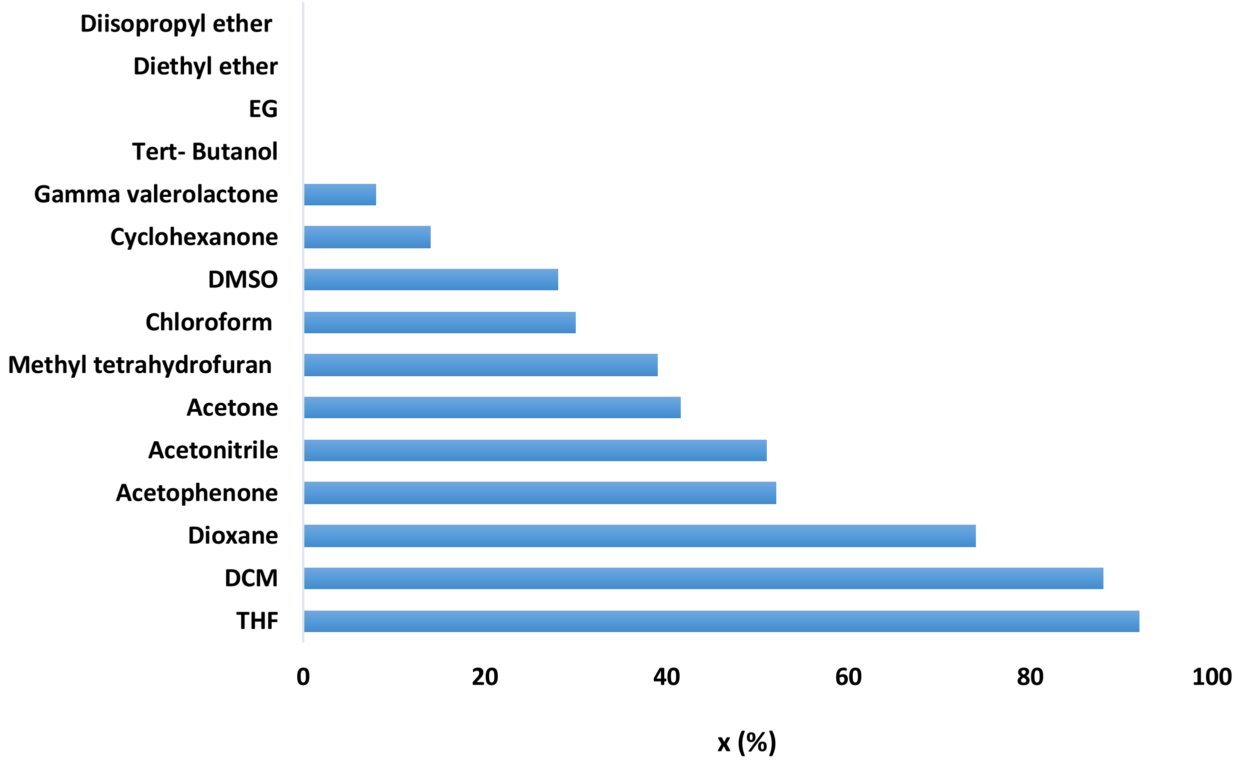


Figure. PET conversion in different solvents

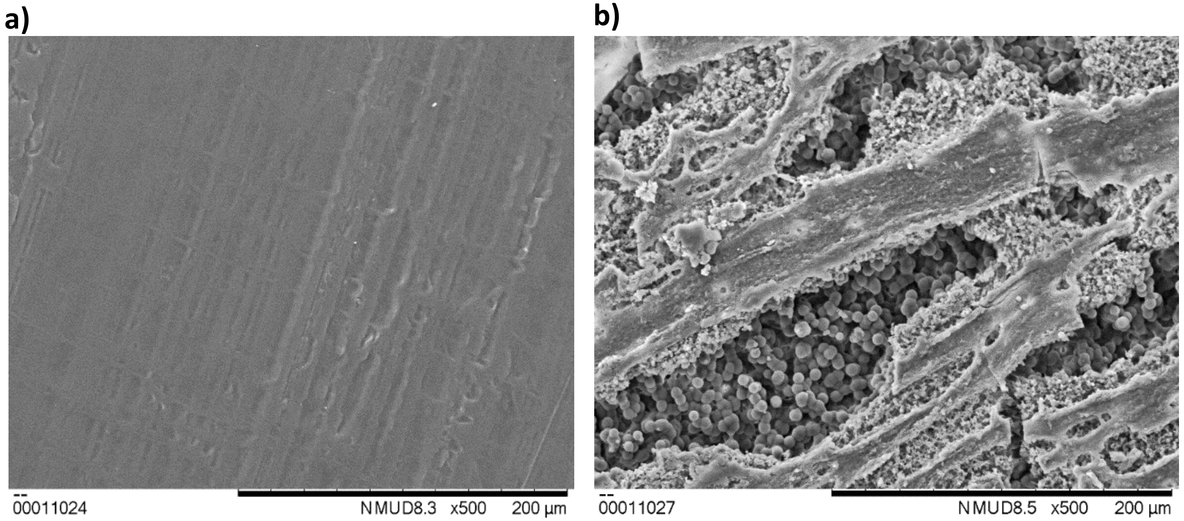
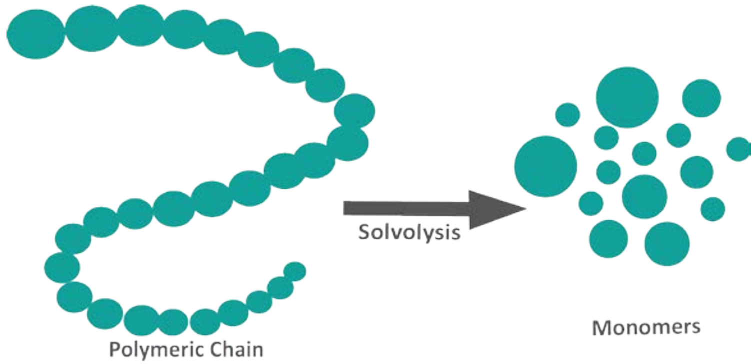


Figure. a) PET particle treated with EG at 65°C for 60 min. **b)** PET particle treated with 1,4-Dioxane at 65°C for 60 min.

Operating Conditions	
T (°C)	65
Pressure (Bar)	1
Stirring rate (rpm)	200
Reaction Time (min)	60

*A **smart** co-solvent selection in solvolysis of heterogeneous residues can reduce energy consumption and contribute to the recovery of highly **pure** products.*

Conclusions and Perspectives



1

Solvolysis allows the recovery of monomers and the synthesis of new chemicals, being glycolysis the most explored method.

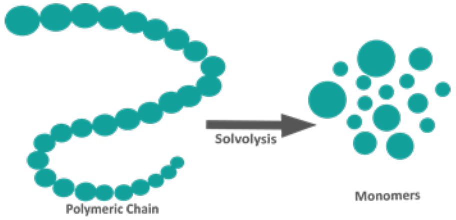
2

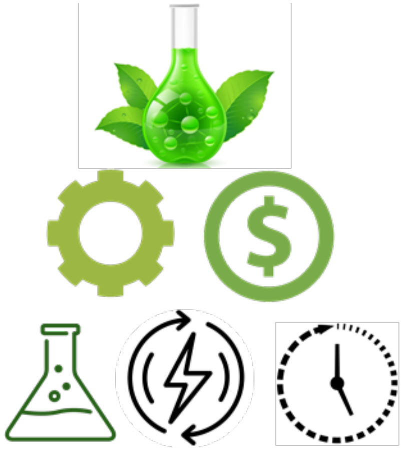
Sustainable Process Design (***SPD***) principles have being proved as powerfull tools to design efficient and competitive solvolysis processes.

3

Upcoming designing proposals for solvolysis processes will be carried out not only following the SPD principles but also taking advantage of other design tools.

Thank you for your attention!





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