Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Opportunities and challenges of chemical recycling of plastic waste. The Italian experience.

2023 Resource Circulation International Conference

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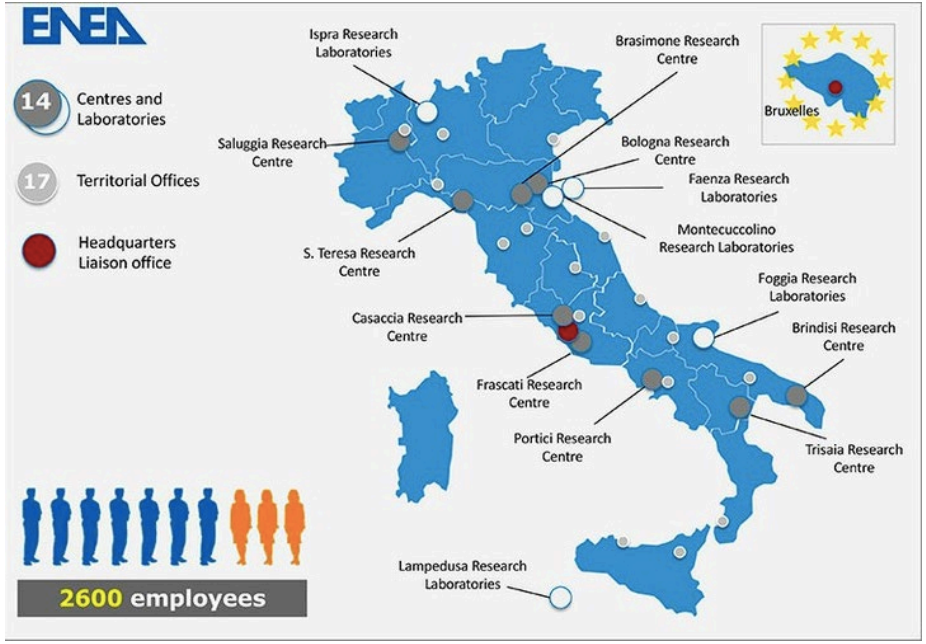
Riccardo Tuffi – ENEA - SSPT-USER-T4RM

ENEA – Who we are I

ENEA, the **National Agency for New Technologies, Energy and Sustainable Economic Development**, was founded in 1952. It is a public body aimed at research, technological innovation and the provision of advanced services to enterprises, public administration and citizens in the sectors of **energy**, the **environment,** and **sustainable economic development**.

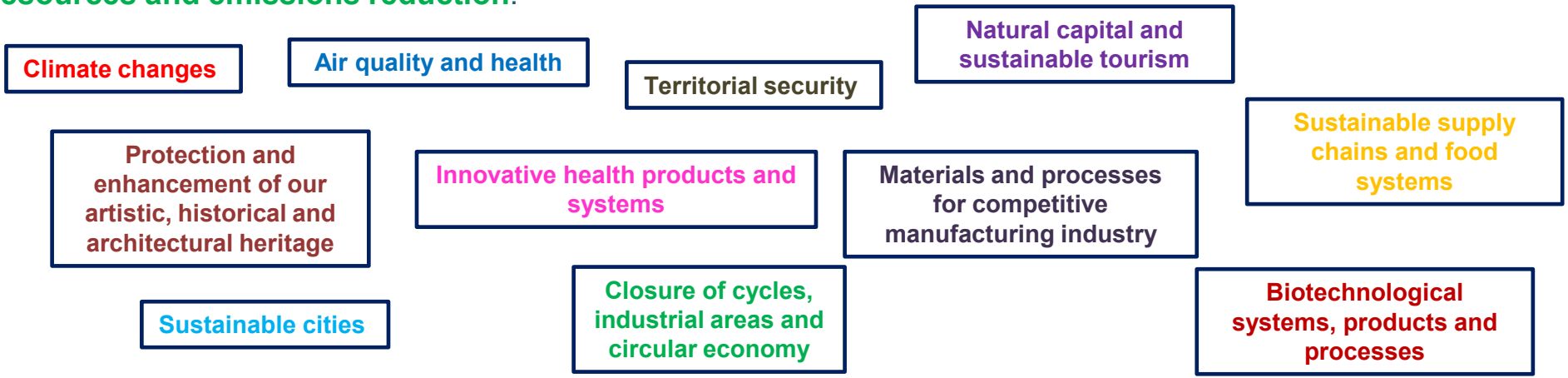


4 Departments:

- Department for Sustainability
- Department for Energy Technologies and Renewable Sources
- Department for Fusion and Technology for Nuclear Safety and Security
- Department for Energy Efficiency

ENEA – Who we are II

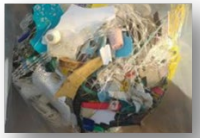
ENEA's Department for Sustainability (SSPT) develops, implements and promotes **eco-innovation in production and consumption systems**, contributing to the definition and implementation of the Country's strategies and policies within the overall framework of **transition towards more sustainable uses of the resources and emissions reduction**.



USER Division works on the «Closing the loops approach» which is pursued as a necessary goal to move towards a circular economy at various levels: within production processes, in industrial areas, and in urban and extra-urban areas. The Division activities are part of the flagship initiative for a resource-efficient Europe, launched under the Europe 2020 strategy.

ENEA – Who we are III

Laboratory Technologies for the Reuse, Recycling, Recovery and valorisation of Waste and Materials


LAB SCALE TEST


PILOT SCALE TESTS

Chemical and physical characterization

↓

Identification of the unit operations (separation, recovery and purification / upgrading)

↓

Process optimization and validation

↓

Scale-up and prototyping

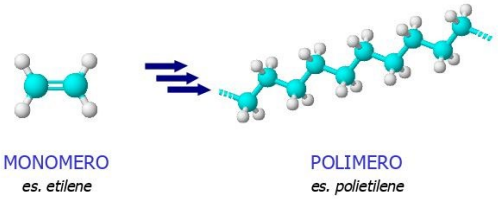
ICESP – Italian Circular Economy Stakeholders Platform

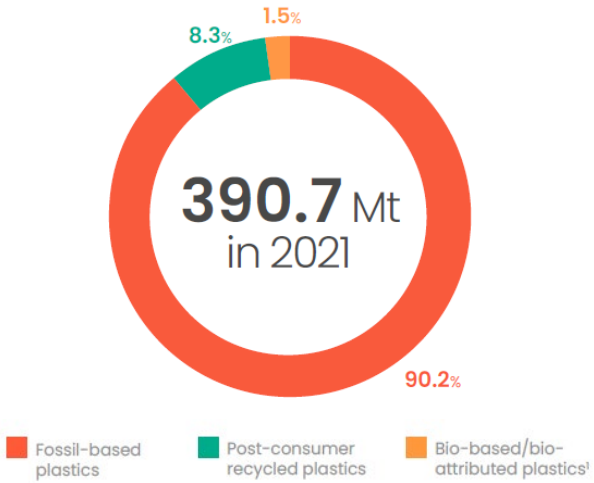
ICESP was launched in May 2018 on the initiative of ENEA to create a national interface to ECESP.

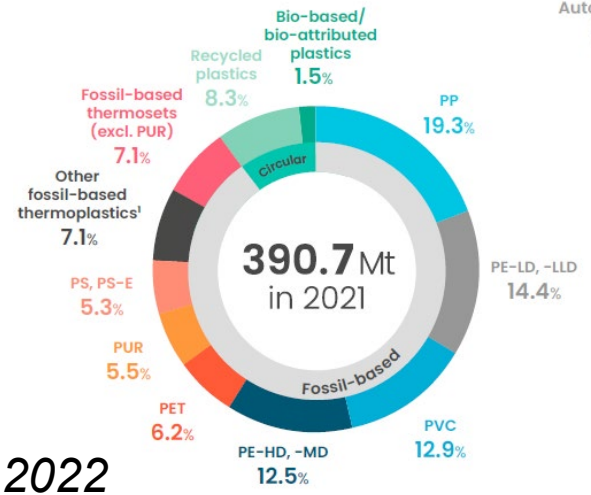
The goal is to strengthen Italy's role as a key country for the promotion, implementation and dissemination of circular strategies and to increase the impact and participation of the country in the international community.

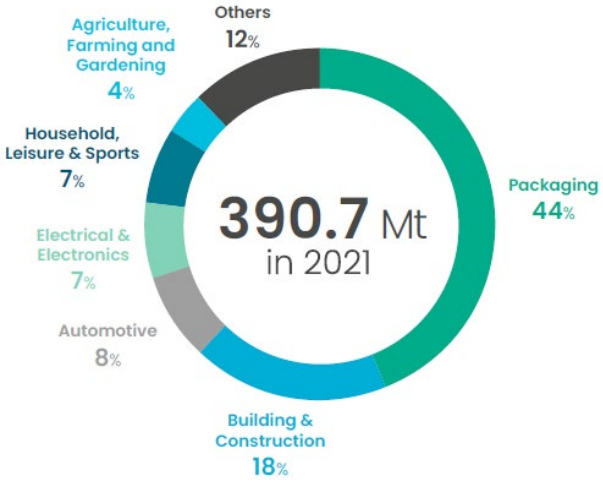
31 Italian companies, associations and public institutions have joined the working group on plastics.

Worldwide production and uses of plastics





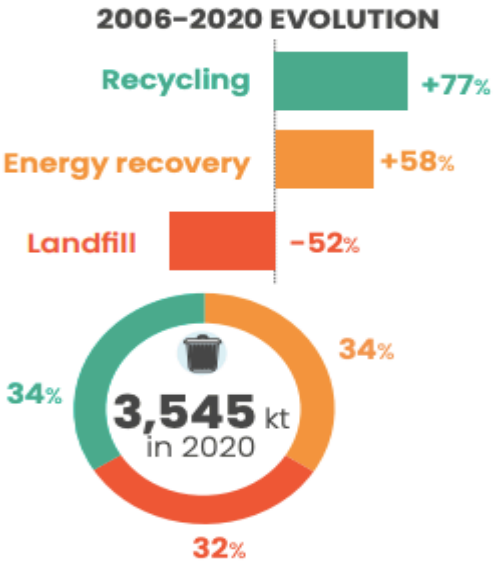




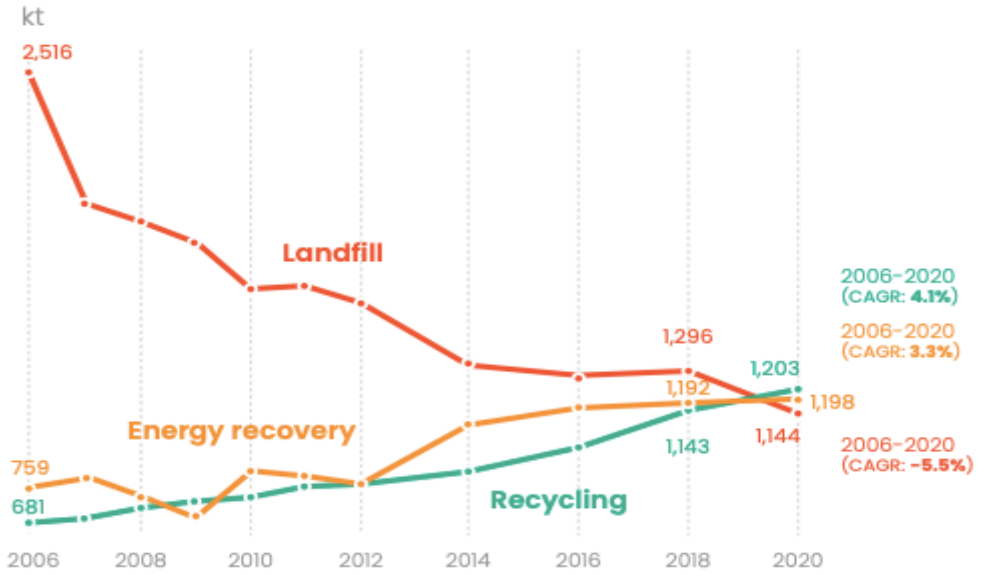
Plastic the Facts: 2022

Italy's post consumer plastics evolution – all plastics

From 2006 to 2020, the quantities sent to recycling increased by 77%, energy recovery increased by 58% and landfill decreased by 52%.



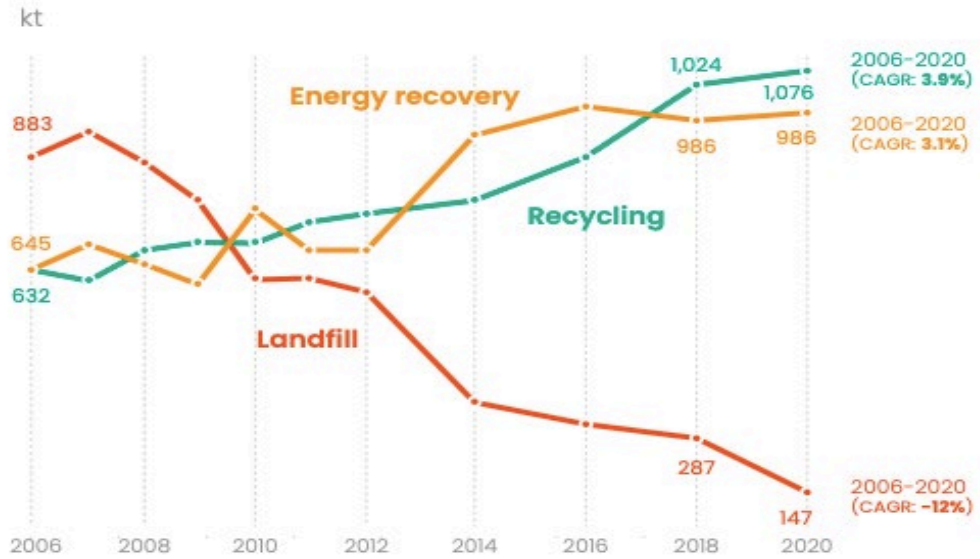
Post-consumer plastics waste treatment evolution 2006–2020 (in kt)



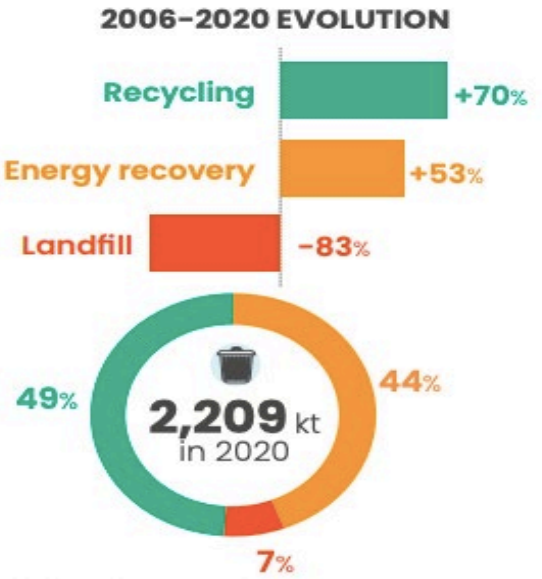
Source: Plastics – The facts 2022

Italy's post consumer plastics evolution – packaging plastics

Post-consumer plastics PACKAGING* waste treatment treatment evolution 2006-2020 (in kt)



From 2006 to 2020, the quantities of post-consumer plastics packaging waste sent to recycling increased by 70%, energy recovery increased by 53% and landfill decreased by 83%.



CAGR: Compound Annual Growth Rate
Non-plastics waste (i.e., textiles, adhesives, sealants, coatings, etc.) is not included.
*From household, industrial and commercial packaging
Source: Conversio Market & Strategy GmbH
The plastics packaging consumption and waste data used for the above graph were extrapolated based on 2019 available figures. The above data were rounded.

Fate of plastic waste

Residue

> 50-60%

Separation, sorting, washing

< 40-50%

Plastic streams:

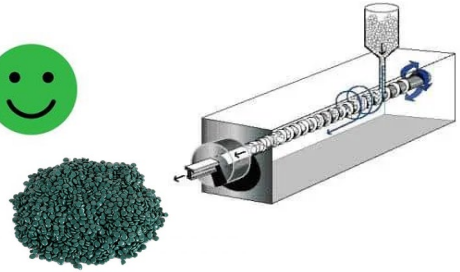
- Heteregoeneus
- Dirty
- Polluted

- 0.2 / -0.3 €/kg

Plastic streams:

- Homogeneus
- Clean
- Not polluted

+0.3 / 0.4 €/kg



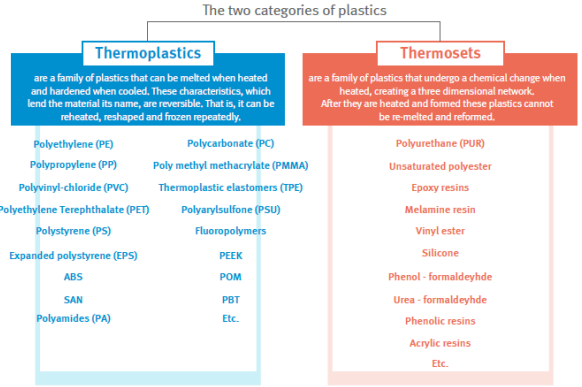
Secondary raw material

+0.7 / 0.8 €/kg

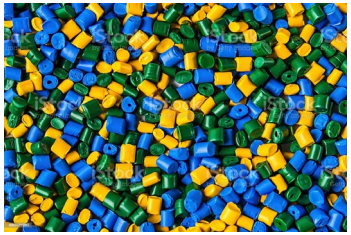
Critical issues of mechanical recycling

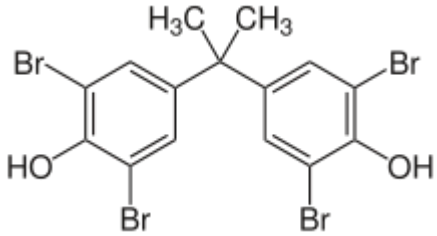
Why is it so difficult to improve the recycling rate of plastic waste?

- Polymeric heterogeneity

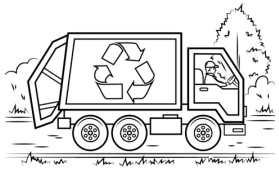


- Additives





- Low density



- Price of crude oil / virgin plastics

Targets and actions in Europe

Directive EU 2018/852 set the new European recycling targets for packaging plastic waste:

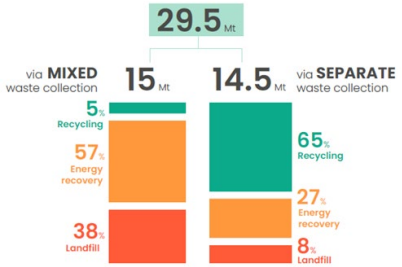
- 50% by 2025
- 55% by 2030

The Circular Plastics Alliance has committed to boosting the EU market for recycled plastics to 10 Mt by 2025. In 2021, the use of post-consumer recycled plastics by European converters reached 5.5 Mt, representing a 9.9% recycled content.

Actions:

- Design for recycling,
- Collection and sorting,
- Recycled content,
- R&D and investments,
- Monitoring,
- Governance.

Eco-design of new objects and packaging

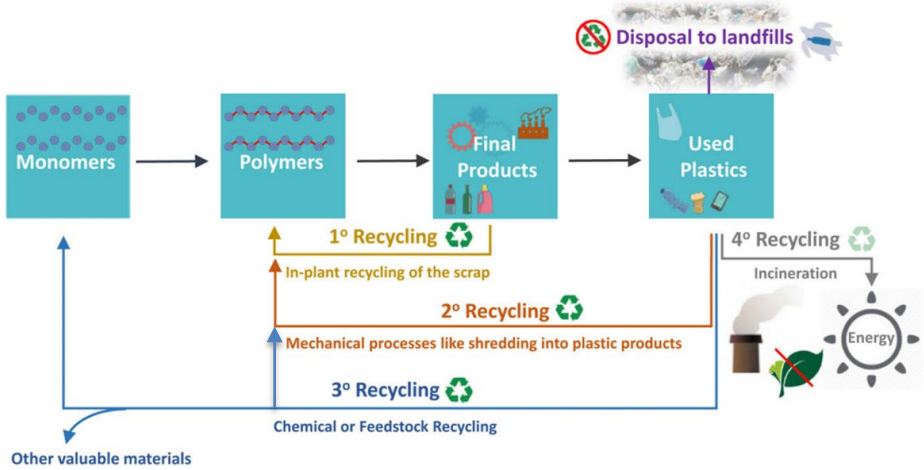


Encourage the use of recycled material in new objects and packaging

«We commit to define the R&D and investment needs, including the scale up of chemical recycling»

Chemical recycling

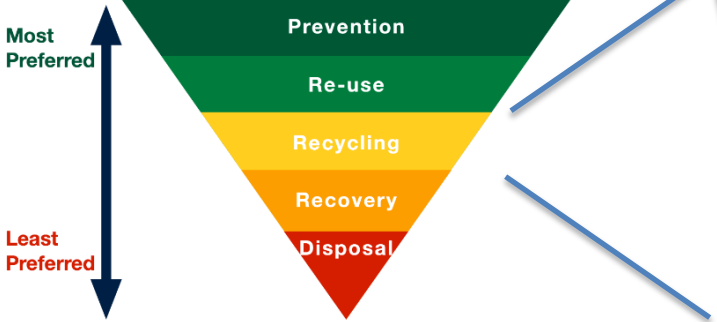
Definition: Feedstock recycling, also known as chemical recycling, aims to convert plastic waste into chemicals. It is a process where the chemical structure of the polymer is changed and converted into chemical building blocks including monomers that are then used again as raw materials in chemical processes.

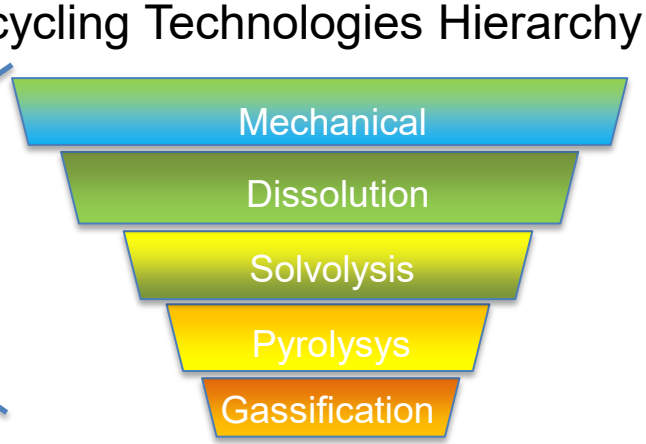


Chemical recycling technologies:

- Solvent-based
  - Dissolution/purification
  - Alcoholysis
  - Hydrolysis
  - Ammonolysis and Aminolysis
  - Enzymolysis
- Thermochemical
  - Pyrolysis
  - Gasification
  - Hydrocracking

Recycling technologies





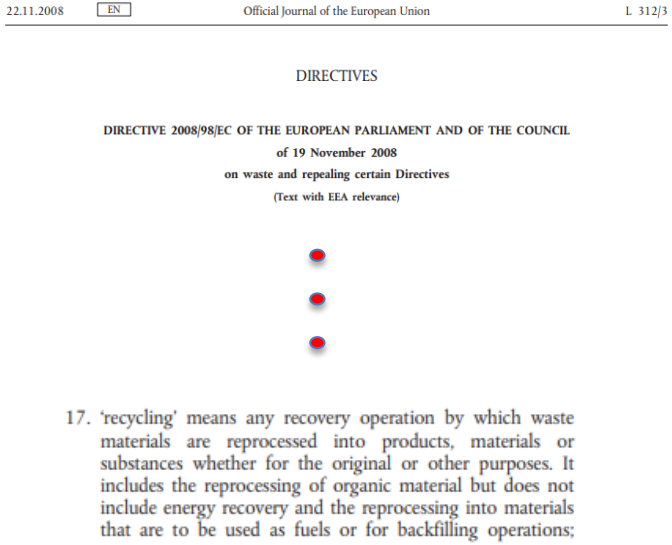
Complexity of products:

- Polymer
- Monomer
- Chemicals
- Syngas

Complexity of waste:

- Single materials
- Mixed materials
- Polluted materials
- Solid recovered fuel
- Car fluff

Is it really chemical recycling?



22.11.2008 EN Official Journal of the European Union L 312/3

DIRECTIVES

DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 19 November 2008
on waste and repealing certain Directives
(Text with EEA relevance)

17. 'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;

Fate of products of chemical recycling technologies

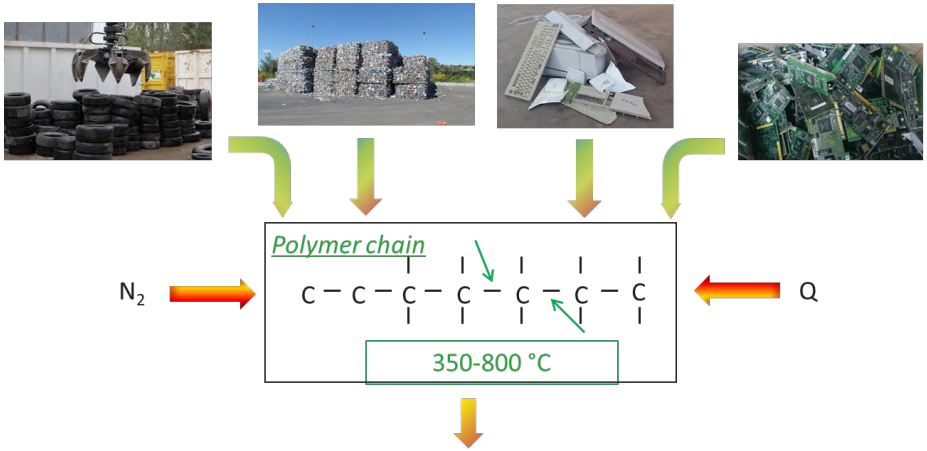
X Direct combustion – energy production

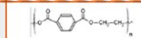
X Fuels

✓ Chemicals / Synthesis intermediates

✓ Monomers

Pyrolysis



RESIN	STRUCTURE	MAJOR ORIGIN OF WASTE	THERMOLYSIS PRODUCT	
PE		Household, industrial plastic packaging, agricultural plastics	Waxes, paraffins, olefins	OIL REFINERY FEEDS > CHEMICALS, DIESEL
PP		Household and industrial plastic packaging, automotive	Waxes, paraffins, olefins	
PS		Household, industrial plastic packaging, construction, demolition, WEEE	Styrene, its oligomers	MONOMERS
PA-6		Automotive waste	Caprolactam	
PMMA		Automotive, construction waste	MMA (methyl methacrylate)	
PET		Household plastic packaging	Benzoic acid, vinyl terephthalate	UPGRADING > CHEMICALS, FUELS
PUR		Construction, demolition, automotive	Benzene, methane, ethylene, NH3, HCN	
PVC		Construction plastic waste	HCl (< 300C), benzene	

- Process parameters
- Plastic load
- Geometry reactor
- Catalysts

Pyrolysis – Pros & Cons

- Low quality of plastic feedstock
  - Heterogeneous mixtures
  - Thermosets
  - Composite and laminate materials
  - Deteriorated plastics
  - Contaminated plastics by foreing materials
- Product selection
- Industrial integration
- Energy storage
- Simple and advantageous process
- Low gas volumes
- Recovery of not oxydezed metals

- Low quality of plastic feedstock often means low quality of the products
- Feedstock availability and selection
- Upgrading of the products
- Fate of the products
- Industrial integration
- Low yields and self-sustained heating
- Formation of unwanted products, such as wax, tar, corrosive acids,…
- Toxicity of feedstock and products
- Non – existent analytical standards
- Plant solution: choice of the reactor and pretreatment units

Potential solutions

- ✓ Integration with refineries and chemical plants
- ✓ Acceptance of chemical recycling as an integral solution
- ✓ Establishment of End-of-Waste criteria to pyrolysis oil
- ✓ Access to waste
- ✓ Promote the principles of a chain of custody mass balance approach
- ✓ Implement and enforce the existing waste legislation
- ✓ <u>Enable investments</u>

REACH COMPLIANCE

End of Waste

BASF We create chemistry

eni

Chevron Phillips CHEMICAL

NextChem Maire Tecnimont for Energy Transition

bp

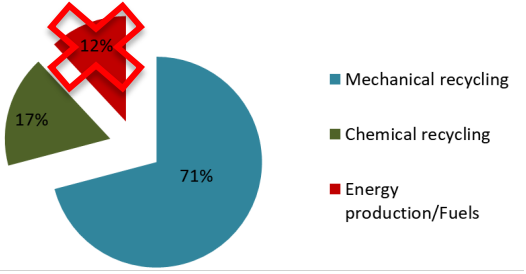
Continental

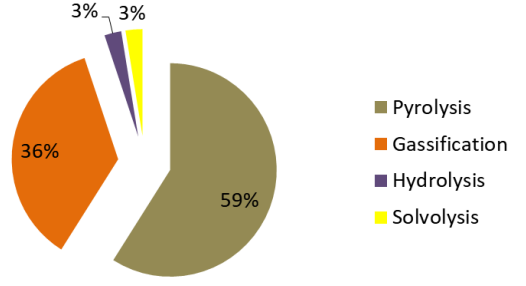
ENEA

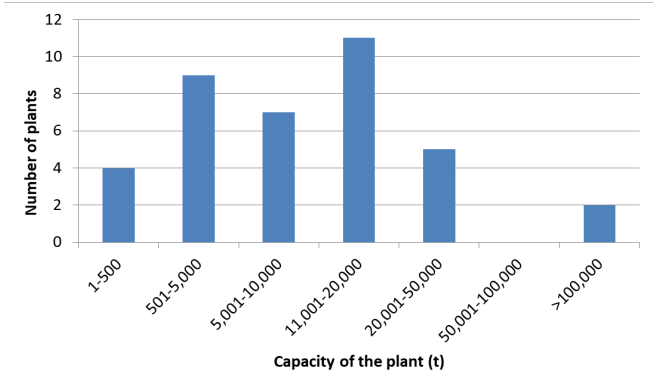
PNNR on plastic waste

The National Recovery and Resilience Plan, Investiment 1.2 – “Lighthouse” projects for circular economy has allocated 265 M€ for the plastic waste line.

134 project proposals presented by Italian private companies





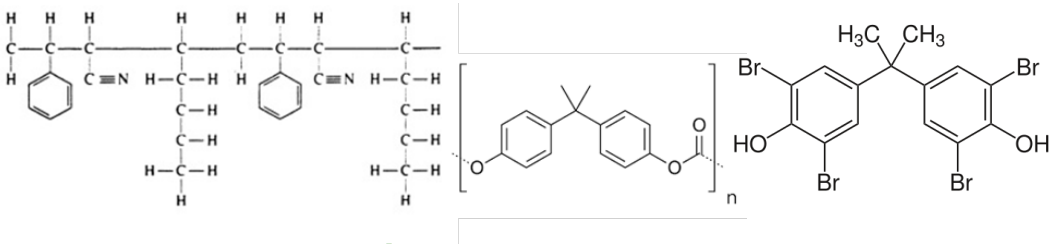


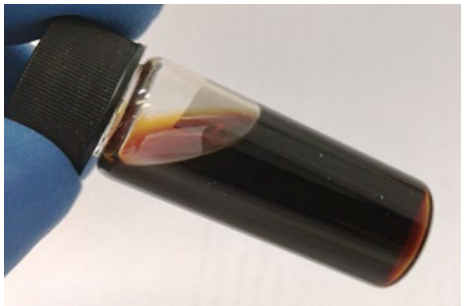
Average capacity: 21 kt

Geographic distribution of of the projects

What ENEA does about pyrolysis of plastics I

Plastics from small WEEE (ABS, PC, HIPS,…) + brominated flame retardants





400 °C, N_2

- Monoaromatics:
  - Benzene,
  - Styrene,
  - Toluene,
  - Phenol,…

55 %wt

- Nitrogen compounds
- Brominated compounds
- Oxygenated compounds
- Polycyclic aromatic hydrocarbons

➢ **Upgrading processes of oil from difficult plastic streams:**

- Catalytic pyrolysis
- Hydrotreating
- Distillation

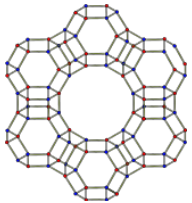
What ENEA does about pyrolysis of plastics II

➢ **Synthesis of low-cost catalysts from industrial waste:**

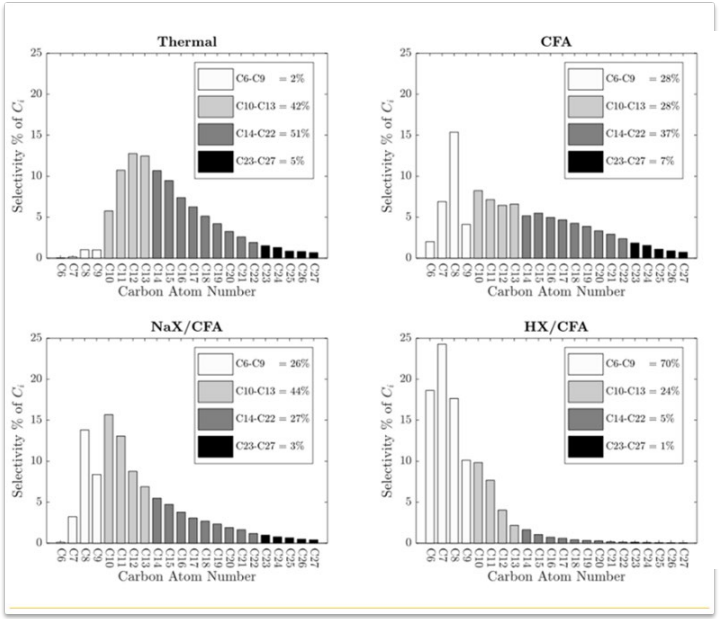
Coal Fly Ash

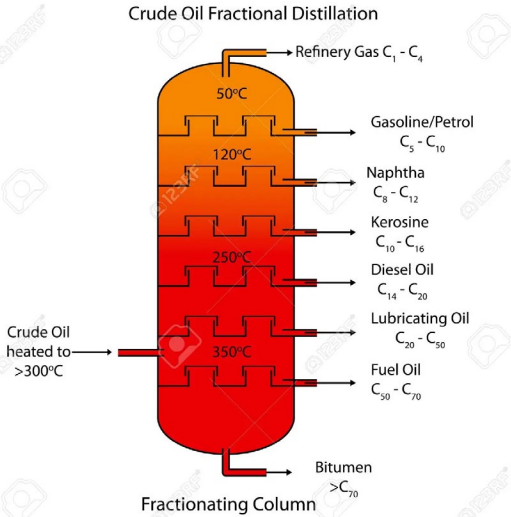
Red Mud

Hydrothermal process



Zeolitic catalysts



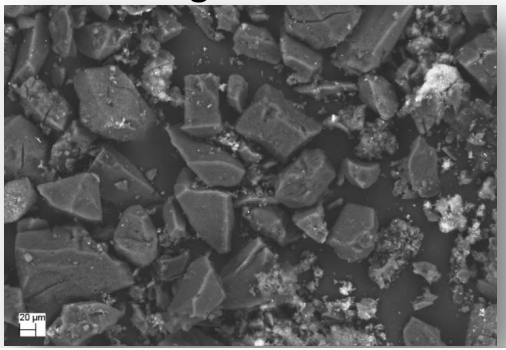


What ENEA does about pyrolysis of plastics III

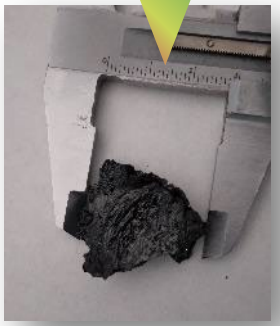
- **Valorization of pyrolysis by-products**

Thermochemical process

Adsorbing material



Specific surface area = 1841 m²/g



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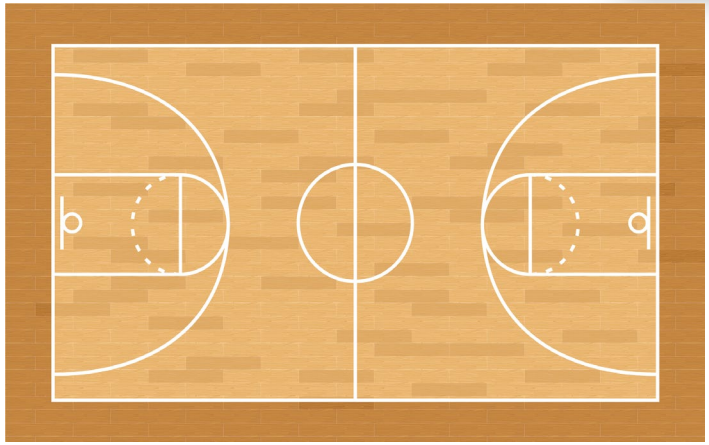

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Thank you for your attention!