

Plastic Recycling: from Technology to Business

Meet the Industry

ing. Edoardo Vitto
Responsabile Tech Transfert
a2a Life Ventures

Milano, 25 marzo 2026



Contents

1. Meet a2a
2. What are plastic wastes?
3. Mixed plastic waste composition
4. Plastic waste treatment: current scenario
5. Advanced recycling processes
6. Mixed plastic waste pyrolysis
7. Plastic pyrolysis naphtha as steam cracking feedstock
8. Conclusions

MEET a2a

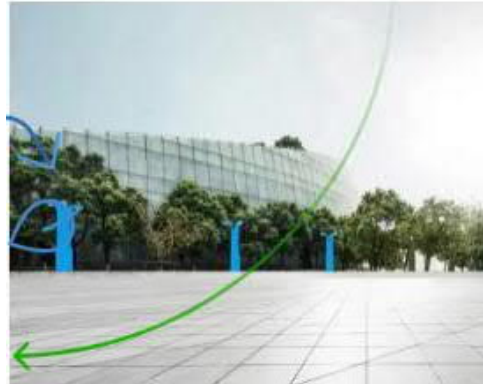


Energy

Production and sale of electricity, gas and energy efficiency and electric mobility services



Second operator
on Energy in Italy
for installed capacity
and 4th on renewables



Network services

Electricity and gas distribution



Second operator
on Electric networks in Italy
for distributed energy

BU Circular Economy




Circular economy

From integrated waste management to material and energy recovery, water management and district heating




First operator
on waste in Italy
for treated waste


Economics 2024

 **Operating profit**

864
million euros

 **EBITDA**

2.328
million euros

 **Employees**

Approximately
14,000
Group employees

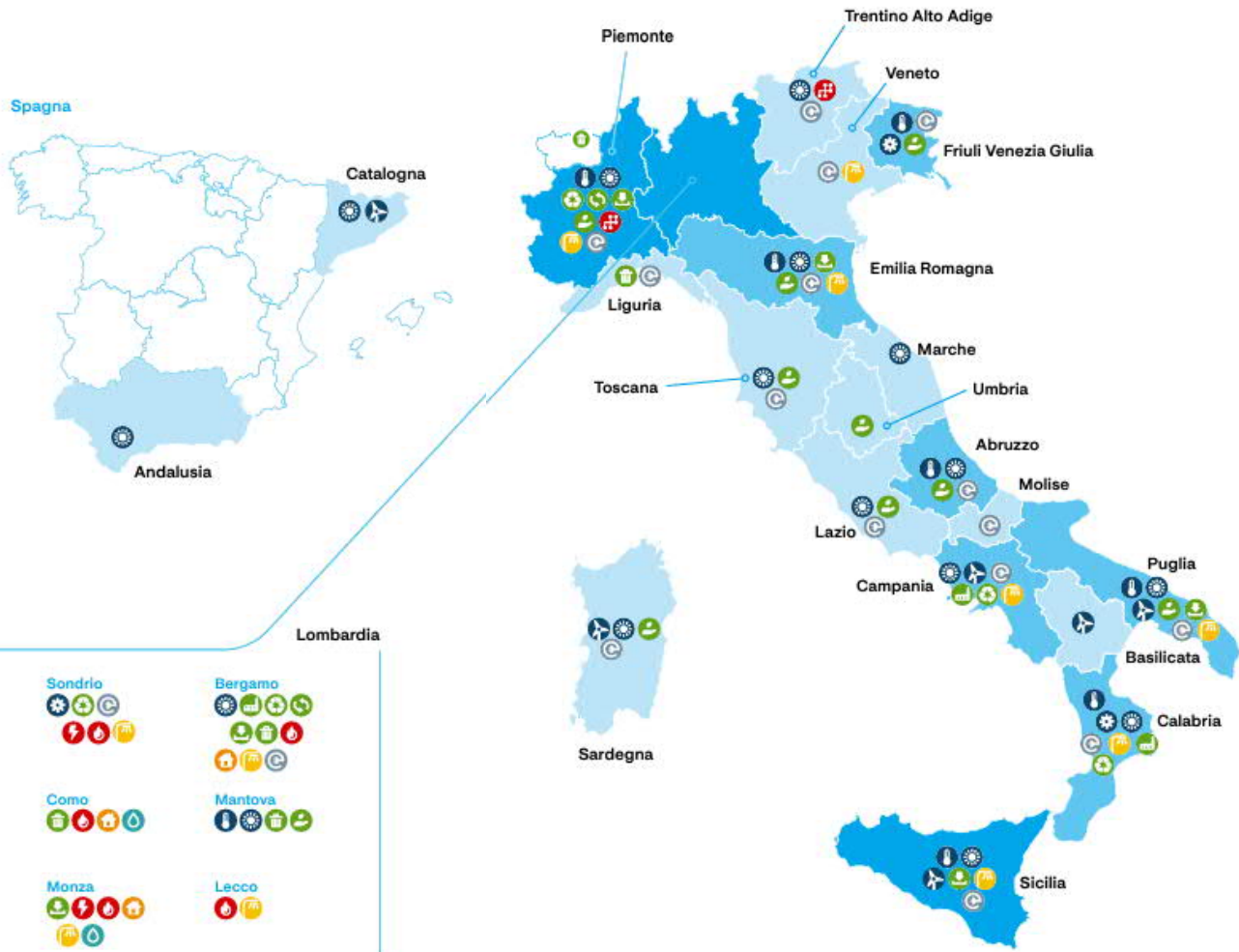


MEET a2a - GEOGRAPHICAL LOCATION

Impianti e servizi del Gruppo A2A

Impianti		
Energia	Termoelettrico	
	Idroelettrico	
	Fotovoltaico	
	Eolico	
Ambiente	Termovalorizzatore	
	Impianto trattamento rifiuti	
	Impianto recupero materia	
	Discarica	
	Produzione biogas	

Servizi		
Rifiuti	Raccolta rifiuti	
Distribuzione e trasporto	Distribuzione energia elettrica	
	Distribuzione gas	
	Trasporto gas	
Teleriscaldamento	Teleriscaldamento	
Acqua	Servizio idrico integrato	
Illuminazione	Illuminazione pubblica	
Mobilità elettrica	Colonnine ricarica e-Moving	



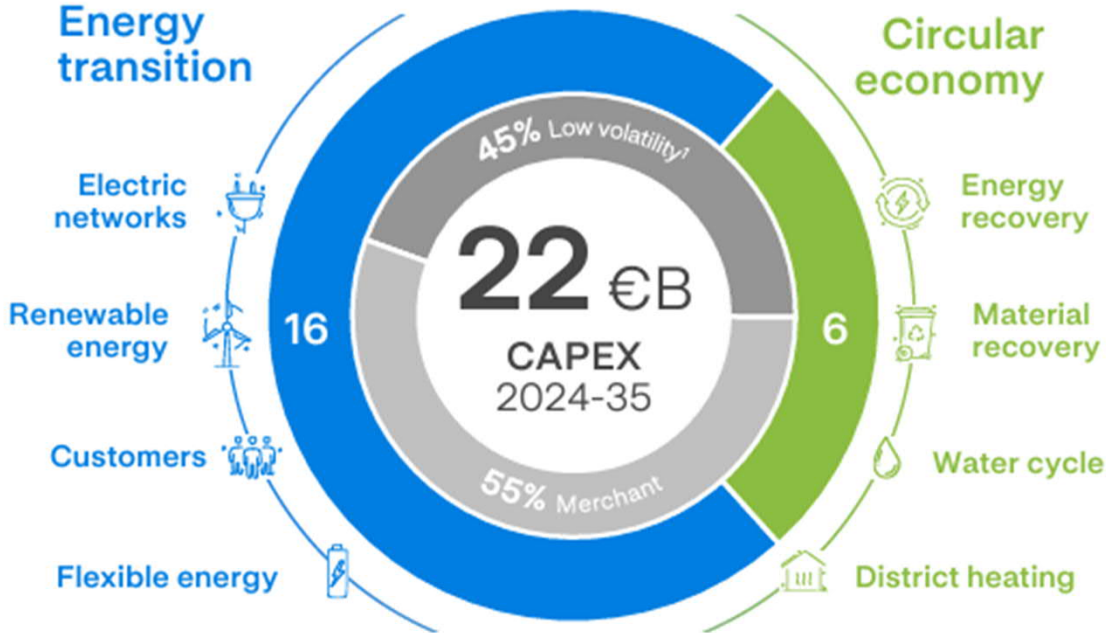
Lombardia

Milano 	Brescia - Sede Legale 	Sondrio 	Bergamo
Pavia 	Varese 	Como 	Mantova
Lodi 	Cremona 	Monza 	Lecco

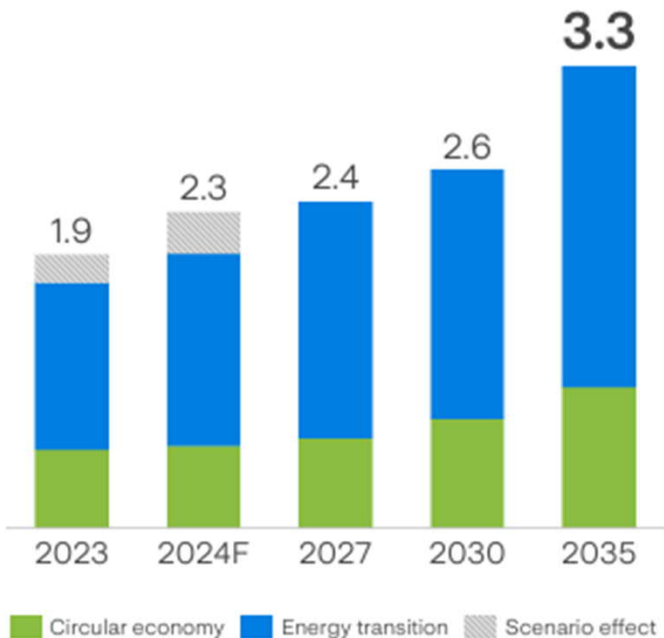
MEET a2a – STRATEGIC PLAN

Strategic pillars to support the ecological transition

CAPEX by pillar | €B



EBITDA by pillar | €B



MEET a2a - LIFE VENTURES: MULTILEVEL INNOVATION



Multilever Innovation

A multi-level system to tackle the new challenges of the ecological transition

The A2A Life Ventures model integrates various innovation programs and tools into a single, coherent system. This approach makes it possible to activate, each time, the most suitable project pathway to capture and develop new opportunities.

In this way, the model supports the entire innovation lifecycle from ideation to implementation, including the management and enhancement of intangible assets.

FIGURE 4: MULTILEVER INNOVATION MODEL



MEET a2a - CVC PROJECTS

Waste Analytics - Robot Validation

AI combined with industrial robots for the automatic sorting of plastic materials.



Energy Dome

Investment in a technology that enables the long-term storage of large amounts of energy through the CO₂ Battery.



Pallon: looking for more efficient sewer networks

Use of AI to analyze and optimize sewer networks.



MEET a2a - INNOVATION PROJECT

Underground Compact Substation

Design and development of a fully underground and waterproof electrical cabinet, ready for use in urban and industrial settings



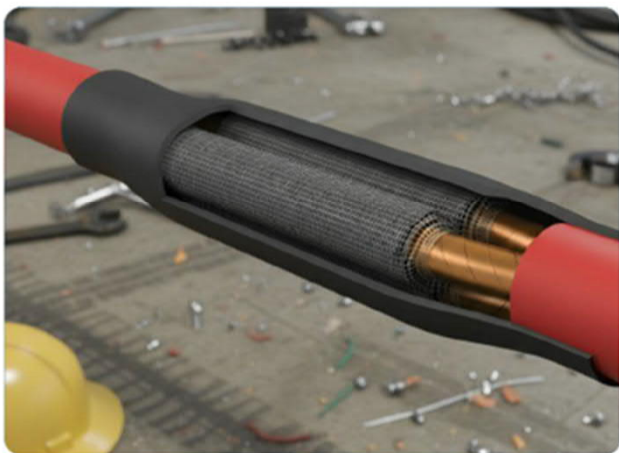
Glass Collection Noise Reduction

Co-development of a solution to be applied to collection vehicles to mitigate noise

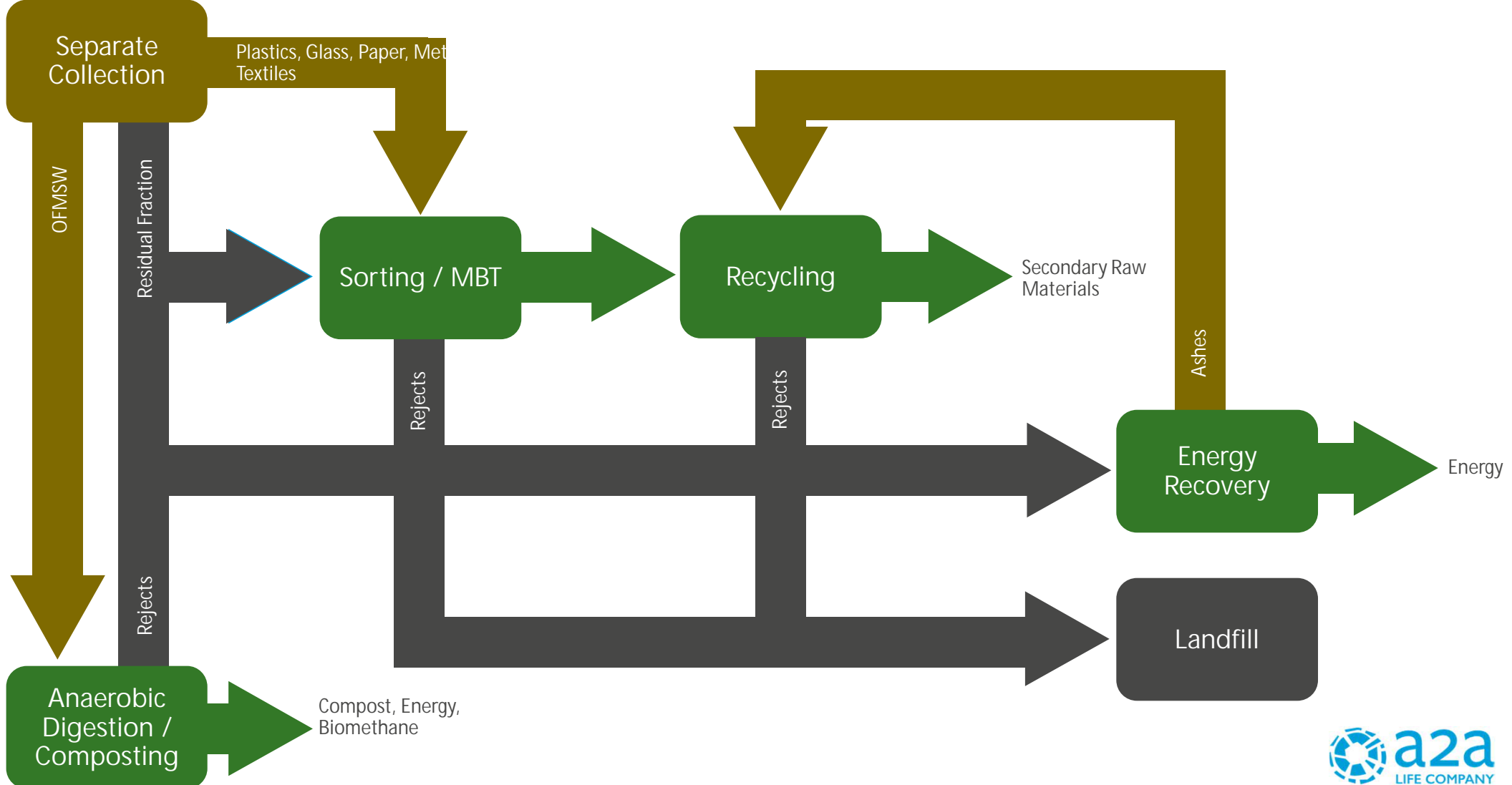


MV End Cable Automation

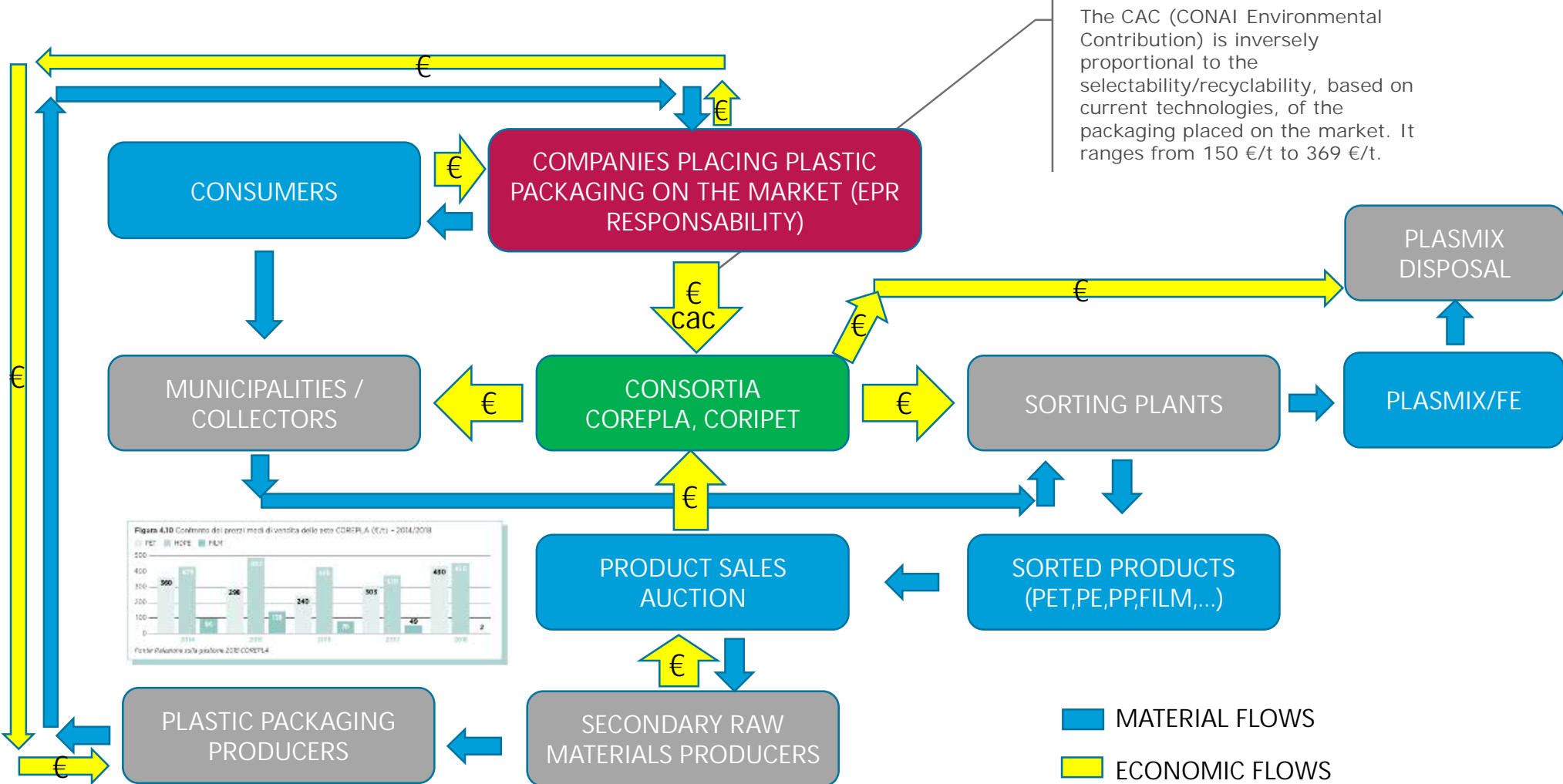
Design and development of robotic prototypes to automate the packaging of medium-voltage joints.



MEET a2a – MUNICIPAL SOLID WASTE MANAGEMENT

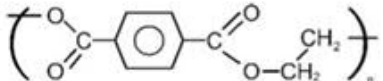

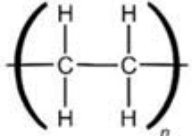

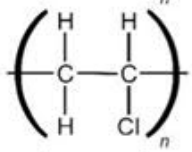

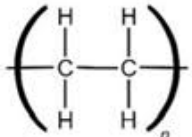

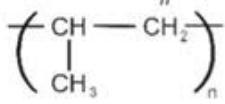

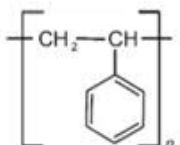



MEET a2a - THE CONSORTIUM SYSTEM: SCHEMATIC OVERVIEW



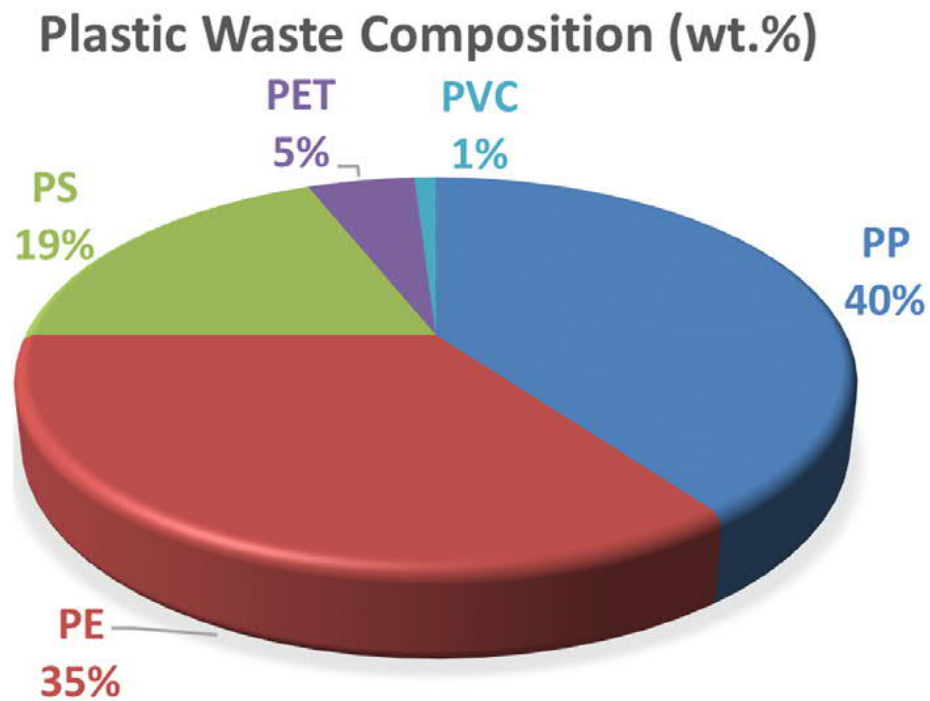
WHAT ARE PLASTIC WASTES?

Main polymers present in mixed plastic wastes

Plastic name (SPI code)	Chemical structure	Degradation Temperature	Applications	Example
PET (1)		> 300 °C	Sheets, films, plastic bottles, and food trays.	
HDPE (2)		> 400 °C	Milk and shampoo bottles, detergent containers.	
PVC (3)		250 – 350 °C: dechlorination > 350 °C: further degradation	Pipes, electrical wiring insulation, and wall covering.	
LDPE (4)		> 400 °C	Ziploc bags, plastic bags, cling wraps, and agricultural films.	
PP (5)		> 370 °C	Food packaging, microwave-safe containers.	
PS (6)		> 300 °C	Styrofoam, plastic utensils, building insulation, and packaging.	

MIXED PLASTIC WASTE COMPOSITION

Mixed plastic waste polymeric composition



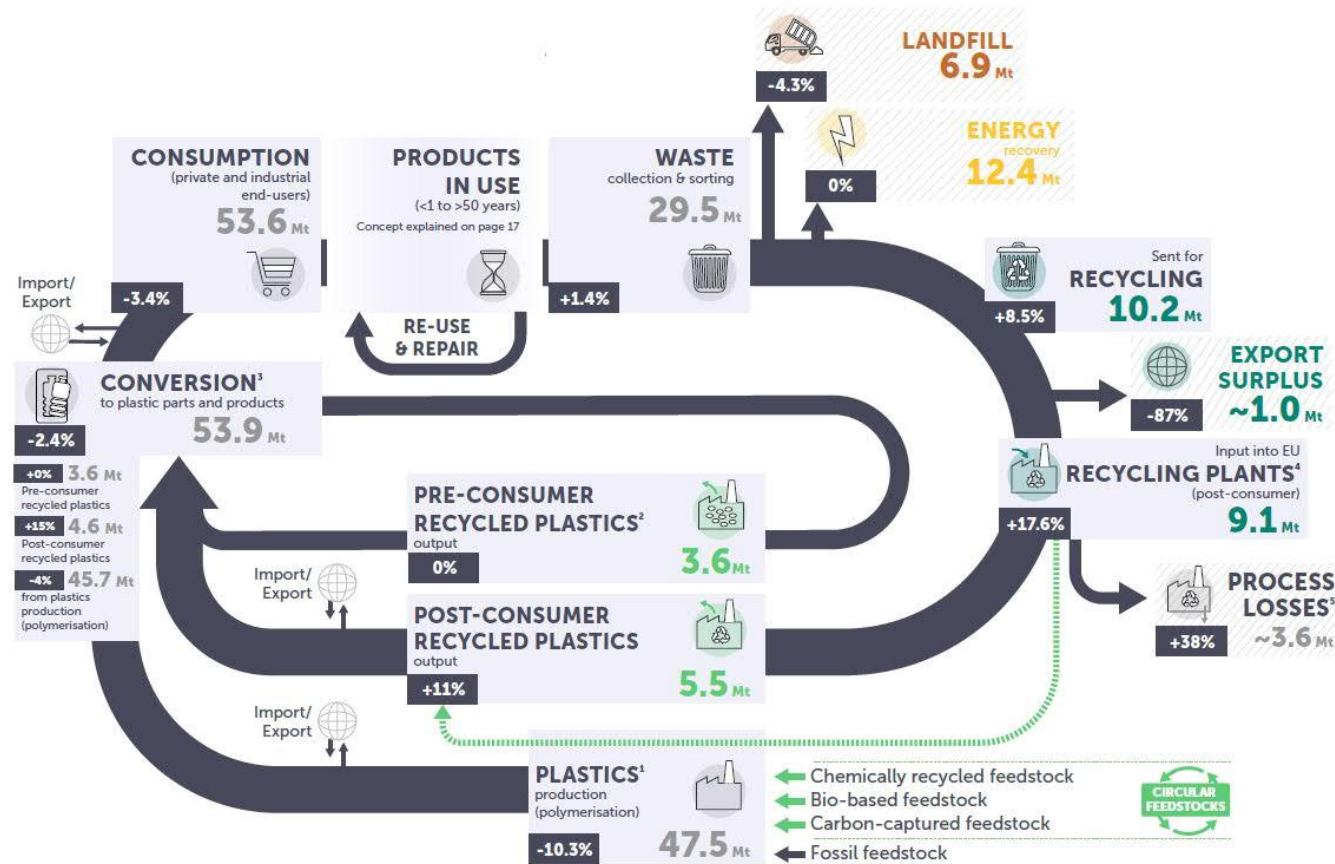
- Plastic wastes composed by several polymers (and other non-polymeric contaminants in traces).
- After removal of PET, representing usually the largest quantity, a residue constituted by other 5 major polymers is obtained

PLASTIC WASTE TREATMENT: CURRENT SCENARIO

European scenario (EU+3*)

Plastic materials life cycle (data referring to 2020)

Figures in black squares referring to shifts between 2020 and 2018

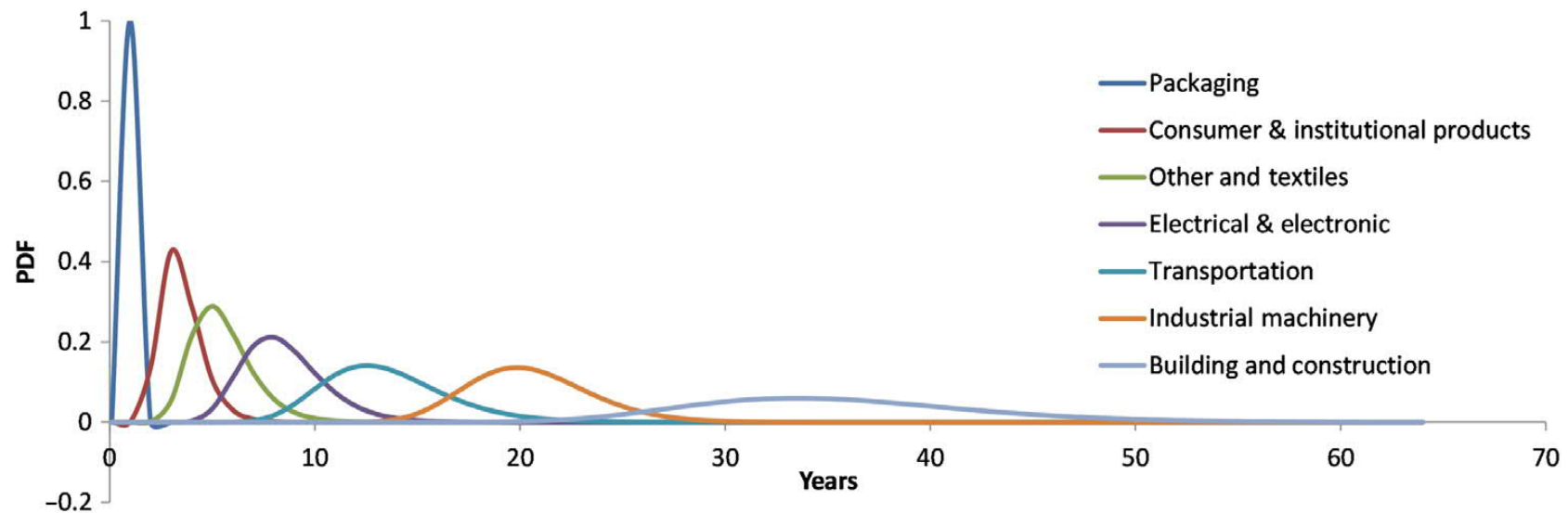


*EU+3: all European Union member states plus Iceland, Liechtenstein and Norway
Plastics Europe, "The Circular Economy for Plastics – A European Overview 2022", 2022.

PLASTIC WASTE TREATMENT: CURRENT SCENARIO

Plastic products life span

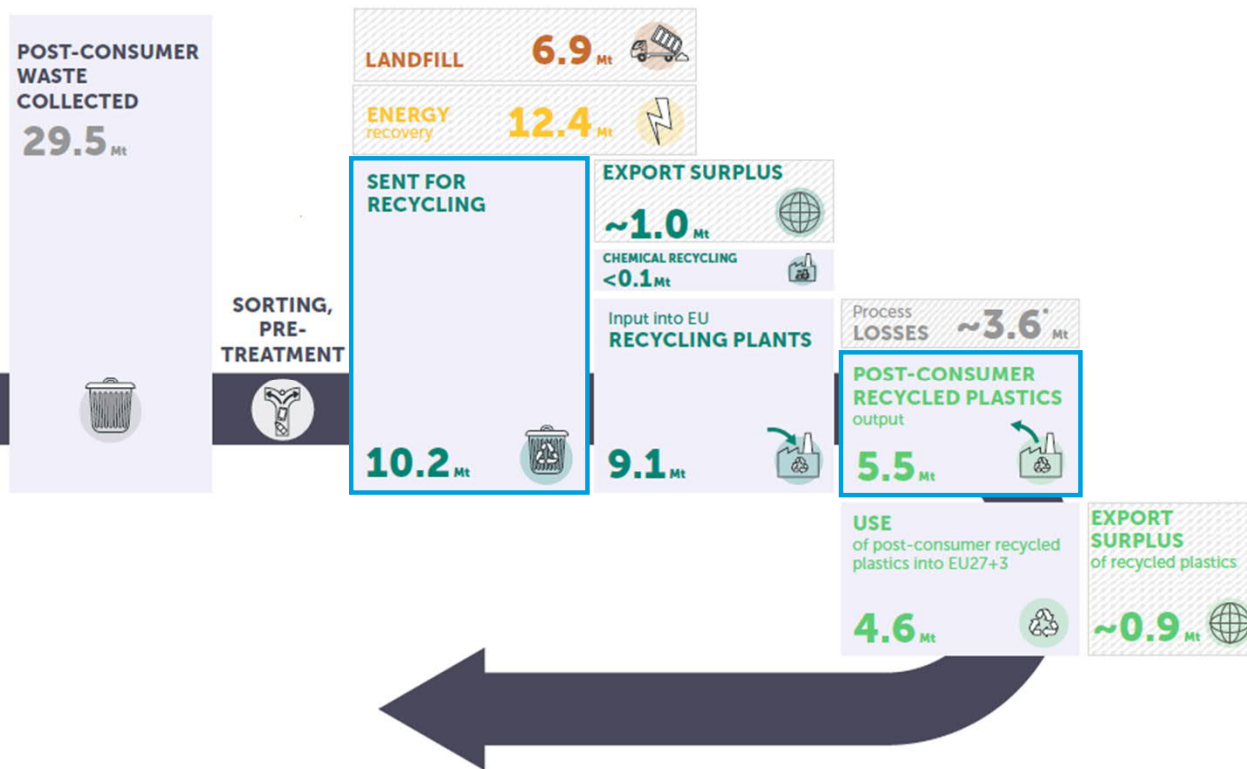
According to specific products, large differences in life span, from few months for packaging, to several decades for building and construction plastic products.



Probability density function (PDF) of lifetime of several plastic products categories

PLASTIC WASTE TREATMENT: CURRENT SCENARIO

European scenario (EU+3*) V: focus on plastic waste recycling



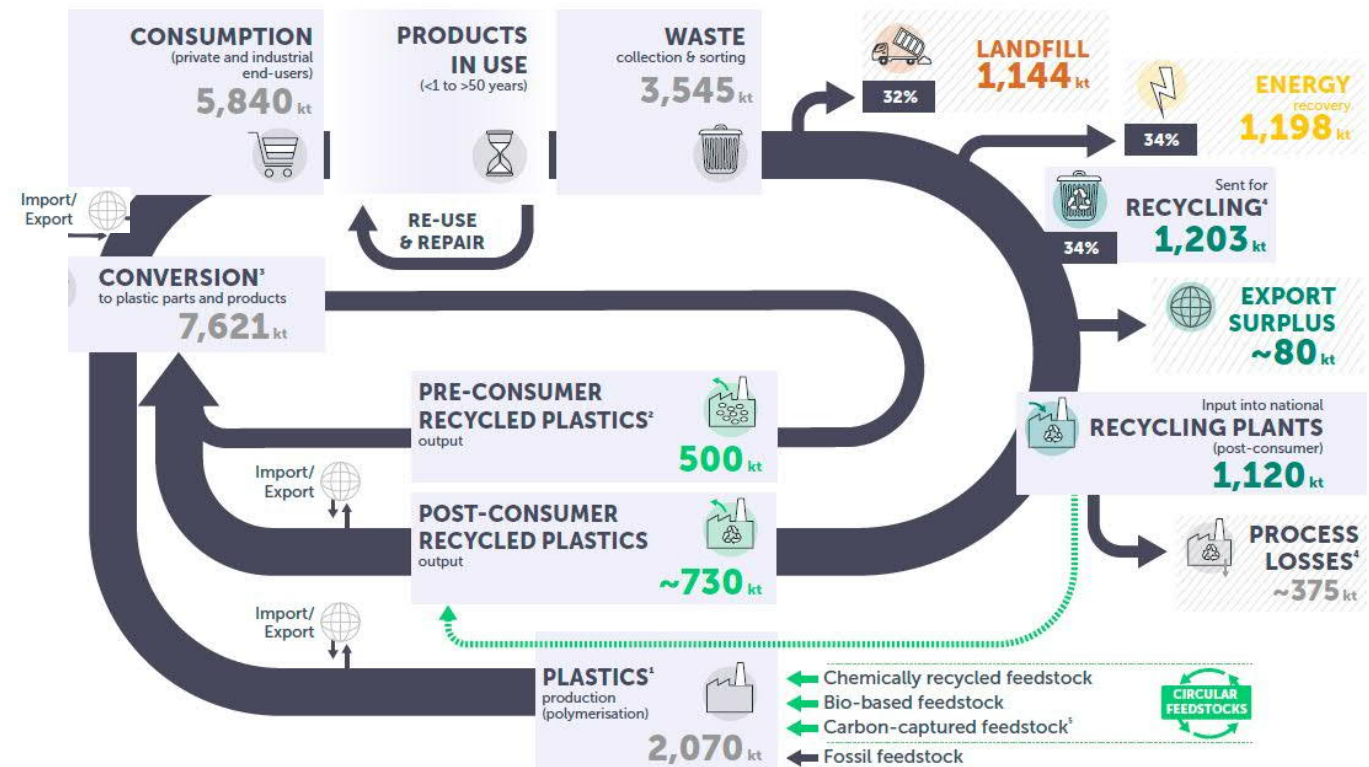
- Recycling mismanagement: currently a rather low quantity of plastic wastes is actually recycled in the European value chain (4.6 million tonnes in 2020)
- Large losses (3.6 million tonnes), which are sent to landfill or energy recovery.
- Recycling rate vary broadly according to different definitions: 34.6 % vs 18.6 %

*EU+3: all European Union member states plus Iceland, Liechtenstein and Norway
 Plastics Europe, "The Circular Economy for Plastics – A European Overview 2022", 2022.

PLASTIC WASTE TREATMENT: CURRENT SCENARIO

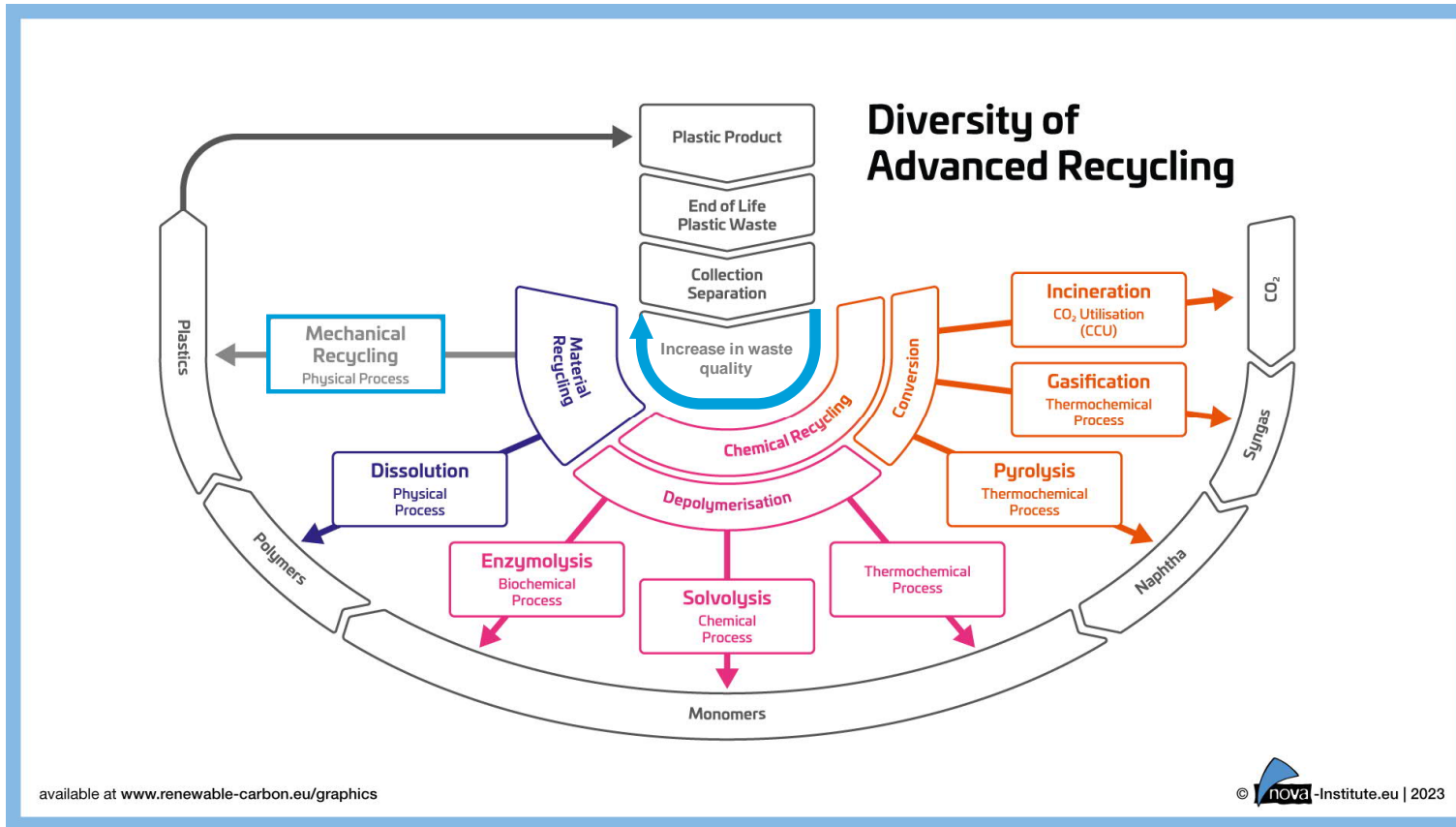
Italian scenario

- In Italy larger share of landfilling (32.3 % versus 23.4 % in Europe).
- Lower share of energy recovery (33.8 % versus 42 %) and recycling (33.9 % versus 34.6).
- However, large recycling rate according to a more strict definition: 20.6 % versus 18.6 %.



ADVANCED RECYCLING PROCESSES

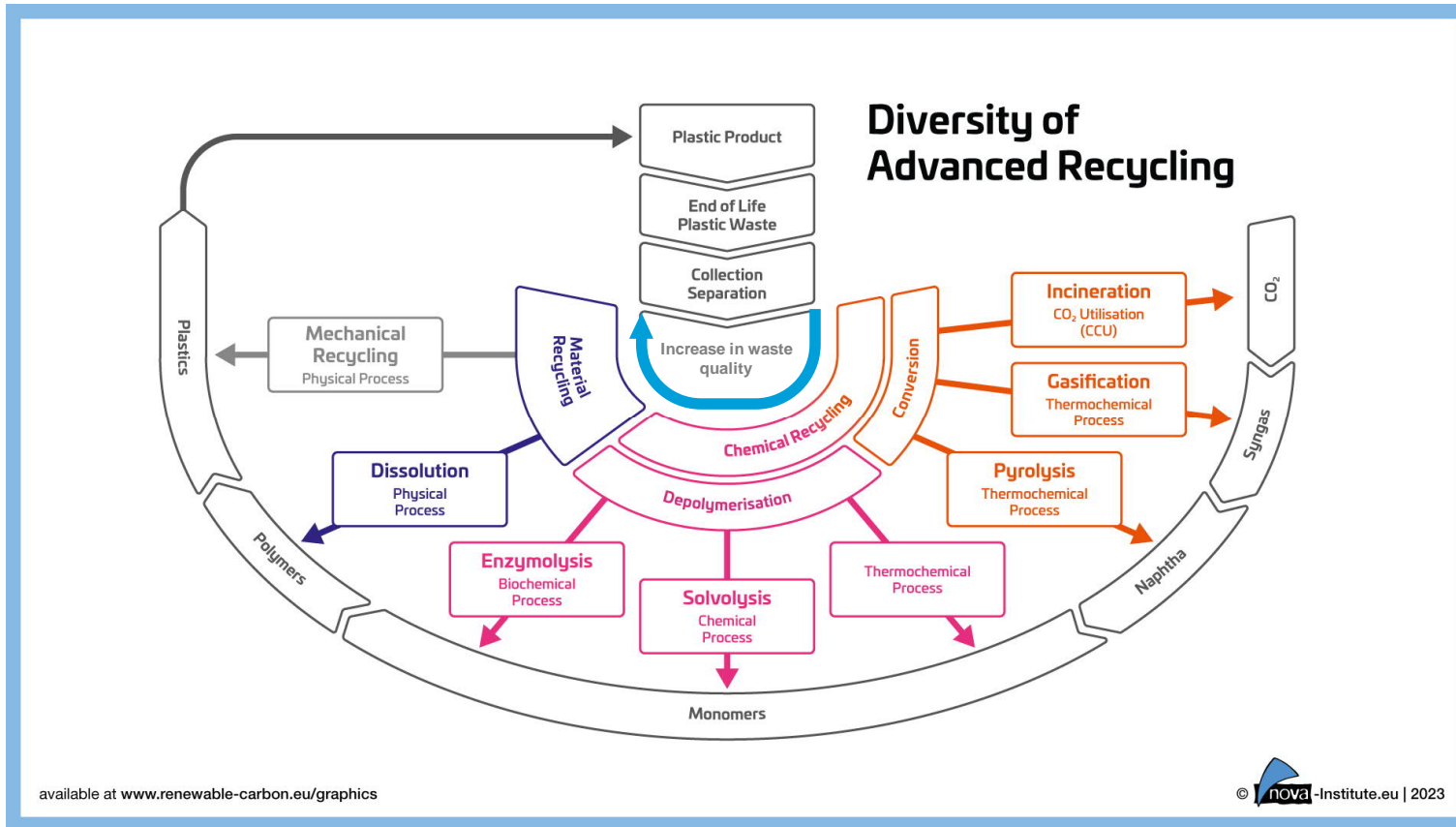
Innovative recycling routes I



- Current recycling process: mechanical recycling.
- Well-established and effective for single sorted polymers
- Degradation of polymeric chains occur, making not possible to obtain virgin quality feedstock: need for other processes to increase recycling rate

ADVANCED RECYCLING PROCESSES

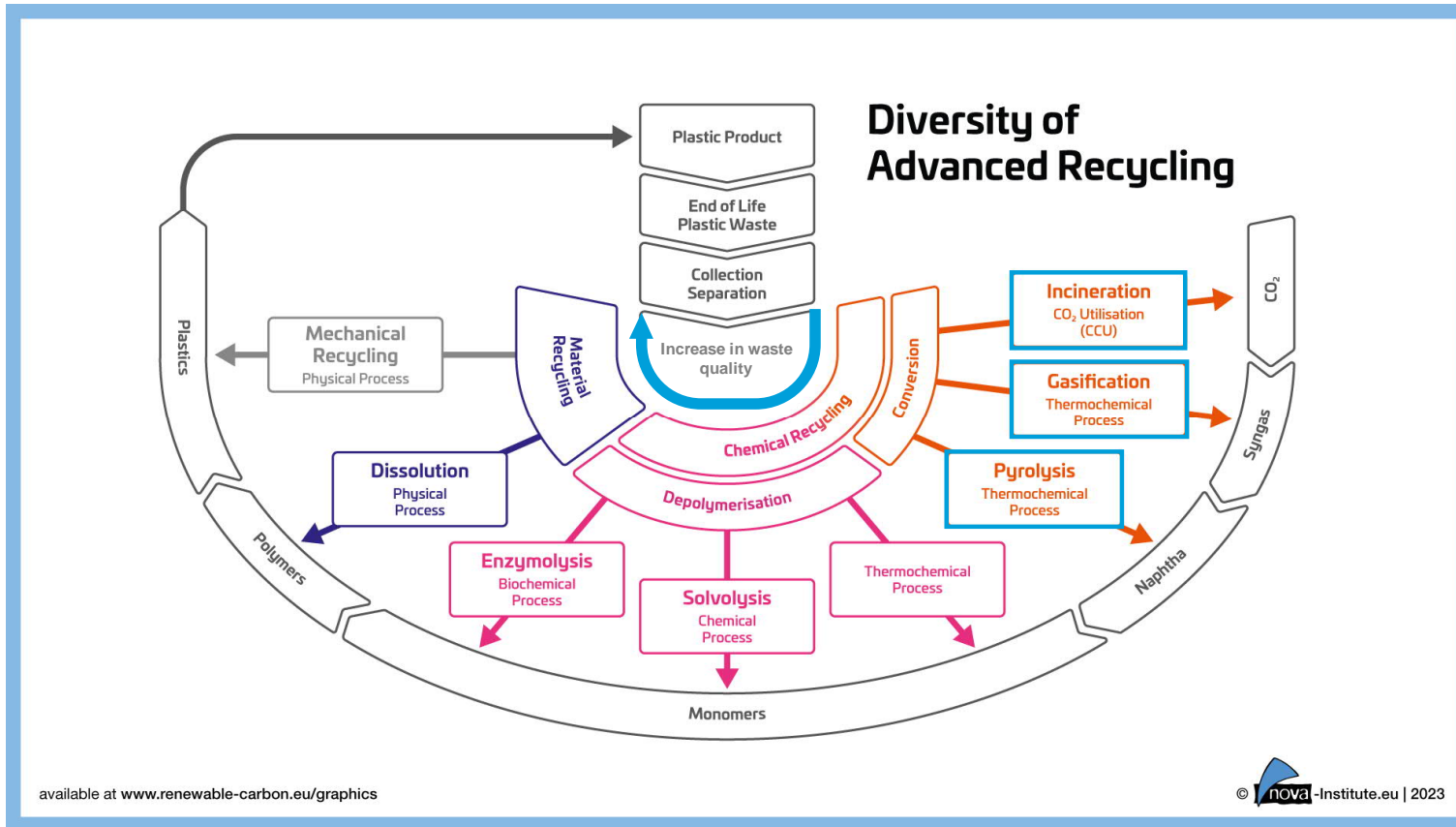
Innovative recycling routes II



- Different process outputs:
 - ❖ From plastics or chemicals building blocks as carbon dioxide or syngas (from gasification, mixture of CO and hydrogen)
 - ❖ To recovered polymers (from dissolution)

ADVANCED RECYCLING PROCESSES

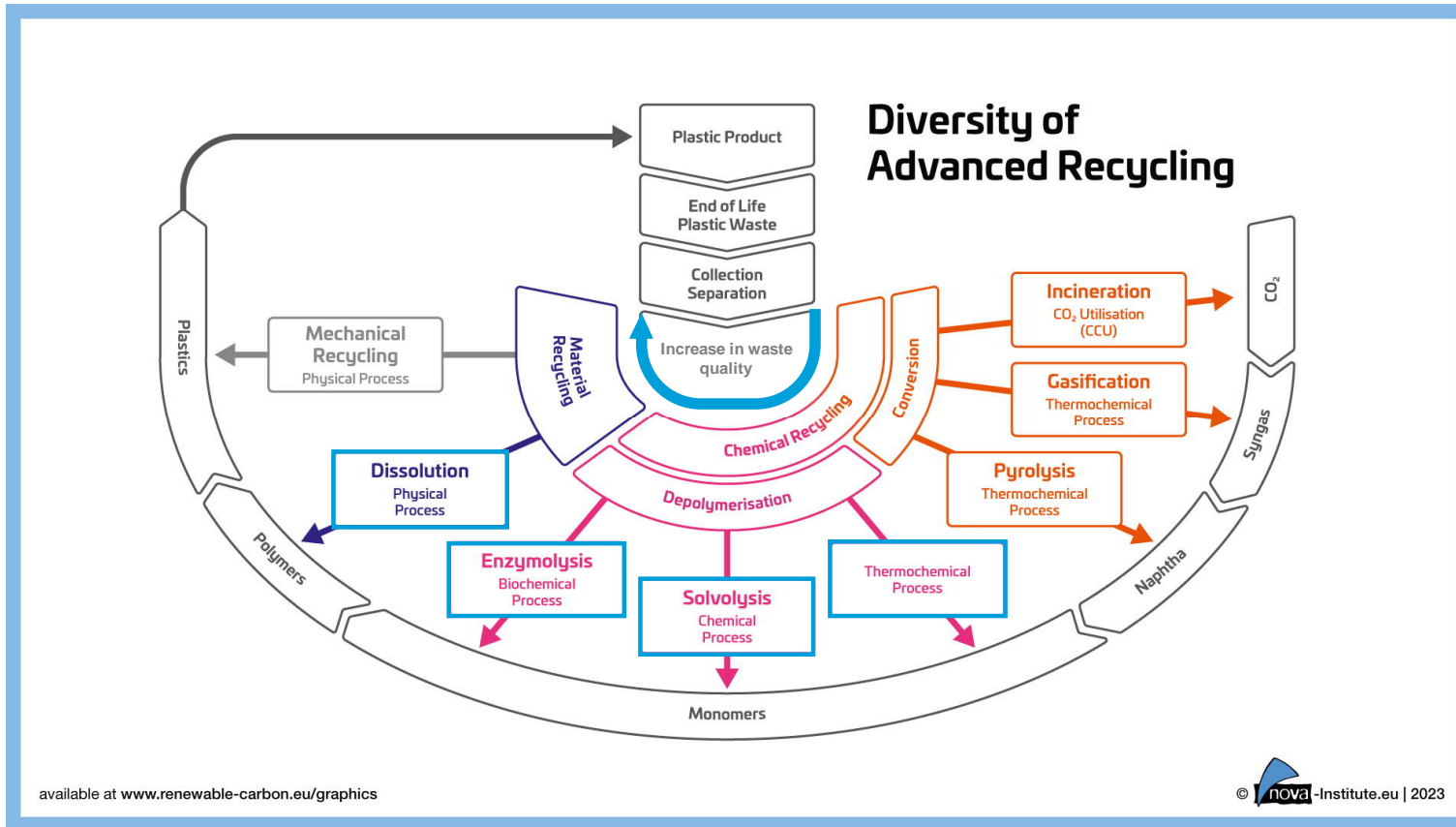
Innovative recycling routes III



- Different feedstocks:
 - ❖ Energy recovery with CCU, gasification and pyrolysis suitable for mixed plastic wastes (with proper polymeric composition)

ADVANCED RECYCLING PROCESSES

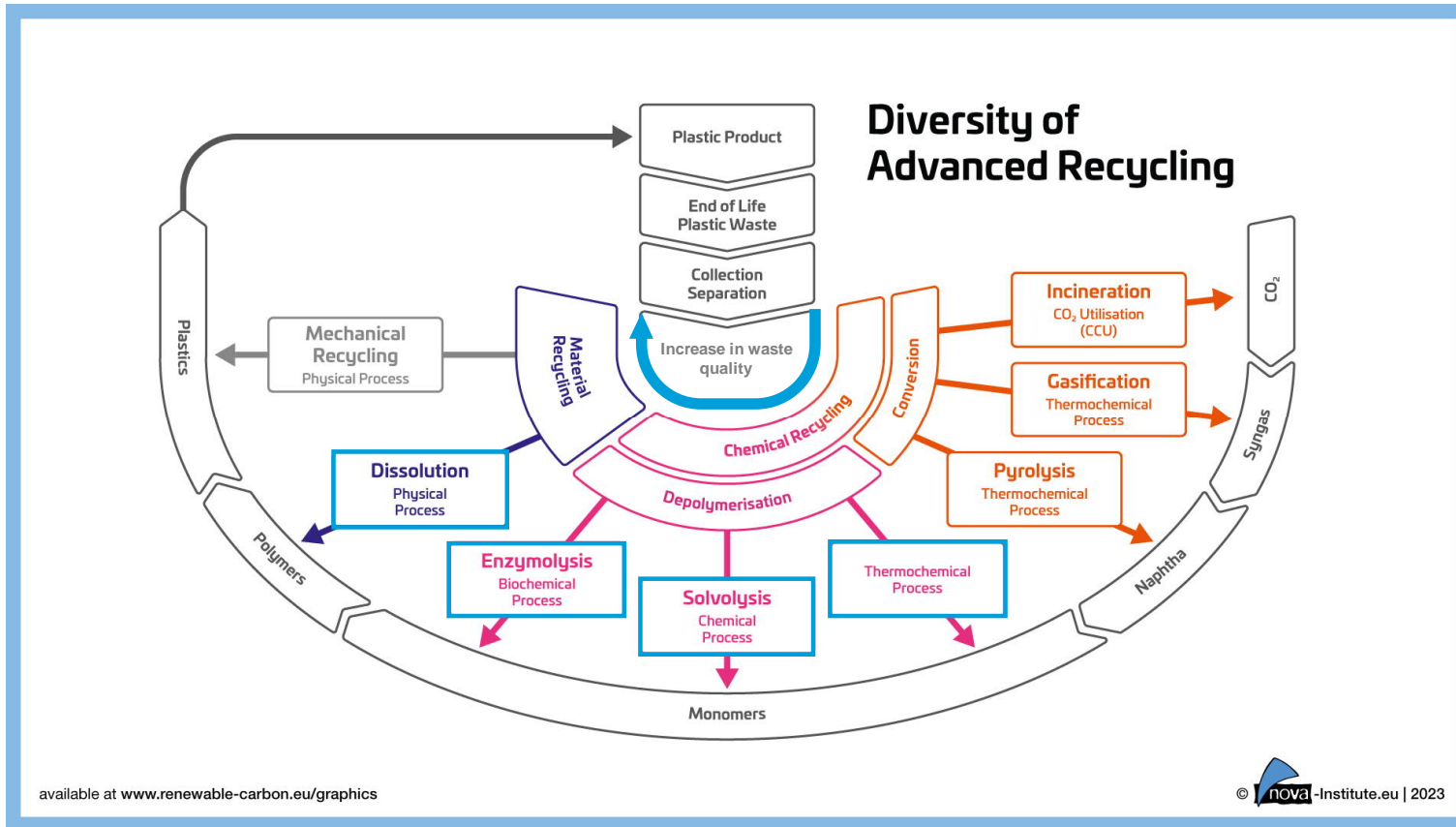
Innovative recycling routes IV



- Different feedstocks:
 - ❖ Energy recovery with CCU, gasification and pyrolysis suitable for mixed plastic wastes (with proper polymeric composition)
 - ❖ Depolymerizations and dissolution rely on properly sorted single polymers

ADVANCED RECYCLING PROCESSES

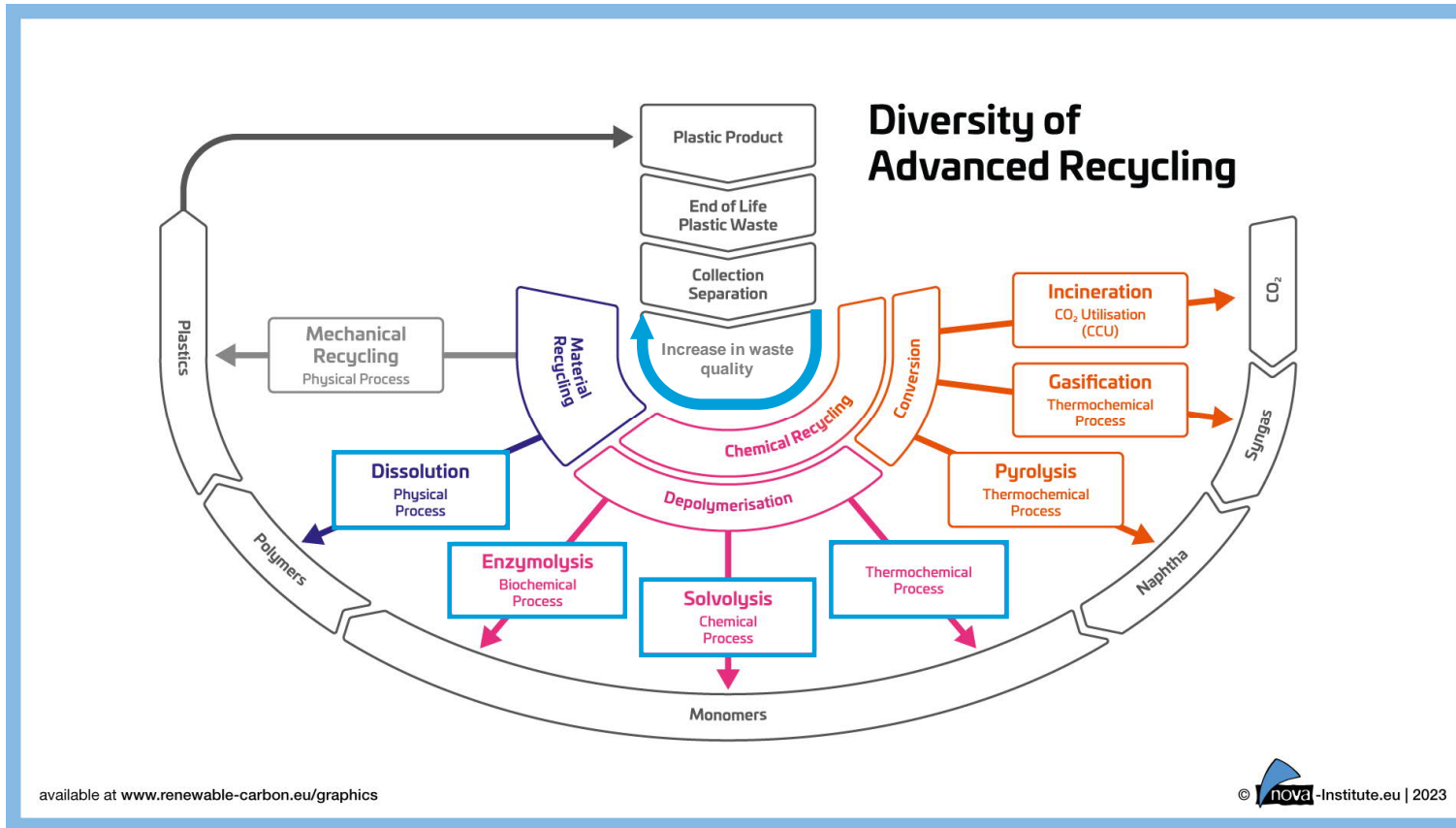
Innovative recycling routes V



- They can be considered alternatives to mechanical recycling (same sorted feedstock)
- Their implementation is not straightforward: higher costs and larger energy demand

ADVANCED RECYCLING PROCESSES

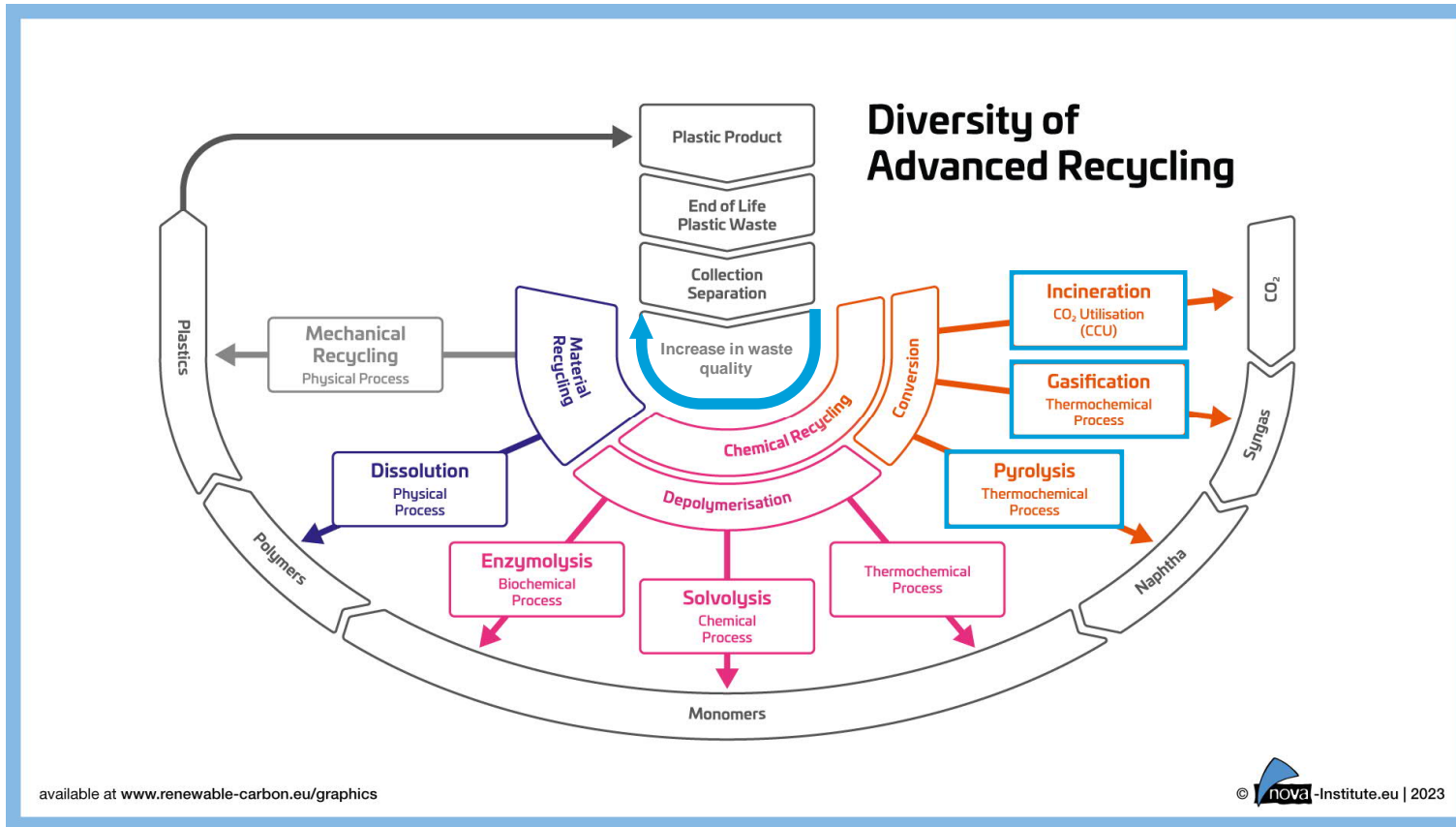
Innovative recycling routes VI



- In addition, every time a polymer sorting is done, a mixed plastics residue is obtained as by-product
- It cannot be effectively recycled mechanically or with depolymerizations or dissolution
- So, focus on mixed plastic waste recycling processes

ADVANCED RECYCLING PROCESSES

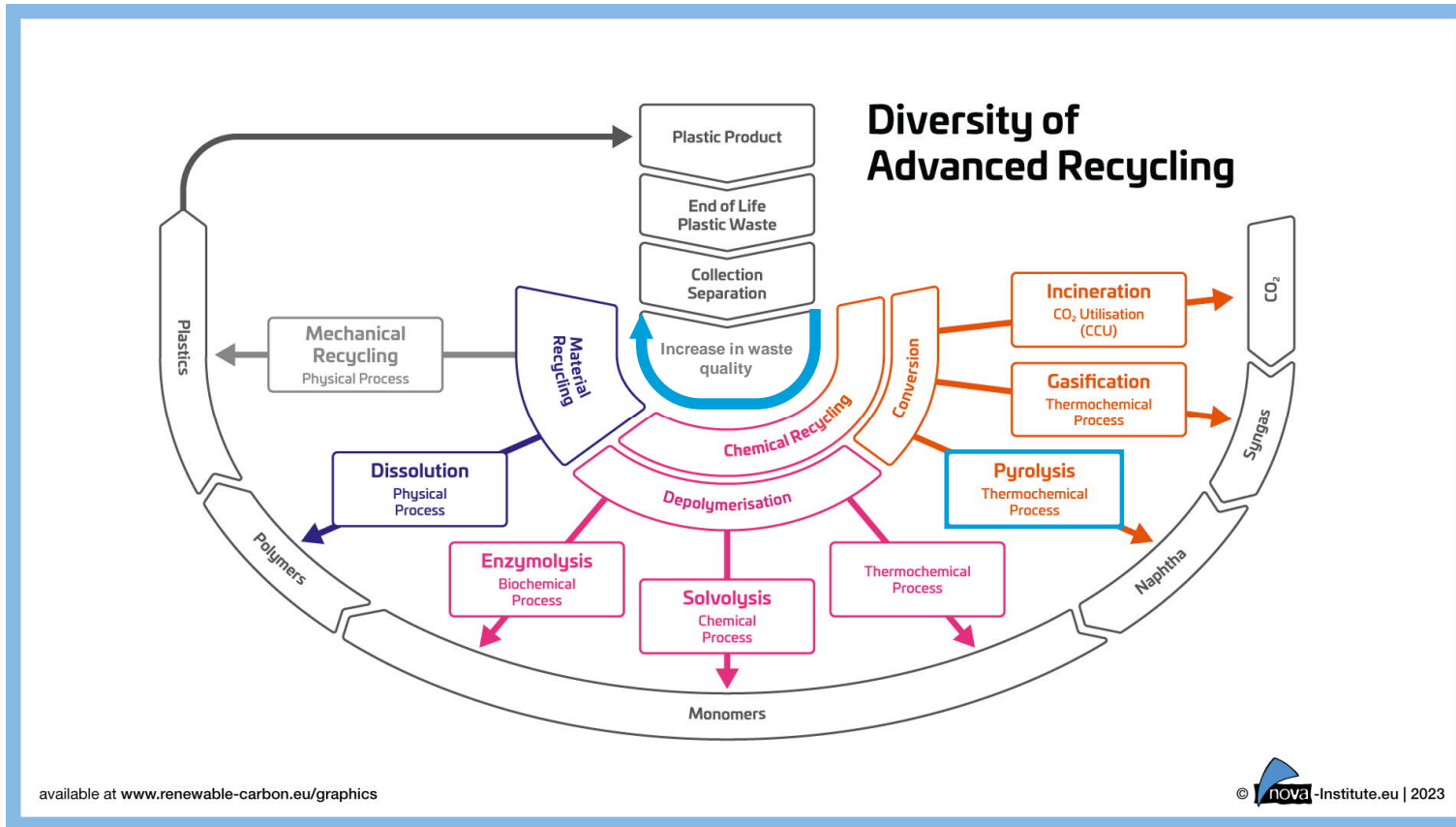
Innovative recycling routes VII



- Three main routes to convert mixed plastics in valuable feedstock:
 - ❖ Energy recovery coupled with carbon dioxide utilization: need for hydrogen as additional reagent
 - ❖ Gasification: energy intensive and need to further convert syngas in order to become economically viable

ADVANCED RECYCLING PROCESSES

Innovative recycling routes VIII



- ❖ Focus on pyrolysis: less energy intensive than gasification and production of a liquid hydrocarbon oil (naphtha and usually a heavier oil) which could be employed to produce new monomers of chemicals.

MIXED PLASTIC WASTE PYROLYSIS

Operating conditions I

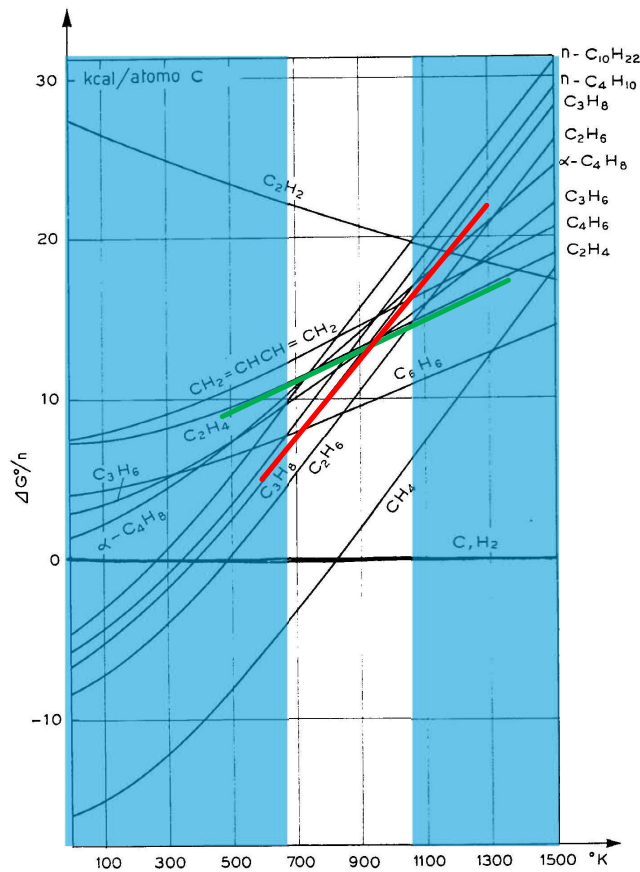
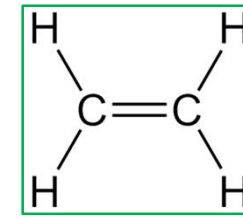
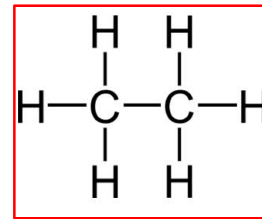


Fig. 7, III - Diagramma di FRANCIS per gli idrocarburi.

- Pyrolysis consists in the chemical decomposition, in absence of oxygen, of carbon-based materials through the action of heat.
- Typical pyrolysis temperatures: 400-800 ° C (673-1073 K)
- In the typical pyrolysis range, production of methane or carbon residues is favored. At the same time, **olefins** start to be favored with respect to **paraffins**.



Example of a paraffin (or alkane), **ethane**, and an olefin (or alkene), **ethylene**

MIXED PLASTIC WASTE PYROLYSIS

Operating conditions II

Heating rate and residence time influence product distribution: reacting system far from thermodynamic equilibrium

- Larger residence times shift the product distribution to coke (charcoal) and hydrogen, which are the stable products at the typical pyrolysis operating temperatures.
- Most common operating conditions: residence time close to 30 min and temperature of about 450 °C.

Process	Heating Rate	Residence Time	Temperature (°C)	Major Products
Slow carbonization	Very low	days	450–600	Charcoal
Slow pyrolysis	<5 °C/s	10–60 min	450–600	Char, oil
Fast pyrolysis	10–200 °C/s	0.5–5 s	550–650	Oil
Flash pyrolysis	1000 °C/s	<1 s	450–900	Oil, gas

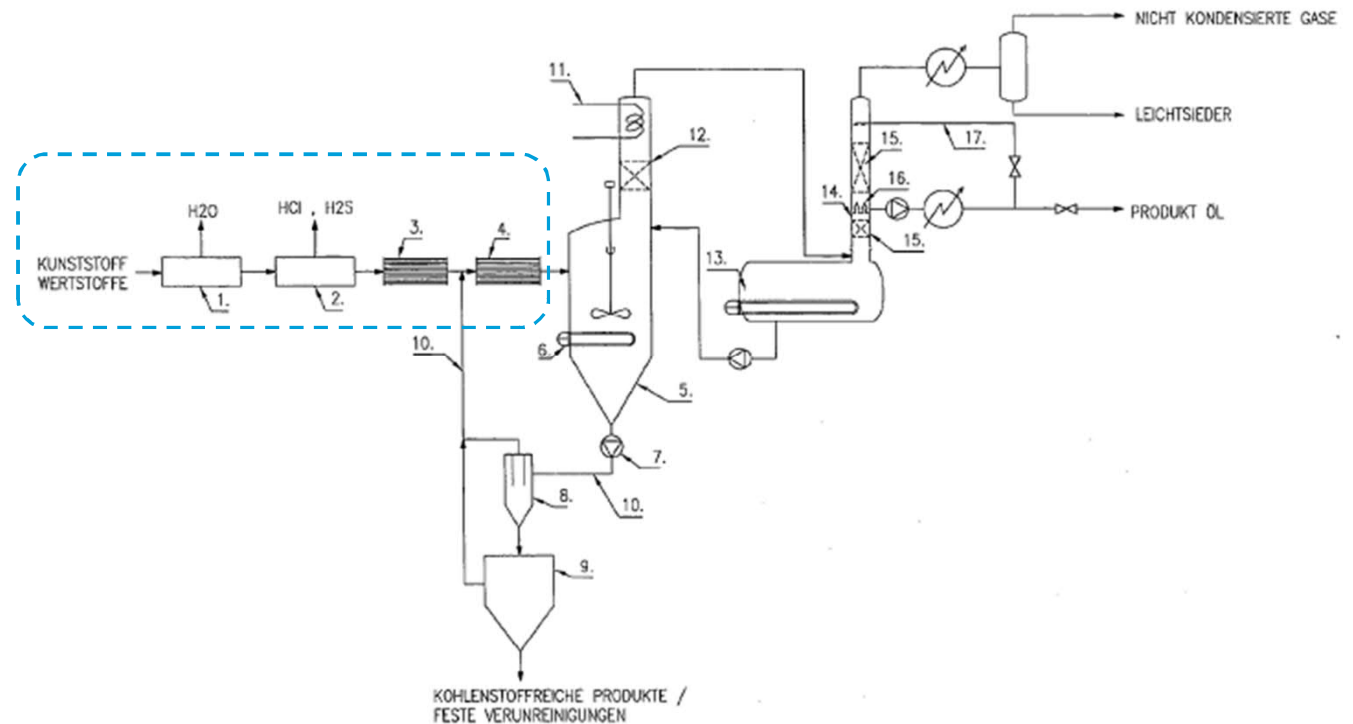
MIXED PLASTIC WASTE PYROLYSIS

Plant scale technology example: BlueAlp process flow diagram I

Plant sections:

- Pretreatments:

- ❖ Water removal unit (1), the first heating device (up to 120-150 °C).
- ❖ Pre-dehalogenation step (ex-situ dehalogenation): device (2) is an extruder which raises feedstock temperature to 250-300 °C. PVC and sulfur-containing plastics release chlorine and sulfur producing HCl and H₂S. Gases are removed by means of vacuum.
- ❖ Plastic feedstock is heated from 300 to 380 °C in heat exchanger (3), achieving a temperature close to the recycle stream (10). The resulting stream is further heated up to 400-450 °C in (4).



MIXED PLASTIC WASTE PYROLYSIS

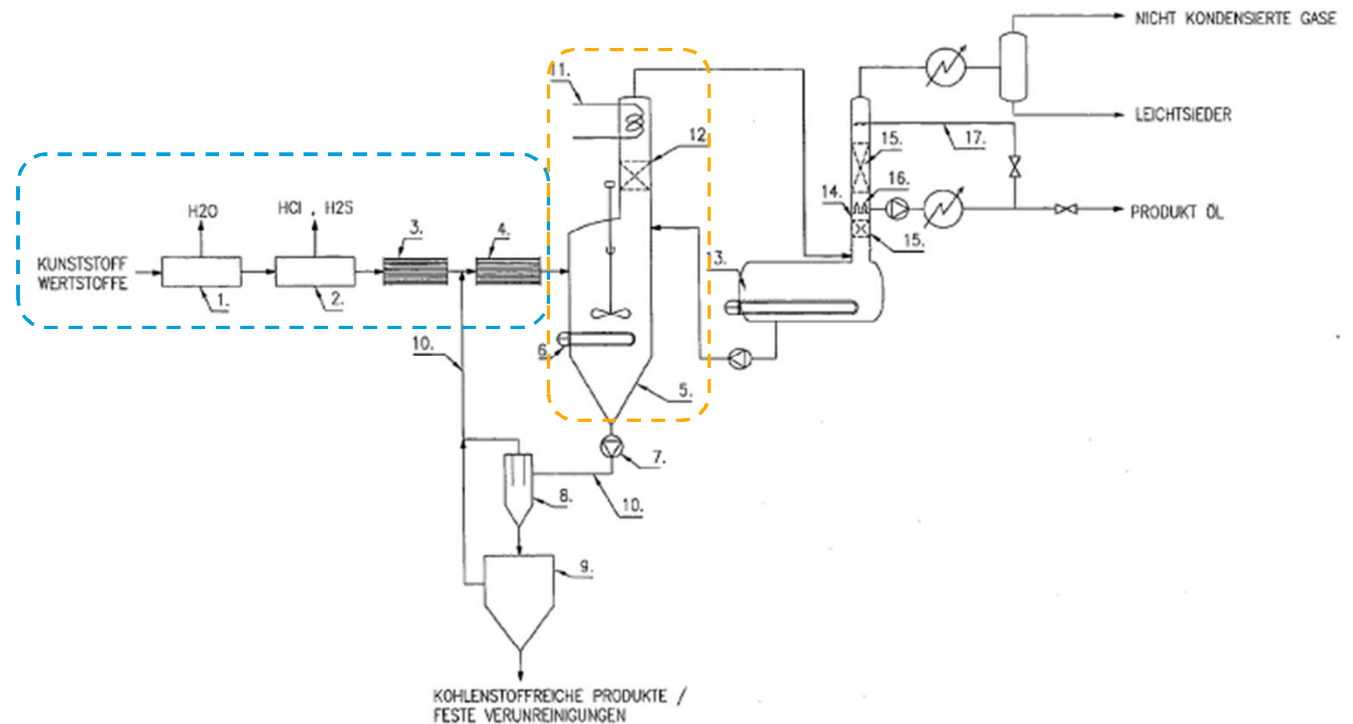
Plant scale technology example: BlueAlp process flow diagram II

Plant sections:

- **Reactor**

- ❖ Reactor consist in a bubbling bed heated by the element (6). In the pyrolysis reactor, tar-like hydrocarbons (heavy residues which are not desirable products) and solids are withdrawn from the bottom. After solids-tar separation (cyclone (8), settler (9)), tar-like hydrocarbons are recycled being mixed with the feed stream from heat exchanger (3)

- ❖ First cooling element (11) allows to condense some heavy hydrocarbons, which return in the reacting zone to be further cracked.

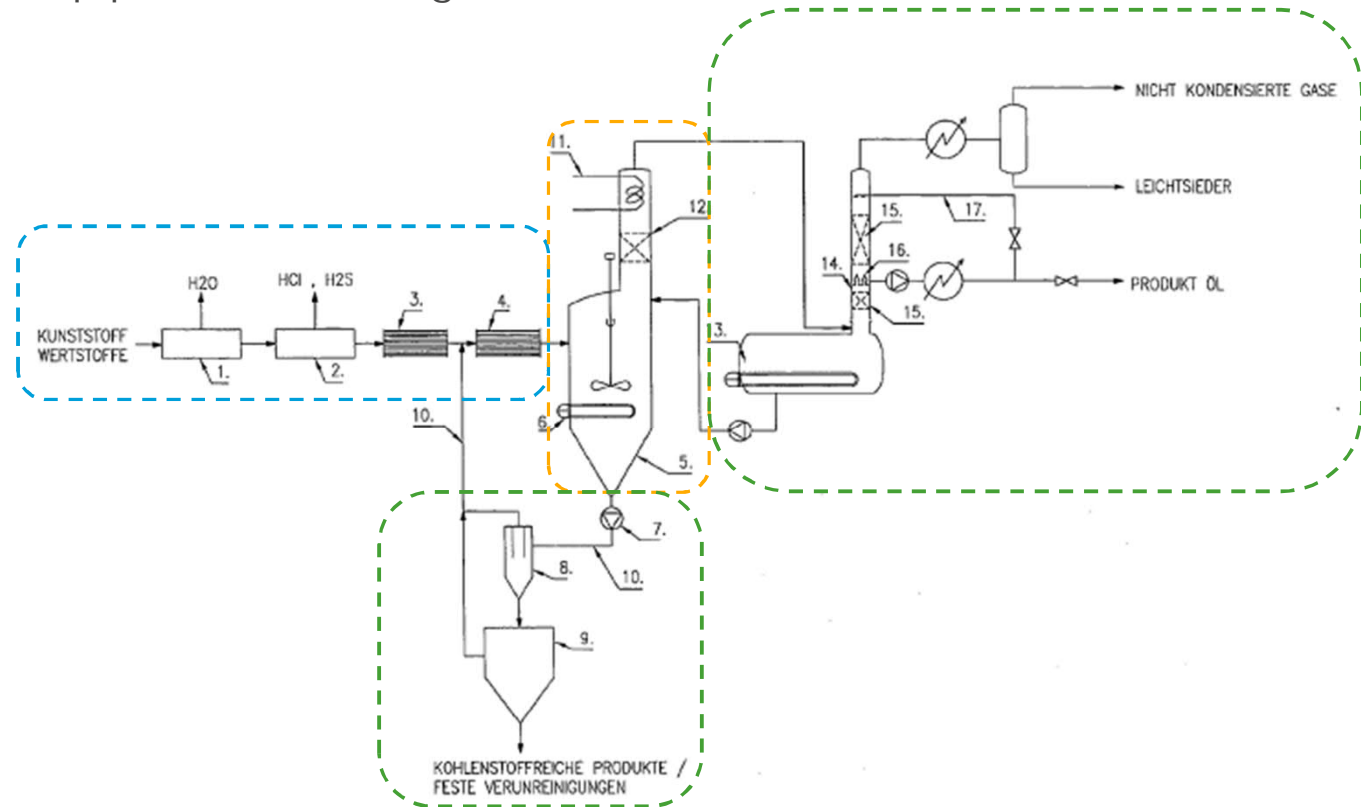


MIXED PLASTIC WASTE PYROLYSIS

Plant scale technology example: BlueAlp process flow diagram III

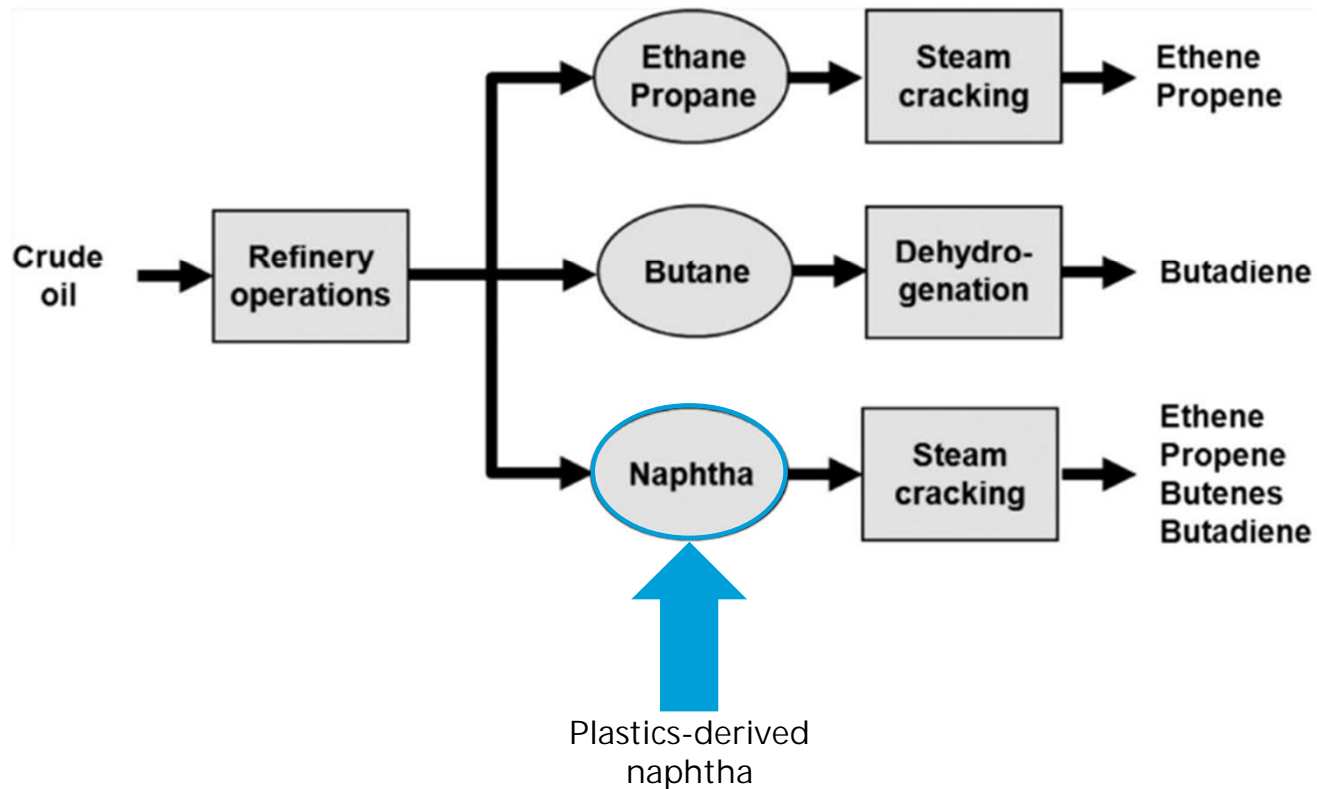
Plant sections:

- Separation section
 - ❖ A distillation column separates vapors in 3 product streams. The products obtained are incondensable gases (c1-c4, top right), light hydrocarbons (e. g. c5-c8), and another stream with heavier hydrocarbons called product oil.
 - ❖ The distillation column also separates some heavy hydrocarbons, which condense at larger temperatures with respect to the other components. For this reason, they are collected in liquid phase from the column bottom, and they are recycled to the pyrolysis reactor.



PLASTICS PYROLYSIS NAPHTHA AS STEAM CRACKING FEEDSTOCK

Plastic pyrolysis oil: a possible refinery feedstock I



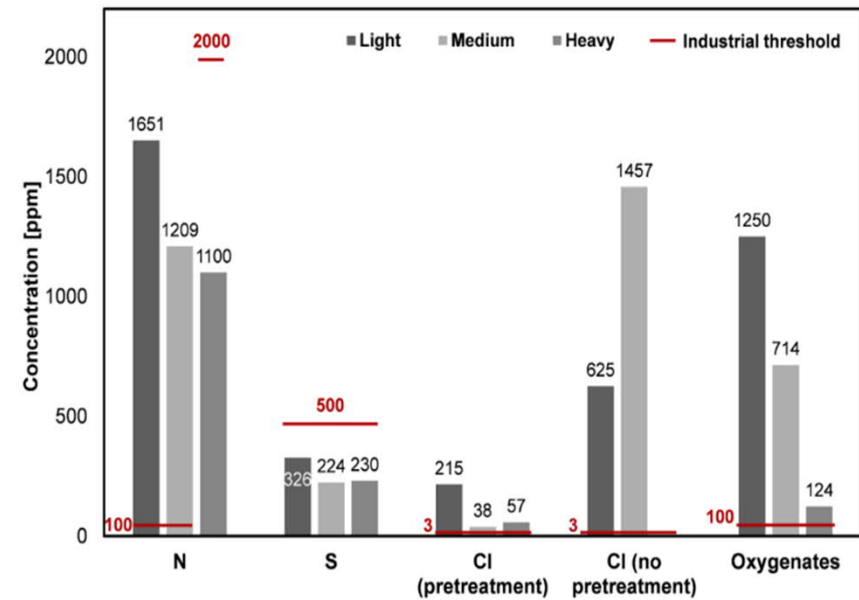
Adapted from: Jacob A. Moulijn, Michiel Makkee, Annelies E. Van Diepen, Chemical Process Technology, second edition, 2013

PLASTICS PYROLYSIS NAPHTHA AS STEAM CRACKING FEEDSTOCK

Plastic waste pyrolysis naphtha: impurities I

Heteroatoms (every atom which is not C either H) presence affects steam cracking performances, owing to:

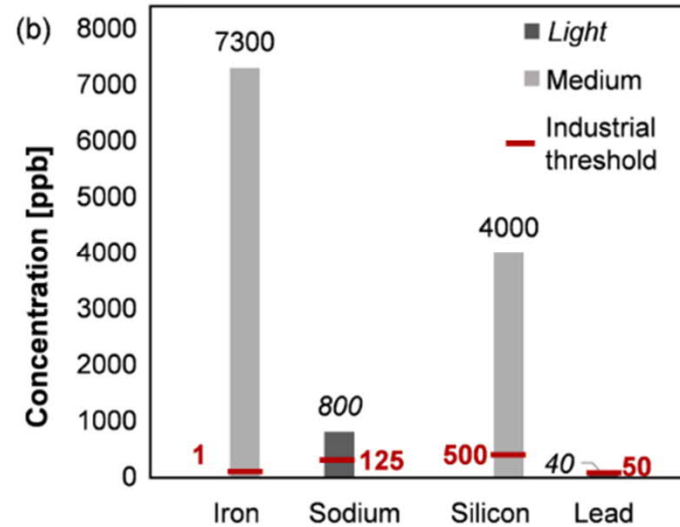
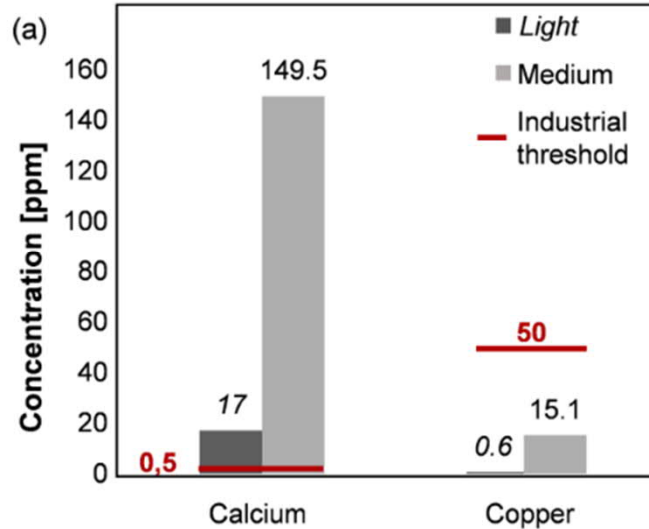
- catalyst deactivation (N in HDS, hydrocrackers, reformers, CO in downstream operations; N presence due to organic contaminants in plastics and detergents from bottles),
- off-spec impurities in products (ammonia from N, methanol, CO, formaldehyde from O)
- corrosion (Ni-Cr-Fe alloys by hydrogen sulfide, organic and inorganic chlorides)
- plugging (ammonium chloride)
- environmental concern impurities in gaseous streams (chlorinated compound, oxides formation as NO_x, SO_x)
- specific issues (explosive gums in downstream cold boxes for N, organic acids in quench water promoting gum formation with butadiene)



PLASTICS PYROLYSIS NAPHTHA AS STEAM CRACKING FEEDSTOCK

Plastic waste pyrolysis naphtha: impurities II

- Some metals present in traces are known to be source of increased coking rate (Cu, Fe, Na) upstream or downstream catalyst poisoning (Si, Fe, Pb), corrosion enhancement (Fe, Pb, Ca products which are corrosive) plugging (iron oxides), steam cracking coils corrosion (Na producing sodium chromite).
- Metal present in significant amount in plastic pyrolysis naphtha only: Al



MIXED PLASTIC WASTE PYROLYSIS

Feedstock & Product

- Post-consumer plastics are low-quality materials due to contaminants such as salts, food residues, cellulose, inerts, and additives.
- The quality of the feedstock directly affects the quality of the pyrolysis oil: approximately 50% of the impurities are transferred from the feedstock into the oil.
- The presence of cyclic and aromatic compounds increases char formation and worsens oil quality; among commercial plastics, polyolefins are the best candidates for pyrolysis processes.
- Plasmix contains about 50% polyolefins and therefore must be further refined before it can be used as feedstock in pyrolysis plants. However, feedstock specifications for Pyrolysis are less stringent than those for mechanical treatment (85% vs 95%), making selection easier.
- Additional treatments can also be evaluated to reduce impurities.
- The pyrolysis oil obtained cannot meet high-quality naphtha specifications and therefore must be further purified or blended before subsequent applications

CONCLUSIONS

- Sorting of mixed plastic wastes to obtain (almost) single polymers produces a residue which at present cannot be recycled (through mechanical recycling but also with depolymerizations and dissolution), PLASMIX
- Mixed plastic waste pyrolysis could be an effective way to avoid treating this residues through energy recovery or landfill
- However, pyrolysis oil have a different composition compared to fossil-based feedstock, both in terms of hydrocarbon classes and heteroatoms contaminants. Then:
 - Plasmix has to be refined to an high quality feedstock for pyrolysis
 - PyOil needs further upgrading and/or blending with fossil feedstock before steam cracking

BIBLIOGRAFIA

Plastics Europe, "The Circular Economy for Plastics – A European Overview 2022", 2022.

Kusemberg et al. ,Opportunities and challenges for the application of post-consumer plastic waste pyrolysis oils as steam cracker feedstocks: To decontaminate or not to decontaminate?, Waste Management 138 (2022) 83–115

Jacob A. Moulijn, Michiel Makkee, Annelies E. Van Diepen, Chemical Process Technology, second edition, 2013