Technologies, Markets and Policies on "Chemical Recycling"

Main Results for the Year 2020 from the Latest Market Reports

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Webinars on Markets and Strategies for Renewable Chemicals and Materials 2021-10-14

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- Political Framework, Measures & Instruments
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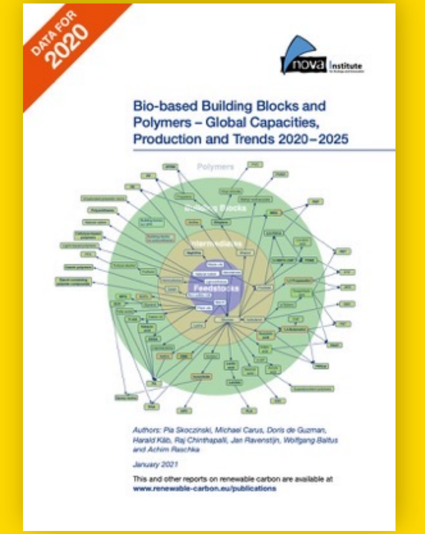
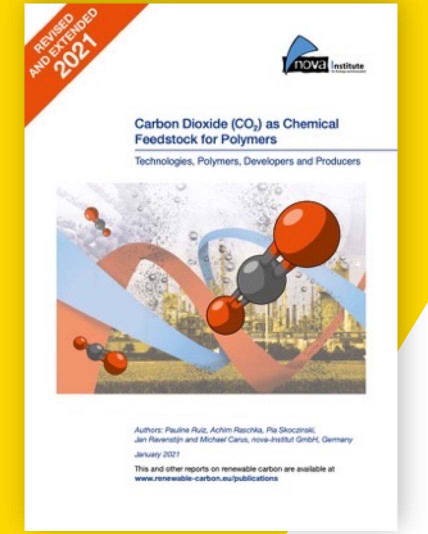
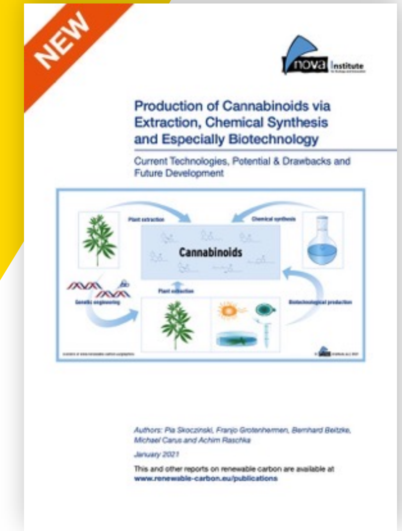
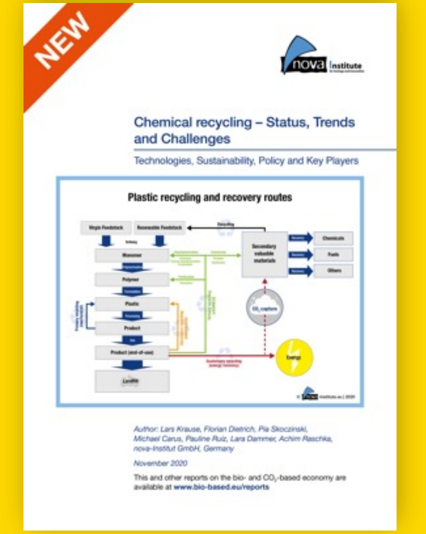
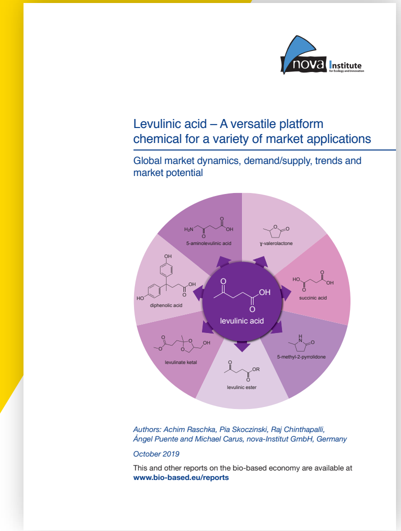
Market and Trend Reports on Renewable Carbon

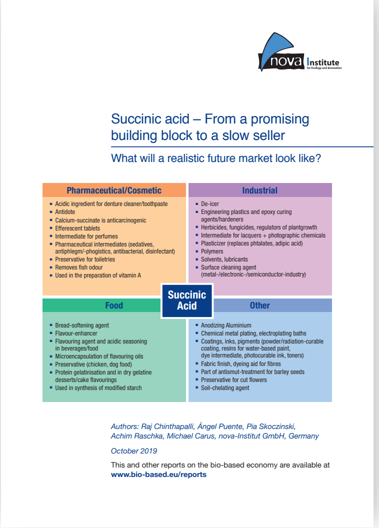












The Best Available on Bio- an CO_2-based Polymers & Building Blocks and Chemical Recycling

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Save the Date

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International Conference on
CELLULOSE FIBRES
2–3 February 2022
Hybrid Event

Conference on
CO_2-based Fuels
& Chemicals 2022
23 – 24 March • Hybrid Event

RENEWABLE
MATERIALS
CONFERENCE 2022
10-12 May
Hybrid Event

Contact: Mr. Dominik Vogt, +49 (0) 2233 48 14 49, dominik.vogt@nova-institut.de

All conferences at renewable-carbon.eu/events

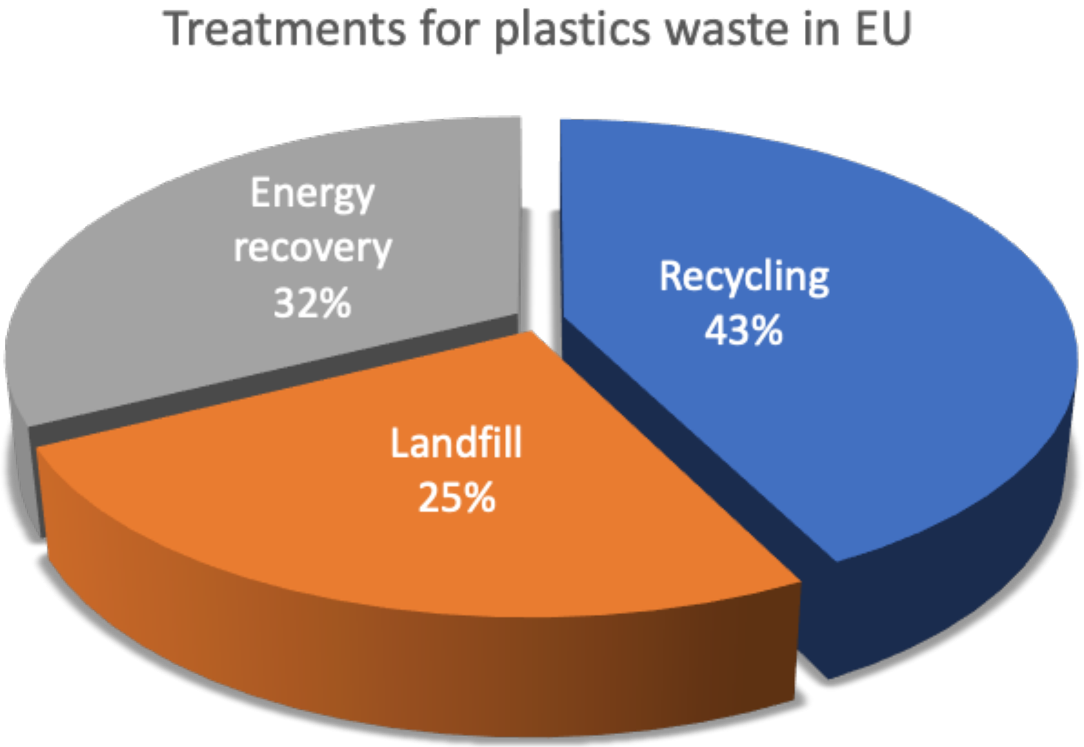
Introduction – waste generation & treatment

Plastics waste in Europe

- 30 million tonnes plastic waste
- 29 million tonnes collected
- 1 million tonnes leaked

Plastics waste treatment

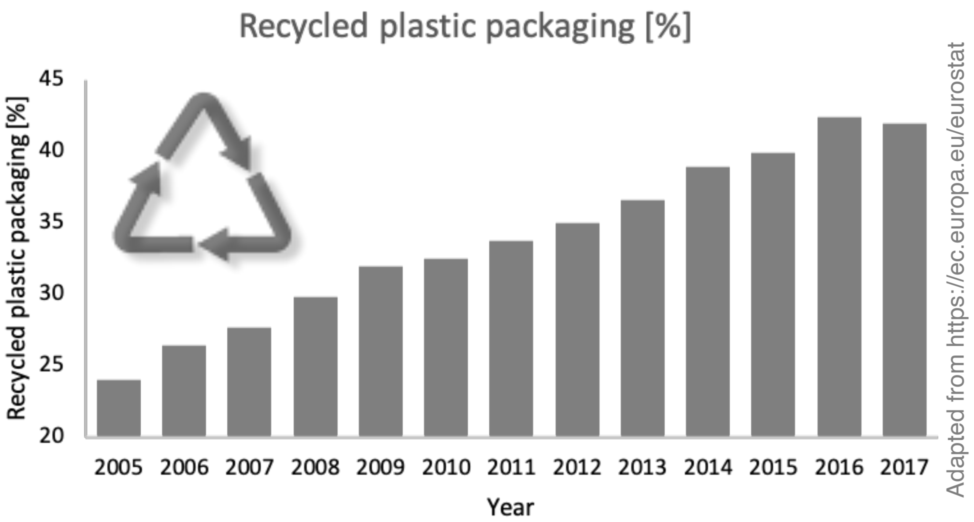
- Recycling
- Incineration
- Landfill



Introduction – ambitions of the EU

Recycling quotas until 2030 (EU Directive 2018/852)

- 70 % for all packaging materials
- 55 % for plastic



The European green deal

- Until 2030 all packaging materials should be
  - Recyclable
  - Reusable
- Until 2050 the EU will be climate neutral

How do we achieve these targets?

→ Prevention, Reduce, Re-use, Recycling, Alternative feedstocks

Introduction – what are the options?

Prevention

- Economically and ecologically senseful for only few applications
- Non-existent/limited alternatives for most applications
- Reason (overall performance and efficiency):
  - Density + strength (strong and lightweight materials)
  - Processing properties (forming, re-shaping)
  - Specialty and high performance materials (tailored properties)
  - Better performance than other materials for most sustainability criteria

Reduce/Re-use

- Certain potential (less generated waste, keep plastics in the loop)
- Re-use can't fully prevent waste ("delayed waste generation")

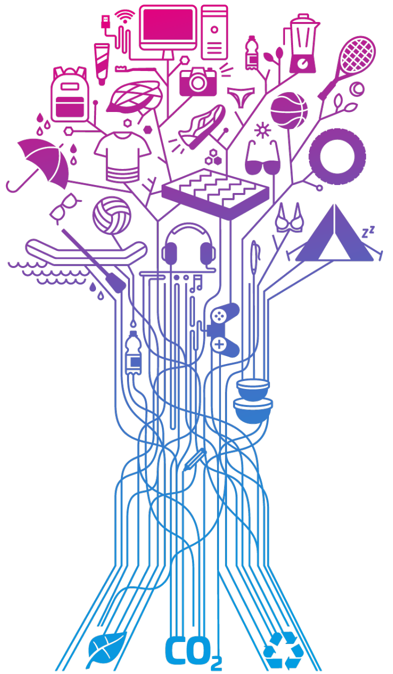
Introduction – what are the options?

CO_2 Alternative (renewable) feedstocks

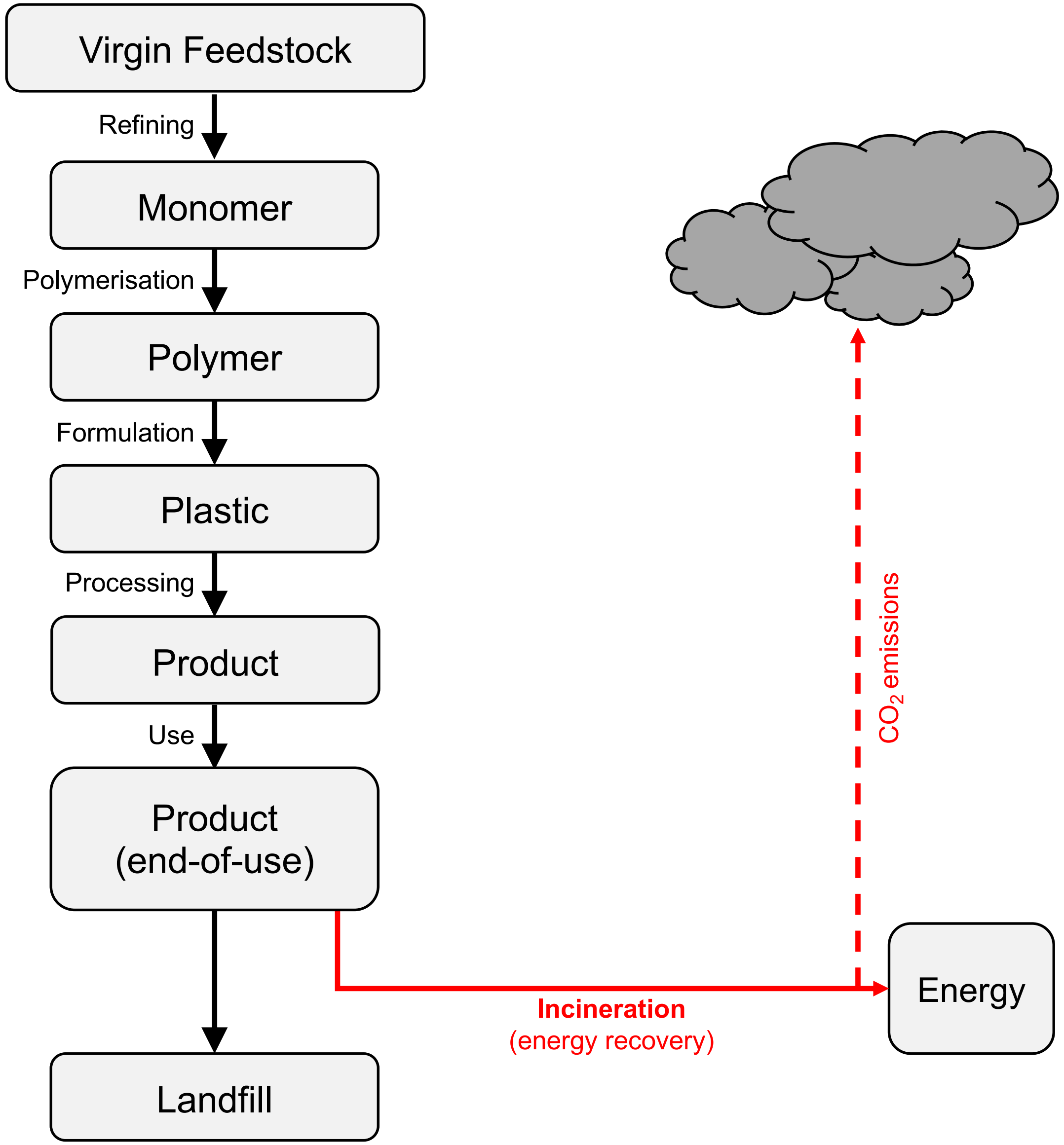
- Bio-based or CO_2-based
- Prevents the introduction of fossil carbon into the cycle
- No direct solution for wastes

Recycle

- Only direct solution for wastes to largely prevent landfill/incineration
- Keeps plastics in the loop
- Various options available
- Requires a fully established circular economy across the value chain



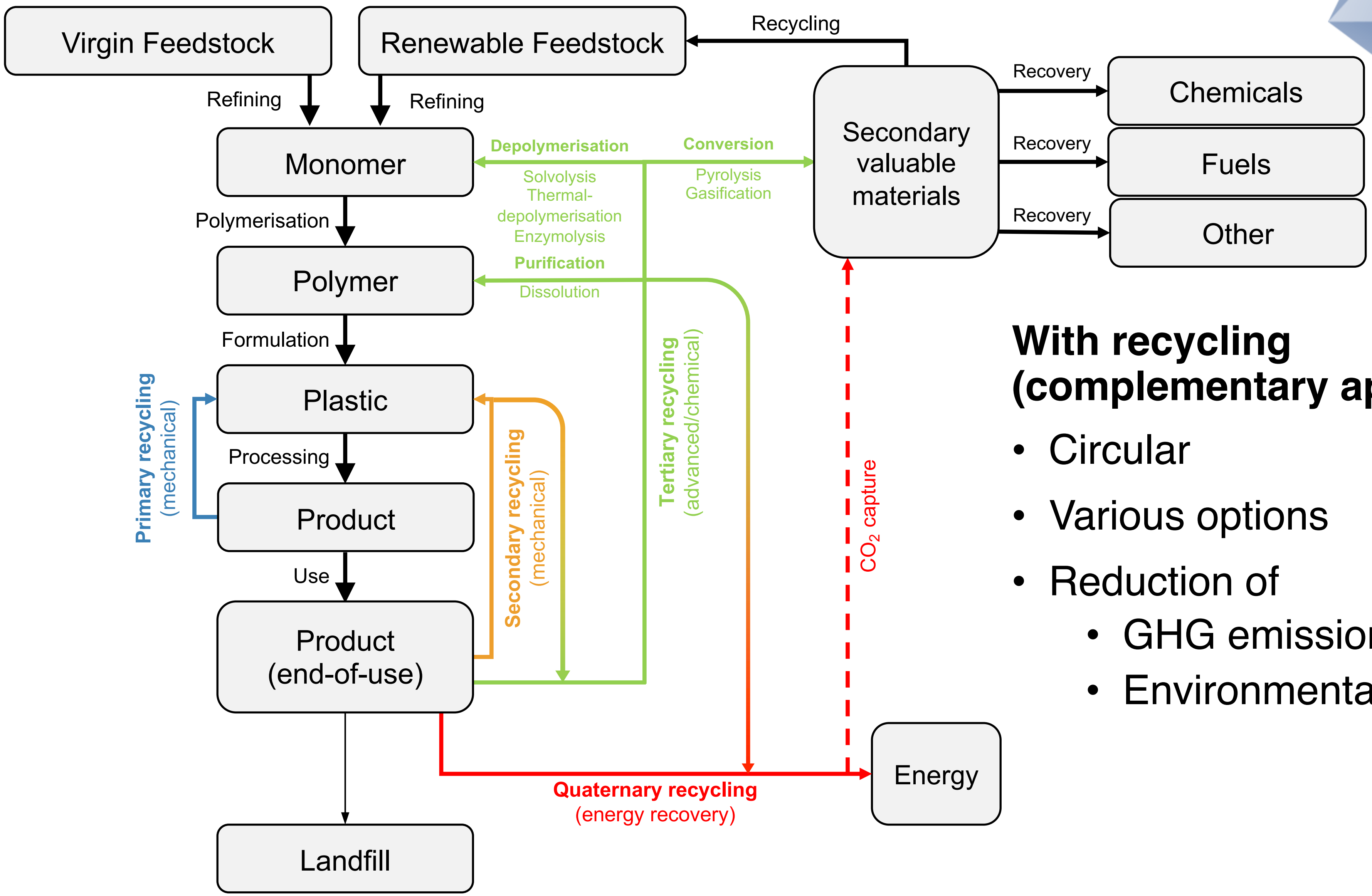
Life of a polymer without recycling



Without recycling

- Linear
- Limited options
- Coupled with
  - GHG emissions
  - Environmental pollution

Life of a polymer with recycling



With recycling (complementary approach)

- Circular
- Various options
- Reduction of
  - GHG emissions (e.g. CCU)
  - Environmental pollution

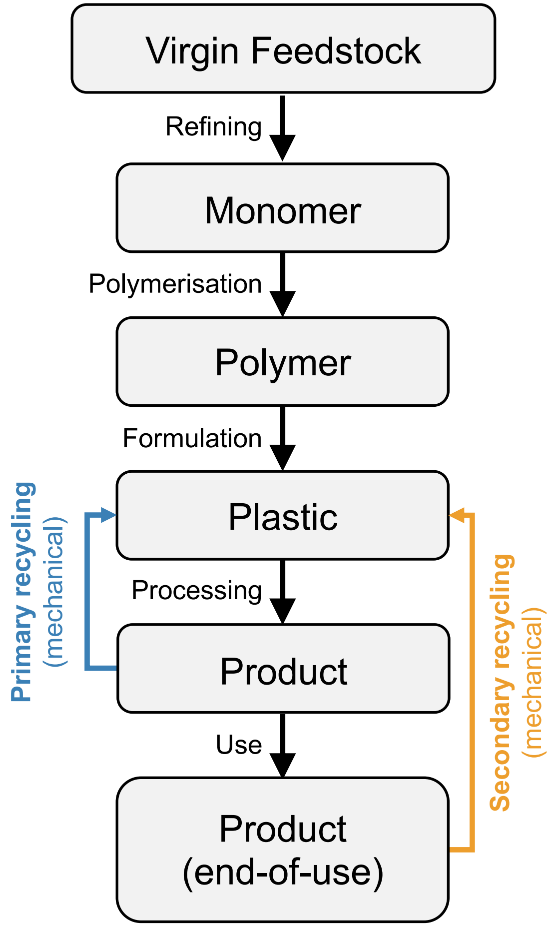
Mechanical recycling – Definition

ISO 15270:2008[1] "Guidelines for the recovery and recycling of plastics waste"

mechanical recycling: processing of plastics waste into secondary raw material or products without significantly changing the chemical structure of the material.

[1]ISO 15270:2008 Plastics - Guidelines for the recovery and recycling of plastics waste. ISO copyright office (Ed.), Switzerland

Mechanical recycling



Mechanical recycling (primary & secondary recycling)

- Advantages
  - Well established
  - Simplicity
- Limitations
  - Limited to thermoplastics
  - Need of “pure fractions”
  - No removal of contaminations
  - Loss of molecular weight (e.g. 1x=26%, 3x=56% loss)
  - Loss of quality (3x=13%IS, 8%TS)

Chemical recycling – Definition

ISO 15270:2008[1] "Guidelines for the recovery and recycling of plastics waste"

Chemical/feedstock recycling: conversion to monomer or production of new raw materials by changing the chemical structure of plastics waste through cracking, gasification or depolymerization, excluding energy recovery and incineration.

Note 1 to entry: Feedstock recycling and chemical recycling are synonyms.

- Includes: Solvolysis, Pyrolysis, Gasification, Enzymolysis
- Excludes: Dissolution

[1]ISO 15270:2008 Plastics - Guidelines for the recovery and recycling of plastics waste. ISO copyright office (Ed.), Switzerland

Chemical recycling – Definition

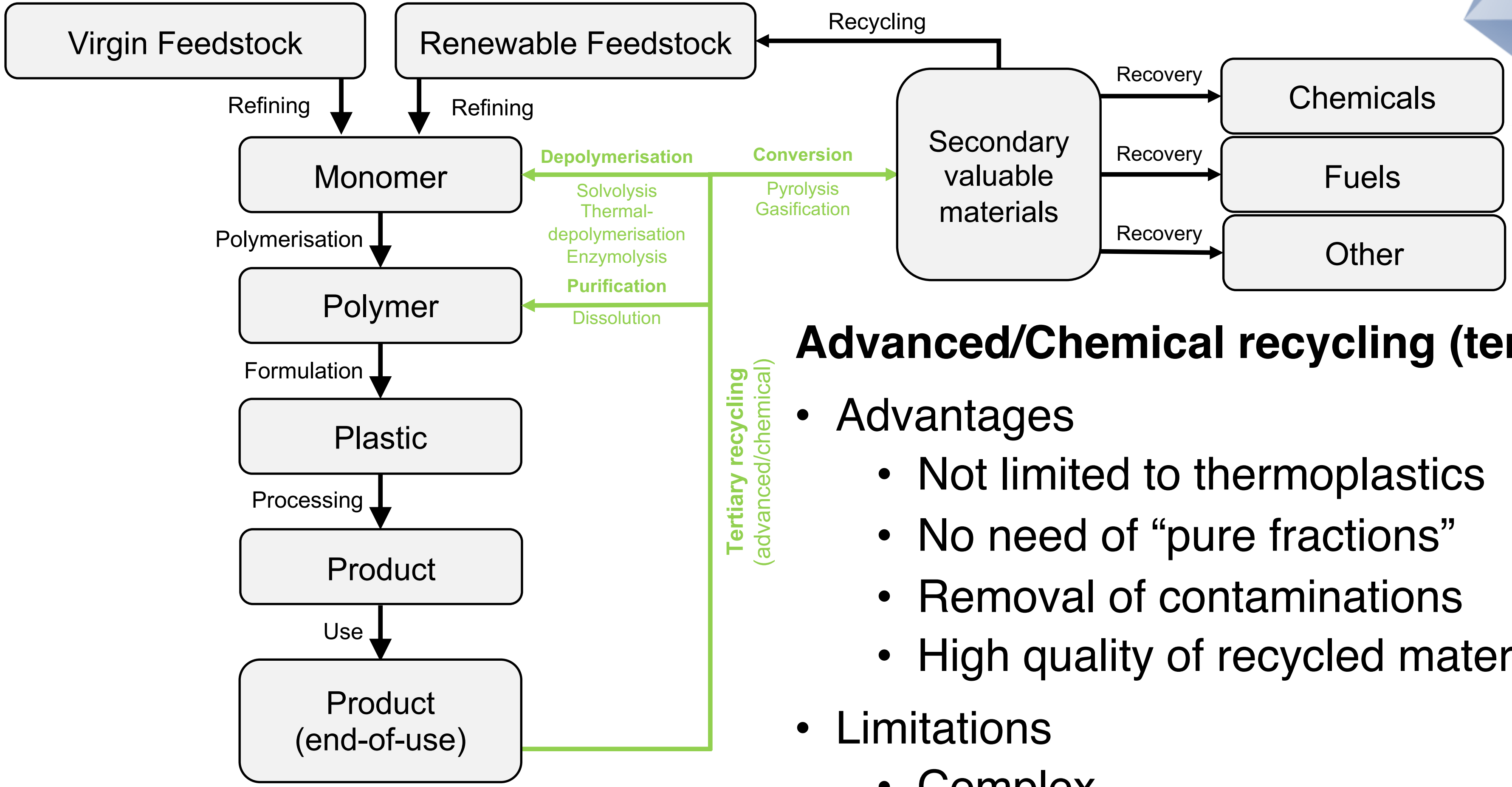
Chemical Recycling Europe

"According to Chemical Recycling Europe (CRE), Chemical Recycling is defined as any reprocessing technology that directly affects either the formulation of the polymeric waste or the polymer itself and converts them into chemical substances and/or products whether for the original or other purposes, excluding energy recovery."[1]

- Includes: Dissolution, Solvolysis, Pyrolysis, Gasification, Enzymolysis

[1]ChemRecEurope (Chemical Recycling Europe) 2020. Chemical Recycling Europe calls for a faster recognition and legislation review to unlock the potential of chemical recycling. Brussels, Belgium

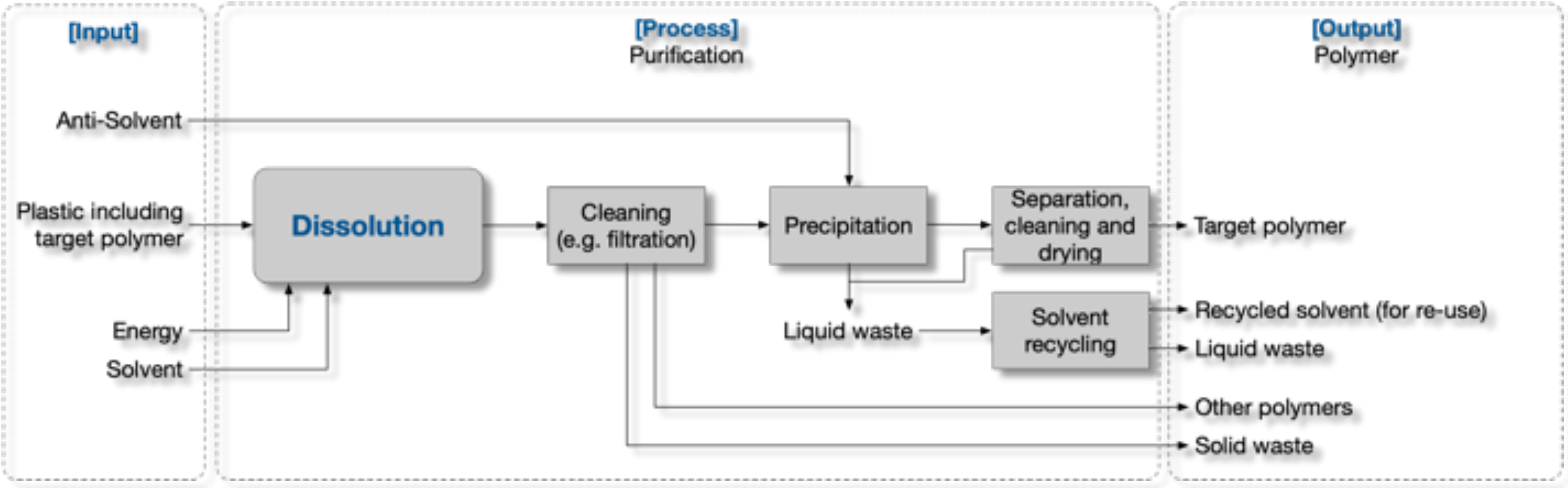
Chemical recycling



Advanced/Chemical recycling (tertiary recycling)

- Advantages
  - Not limited to thermoplastics
  - No need of "pure fractions"
  - Removal of contaminations
  - High quality of recycled material ("virgin quality")
- Limitations
  - Complex
  - Not well established (lack of large-scale units)
  - Difficulties to proof sustainability

Chemical recycling – Dissolution



Stats – nova report	
Identified providers:	6
Max. capacity:	8,000 t a^{-1}

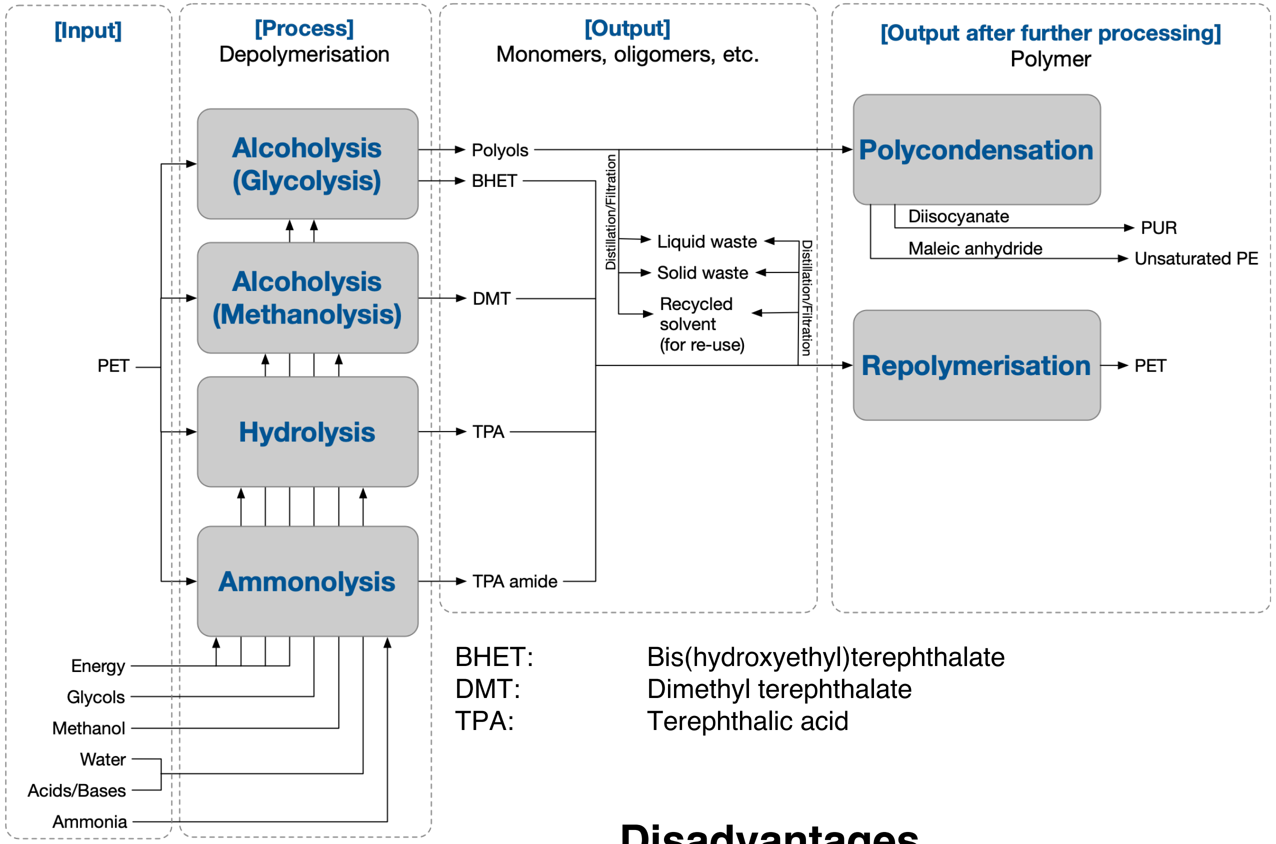
Advantages

- Selectivity
- Mixed/Multilayer material can be addressed
- Output can be directly used (no polymerisation necessary)
- Removal of hazardous substances

Disadvantages

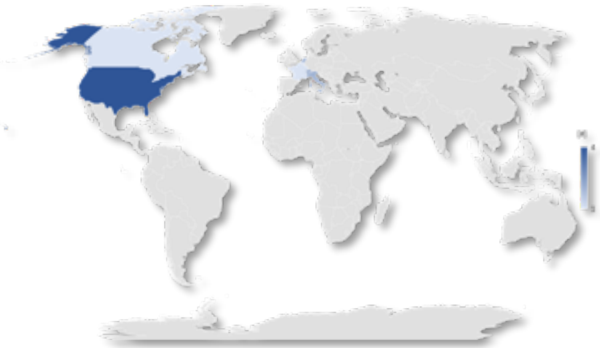
- Requirements on the composition of input material
- Limited to thermoplastics
- Purification of solvents necessary

Chemical recycling – Solvolysis



BHET: Bis(hydroxyethyl)terephthalate
DMT: Dimethyl terephthalate
TPA: Terephthalic acid

Stats – nova report	
Identified providers:	14
Max. capacity:	10,800 t a^{-1}



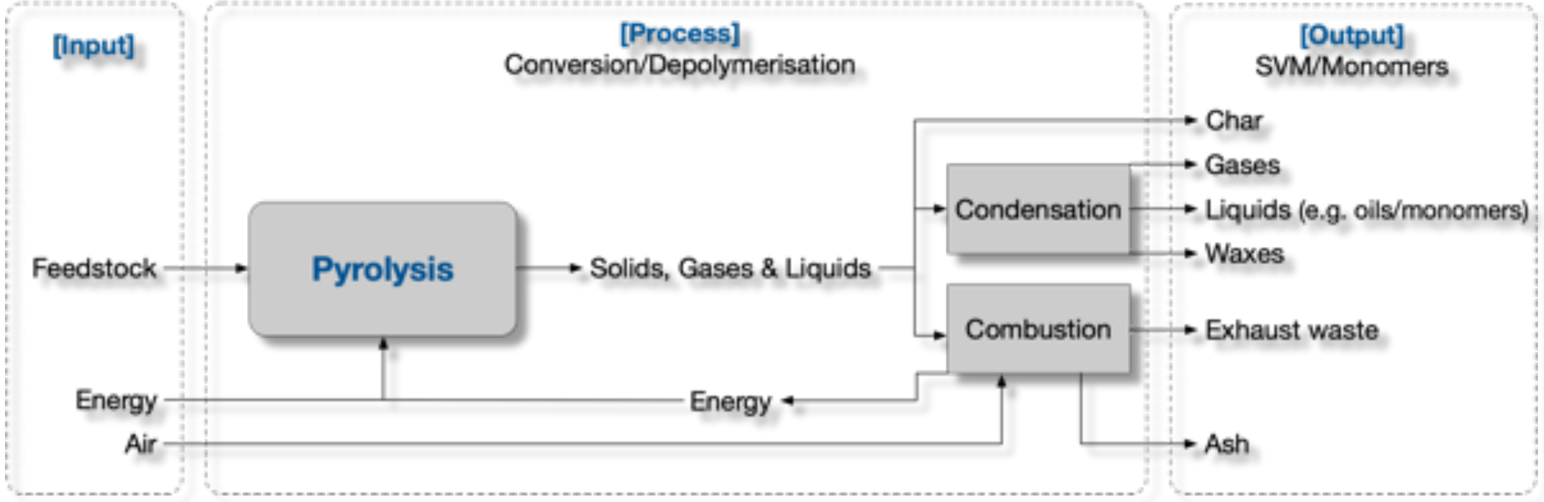
Advantages

- Selectivity
- Mixed/Multilayer material can be addressed
- Removal of hazardous substances

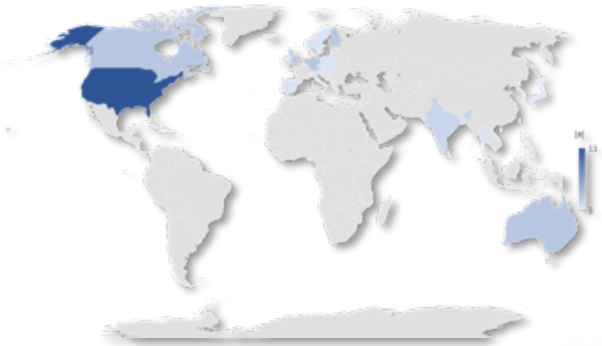
Disadvantages

- Requirements on the composition of input material
- Purification of solvents necessary
- Processing of polyolefines or polystyrene excluded

Chemical recycling – Pyrolysis



Stats – nova report	
Identified providers:	44
Max. capacity:	38,000 t a^{-1}



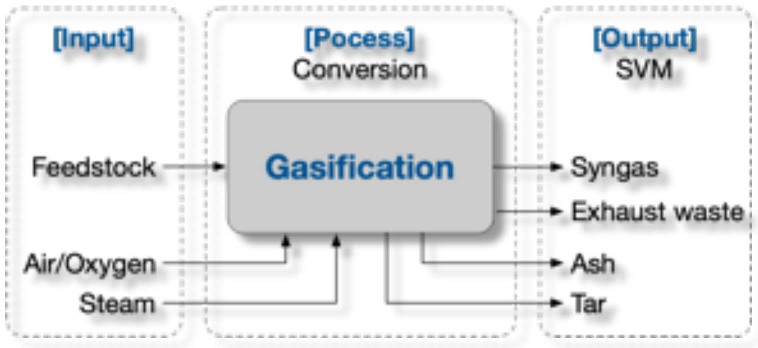
Advantages

- Wide range of possible input materials
- Large spectrum of obtained products
- Removal of hazardous substances

Disadvantages

- High energy demand, emission of pollutants
- Less selectivity for products (wide product spectrum)
- Products often needs to be further processed/upgraded
- low tolerance to PVC

Chemical recycling – Gasification



Stats – nova report	
Identified providers:	8
Max. capacity:	100,000 t a^{-1}

Advantages

- Very robust regarding input material
- Various applications for produced synthesis gas
- Removal of hazardous substances

Disadvantages

- High energy demand due to high temperatures and pressures, generation of pollutants
- Generation of higher tar contents upon gasification of plastics limits the utilisation in turbines/engines and further processing is necessary
- reduced caloric value of product due to oxygenation

Chemical recycling – Enzymolysis

Advantages

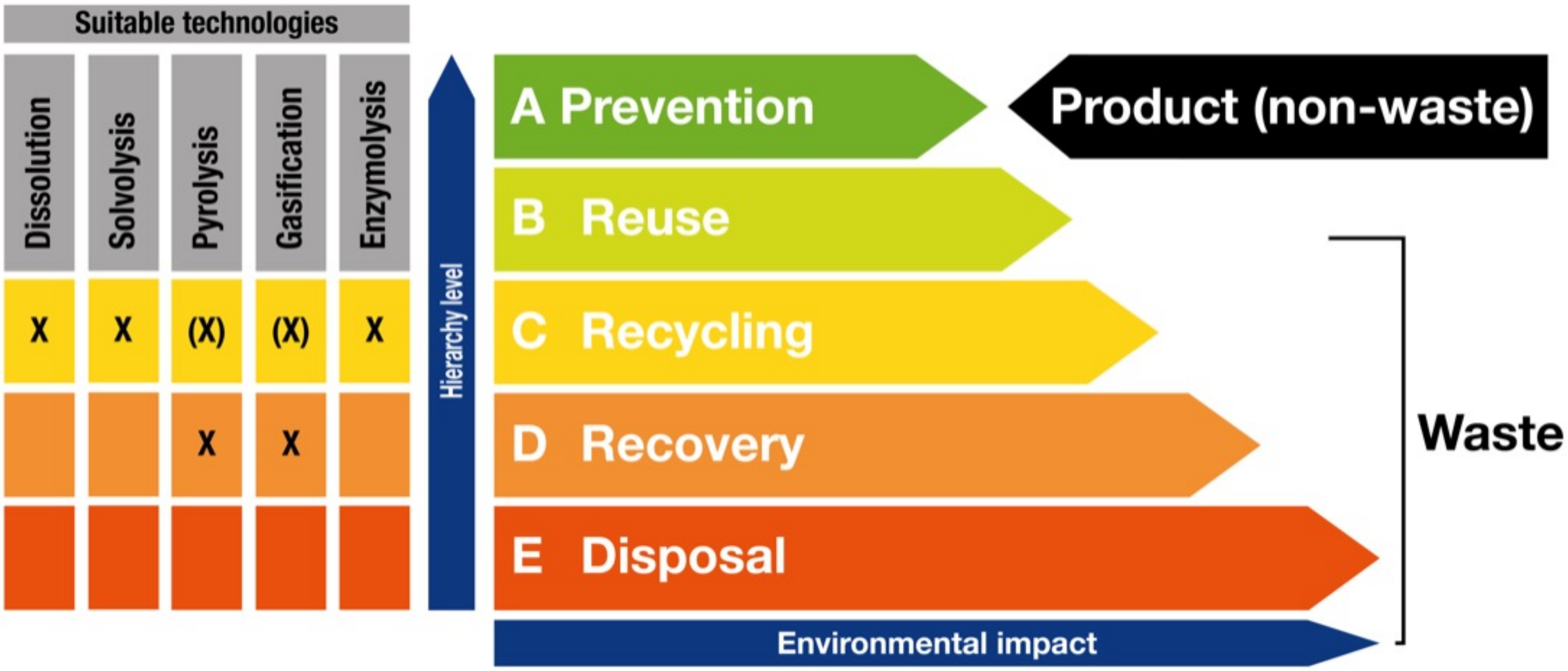
- Depolymerisation via biocatalysts
- Highly specific (chemo-, regio-, enatio-, stereo-)
- Mild conditions (e.g. room temperature, atmospheric pressure)
- Fine tuning via enzyme- and metabolic engineering

Disadvantages

- Rarely developed
- Lab-scale
- Relatively slow turnover

Stats – nova report	
Identified providers:	1
Max. capacity:	Lab scale

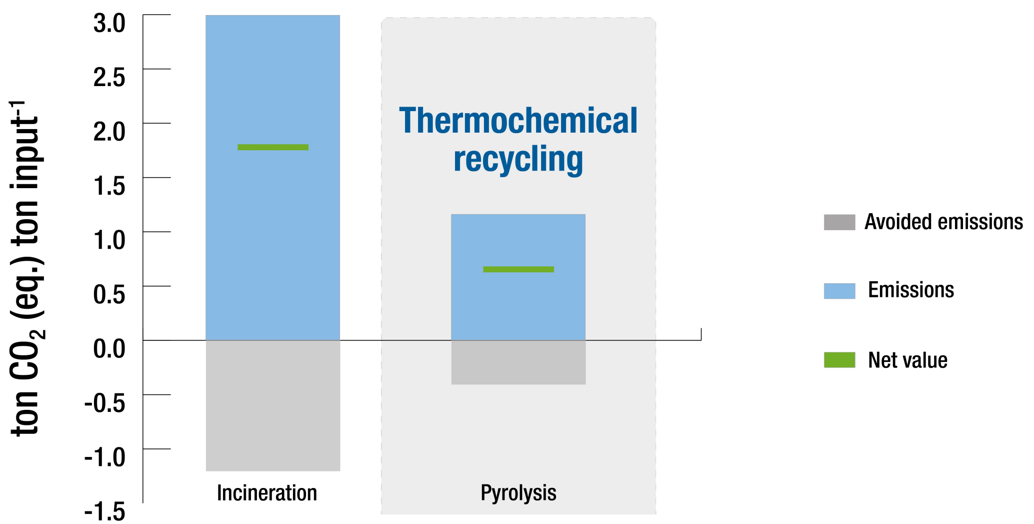
Waste hierarchy and placement of chemical recycling technologies



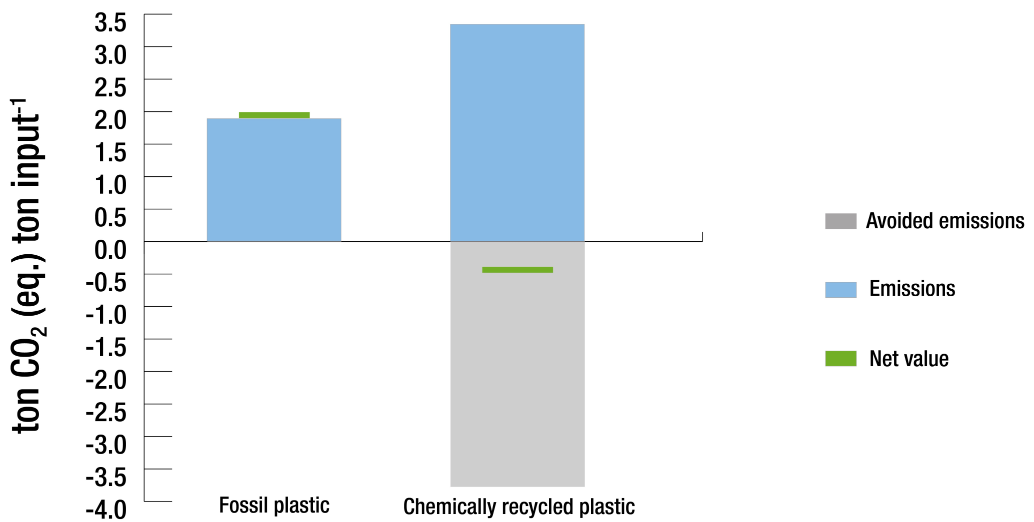
Crediting for recycling rates?

- Life Cycle Assessment (LCA)
- Different approaches available
- GHG emissions in comparison to other waste treatments
- GHG emissions in comparison to the production of fossil based polymers

LCA on thermochemical recycling (BASF)



LCA on plastic production (BASF)



[1]BASF 2020. Slide Deck - ChemCycling: Environmental Evaluation by Life Cycle Assessment (LCA). BASF, Ludwigshafen, Germany

Report on chemical recycling

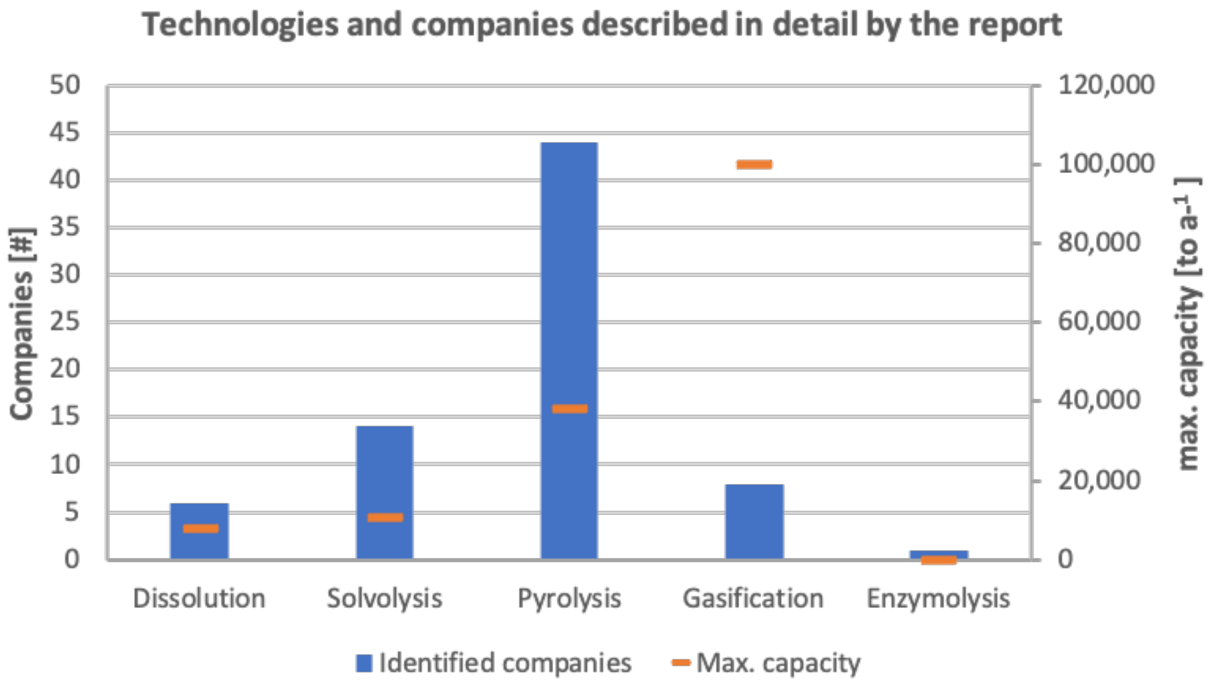
Supporters

„A modern, sustainable plastics industry that fits into a circular economy cannot do without chemical recycling since the targets set up in the EU plastic strategy will not be achievable without implementing chemical recycling technologies. However, supporters call for a clear policy framework from EU policy makers."

-VS.-

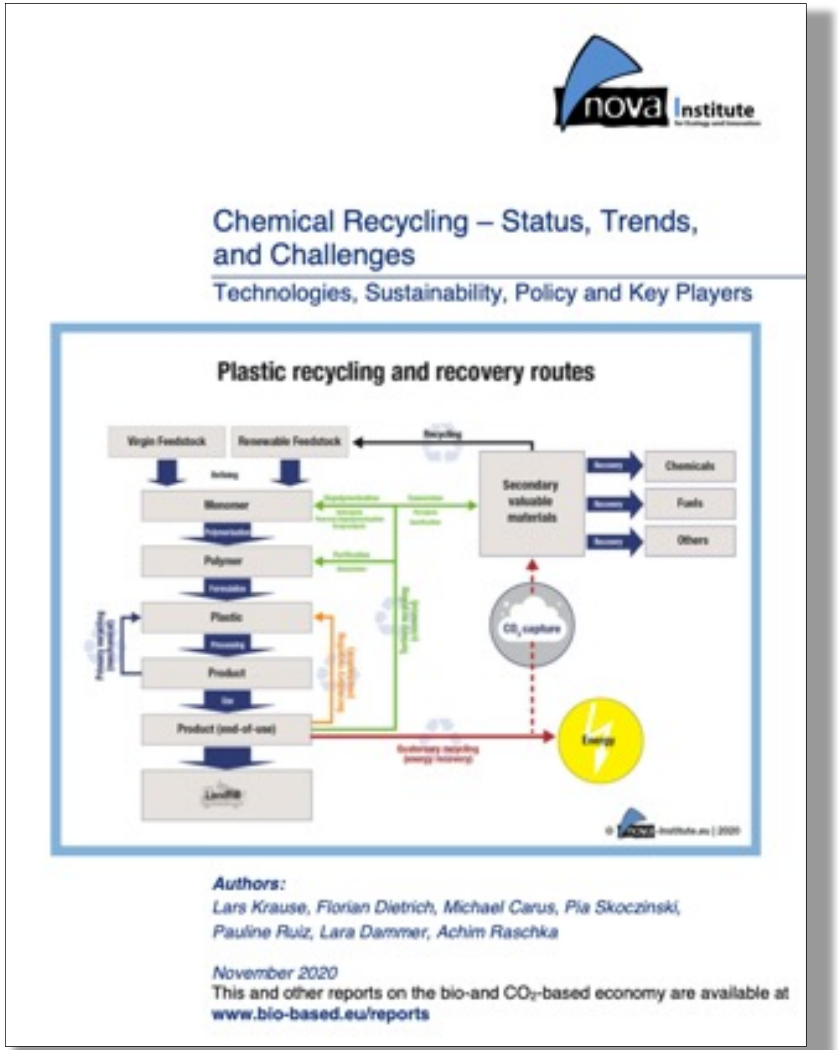
Critics

„Critics of chemical recycling refer to the low maturity of the technologies and the wide uncertainty ranges of existing assessments. Another overarching point of criticism refers to gasification and pyrolysis, which could undermine meaningful activities towards the circular economy."



- Sector is characterised by great dynamics, high expectations and investment interest
- Great uncertainties and scepticism as to how the new technologies should be evaluated and regulated
- In Europe, the chemical recycling sector is waiting for the start signal via clear political framework conditions

Report on chemical recycling



- Published in November 2020
- Overview of main polymer types and their applications
- Status quo of plastic recycling (incl. statistics)
- Description of chemical recycling technologies (Dissolution, Solvolysis, Pyrolysis, Gasification, Enzymolysis)
- Market and technology data for 2020 (70 company profiles)
- Literature review of available LCAs
- Status quo and ambitions of Policy including directives, definitions, waste hierarchy, quotas
- Industries' point of view

- 190 pages
- 2.500 € – www.bio-based.eu/reports

Österreichische Mineralölverwaltung (OMV)

Technology:	ReOil® technology		
Location (HQ):	Vienna, Austria	Founded:	1956
Method:	Pyrolysis, Thermal cracking	Employees:	> 1,000
Feedstock:	Mixed plastic waste containing PE-HD, PE-LD, PP, PS	Capacity [t a^{-1}]:	770
Products:	Naphtha, gas (C1-C4)		
Webpage:	www.omv.com/en		

Company profile and strategy

OMV markets oil and gas for different energy solutions and worked since 2011 on possibilities for downstream treatments on plastic waste. After three years of research and development on a smaller scale pyrolysis technology with a capacity of 5 kg h^{-1} in Schwechat, Austria, a larger ReOil plant started its operation with a capacity of 100 kg h^{-1}. The new plant started its operation in 2018 and is integrated to an existing oil refinery and was funded by the Österreichischen Forschungsförderungsgesellschaft (FFG) in the framework of the Competence Headquarter Program.

Technology

OMV owns patents on this process in Europe, USA, Russia, Australia, Japan, India, and China besides other countries. The process accepts mixed plastic waste, preferably composed of 93-94 % of polyolefins including a certain degree of contamination including ABS, PVC, or biomass. However, the feedstock should not exceed a share of 0.5 % PVC, 1 % biomass, and 15 % humidity. Additionally, the feedstock has to be free of solids > 8 mm such as glass, metal, or ceramics. The process operates continuously under an oxygen free atmosphere by using an inert gas at pressures up to 30 bar. At temperatures between 280-250 °C the plastic waste is melted in a hot liquid solvent with a high boiling point (400-700 °C) which is produced by OMV as a side-product from their refinery. The utilisation of a hot liquid solvent for melting the plastic waste prior pyrolysis is relatively unique in comparison to the other known processes and helps to overcome the low thermal conductivity and high viscosity of plastics including further benefits in view of the energy consumption and pumping of molten plastics through the system with high a throughput. The plastic is converted and vaporised at 400-420 °C under pressures up to 30 bar, after cracking, the solvent can be directly reintroduced into the process. Obtained products from the process are divided into a light fraction in form of gases (C1-C4), an intermediate naphtha fraction, and a heavy naphtha fraction via condensation. Furthermore, around 5 % of coke is produced which is utilised thermally by the cement industry. The pyrolysis plant has a capacity to process 100 kg waste into 100 litres of raw oil per hour. A study was conducted by the Austrian Umweltbundesamt in 2016 showing that 45 % of the GHG emissions and 20 % of the energy demand are reduced in comparison to classical raw oil production.

Partnerships, Joint ventures, Associations

OMV had a long-time partnership with the Borealis since 1998. Together they share a facility area in Schwechat, Austria in which OMV produce and delivers petrochemicals to Borealis. As a next step, both companies want to extend their partnership to work together on the chemical recycling of post-consumer waste. In 2020 OMV acquired an 39 % Borealis stake from the strategic investment company Mubadala for $ 4.86 billion to increase the overall stake to 75 %. Furthermore, OMV signed a memorandum of understanding together with Borealis, Lafarge, a cement company, and VERBUND, a hydroelectricity producer for the planning and construction of a full scale CCU plant by 2030.

Report on chemical recycling – 11 Associations/Industry-groups profiles

4.5 European Coalition for Chemical Recycling

Official webpage: www.coalition-chemical-recycling.eu
Founded: 2019
Partners: 13

The European Coalition for Chemical Recycling was founded by Cefic (see chapter 4.4) and PlasticsEurope (see chapter 4.11) in 2019. The coalition aims to bring together different associations across the whole value chain of plastics in order to support the development and implementation of chemical recycling technologies. In order to improve the circularity of plastics, the chemical recycling is highlighted as a complementing technology and therefore the coalition calls for enabling conditions and integration and consideration of this technology into the whole value chain of plastics. The potential of chemical recycling is explained by the European Coalition for Chemical Recycling on their webpage[2] and is cited as follows:

> "The change from virgin polymers based on fossil fuels to recycled polymers as raw materials for the creation of plastics products saves energy and reduces CO_2 emissions. This is why chemical recycling can help to combat global warming and further limit the CO_2 footprint of plastic products."

> "The capability to treat all kinds of plastic waste, even those untreatable with mechanical recycling, gives plastic waste a new value and will help to reduce its landfilling or incineration. All plastic waste should be recycled and reused to benefit from its full potential without wasting valuable resources."

Report on chemical recycling – 21 waste management companies

Company	Headquarter	Revenue [€ million]	Area of activity	Company Webpage
AGR Abfallentsorgungsgesellschaft Ruhrgebiet mbH	Germany, Herten	200	DE	www.agr.de
Alba Group plc & Co. KG	Germany, Berlin	2100	DE, EU, Asia	www.alba.info
Amey plc (Ferrovial S.A.)	United Kingdom, London	2585	UK	www.amey.co.uk