Mechanical & chemical recycling of packaging plastics

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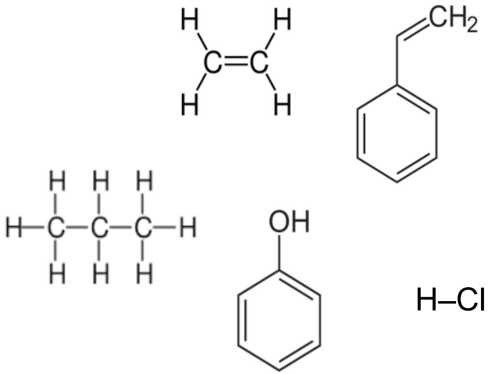
Dieter Stapf



Plastics Production and Plastics Waste Generation

[million t / a]	EU 28+2*	Germany**
Plastics production	61.8	19.9
Plastics consumption	51.2	12.6
Plastic waste	29.1	6.2
- Landfill	7.2	< 0.1
- Energy recovery	12.4	3.2
- Recycling	9.4 (export 1.8)	2.9 (export: 0.6)

*) Lindner,C. et al.: Circular Economy of Plastics 2018 EU-28+2, Conversio Market & Strategy GmbH, Mainaschaff (2019)
**) Lindner,C., Schmitt, J.: Stoffstrombild Kunststoffe in Deutschland 2017, Conversio Market & Strategy GmbH, Mainaschaff (2018)

Industry investments into plastics pyrolysis (excerpt):

- Recycling Technologies, UK
  → RT7000 project, Perthshire, Scotland
- Plastic Energy, UK
  - Operations @ Almeria & Sevilla, ES
- Sabic
  → Cooperation with Plastic Energy, Geleen, NL
- LyondellBasell
  → MoReTec-Pilot plant, Ferrara, IT
- BASF
  → Cooperation with Quantafuel, NOR
  → Cooperation with Pyrum, GER
  → Cooperation with Arcus Greencycling Technologies, GER

www.plasticenergy.com

Recycling Processes for Mixed Plastic Waste and Key Products

Karlsruhe Institute of Technology

Physical processes
➢ Recovered polymer

- **Mechanical sorting**
- **Solvent extraction**

Chemical processes
➢ New product

- **Solvolysis**
  ➢ Monomer
- **Thermochemical conversion**
  - **Gasification**
    ➢ Syngas
  - **Pyrolysis**
    ➢ Pygas / -oil

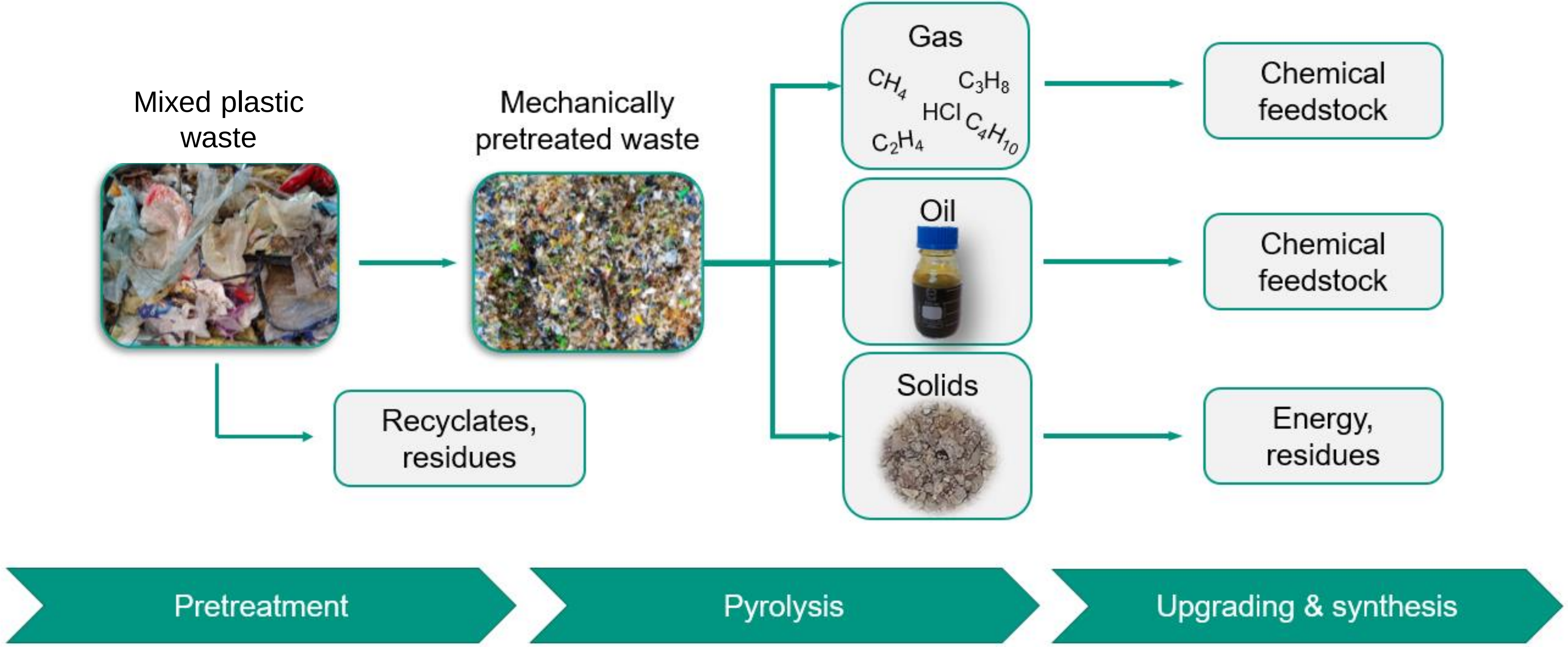
applied to:

Mechanical sorting	Solvent extraction	Solvolysis	Thermochemical conversion
➢ standard thermoplastics	➢ Pure polymers	➢ Polycondensates	➢ Mixed wastes, composite materials

Collection and Sorting of Lightweight Packaging Waste

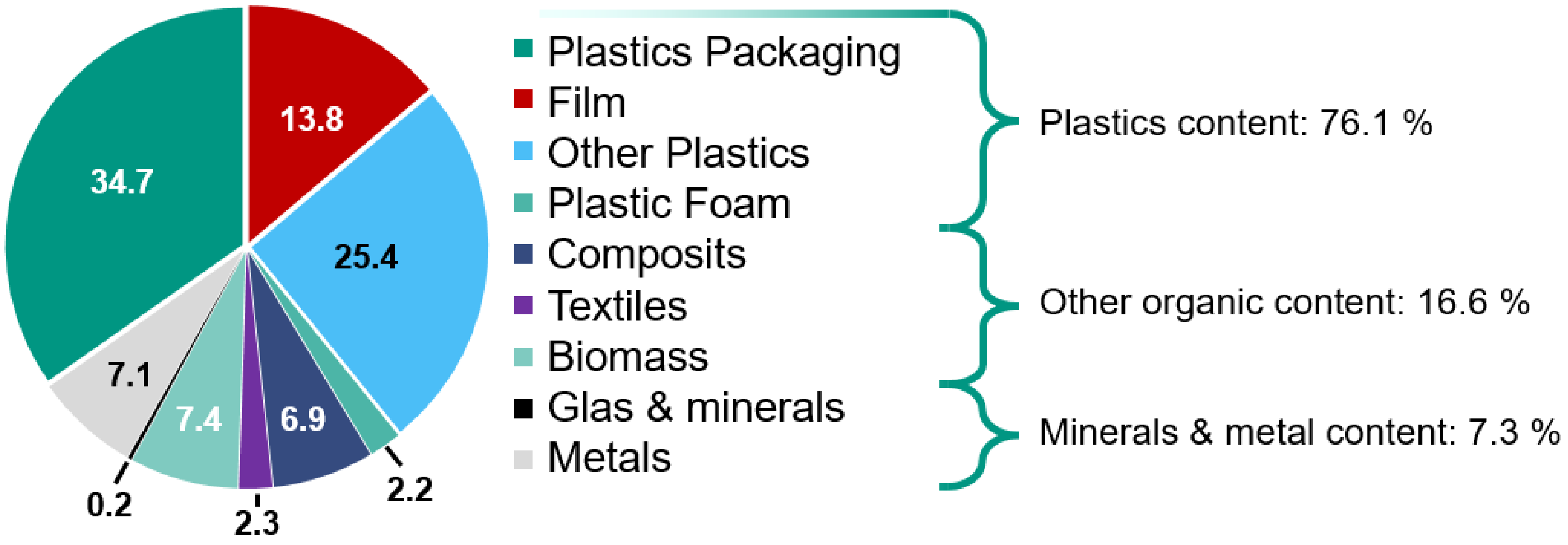
Images: www.awg-info.de/index.php?id=65, www.erema.com/de/erema_news/IDobj=200, ww.reclaygroup.com/de/images/Content/Presse/pressefotos/bilddatenbank/sortierung/161010_Sortieranlage_Reclay_by-ASP_DSF3429.jpg

Recycling of Collected Plastic Waste - The Pyrolysis Value Chain Example



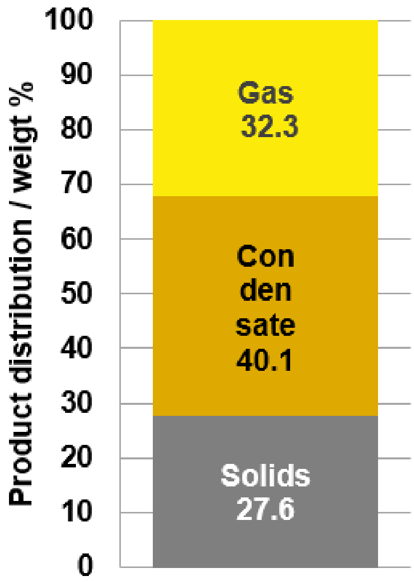
Composition of LWP-SR as Pyrolysis Feedstock

- Mechanical treatment of leight weight packaging (LWP) collected
- Sorting residues (SR) resulting from separation of high value plastics & metals for recycling as well as coarse mineral fraction → energy recovery



Composition of a sorting plant random sample

Pyrolysis of Light weight packing (LWP) sorting residues



Product distribution (pyrolysis of LWP sorting residues at 450 °C)

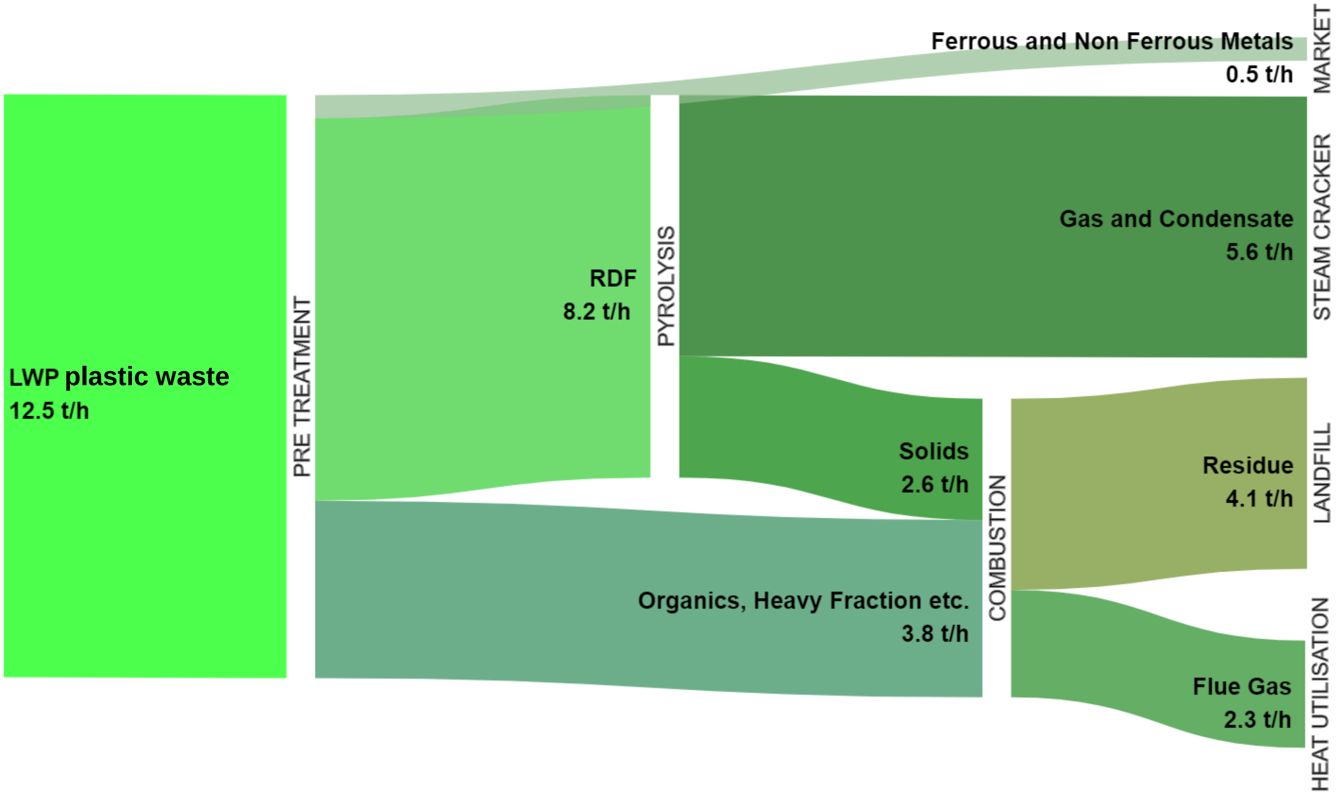
Process efficiency:

- Carbon recovery in condensate: 51.1%
- Energy demand*: 5.1% of feedstock higher heating value

*) for heating, melting, thermal degradation & evaporation

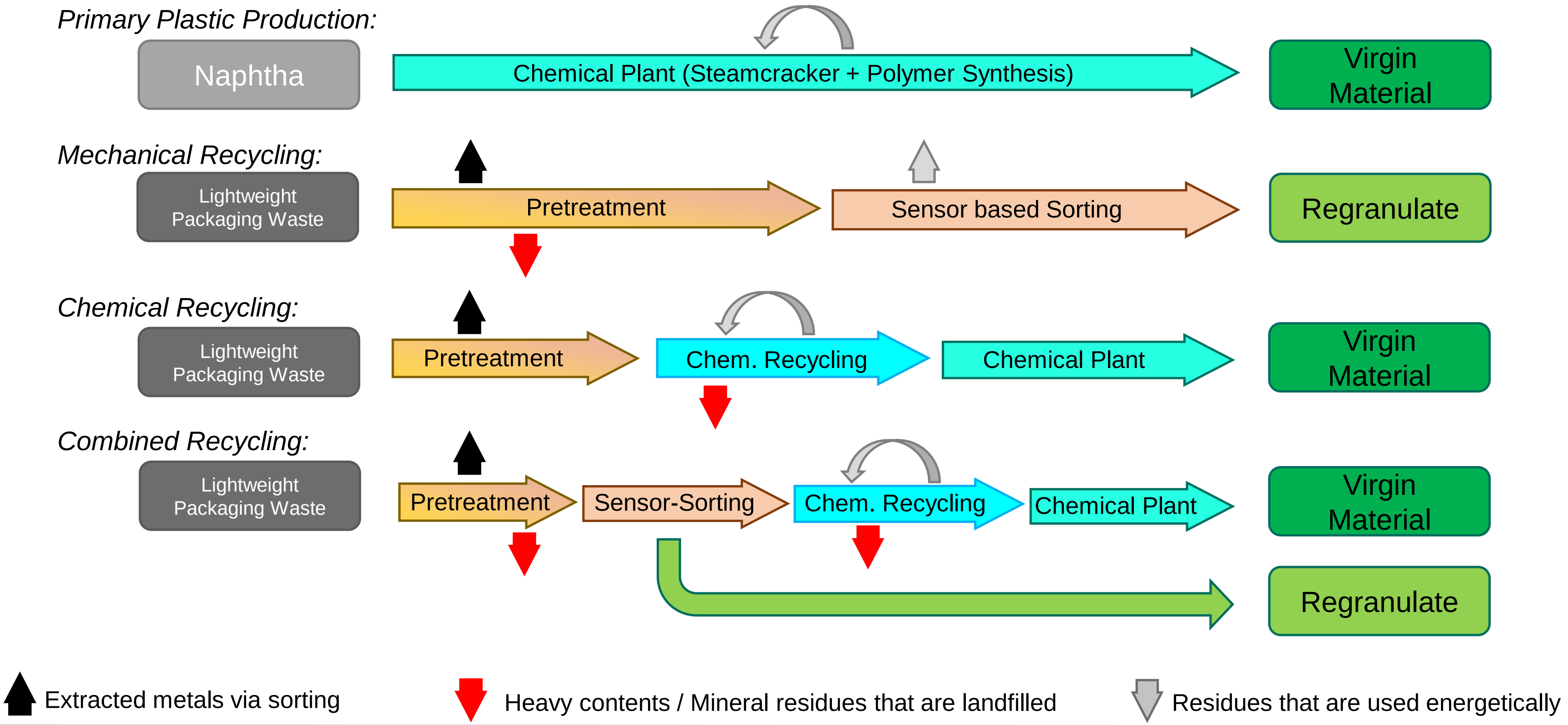
Zeller, M., et al.: Chemical recycling of mixed plastic wastes by pyrolysis. Chem. Ing. Tech. 2021, 93 (11), 1-9. https://doi.org/10.1002/cite.202100102

Mass Flow Diagram of LWP Waste Pyrolysis Route



Case Study: Recycling of Light Weight Packaging Waste

Comparison of Recovery Routes



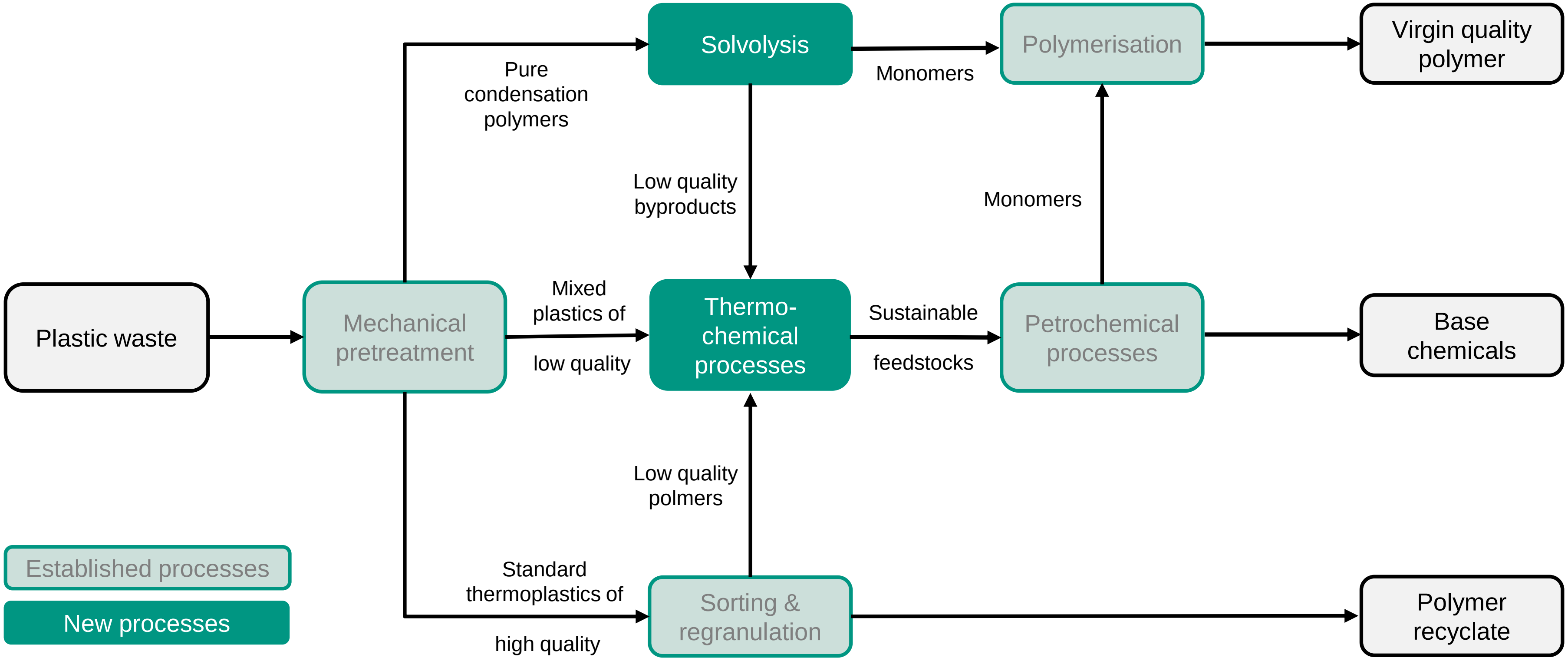
LWP Waste Recycling Routes Compared to Primary Plastics Production of HDPE

Recycling scenario	Cost [€/kg_{Input}]	CED [MJ/kg_{Input}]	GWP [$kgCO_2e/kg_{Input}$]	Overall Carbon Recycled
Mechanical, 42% yield	-0.16	-18.1	0.2	42%
Mechanical, 22% yield	-0.08	-6.9	0.6	22%
Chemical recycling	-0.24	-15.9	0.3	59%
Combined recycling, mech. 42%	-0.29	-30.1	-0.2	74%
Combined recycling, mech. 22%	-0.25	-23.1	0.0	66%

Volk,R., et al.: Techno-economic Assessment and Comparison of Different Plastic Recycling Pathways - a German Case Study, Journal of Industrial Ecology, 2021, 1-20; https://doi.org/10.1111/jiec.13145

THINKTANK INDUSTRIELLE RESSOURCEN-STRATEGIEN

Technology infrastructure of a circular economy of plastics



Conclusions

Technical assessment of combined mechanical and chemical recycling

Comparison of the production of plastics from fossil raw materials with the combined mechanical / chemical recycling of post-consumer waste, taking into account energy recovery

- **Costs:** Economic attractiveness of both, mechanical and chemical recycling
- **Energy:** Mechanical and chemical recycling perform similar; advantageous over crude oil based products
- **CO_2 emissions**: Mechanical and chemical recycling perform similar; at high recycling rates advantegous over crude oil based products, today already
- **High recycling rates** can be achieved through a combination of mechanical and chemical recycling, only
- Chemical recycling **technology readiness** is insufficient: Reactor scale-up, product upgrading, process evaluation

Acknowledgement

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ARN B.V.

Pre Zero GmbH & Co. KG

Electrocycling GmbH

I.A.R. RWTH Aachen*

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*BMBF-project 033R214D KUBA: Nachhaltige Kunststoffwertschöpfungskette: Pilotfall Kunststoffe in Bauwirtschaft und Gebäuden

KIT/Conversio, 2019: „BKV-Studie“ Thermal Processes for Feedstock Recycling of Plastics Waste, http://www.bkv-gmbh.de/infothek/studien.html