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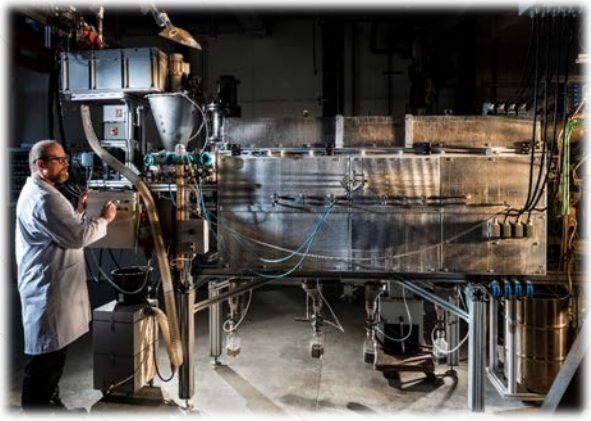
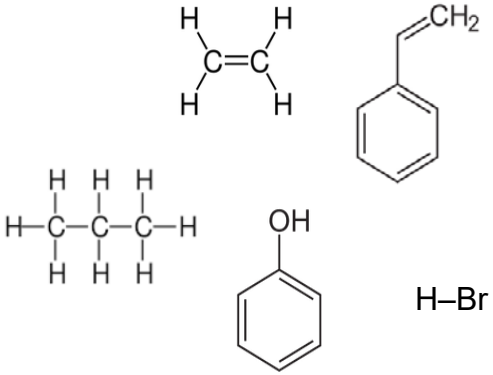
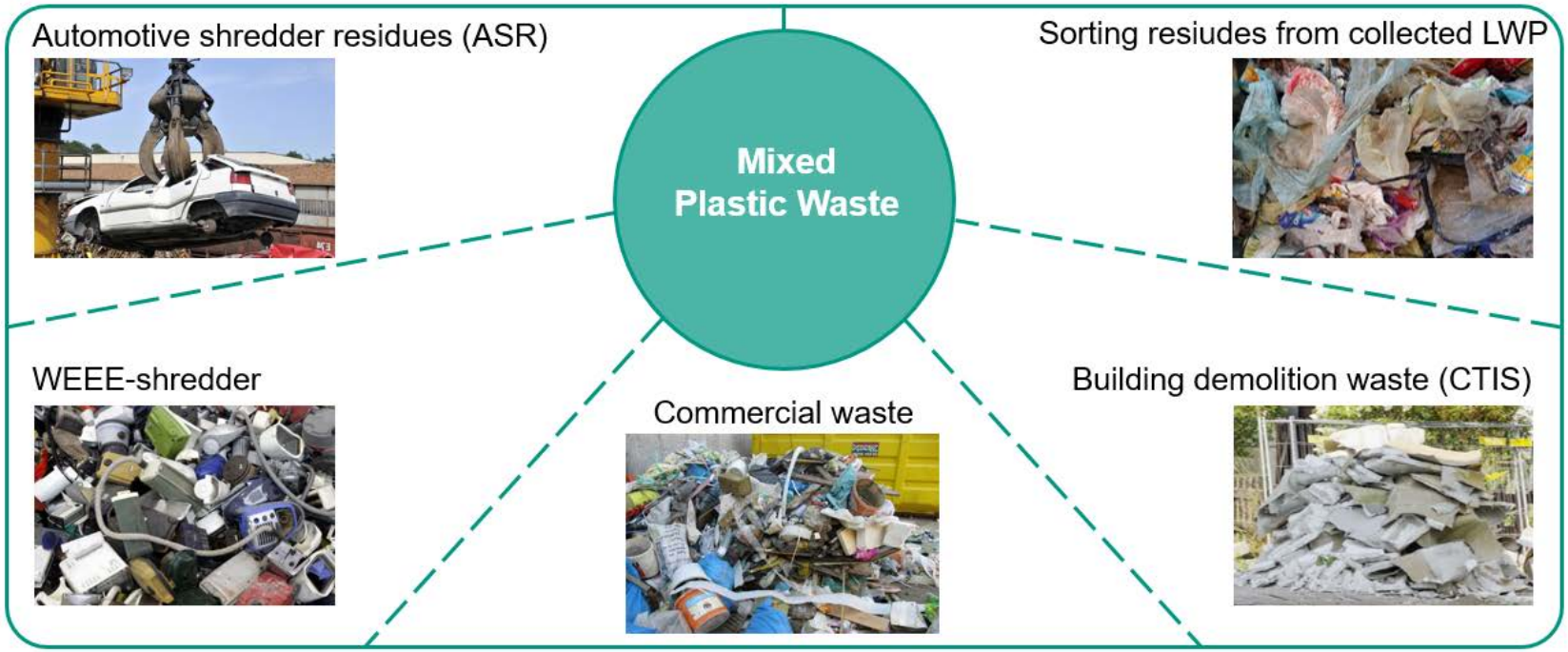
Technical Assessment of Combined Mechanical and Chemical Recycling

Dieter Stapf



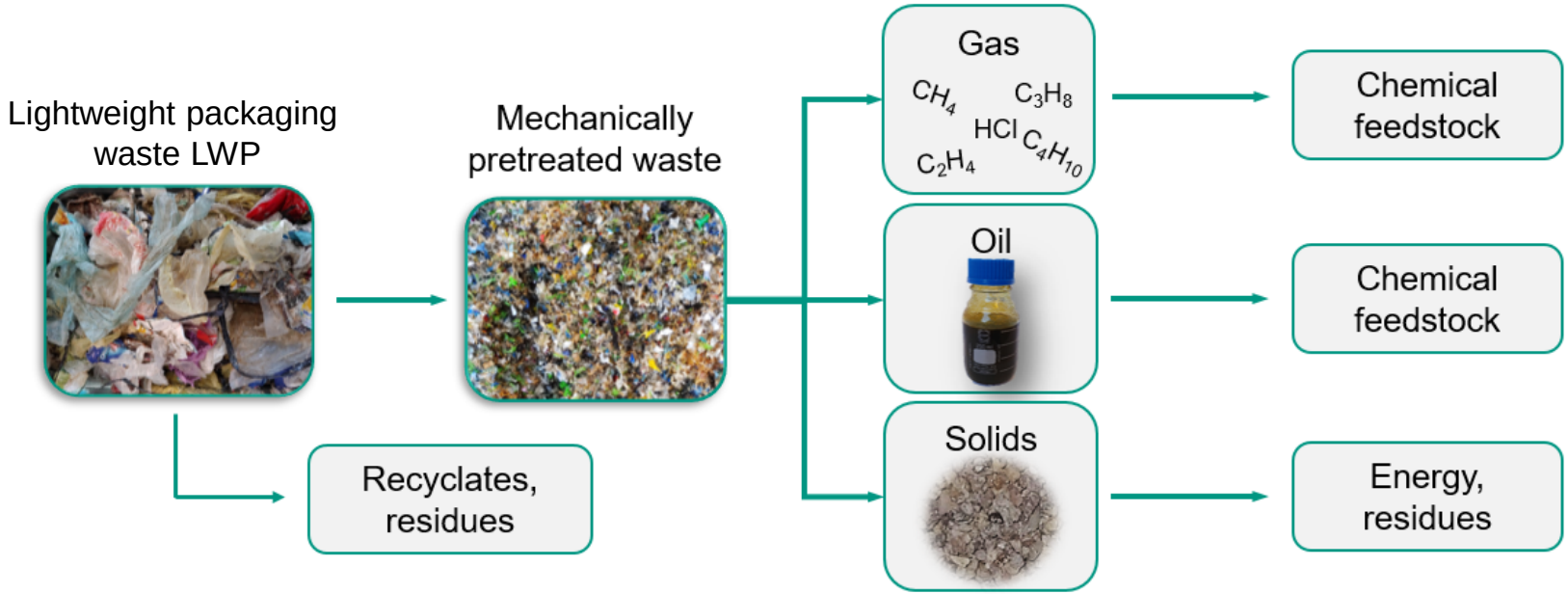


Examples of Plastic Waste Produced

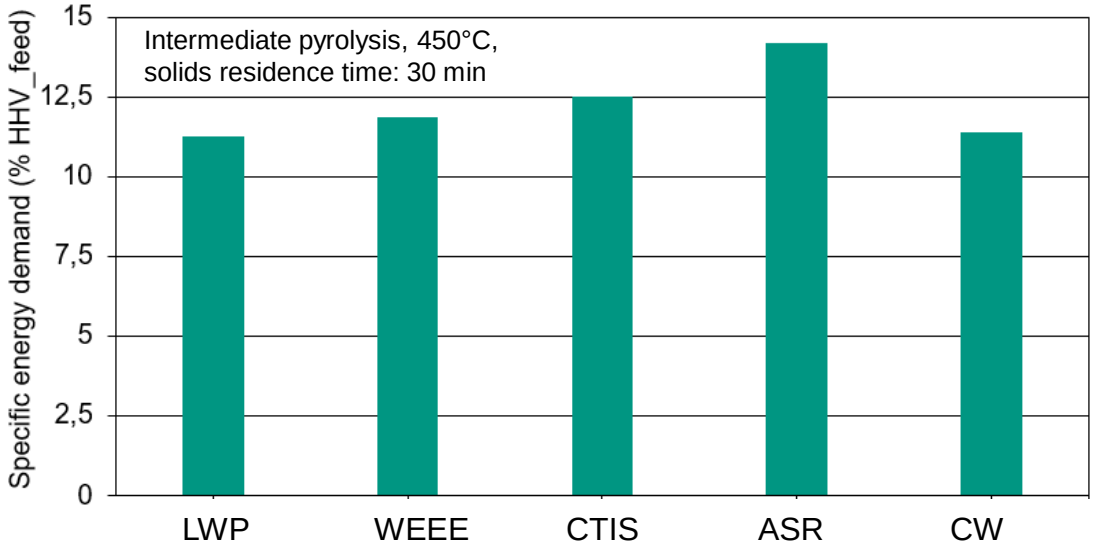


WEEE = Waste of Electrical and Electronic Equipment
LWP = Light Weight Packaging Waste
CTIS = Compound Thermal Insulation System

Recycling of Collected Plastic Waste - The Pyrolysis Value Chain Example



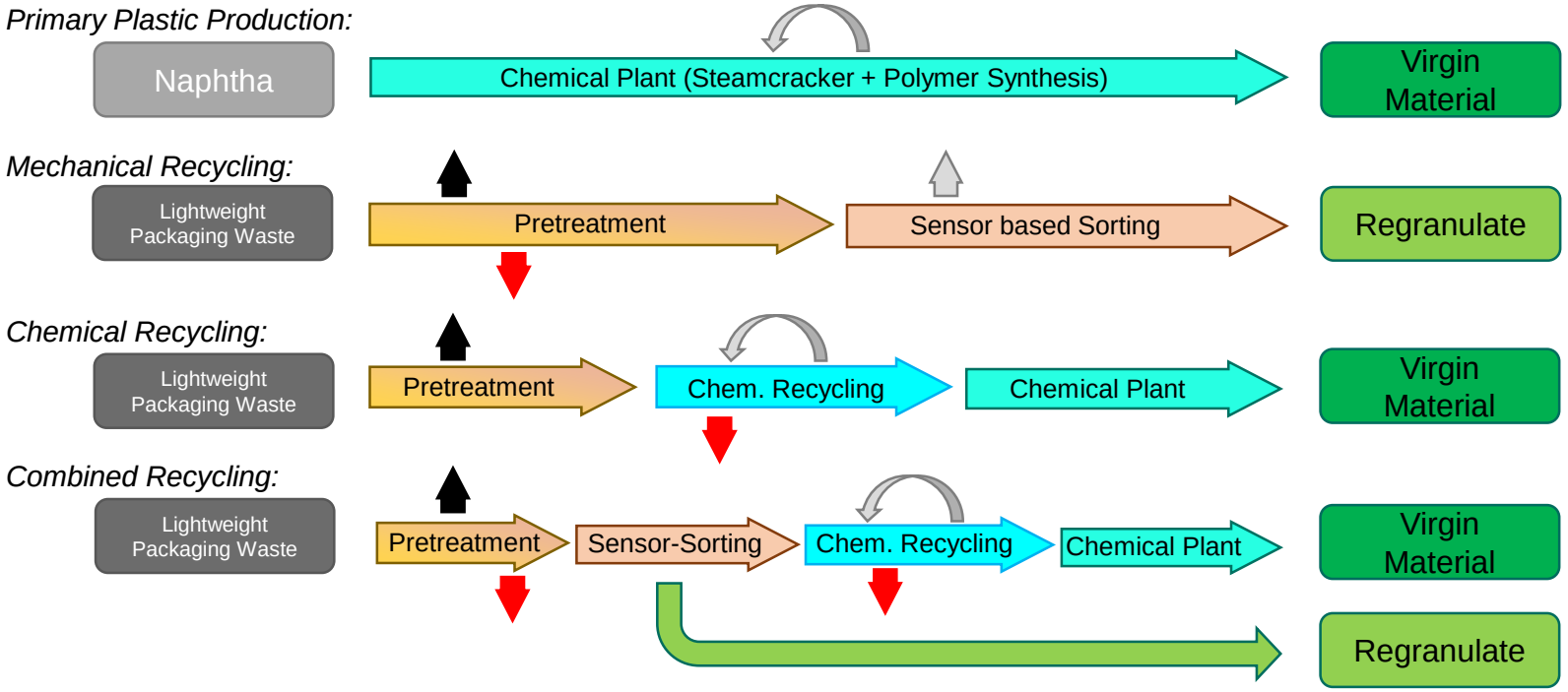
Pyrolysis Process Energy Demand (for heating, melting, pyrolysis & evaporation)



Netsch, N., et al., Chemisches Recycling kunststoffhaltiger Abfälle – Das Potenzial der Pyrolyse, Chemie-Ingenieur-Technik 92(9), 2020, p.1260

Recycling of Lightweight Packaging Waste

Recovery Routes

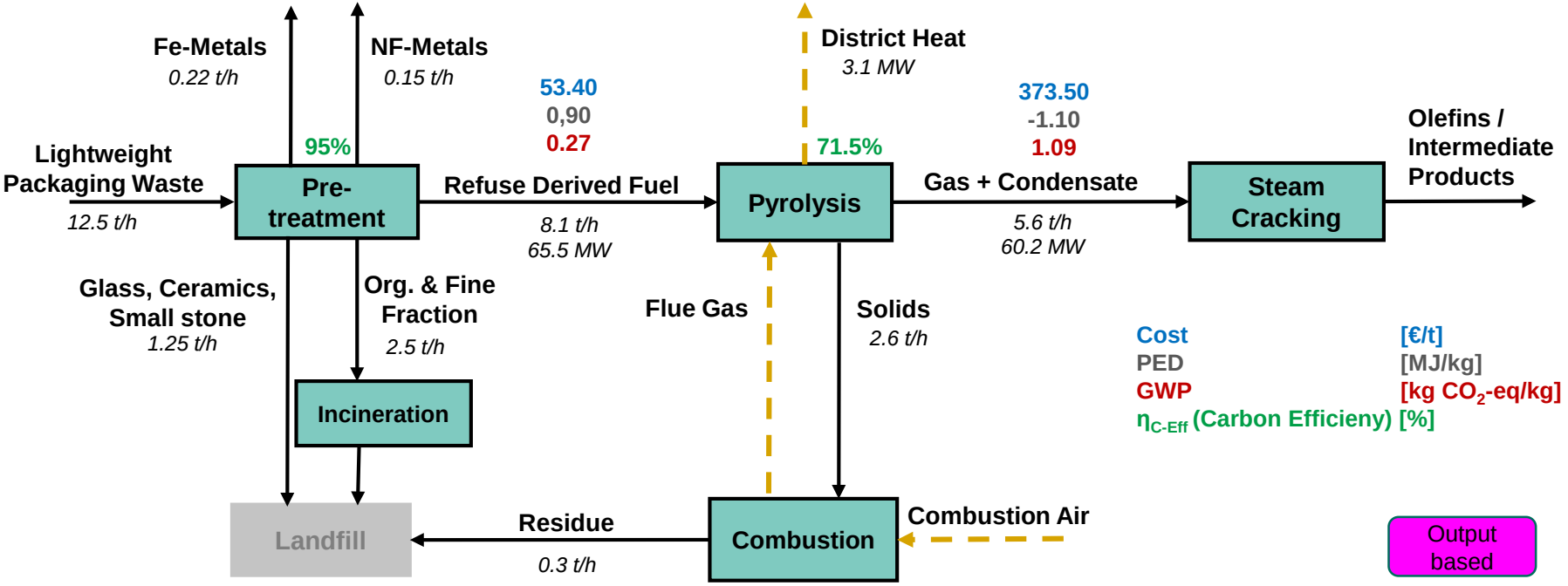


Extracted metals via sorting

Heavy contents/ Residues that are landfilled

Sorting residues that are used energetically

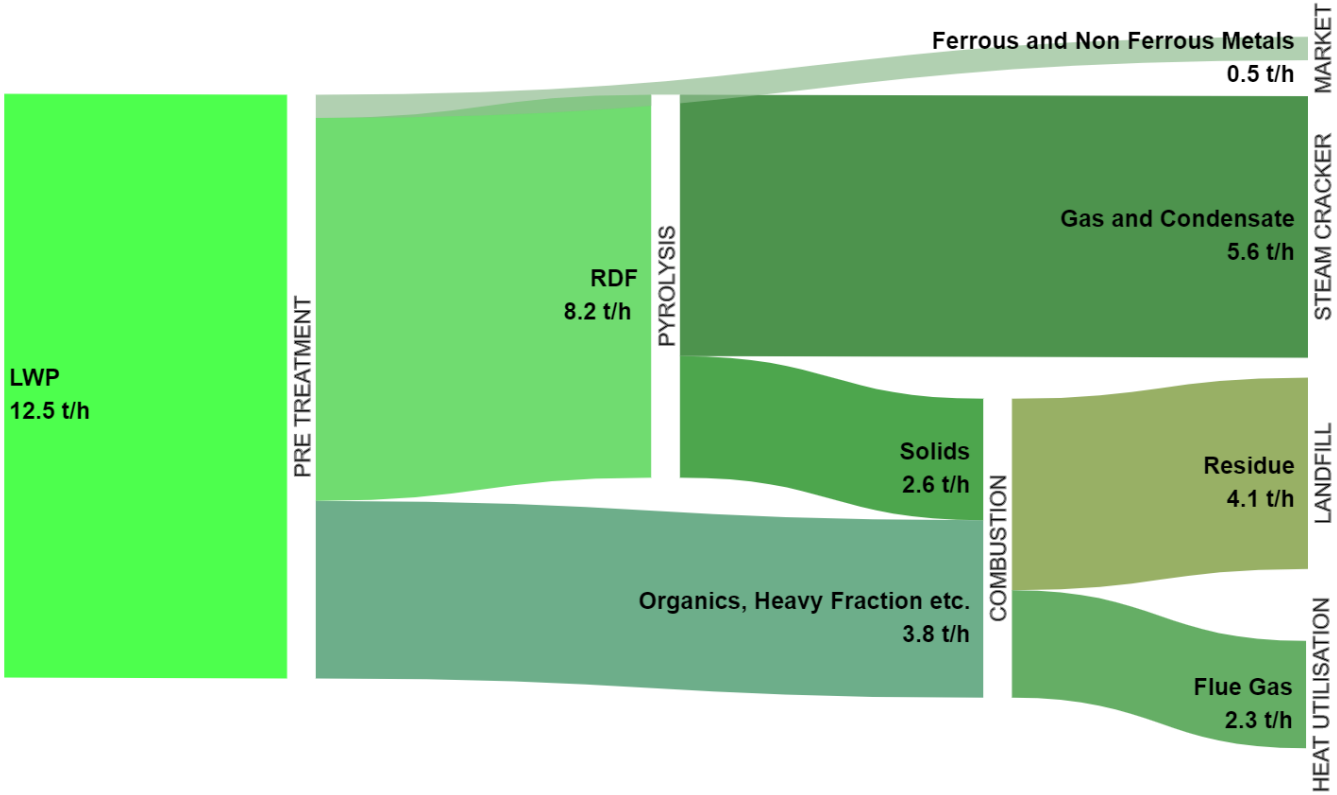
Pyrolysis Route: Material Flow Analysis
Chemical Recycling



Costs: BKV-study: Thermal processes for feedstock recycling of plastics waste, study conducted by KIT and Conversio Market & Strategy GmbH on behalf of BKV GmbH and Plastics Europe AISBL, 2019. https://www.bkv-gmbh.de/en/info-zone/studies.html

Yields: Andreas, B., et al., Pyrolytische Rohstoffrückgewinnung, Mannesmann VEBA Umwelttechnik GmbH, Eisen und Metall AG, Rütgerswerke AG, 1981

Mass Flow Diagram of LWP Waste Pyrolysis Route



LWP 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 Efficiency
Mechanical, 42% yield	-0.15	-15.3	0.4	42
Mechanical, 22% yield	-0.08	-3.5	0.8	22
Chemical recycling	-0.23	-14.4	0.4	59
Combined recycling, mech. 42%	-0.29	-28.6	-0.1	74
Combined recycling, mech. 22%	-0.26	-21.6	0.1	66

Volk,R., et al., Techno-economic Assessment and Comparison of Different Plastic Recycling Pathways - a German Case Study, submitted for journal publication, 2020

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 combined mechanical / chemical recycling in comparison to energetic recovery
- Energy: Mechanical and chemical recycling are similar; advantageous over crude oil based products
- CO_2 emissions: Mechanical and chemical recycling similar; advantegous over crude oil based product
- Recycling quotas can be achieved through a combination of mechanical and chemical recycling

Backup

Team KIT:

Institute for Technical Chemistry: Hans Leibold, Niklas Netsch, Frank Richter, Dieter Stapf, Manuela Wexler, Savrina P. Yogish, Michael Zeller

Institute for Industrial Production: Frank Schultmann, Christoph Stallkamp, Justus Steins, Rebecca Volk

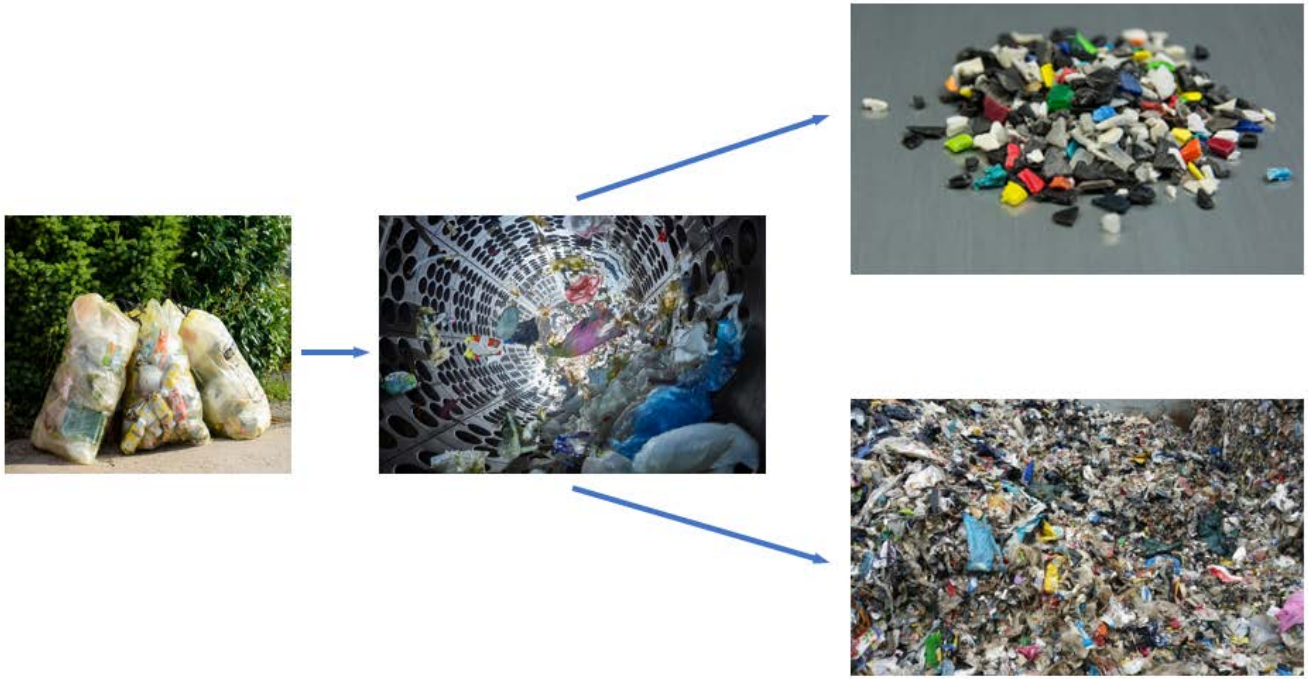
Study funded by:

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)

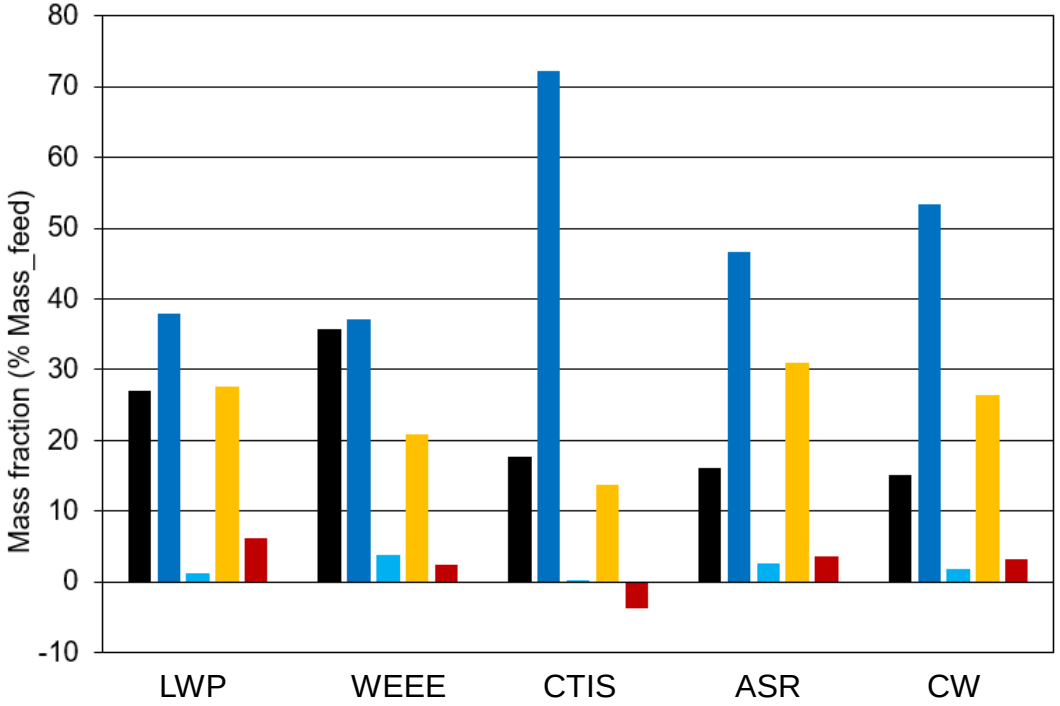
*) Lindner,C. et al., Circular Economy of Plastics 2018 EU-28+2, Conversio Market & Strategy GmbH, Mainaschaff (2019)
**) Lindner,C., Schmitt, J., Stoffstrombild Kunststoffe in Deutschland 2017, Conversio Market & Strategy GmbH, Mainaschaff (2018)

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

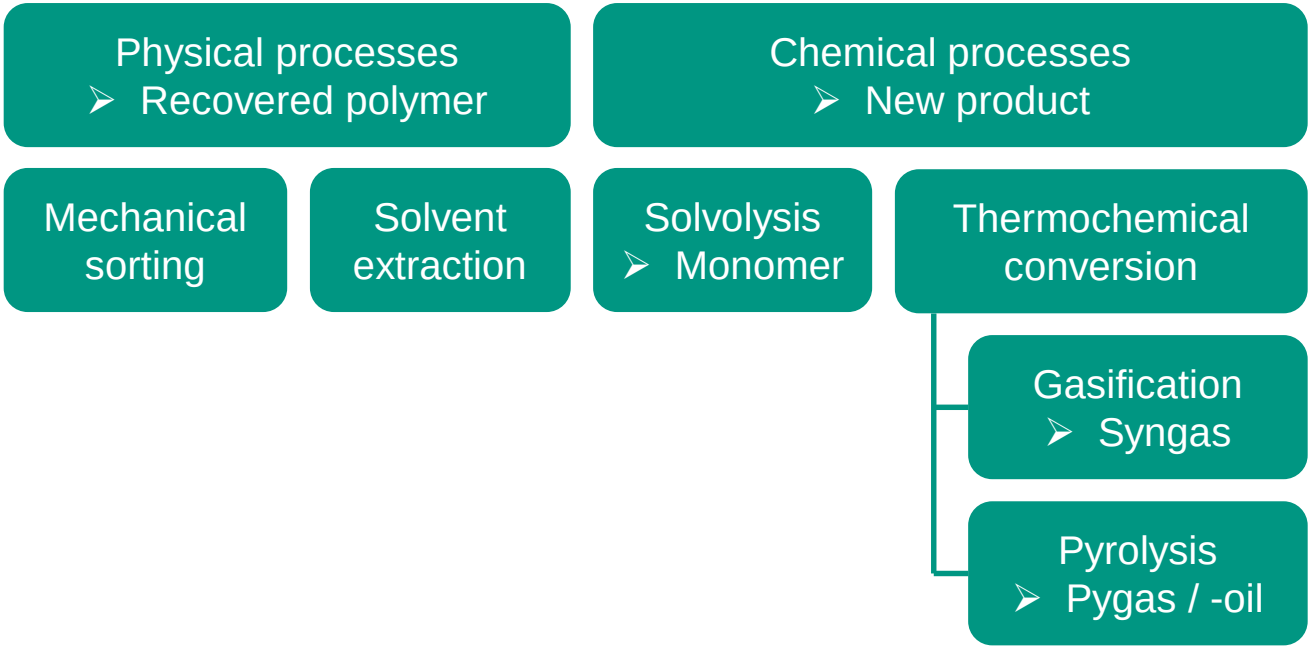
Pyrolysis Products Distribution



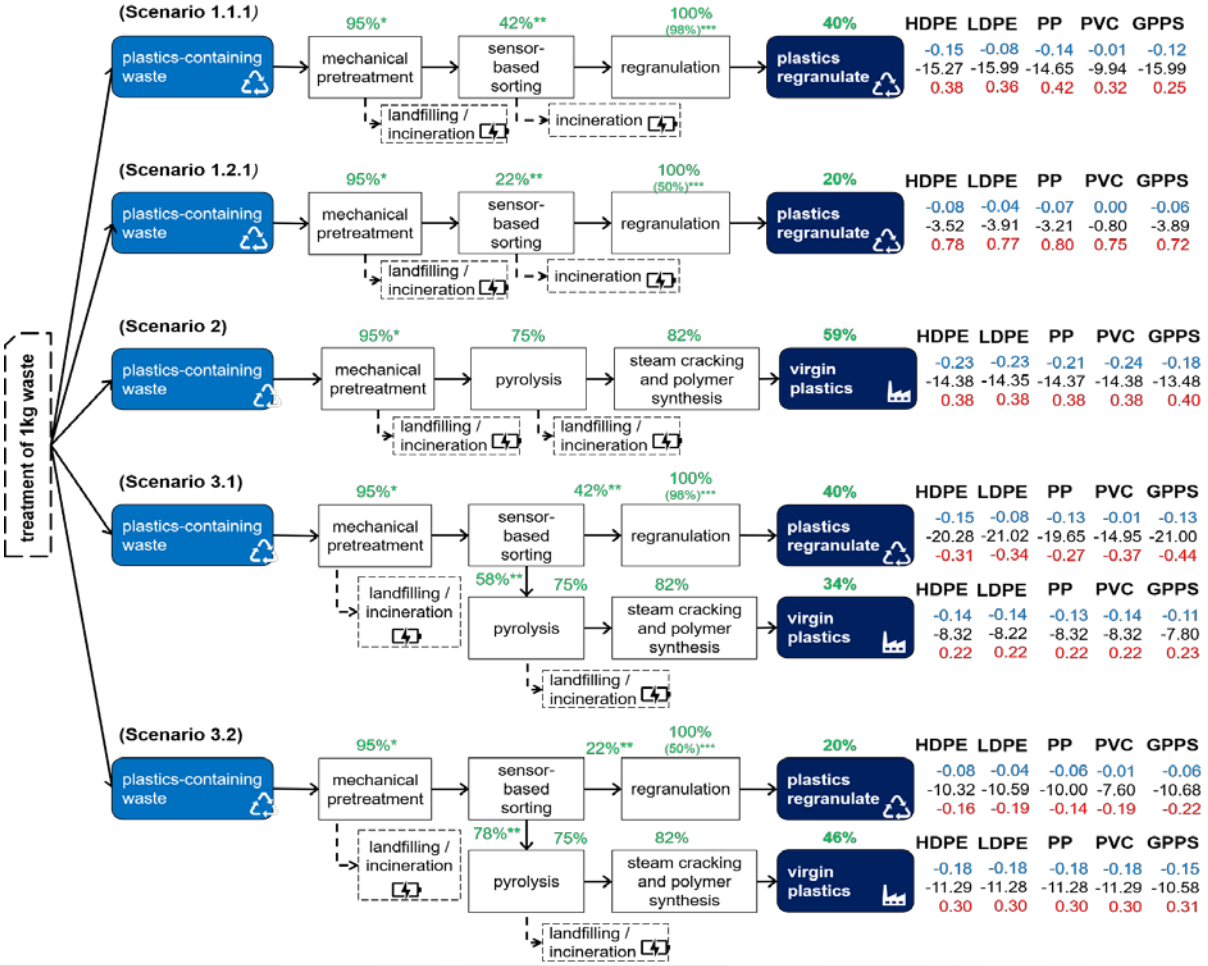
Intermediate pyrolysis, KIT: 450°C,
solids residence time: 30 min

Netsch, N., et al., Chemisches Recycling kunststoffhaltiger Abfälle – Das Potenzial der Pyrolyse, Chemie-Ingenieur-Technik 92(9), 2020, p.1260

Recycling Processes for Mixed Plastic Waste and Key Products



applied to:	➢ standard thermoplastics	➢ Pure polymers	➢ Polycondensates	➢ Mixed wastes, composite materials



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Cost [€/t]
PED [MJ/kg]
GWP [kg CO_2-eq/kg]
$\eta_{C\text{-}Eff}$ (Carbon Efficieny) [%]

Input based

References

Cost:	stock exchange price for crude oil / natural gas / naphtha, Kunststoff Information (2019) for ethylene / benzene / styrene / GPPS / HIPS (last update: 03.07.2019), *estimated value
PEA:	Ecoprofiles PlasticsEurope, **own calculation
GWP_{100}:	Ecoprofiles PlasticsEurope, *estimated value
Rel. share:	own calculation
Carbon Efficiency:	total mass of carbon in the desired product divided by the total mass of carbon of the feedstock