Chemical Recycling of Mixed Plastics Waste by Pyrolysis

VIth International Symposium (Waste), Stuttgart, November 4, 2022

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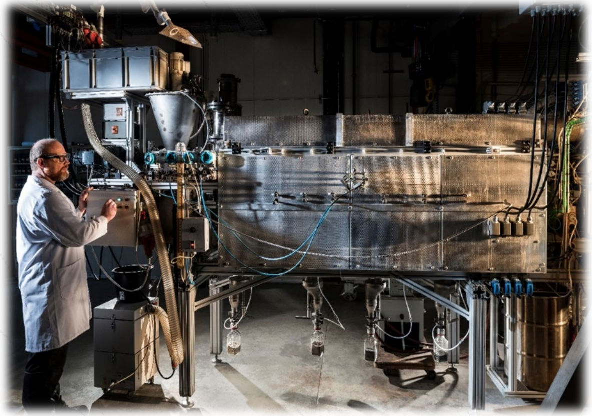

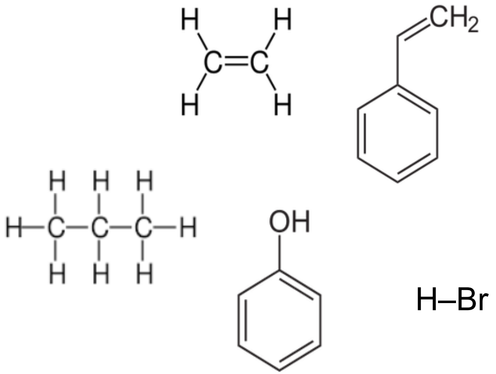

Plastics Production and Plastics Waste Generation

[Mt / year]	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)

Additional plastics recycling capacity demand until 2030: 11 Mt / year

*) 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)

Recycling Processes for Mixed Plastics Waste and Key Products

Physical processes
➢ Recovered polymer

- Mechanical sorting
- Solvent extraction

Chemical processes
➢ New product

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

applicable to:

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

Capital Investments (excerpt):
Chemical Recycling of Plastics Waste

- Enerkem, CAN
  → W2C project, Rotterdam, NL
- Plastic Energy, UK
  - Operations @ Almeria & Sevilla, ES
- Sabic, SAU
  → 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

Collection and Sorting of Lightweight Packaging Waste (LWP)

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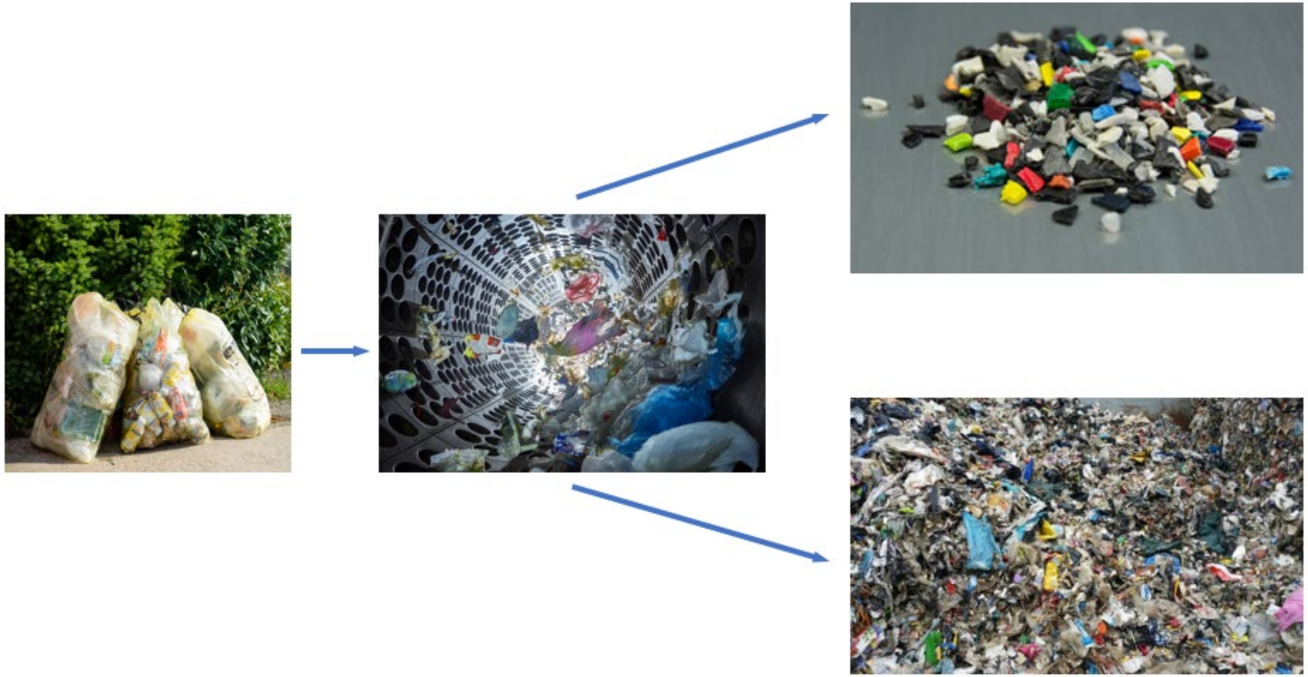
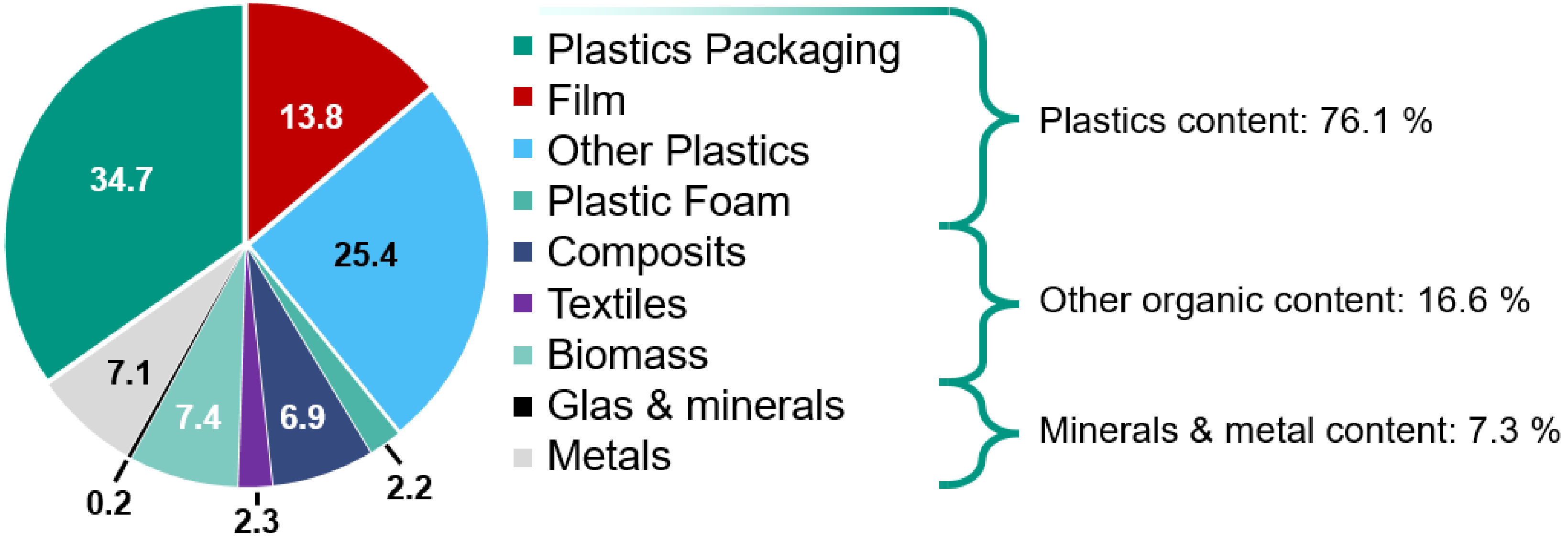


Images: www.awg-info.de/index.php?id=65, www.erema.com/de/erema_news/IDobj=200, ww.reclaygroup.com/de/images/Content/Presse/pressefotos/bilddatenbank/sortierung/161010_Sortieranlage_Reclay_by-ASP_DSF3429.jpg

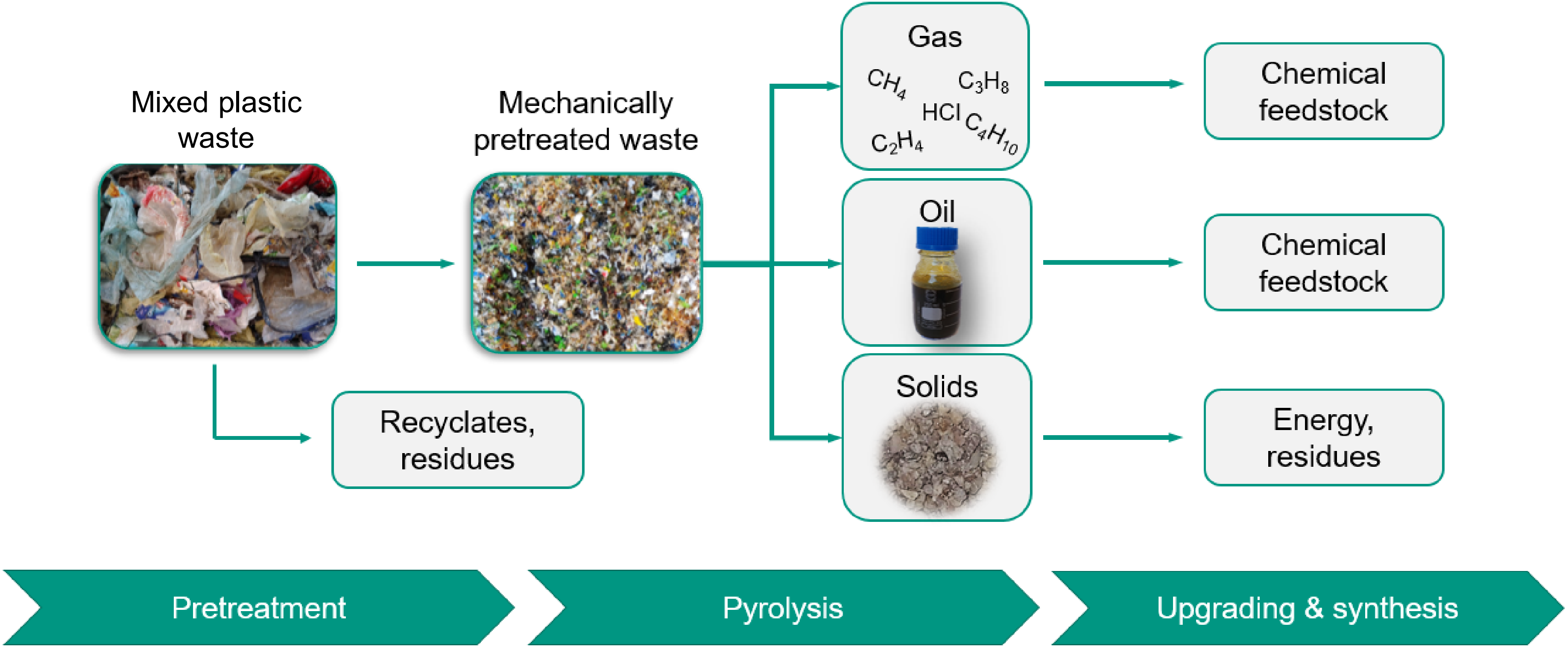
Composition of LWP Waste Sorting Residues

- 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

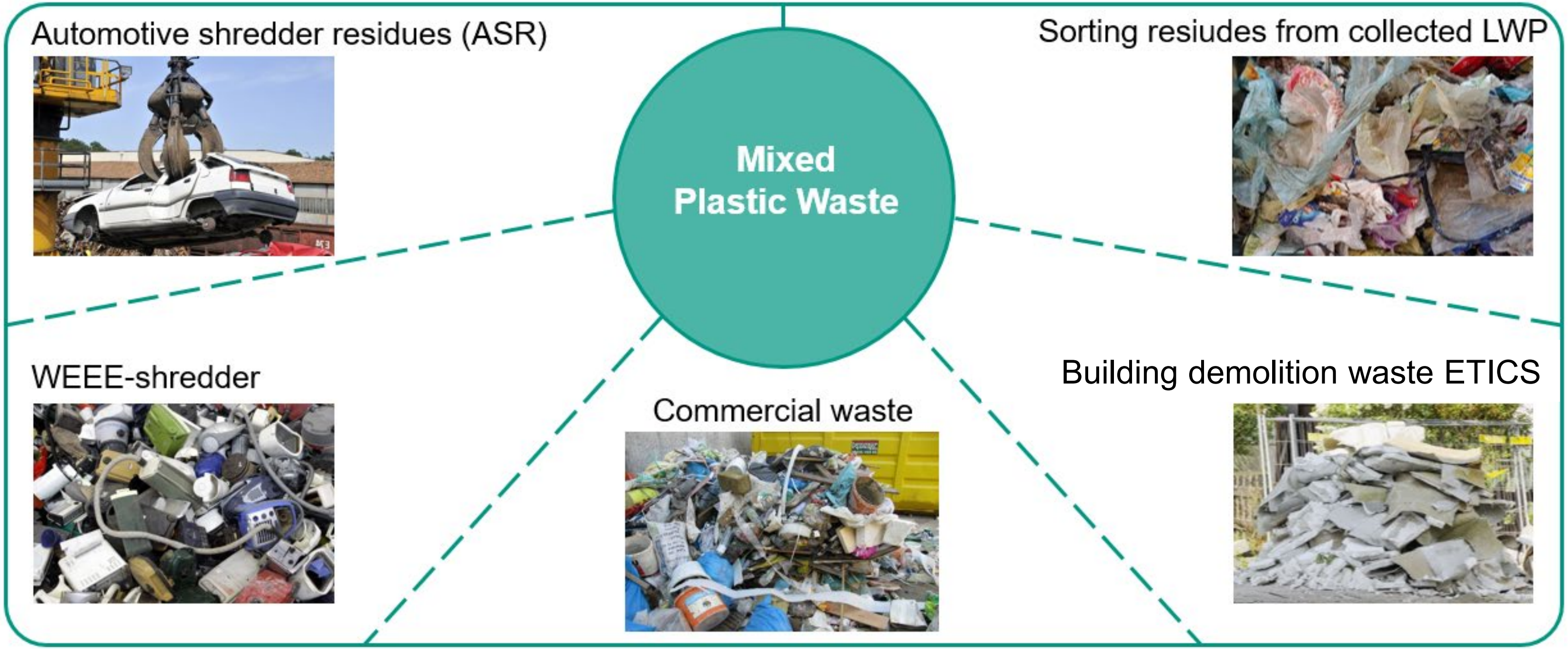


Composition of a sorting plant random sample

Recycling of Mixed Plastics Waste: The Pyrolysis Value Chain Example



Examples of Plastics Waste Produced



WEEE = Waste of Electrical and Electronic Equipment
LWP-SR = Sorting Residues from Light Weight Packaging Waste collected
ETICS = Thermal Insulation Composite System

Waste Feedstock Analysis

	LWP-SR [m.-%]	WEEE [m.-%]	*ETICS* [m.-%]		CW [m.-%]	ASR [m.-%]
			EPS	XPS		
Moisture (1)	1.7	0.5	0.0	0.0	0,0	1.5
Ashes (550 °C) (2)	10.6	27.6	8.2	6.7	9.2	13.3
C (2)	58.5	53.1	82.5	79.4	74.7	67.0
H (2)	7.5	6.1	7.1	7.1	8.8	8.5
N (2)	< 1.0	1.5	< 1.0	< 1.0	< 1.0	1.8
S (2)	0.1	0.1	< 0.1	< 0.1	< 0.1	0.2
Cl + Br (2)	2.0	2.8	0.3	0.1	3.3	1.2
O (2) (3)	21.3	8.8	1.9	6.7	4.0	6.1
Calorific value(2) / MJ/kg	ca. 25	ca. 23	ca. 35	ca. 34	ca. 34	ca. 31

(1) pretreated (2) dry (3) calculated

Waste random samples

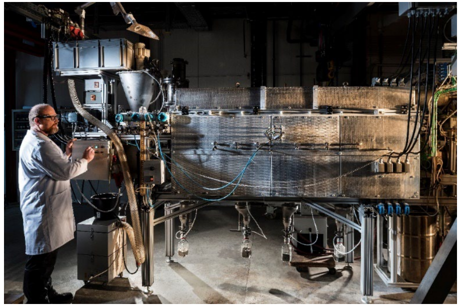
H / C – Ratio

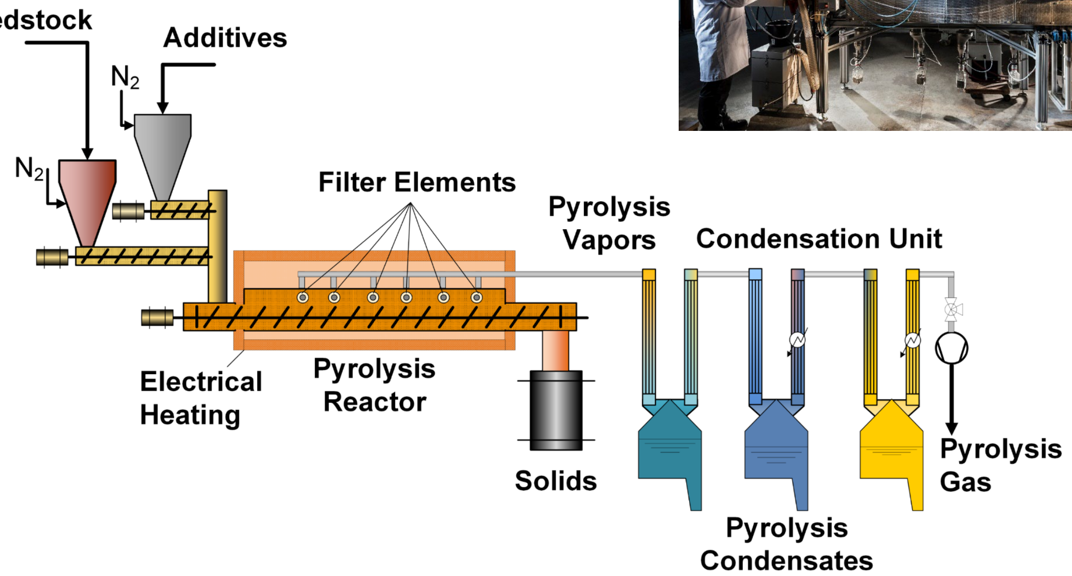
	LWP-SR [m.-%]	WEEE [m.-%]	*ETICS* [m.-%]		CW [m.-%]	ASR [m.-%]
			EPS	XPS		
H / C - ratio	1.5	1.4	1.0	1.0	1.4	1.5

Pyrolysis technology in pilot scale

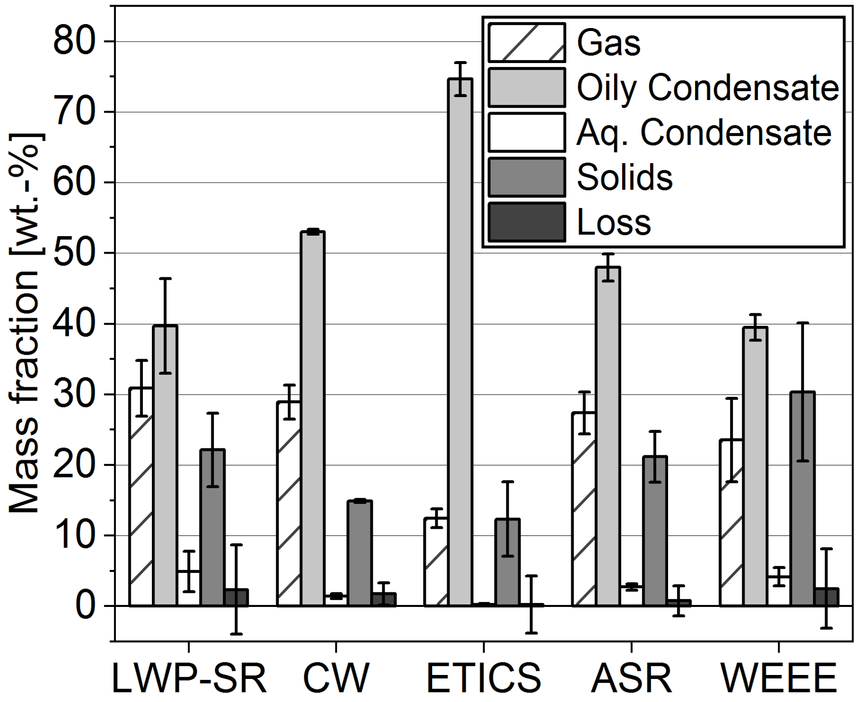
Screw reactor with integrated hot gas/vapour filtration

- Flow rate < 10 kg/h
- Temperature < 550°C
- Pressure: 1 atm
- Solids residence time < 60 min





Pyrolysis Mass Balance



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

Pyrolysis Carbon Recovery

Feedstock	Fraction of C-feed found back in oily condensate
	[wt-%]
LWP-SR	51.1
CW	60.0
ETICS (XPS)	74.6
ETICS (EPS)	72.9
ASR	57.5
WEEE	60.5

Pyrolysis Energy Balance

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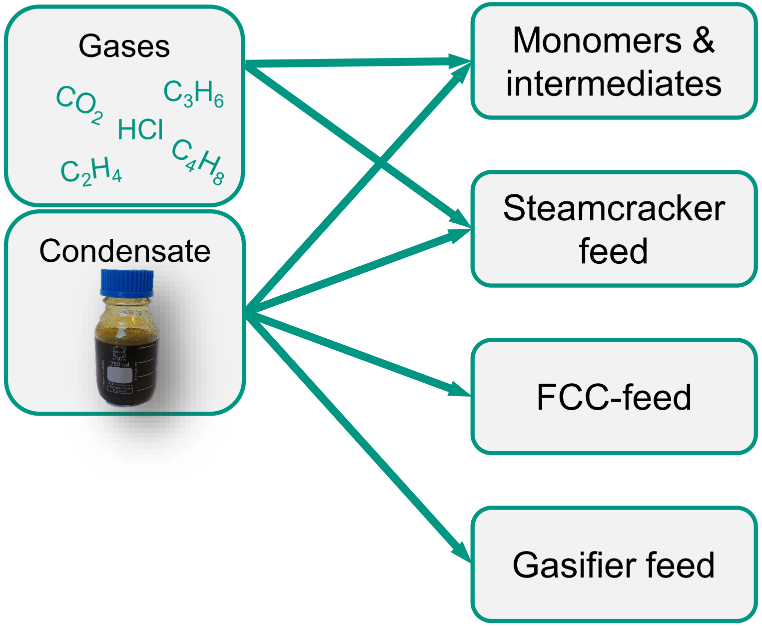
Feedstock	Energy demand for heating, melting, thermal degradation, evaporation
	[% of feedstock higher heating value]
LWP-SR	5.1
CW	5.2
XPS	4.9
ASR	5.4
WEEE	3.7

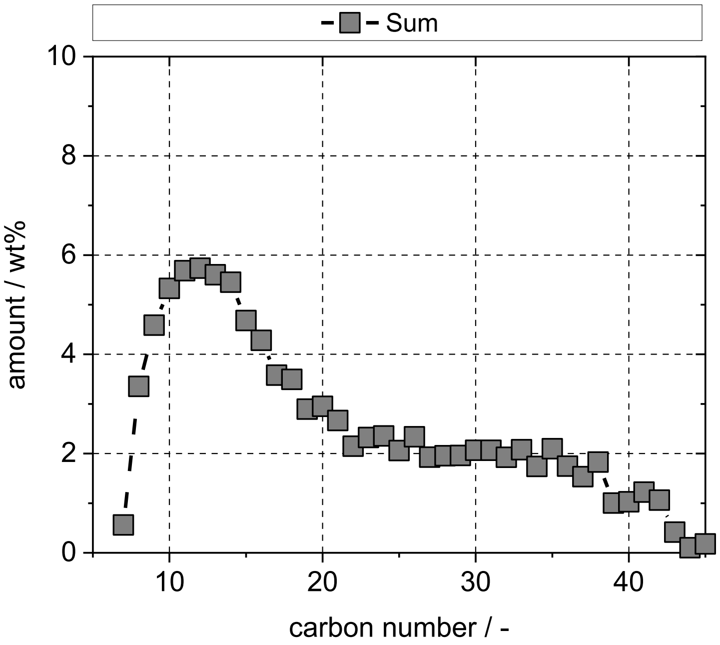
Upgrading of Pyrolysis Products to Secondary Petrochemical Feedstock

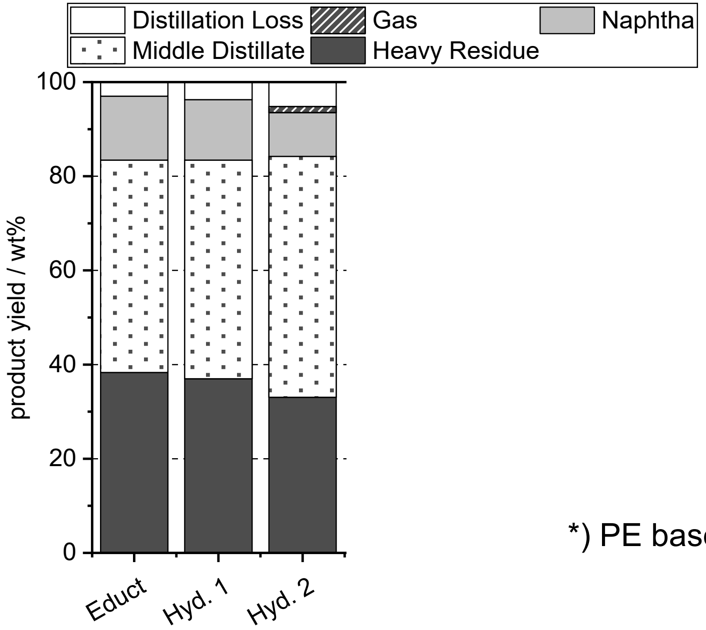


Upgrading of pyrolysis products

- Removal of heteroatoms (N, O, Cl, Br, S, …)
- Fractionating (monomers, petrol refinery boiling cuts)
- Hydroprocessing (adapt hydrocarbon substance group contents)

Pyrolysis Oil Characterization* and Hydrotreatment

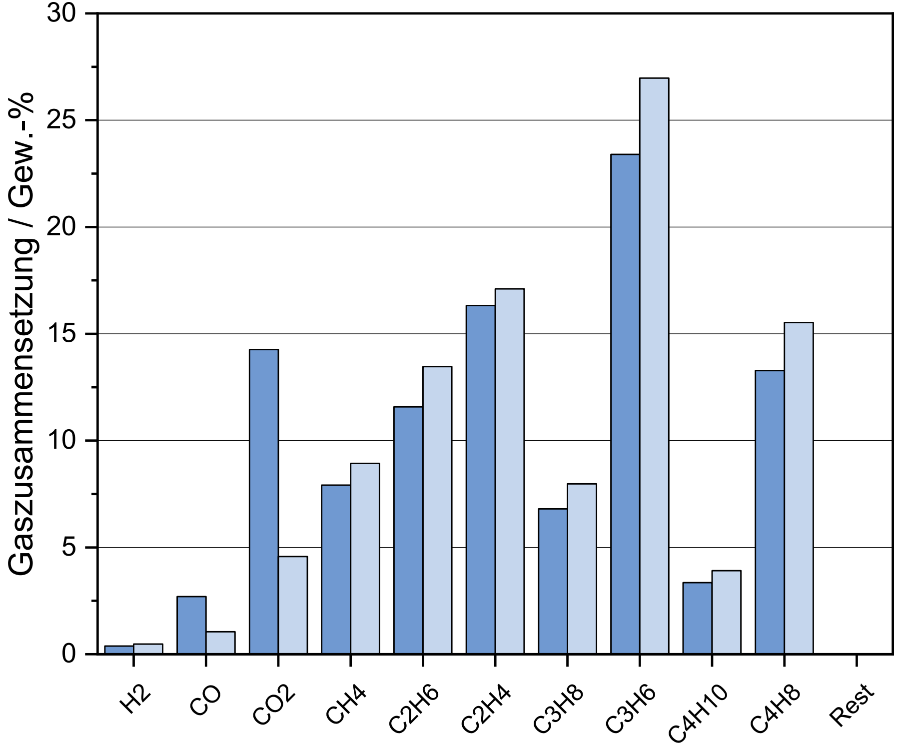




*) PE based wax

Neuner, P. et al.: Chemical Conversion of Fischer–Tropsch Waxes and Plastic Waste Pyrolysis Condensate to Lubricating Oil and Potential Steam Cracker Feedstocks. Reactions 2022, 3, 352–373. https://doi.org/10.3390/reactions3030026

Pyrolysis Gas Characterization*



***) Polyolefinic waste based pyrolysis gases as petrochemical feedstock**

- Thermal, non-catalytic pyrolysis of collected waste agricultural films, screw-pyrolysis @ 450°C, 30 min
- Contaminated polyolefinic waste (LDPE basis)
- Average gas composition of 2 waste samples

Research on Chemical Recycling of Mixed Plastics Waste by Pyrolysis

Karlsruhe Institute of Technology

- Growing volume of complex (plastics) waste that can hardly or cannot be recycled to high value products through collection, sorting and regranulation
- **High recycling rates** can be achieved through a **combination of mechanical and chemical recycling**, only
- **Pyrolysis** as a thermal separation and product conditioning step
- **Carbon efficiency:** yield and composition of liquid (and gaseous) pyrolysis products; product upgrading depending on feedstock utilization
- **Energy efficiency:** no external energy demand of integrated pyrolysis process
- Chemical recycling **technology readiness** is developping towards flexibility and efficiency: mixed plastic waste feedstocks, reactor scale-up, product upgrading, process evaluation

Acknowledgement

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I.A.R. RWTH Aachen*

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VCI

BKV Kunststoff Konzepte Verwertung

HELMHOLTZ Research for Grand Challenges

Thinktank Industrielle Ressourcen-Strategien

*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