IEA Bioenergy
Technology Collaboration Programme

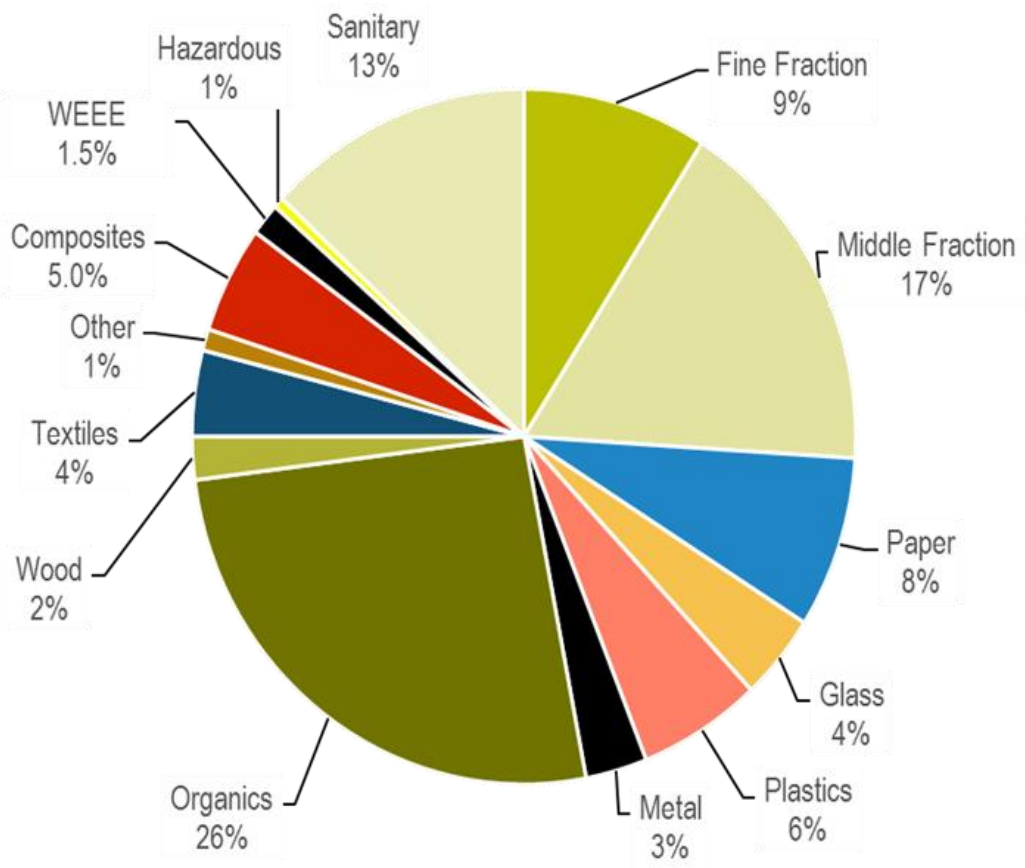
Trends and Drivers in Alternative Thermal Conversion of Waste

Task 36 – Material and Energy Valorisation of Waste in a Circular Economy

Dieter Stapf, Karlsruhe Institute of Technology (KIT)

Webinar, September 16, 2020

Typical Composition* of Residual Household Waste in Developed Countries

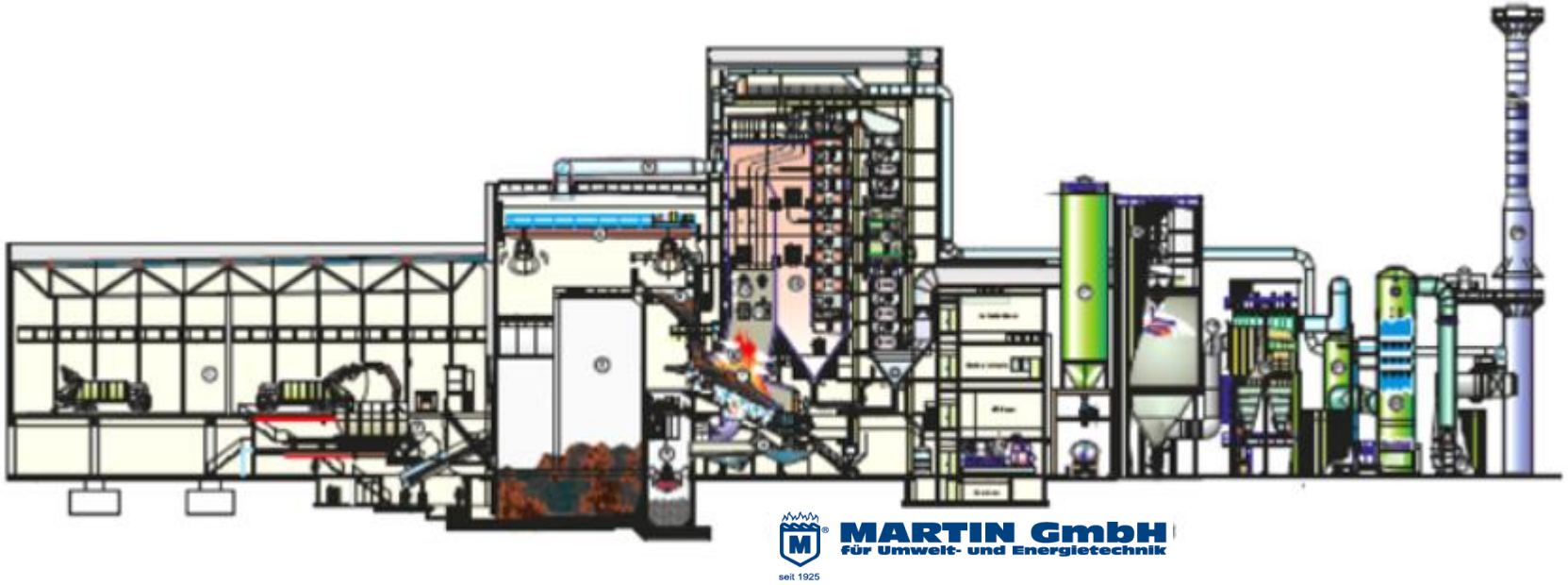


WEEE: Waste Electrical and Electronic Equipment

*) 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

State-of-the-art Waste Incineration Technology:

Wast-to-Energy plant converting collected untreated waste to heat and power

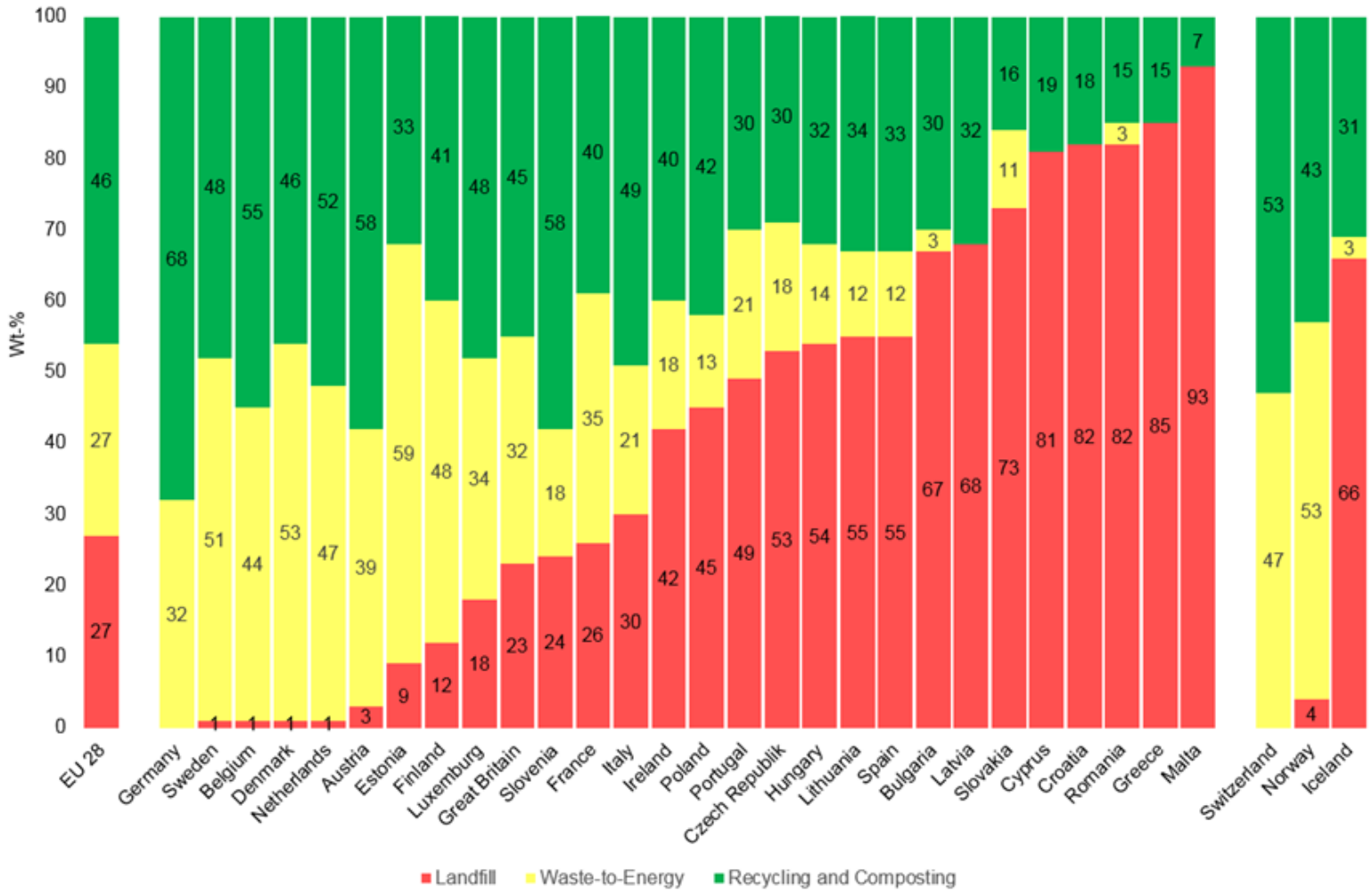


IEA Bioenergy T36 webinar on „Valorization of fly ash from Waste-to-Energy plants“, October 7, 12:00 CEST

The EU Waste Hierarchy

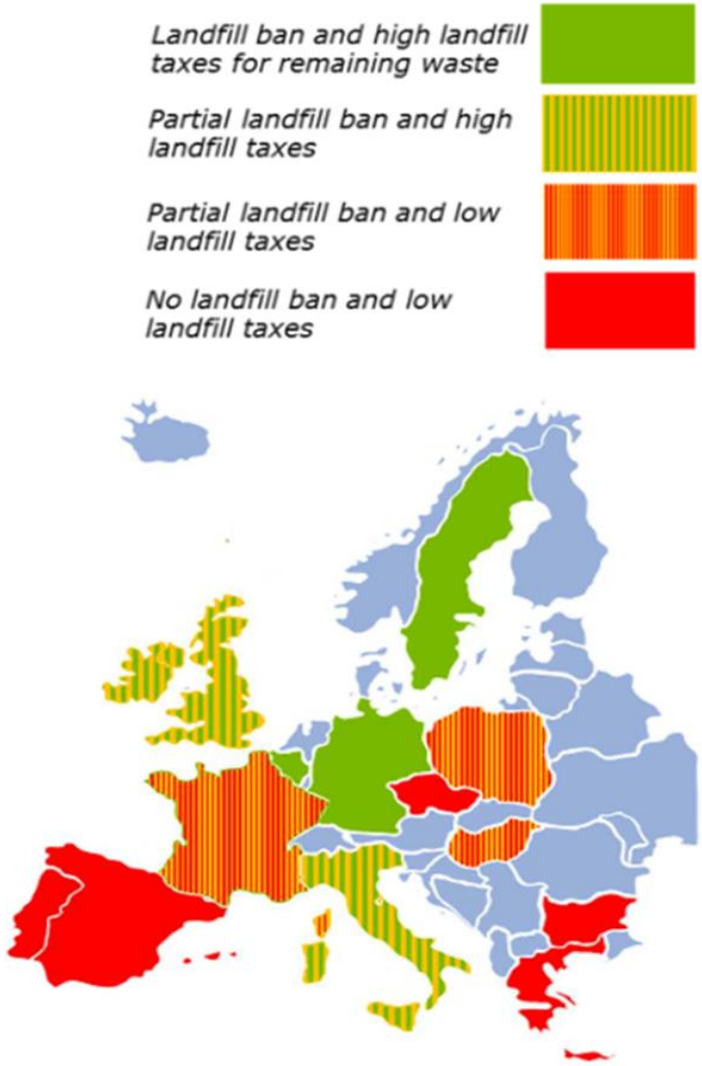
- In the context of climate protection, environmental protection and the concept of a Circular Economy

European Waste Treatment Status in 2014



Spohn,C., Aktuelle Situation der Thermischen Abfallbehandlung in Deutschland vor dem Hintergrund der nationalen und europäischen Entwicklungen, Energie aus Abfall, 15, 2018, https://www.vivis.de/2018/01/energie-aus-abfall-band-15/471/#more-471

Policy Related to Landfilling* in Selected EU Countries



- Landfilling of untreated (combustible) waste to be terminated
  - Long lasting expiry periods
- Insufficient (or even no) incineration capacities in some countries
  - Growing waste produced, incineration capacities fully utilized
- Low acceptance of incineration in some countries

*) De Beer, J, Cihlar, J., Hensing, I., Status and prospects of co-processing of waste in EU cement plants, Executive summary, 2017. https://cembureau.eu/media/1612/2017-05-11_ecofys_publication_alternativefuels_report.pdf ECOFYS-report

Underlying Legal Boundary Conditions

- Target „Recycling quotas“ 2030 (wt-%):

Plastic waste:	55 %	European Commission > News > WEEKLY MEETING | 16 January 2018 | Strasbourg, France **First-ever Europe-wide strategy on plastics**
	60 %	Self-commitment PlasticsEurope Association of Plastics Manufacturers
MSW:	60 %	Council, May 22, 2018
Plastics in packaging waste:	63 % (2022)	Packaging law, Gemany, Jan. 2019

Additional plastic waste recycling capacities required in EU until 2030: 11 Mt/a

Plastics Production and Plastic Waste Generation

[million t / a]	EU 28+2*	Germany**	Italy***	Sweden****
Plastics production	61.8	19.9	9.0[a]	1.3
Plastics consumption	51.2	12.6	7.1	n/a
Plastic waste	29.1	6.2	4.5	1.7
- Landfill	7.2	< 0.1	1.6	< 0.1
- Energy recovery	12.4	3.2	1.5	1.4
- Recycling	9.4 (export 1.8)	2.9 (export: 0.6)	1.4	0.1

*) 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)
***) PlasticEurope, Plastics – the facts, https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_web.pdf; Ispra Rapporto Rifiuti Urbani (2019), https://www.isprambiente.gov.it/files2019/pubblicazioni/rapporti/RapportoRifiutiUrbani_VersioneIntegralen313_2019_agg17_12_2019.pdf

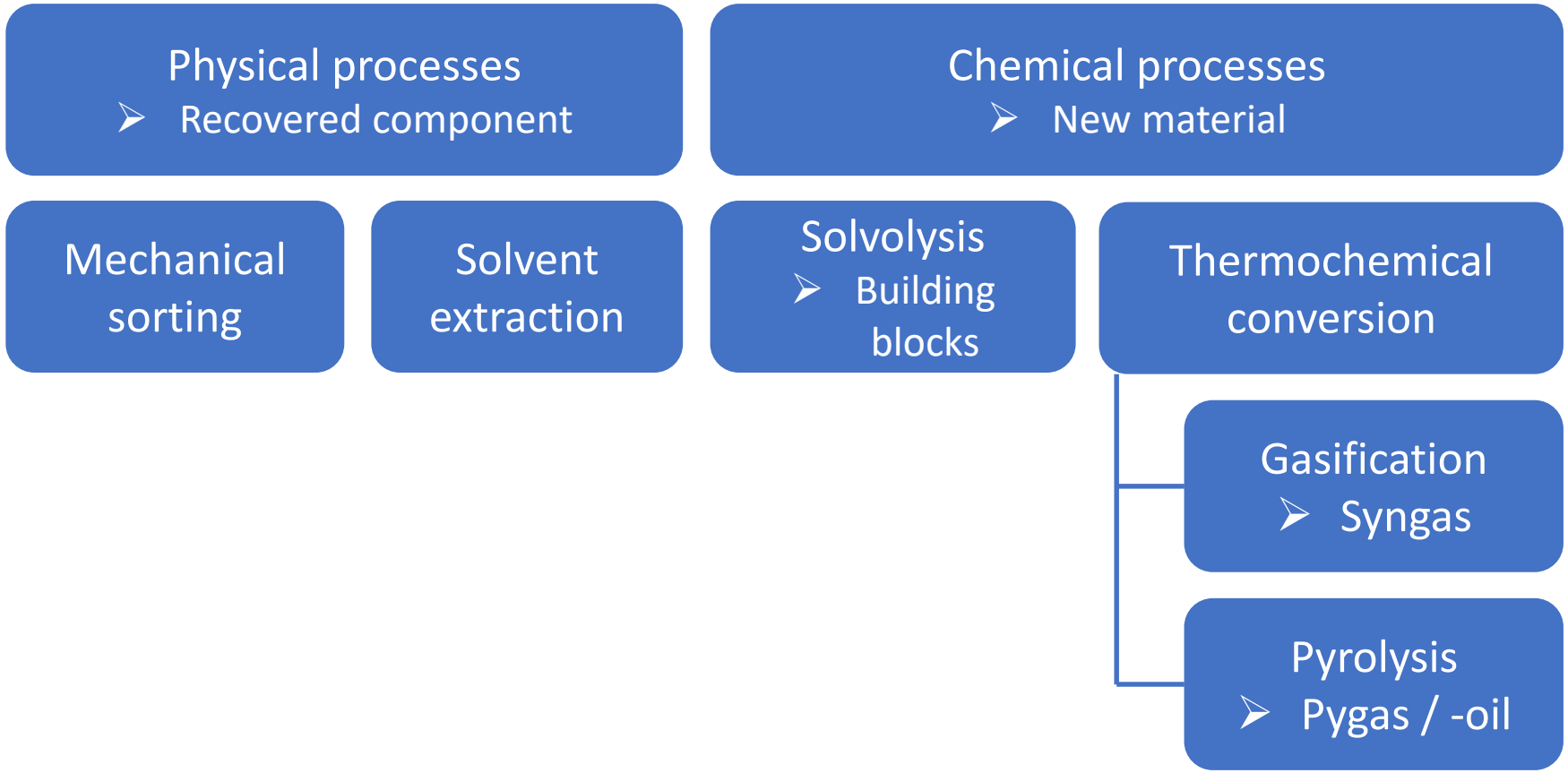
****) Ljungkvist Nordin, H,, Westöö, A.K.,, Boberg. N., Fråne, A., Guban, P., Sörme, L., Ahlm M., SMED Rapport Nr 01 2019 Kartläggning av plastflöden i Sverige: Råvara, produkter, avfall och nedskräpning (2019)

a) estimated

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 Processes for Mixed Waste and their Key Products



- Mixed wastes
- Pure plastics,
- Poly-condensates
- Mixed wastes, composite materials

Thermochemical Recycling of Plastic Wastes

Commercial industrial scale Waste-to-Chemicals operations:

- Showa Denko, Kawasaki, Japan (Ammonia from separately collected packaging waste)
- Enerkem, Edmonton, Canada (Methanol / Ethanol from RDF)
  - → W2C project, Rotterdam
- Nippon Steel, Hirohata (secondary raw materials by waste tire pyrolysis)

Historical (Shut down):

- SVZ, Schwarze Pumpe, Germany (RDF, sewage sludge, packaging waste to Methanol)
- Krupp Ude, Berrenrath, Germany (RDF to Methanol)

Waldheim,L., Gasification of waste for energy carriers – a review, report, IEA Bioenergy, 2018, http://task33.ieabioenergy.com/content/Task%2033%20Projects

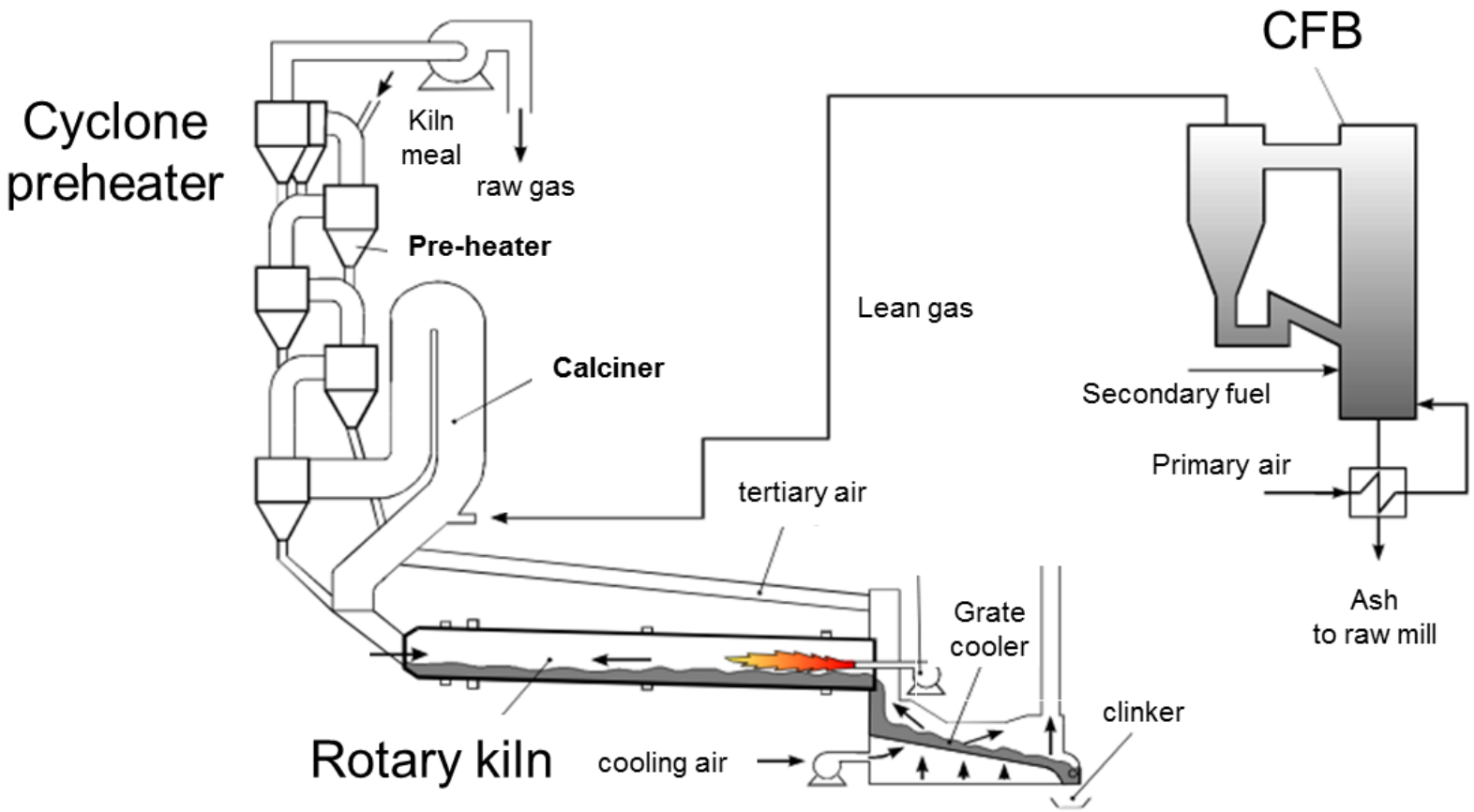
www.enerkem.com

Industrial Capital Investment Projects: Chemical recycling of plastic wastes

- Plastic Energy, London, UK
  - Almeria, Sevilla, ES
- Recycling Technologies, Swindon, UK
  - → RT7000 project, Perthshire, Scotland
- Sabic
  - → Cooperation with Plastic Energy, Geleen, NL
- LyondelBasell
  - → MoReTec-plant, Ferrara, IT
- BASF
  - → Cooperation witht Quantafuel, Oslo, NOR

www.plasticenergy.com

CEMEX Cement Plant at Rüdersdorf, Germany: Waste gasification (CFB) to generate calciner heat

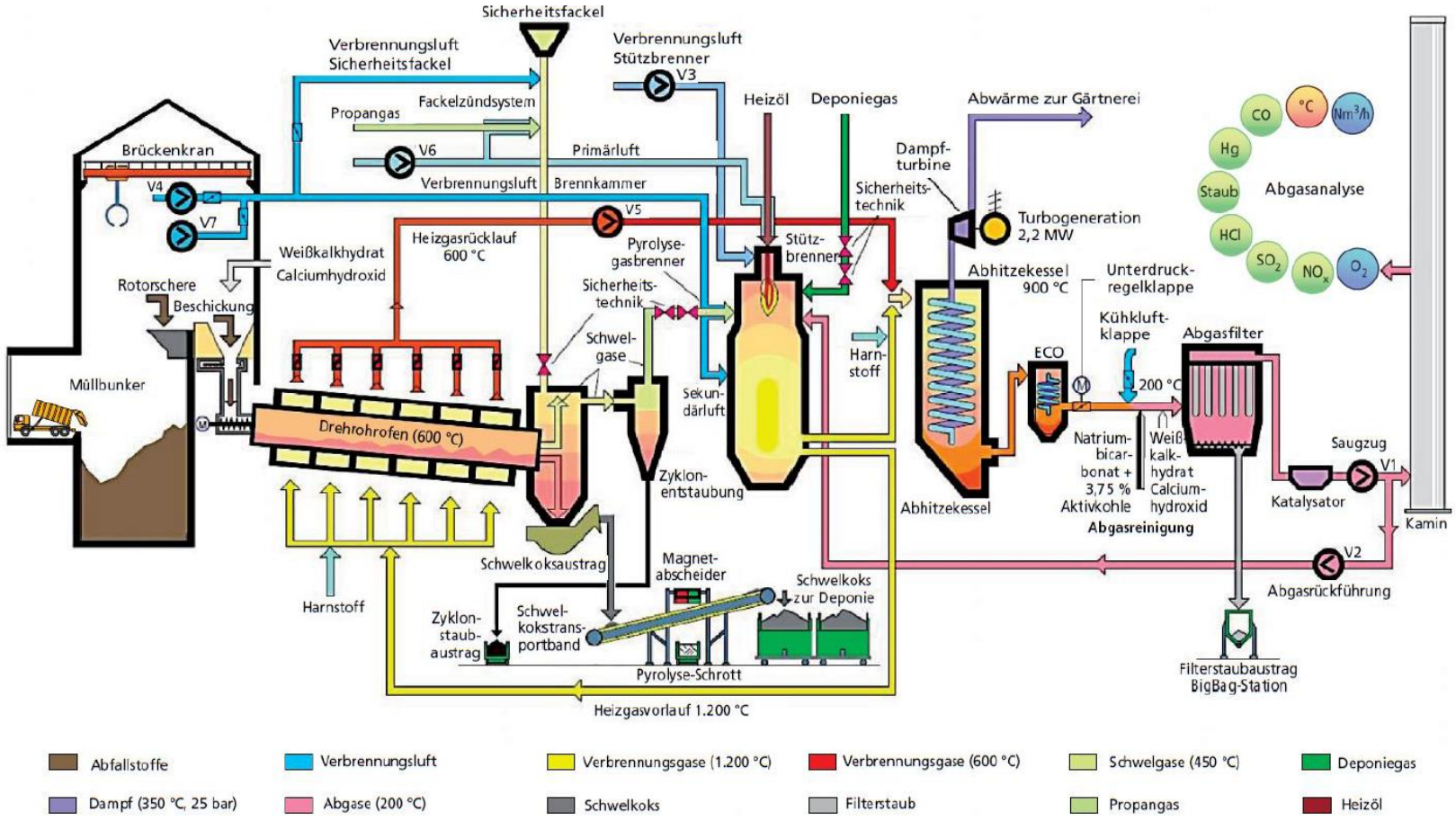


Commissioning	1996
Thermal Capacity	100 MW
Secondary Fuel	20 – 30 t/h
Lean gas (Syngas)	60,000 Nm³/h
	900 – 960 °C
	LHV: 3 – 5 MJ/Nm³

Quicker, P., et al., Status of Alternative Techniques for Thermal Waste Treatment, Expert Report No. 29217 for the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2015. https://www.umweltbundesamt.de/publikationen/sachstand-zu-den-alternativen-verfahren-fuer-die, 2015

RHW Pyrolysis Plant at Burgau, Germany
CHP Production from Waste

- Started up in 1983
- Final capacity of 26 kt/a
- Shut down in Dec 2015



Umwelt Bundesamt

Process Chain of the Thermochemical Recycling of Waste to Secondary (Chemical) Feedstock

Waste-to-Chemicals Process Chain
Case: Gasification of RHW to Syngas for Methanol Production

pretreatment → conversion → upgrading

Household collection waste (RHW)

Gasifier feedstock (RDF, SRF)

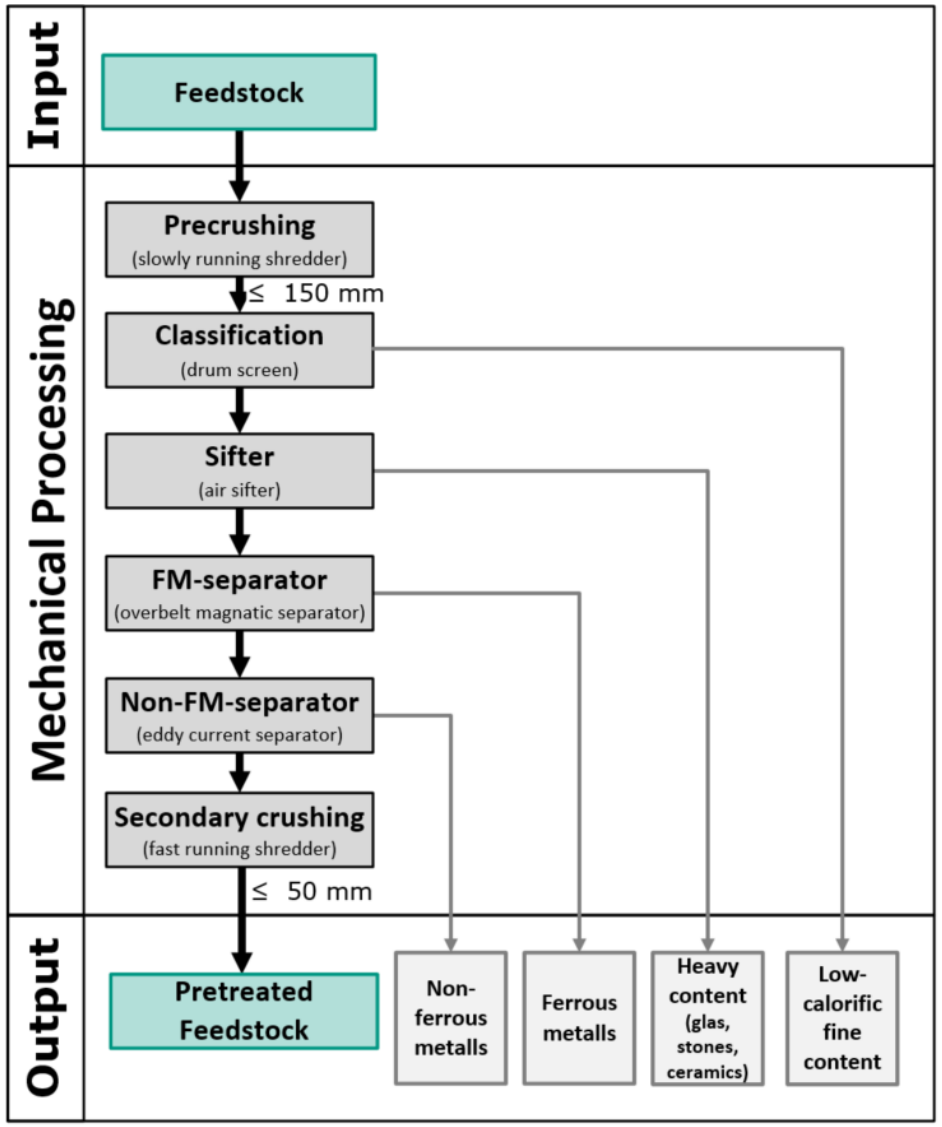
Raw syngas

CO_2, CO, H_2, CH_4,
tar components,
H_2S, HCl, Hg, …

On-spec feed to methanol synthesis

H_2:CO = 2:1,
tar free,
contaminats concentrations below 0.1ppm, …

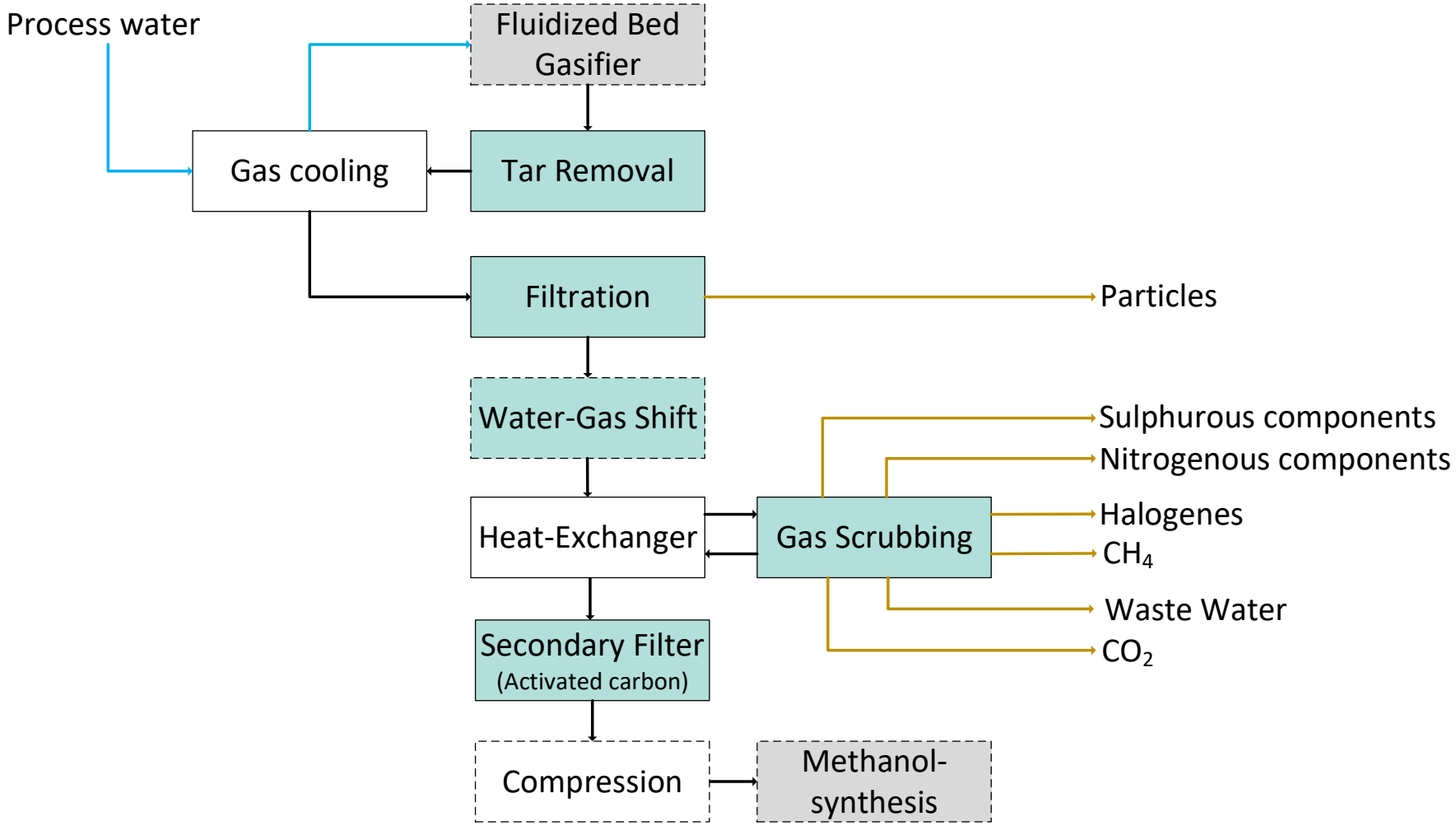
Mechanical Pretreatment of Residual Household Waste RHW



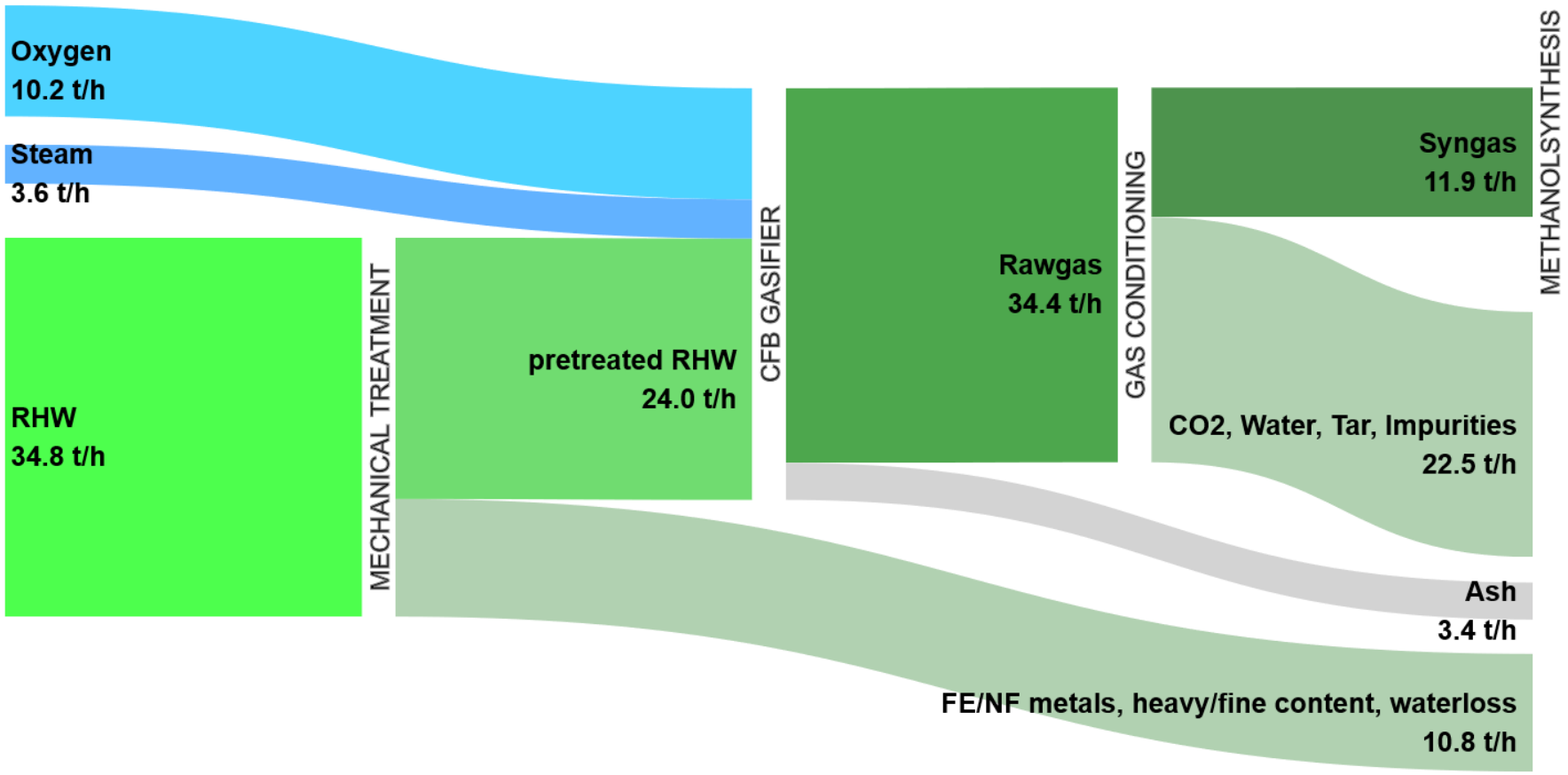
Parameter		RHW	RDF
Proximate analysis			
Moisture content	wt-%	23.8	21.8
Combustibles	wt-%	47.6	64.4
Ash content	wt-%	28.6	13.8
Lower heating value	MJ/kg	10.9	15.0

Stapf, D., Wexler, M., Johansson, I., Ciceri, G., Whitty, K., Pretreatment of municipal solid waste (MSW) for gasification (Biomass pre-treatment for bioenergy – Case study 3), report, IEA Bioenergy, 2019. http://task36.ieabioenergy.com/publications/biomass-pre-treatment-for-bioenergy-case-study-3-msw-pre-treatment-for-gasification/

Syngas Upgrading Process Chain

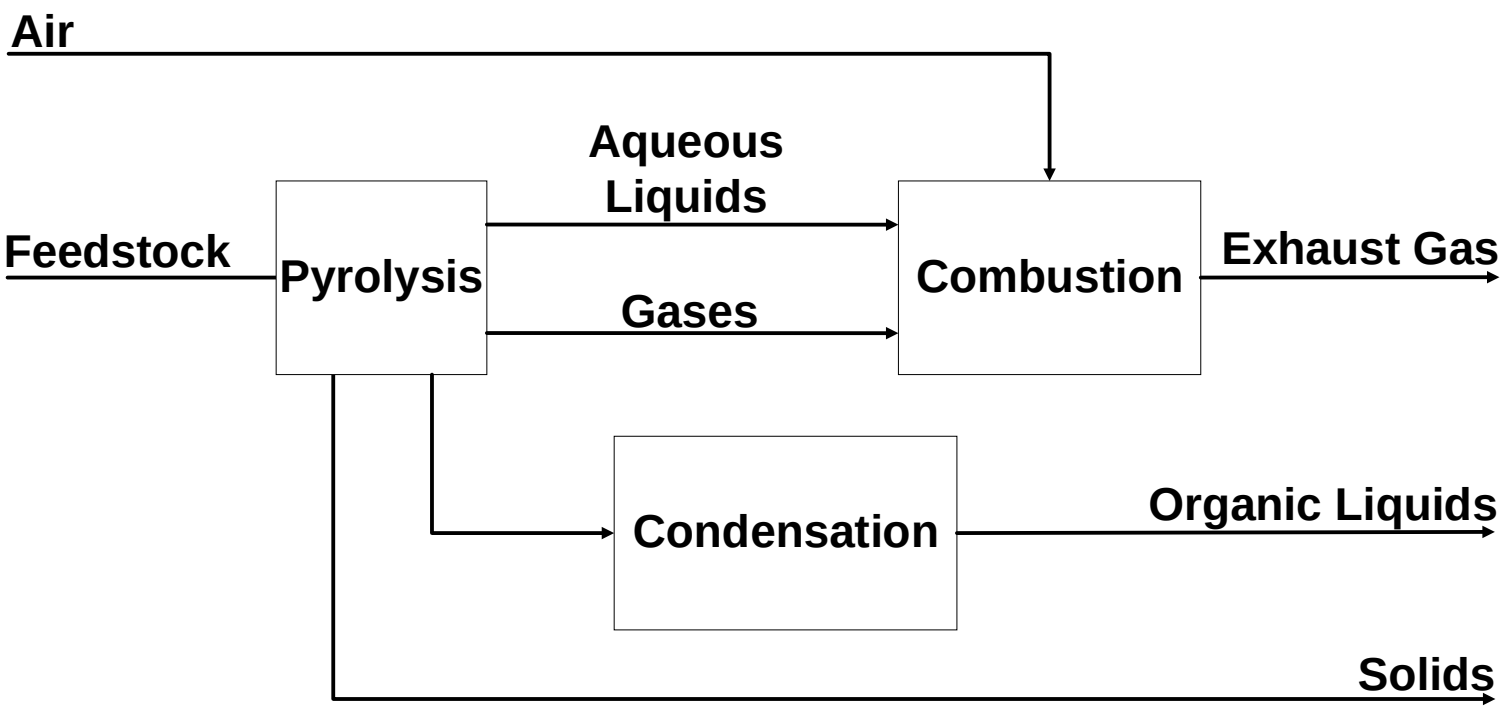


Example of Material Flows in CFB-Gasification of Residual Household Waste to Methanol Syngas

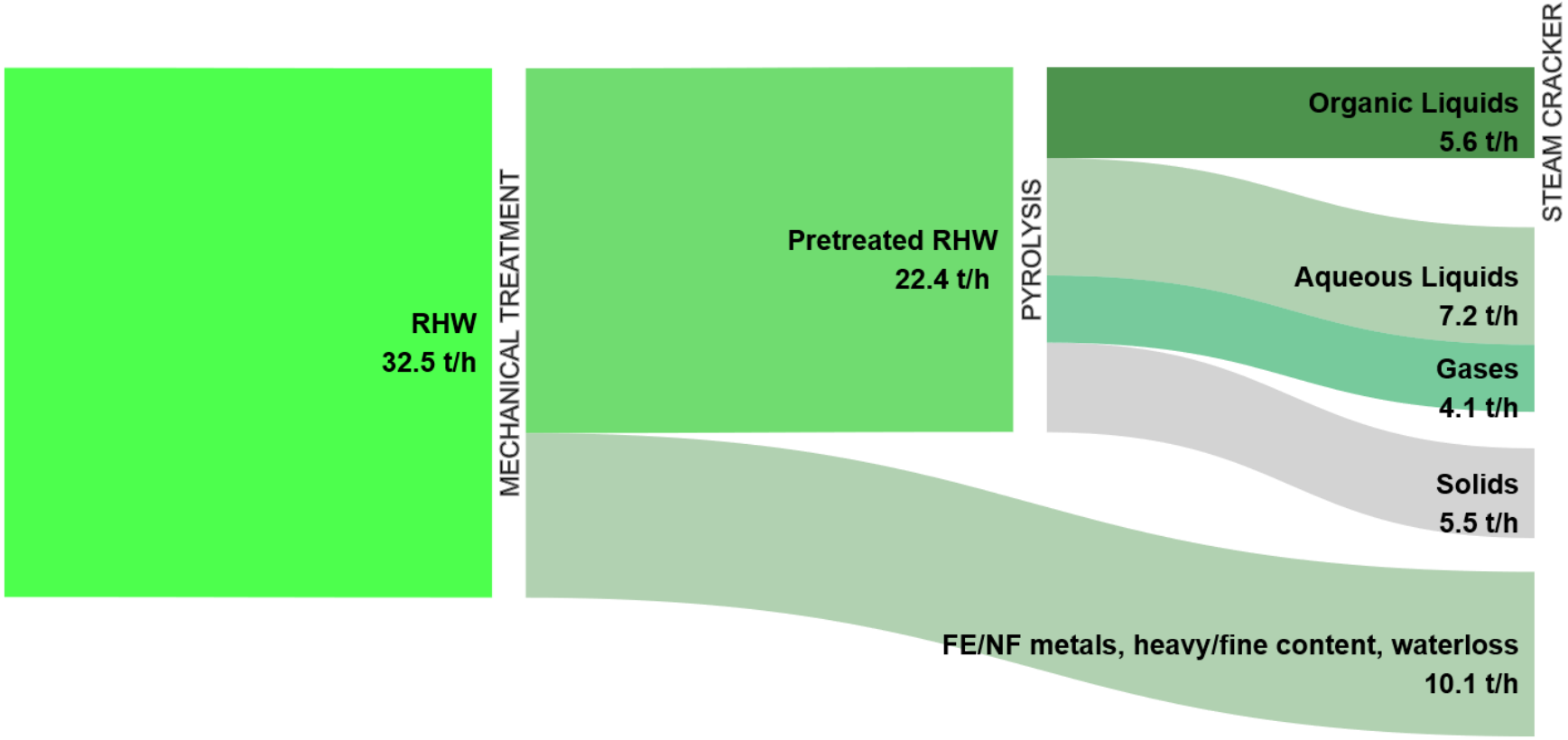


BKV-study: Thermal processes for feedstock recycling of plastics waste, study conducted by KIT and Conversio Market & Strategy GmbH on behalf of BKV GmbH and Plastics Europe AISBL, 2019. https://www.bkv-gmbh.de/en/info-zone/studies.html

Basic Flow Scheme of Pyrolysis Applied to Waste



Example of Material Flows in Rotary Kiln Pyrolysis of Residual Household Waste



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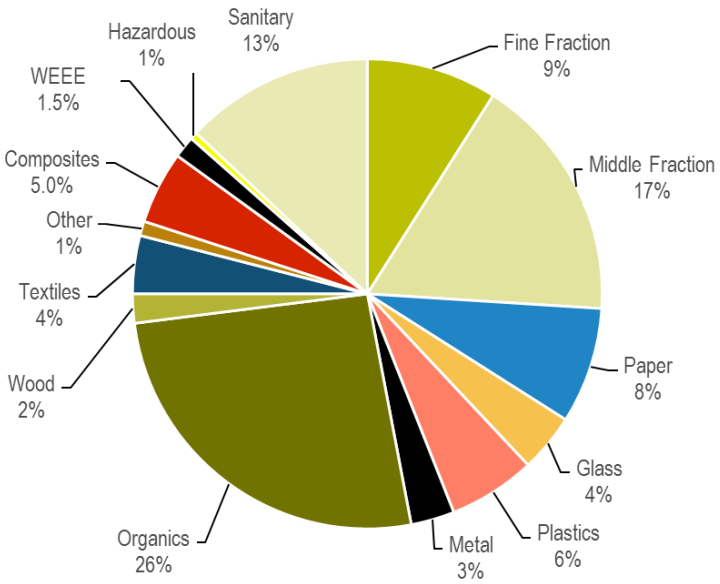
Economics of Selected Waste-to-Chemicals Value Chains**

Process	Pretreatment [€/t_{RHW}]	Conversion [€/t_{RHW}]	Upgrading [€/t_{RHW}]	Total processing cost [€/t_{RHW}]	Revenues* [€/t_{RHW}]
Gasification	21	86	105	212	- 68
Pyrolysis	21	162	0	183	- 86



*) Syngas @ 200 €/t
Naphtha @ 500 €/t

**) Conversion unit size: ca. 100 MW; ca. 25 t/h of pretreated household waste (RDF)

Capital investment cost estimate accuracy: ± 30%

Process Overview: Economies and Risk Technology Readiness Level TRL

Process	Pretreatment feedstock	Conversion	Upgrading Rawgas / crude	Product utilization
Gasification	9	8	7	Methanol Synthesis
Pyrolysis	9	5 - 6	3	Steamcracker

- TRL 3: applied research
- TRL 5: large scale prototype
- TRL 6: prototype system
- TRL 7: demonstration system
- TRL 8: first of a kind commercial system
- TRL 9: full commercial application

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Economical attractiveness vs. technological readiness

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Trends and Drivers in Alternative Thermal Conversion of Waste - Conclusions

- Pyrolysis and gasification thermally separate mixed wastes to generate secondary feedstocks for industrial processing
- Mostly not competitive to waste incineration when focused on power and heat production from waste
- Chemical recycling:
  - Competitiveness results from associated product revenues
  - Complements mechanical sorting
  - Maximizes recycling rates and minimizes greenhouse gas emissions
- Targeted R&D is needed in parallel with the development of policy incentives to allow these technologies to emerge

Report announcement

T36

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