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Valorization of plastic waste via gasification- Chalmers experiences

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Akademiska Hus

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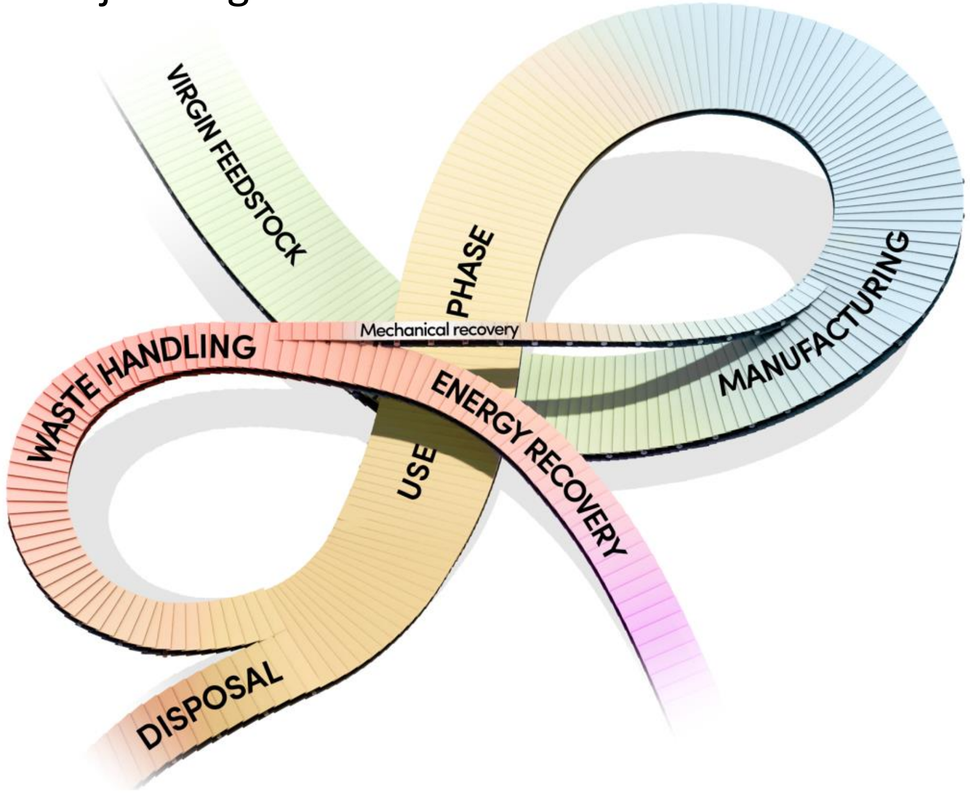
Loop of plastic today

Fossil-based feedstock
olja och gas



Geological disposal

Energy recovery
CO2 till atmosphere

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Plast waste problematic

http://www.dcwastemanagement.co.uk/the-waste-heirarchy/

- The presence of contaminants and additives complicates the mechanical recycling of plastics, down-grading the produced products and/or requiring the use of virgin materials

- In Sweden, where advanced collection and sorting systems already exist, 51% of the 1600 kt of PW handled in Year 2017 was in the form of unsorted streams, which are not suitable for mechanical recycling

- Of all collected PW:
  - **7.2%** recycled into new products,
  - 85.5% was incinerated with energy recovery,
  - 0.35% was sent for deposition,
  - 6.8% the final treatment could not be determined, of this material one part was exported and could not be further tracked

- Despite strenuous efforts in regards to collection and sorting, a substantial fraction of PW ends up as mixed waste that cannot be recycled mechanically
- To avoid disposal and/or incineration, there is a need for efficient industrial processes that enable the recycling of mixed waste streams

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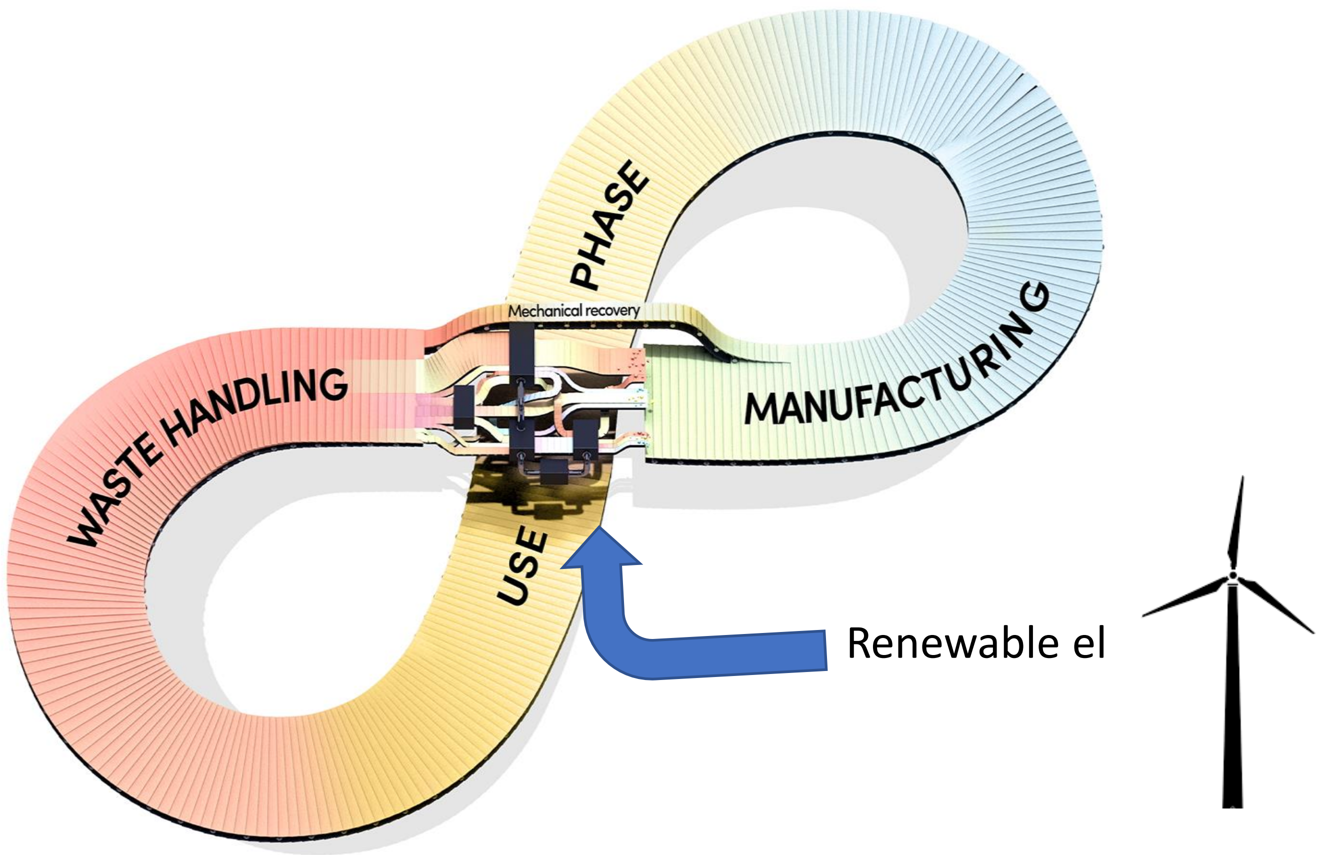
Make a bridge which can close carbon loop

- Thermochemical recycling: an upgrading bridge between PW streams and a phase of new use
- The increase in value of the carbon atom in the PW, compared to that obtained using any other existing recycling route, such as mechanical recycling, where the new use phase is ensured, albeit with a product of lower quality.



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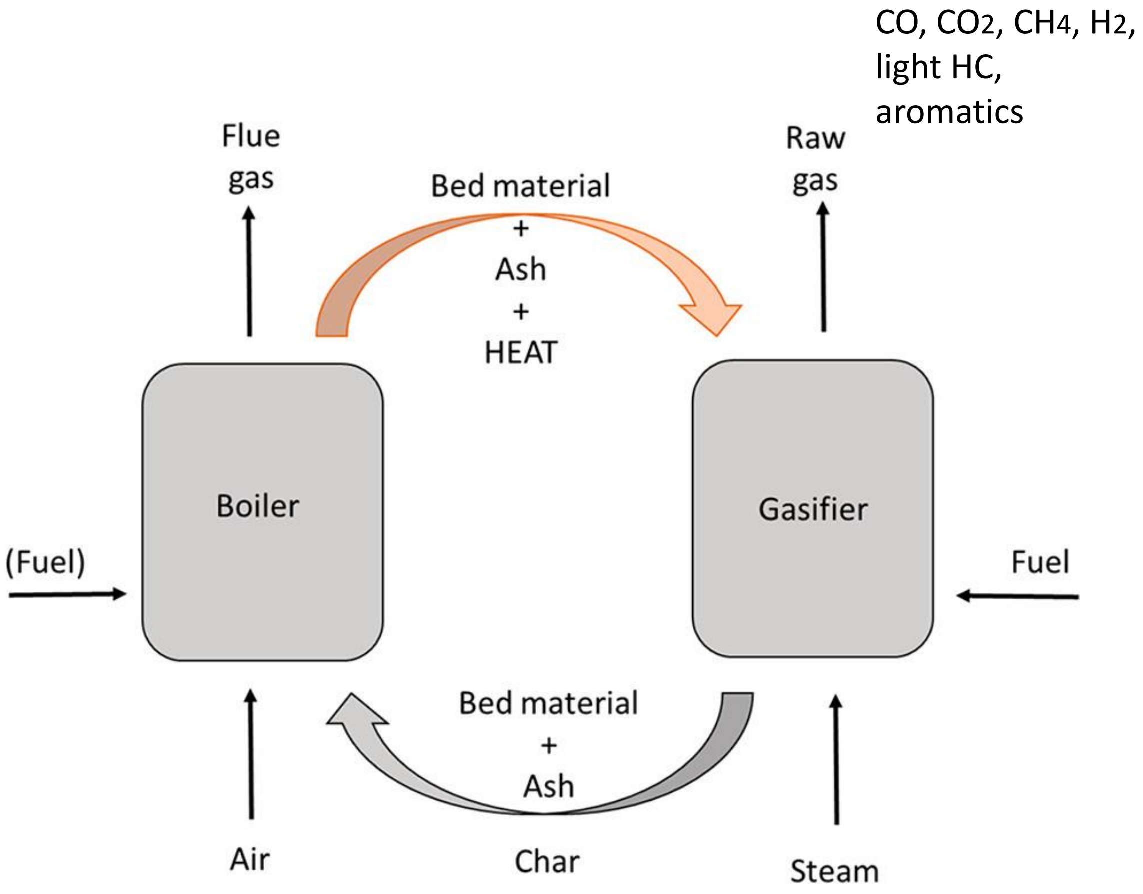
Dual Fluidized Bed Gasification



- Two separated reactors
- Hot bed material circulation provides energy for gasification reaction and eventually behave as catalyst
- The non-gasified char carried by the bed material to the boiler where it is combusted
- The principle of the system considers that the process is providing enough char for the heat balance to be satisfied
- Advantages notably with regard to scalability, feedstock flexibility, and the possibility to re-generate the heat transfer surface, i.e., the bed material

- Examples of proven technology:
  - GoBiGas
  - Senden
  - TIGAR®

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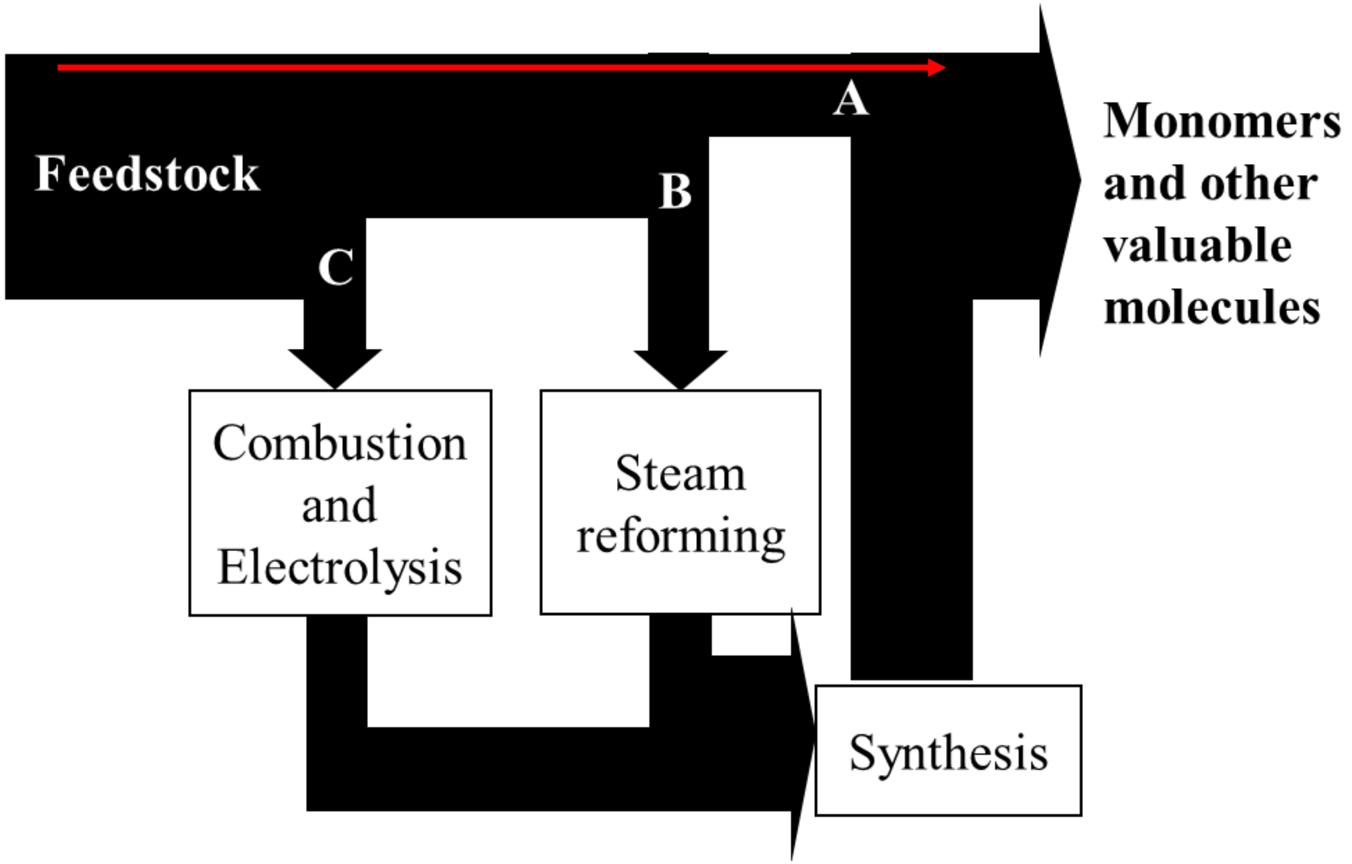
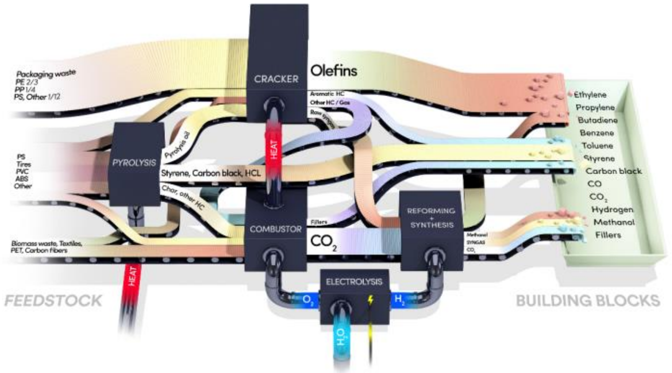
Recycling routes





- *Route A* is based on the direct recovery of monomers and valuable molecules from the original material through thermal cracking of the feedstock
- *Route B* refers to the thermal decomposition of the material into syngas, followed by a synthesis process
- *Route C* refers to the combustion of the feedstock to cover part of the heat demand and to recover the carbon in the form of CO_2

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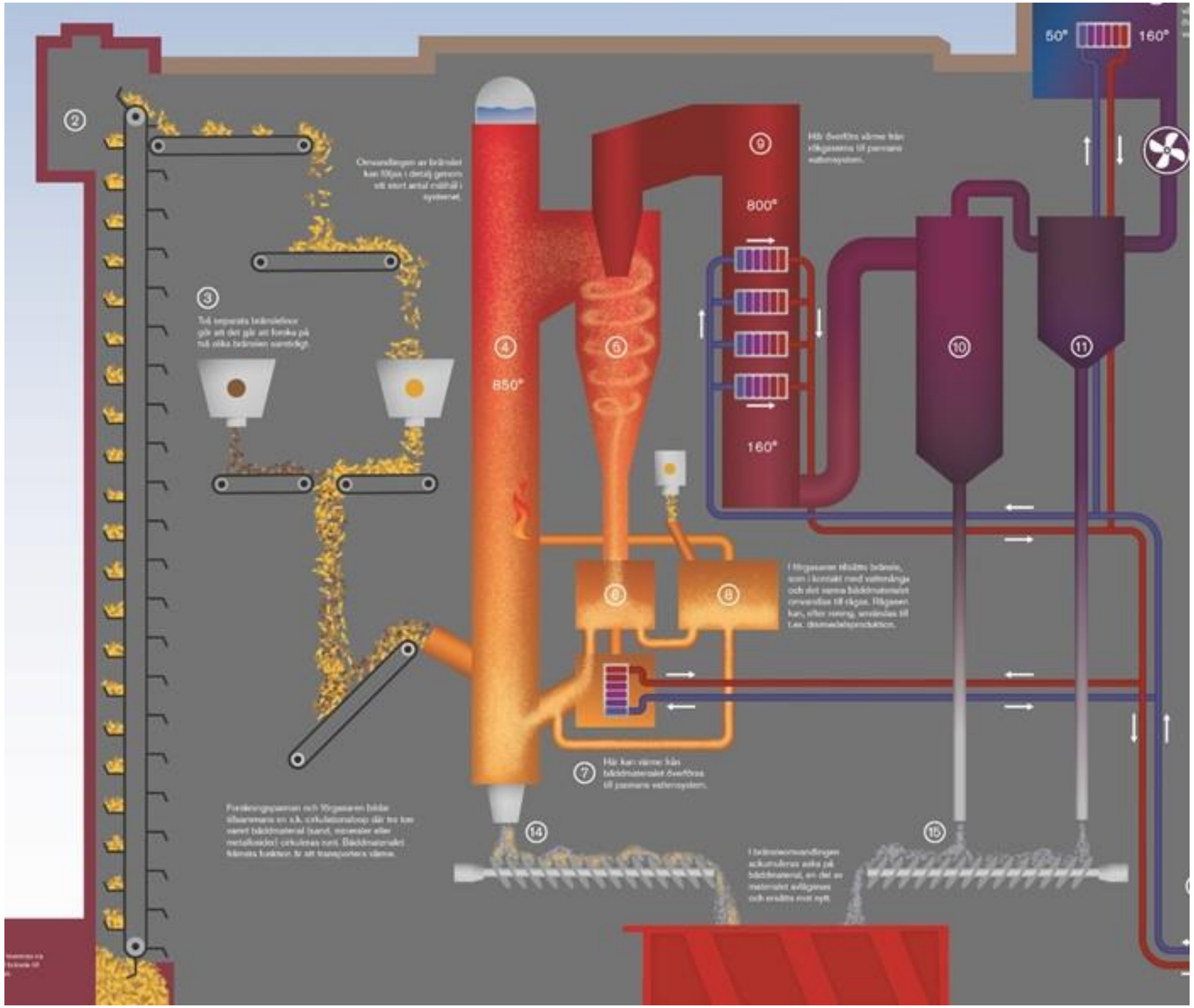
Chalmers Kraftcentralen



Dual Fluidized Bed System

- Boiler- 10-12MW
  - -circulated fluidized bed (air)
  - -woodchips
- Gasifier- 2-4 MW
  - -bubbling fluidized bed (steam)
  - -wood pellets
  - -plastic waste
- Bed material-silica-sand (wood pellets and plastic waste)
  - -olivine (wood pellets and plastic waste)
  - -bauxite (wood pellets)
  - -feldspar (wood pellets)

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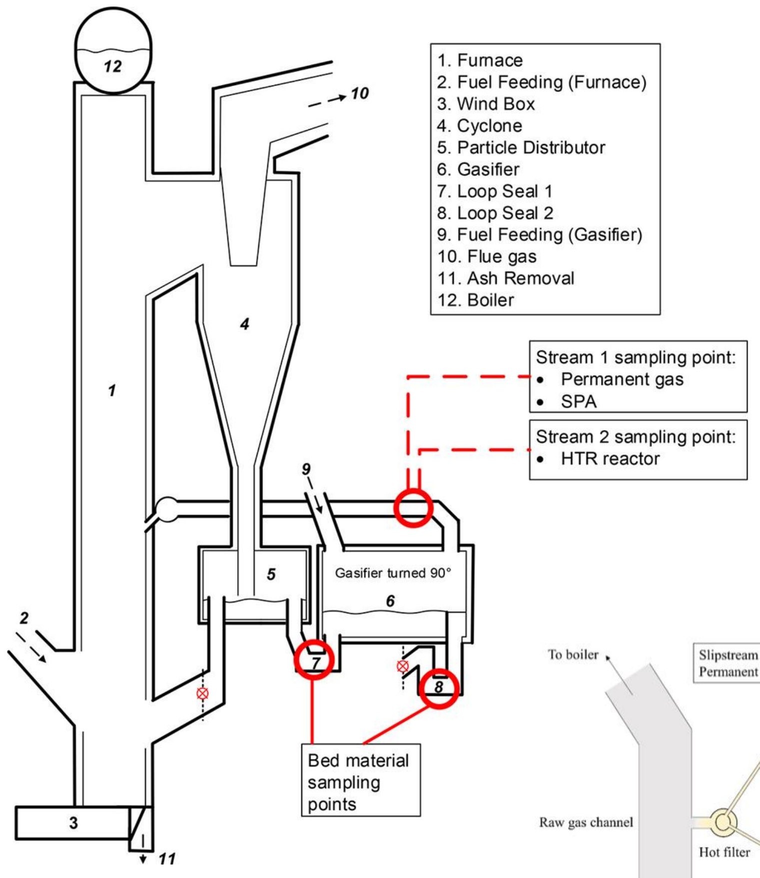
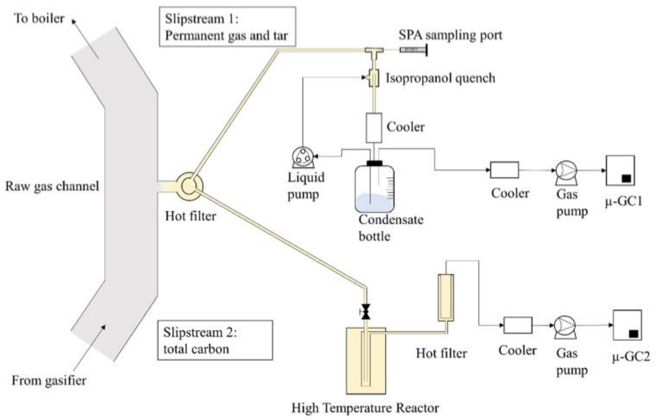
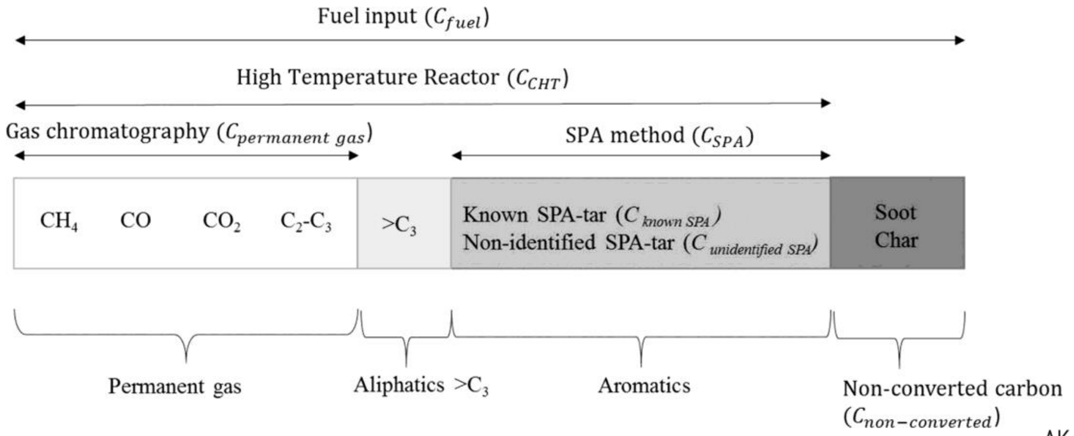
Experiments evaluation





- The main constituents of the *produced gas*, H_2, CO, CO_2, CH_4, and light hydrocarbons (C_2 and C_3 species), measured online using an mGC
- The *aromatic hydrocarbons* in the gas sampled prior to conditioning using the solid phase adsorption (SPA) method and determined by gas chromatography with flame ionization detection
- The *carbon balance* over the gasifier: a parallel measurement of the total carbon in the gas using a high-temperature reactor (HTR).



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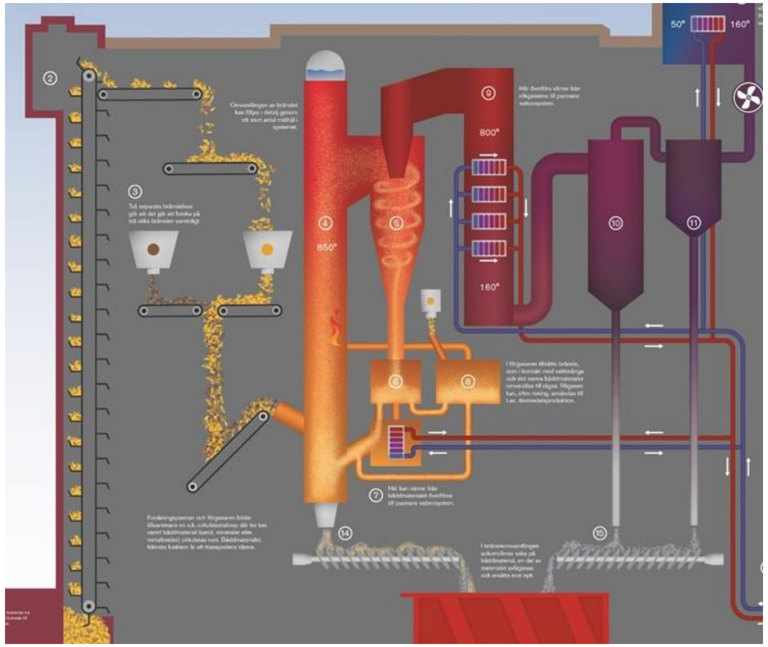
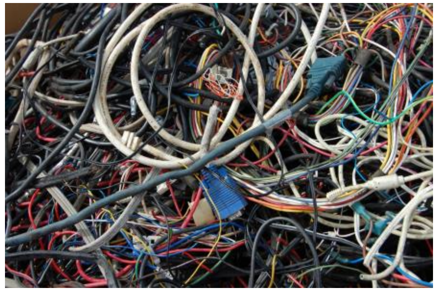
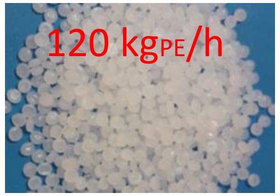
Waste plastic gasifiction – Chalmers gasifier

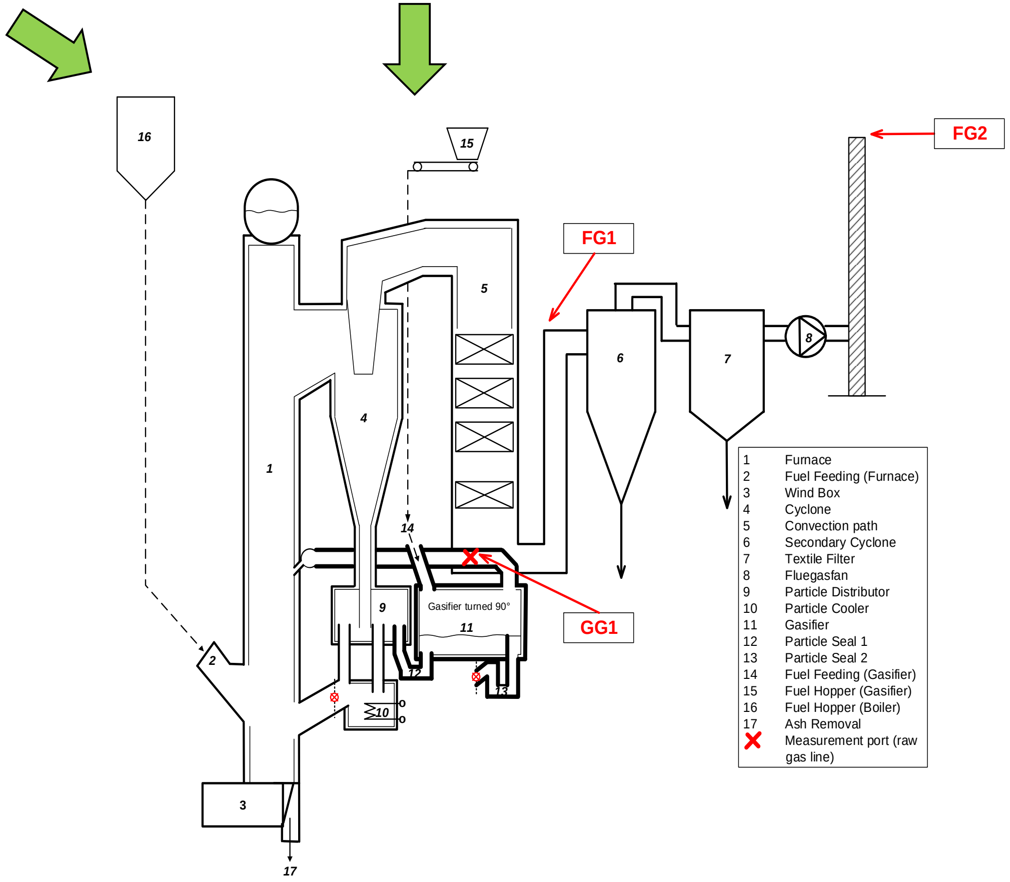
- Polyethilene (PE)- clean reference case
- Automotive Seredder Residue (ASR)
- Cable waste (PEX)





Polyethylene (PE)





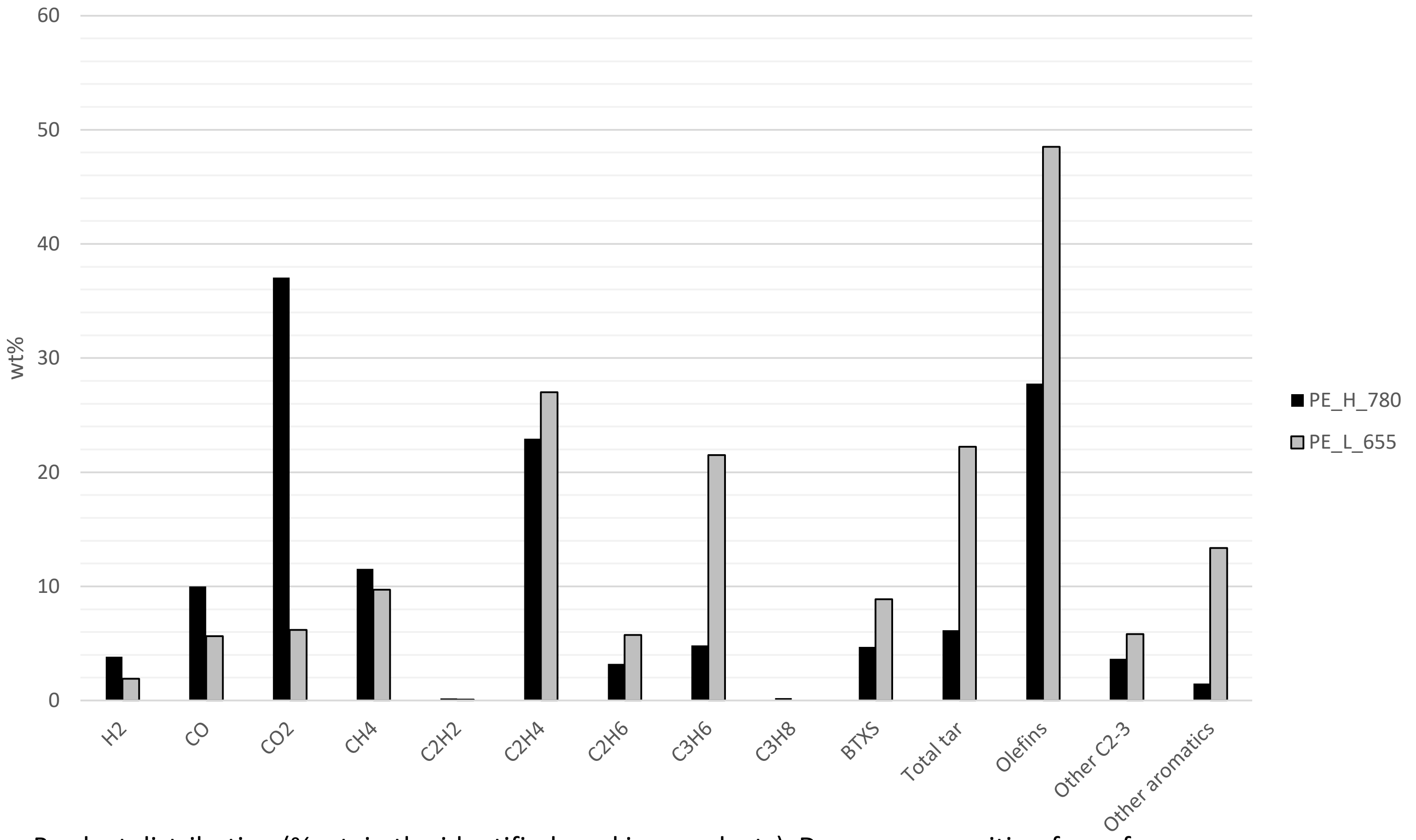
Operational conditions:

- Fuel feed: 120 kg/h
- Temperature: 655-780°C
- Steam feed: 160-220 kg/h
- Active olivine bed used in the process

Evaluation of the process:

- Permanent gases
- Aromatics
- Bed samples

Process evaluation (PE): produced gas composition

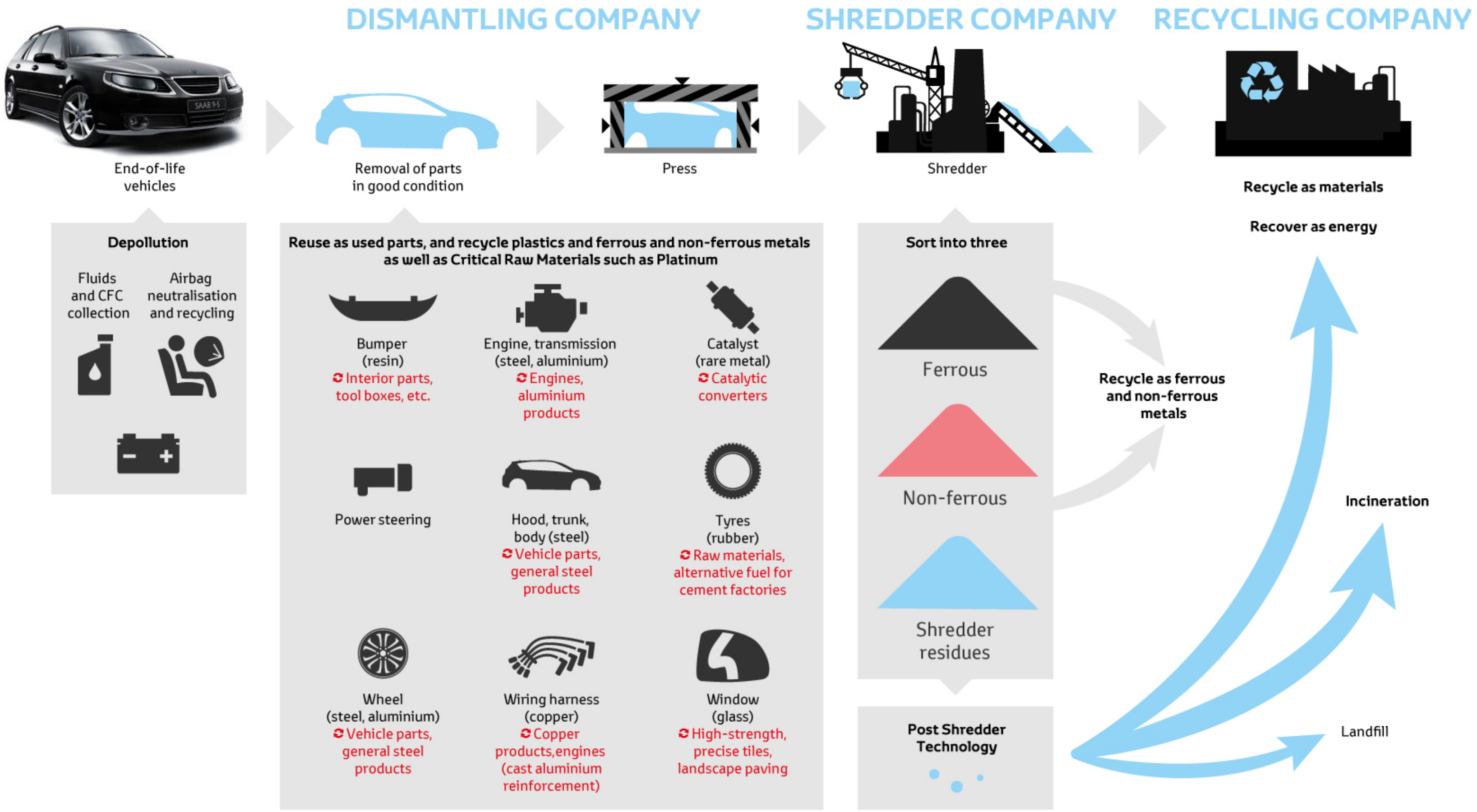


Product distribution (% wt. in the identified cracking products). Dry gas composition free of aliphatic hydrocarbons ≥ C_4, due to measurement limitations

- Closure of the carbon balance showed significant yield of non-measurable fraction (aliphatic species ≥ C_4)
- High olefin content in the produced gas
- At a higher temperature (780 °C), the olefin yield decreases, mainly in favour of CO and CO_2
- High percent of total measured tar is BTXS fraction

https://www.sciencedirect.com/science/article/pii/S2214993719300697?via%3Dihub

Automotive Shredder Residue (ASR)



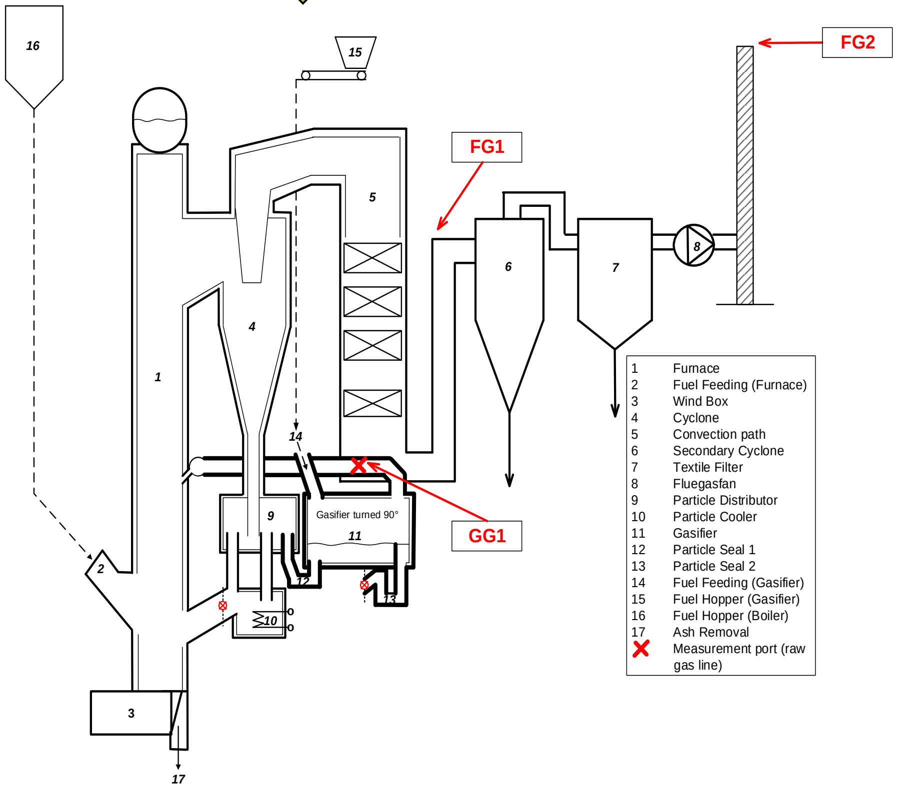
ASR fraction:

- highly nonhomogeneous in composition
- plastics, foams, textiles, glass, rubber, unrecovered metals and wood
- 46% ash

https://www.toyota-europe.com/world-of-toyota/feel/environment/better-earth/recycle

Automotive Shredder Residue tests

Biomass input kept constant in all cases!



Operational conditions:

- Fuel feed: 390 kg/h
- Temperature: 775-840°C
- Steam feed: 160-220 kg/h
- Olivine bed used in tests

Evaluation of the process:

- Permanent gases
- Aromatics
- Bed samples, Fly ash
- PCDD/PCDF emissions

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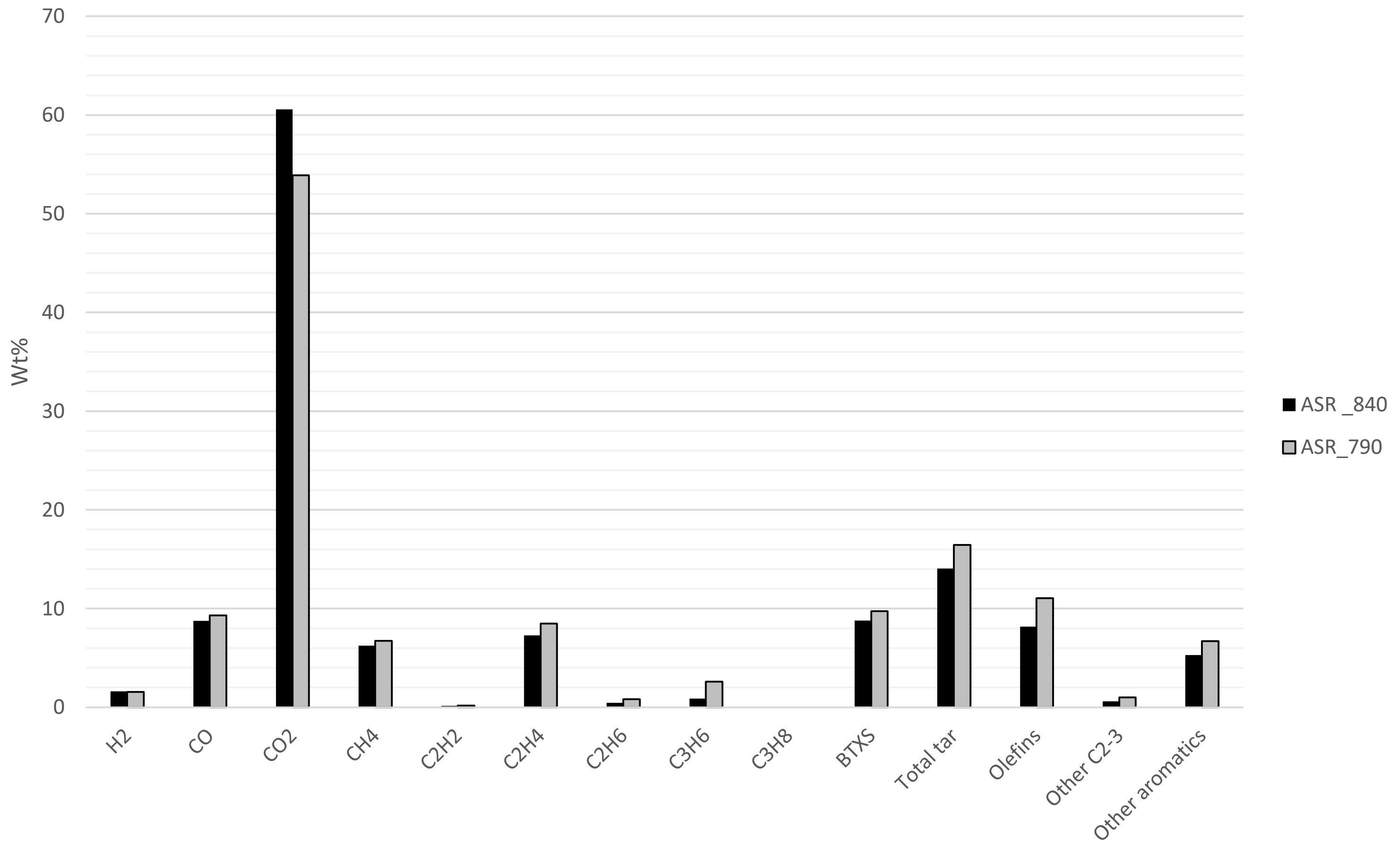
Process evaluation (ASR): produced gas composition



Product distribution (% wt. in the identified cracking products). Dry gas composition free of aliphatic hydrocarbons ≥ C_4, due to measurement limitations

- Closure of the carbon balance showed significant yield of non-measurable fraction (aliphatic species ≥ C_4 and fixed carbon)
- High CO2 content in the produced gas
- No significant change with temperature change
- High levels of aromatic hydrocarbons were detected in the gas, with 60% of these compounds being considered as valuable products for the chemical industry

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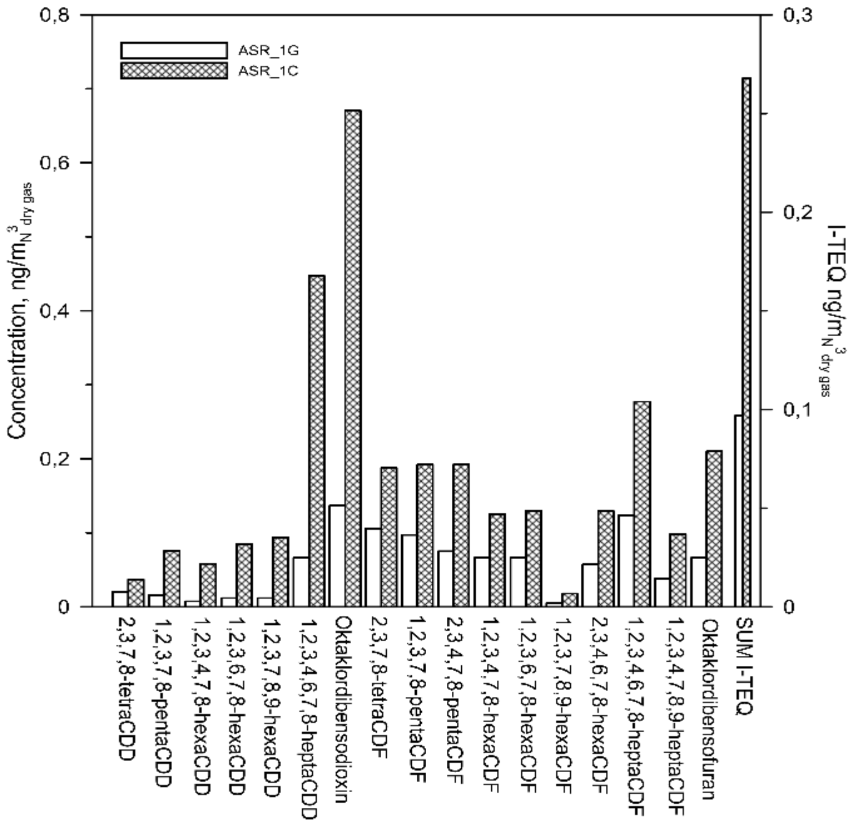
https://www.sciencedirect.com/science/article/pii/S2214993719300697?via%3Dihub

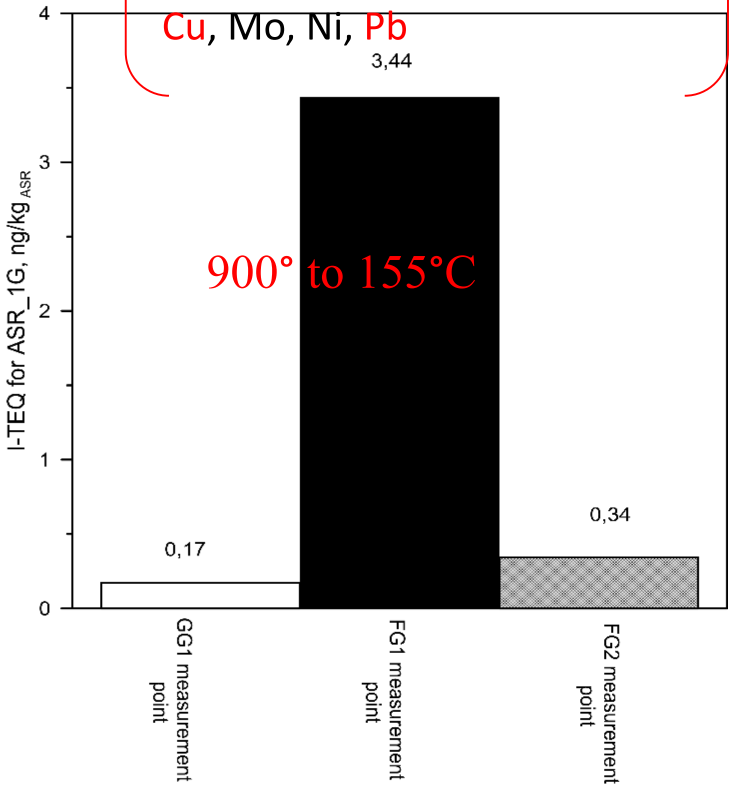
Process evaluation (ASR): dioxins emission

Position FG1.*results valid for the flue gas containing 6% O_2



Toxicity level decreased by 59% compared to the case of direct combustion of ASR

C, H, O, N, Al, Si, Fe, Ti, P, Br, As, Mn, Mg, S, Cr, Cl, Sb, Se, Cd, Co, Ca, Ba, Na, K, Sn, Tl, V, Zn, Cu, Mo, Ni, Pb



Cooling section: building point for PCDD/PCDF

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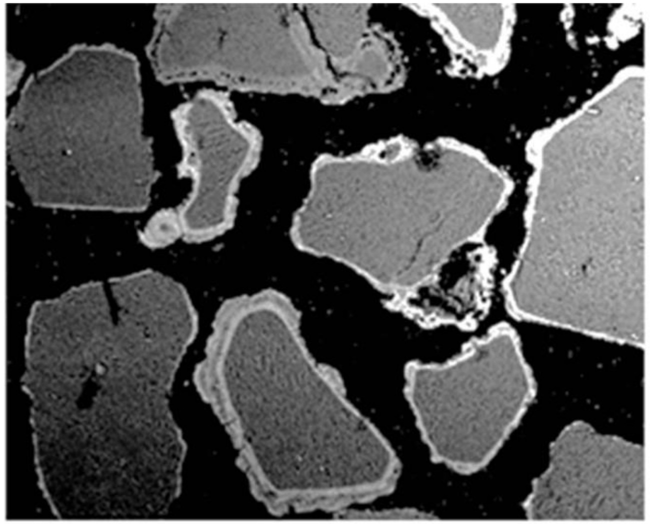
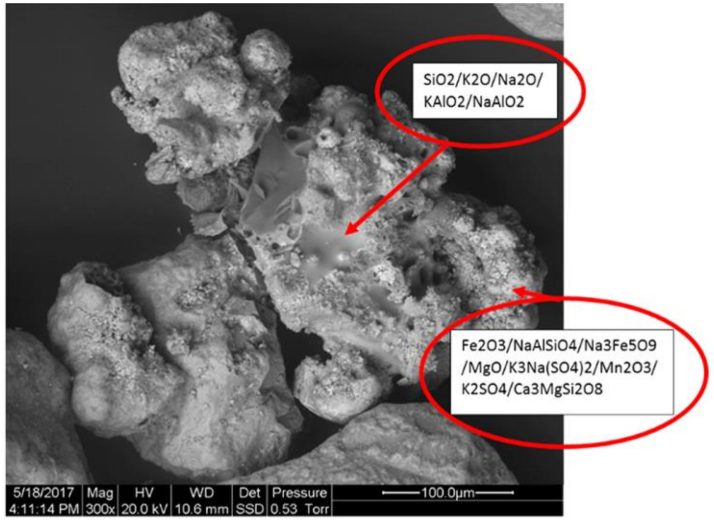
Process evaluation (ASR): bed material





- The application of catalytic bed materials, such as olivine, does not confer additional benefits on the gasification of ASR, and the same is likely to be true for any other ash-rich fuel
- No agglomeration of the bed even after 3 weeks of the process operation without bed regeneration

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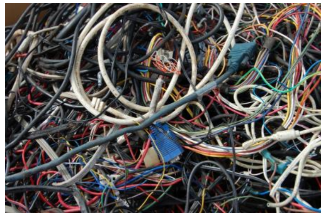
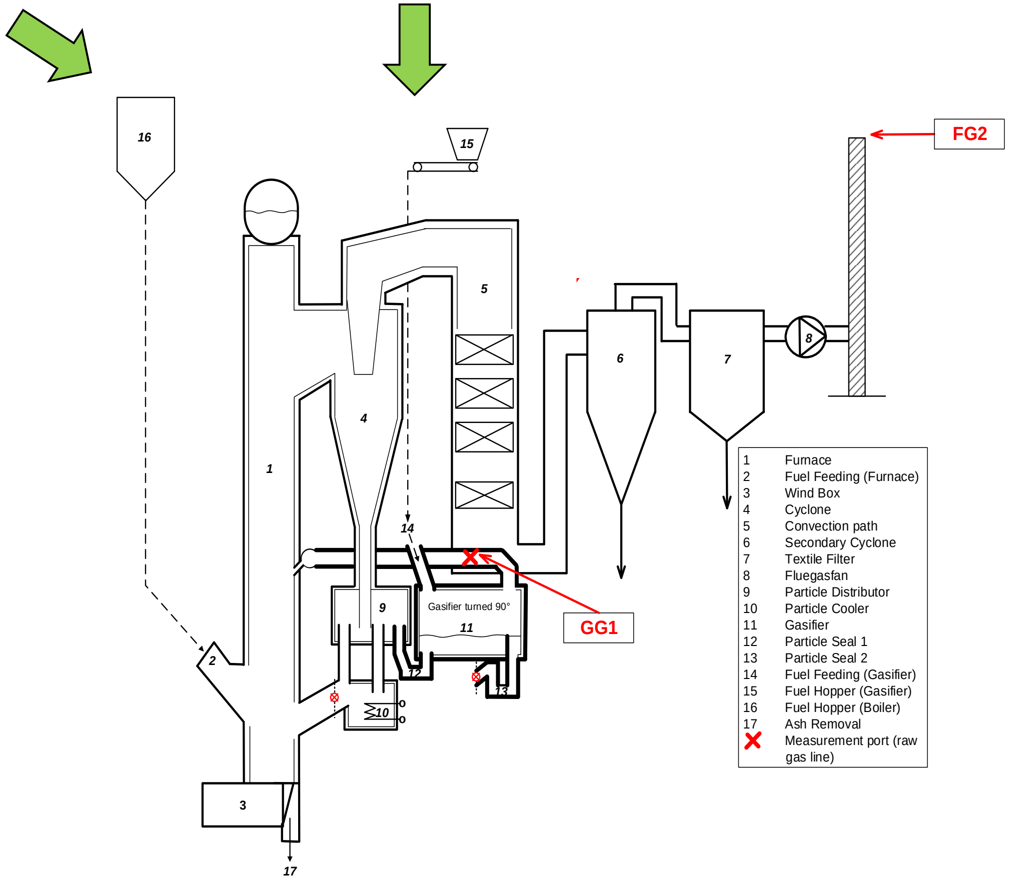
Cable plastic waste



190 kg$_{ASR}$/h



Operational conditions:

- Fuel feed: 190 kg/h
- Temperature: 735-800°C
- Steam feed: 160 kg/h
- Silica-oxide based bed

Evaluation of t' ... ocess:

- Perma ... ses
- Aro
- P ... nples, Fly ash
- ... D/PCDF emissions

Under evaluation

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Summary of results

Wt %	***PE (780C)***	***PE (655C)***	***ASR (840C)***	***ASR (790C)***	***Naphta***
Methane	12	10	6	7	17
H2	4	2	2	2	1
Olefins	28	48	8	11	44
BTXS	5	9	9	10	15
Total others*	52	31	75	71	24
Of which:					
Other aromatics	*1*	*13*	*5*	*7*	
Other C2-3	*4*	*6*	*1*	*1*	
CO	*10*	*6*	*9*	*9*	
CO2	*37*	*6*	*61*	*54*	

Product distribution (% wt. in the identified cracking products). Dry gas composition free of aliphatic hydrocarbons ≥ C_4, due to measurement limitations
*Includes aromatics other than BTXS, CO, CO2 and C2–3 alkanes/alkynes.

- The composition of the cracking products produced by steam cracking of PE and ASR in the Chalmers DFB system is comparable to the typical gas composition obtained from a naphtha/alkane cracker
- The yield of olefins is clearly dependent upon the type of feedstock applied and the operating temperature
- At 655 °C, the concentration of olefins in the product gas derived from PE is similar to that derived from naphtha cracking; at a higher temperature (780 °C), the olefin yield decreases, mainly in favour of CO and CO_2
- The yield of carbon oxides is one of the most remarkable differences- possibly due more intensive gasification and steam reforming of the hydrocarbons in the DFB system, which was not optimised for olefins production, due to, for example, the higher residence time of the gas and the presence of catalytic olivine

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More details?

Circular use of plastics-transformation of existing petrochemical clusters into thermochemical recycling plants with 100% plastic recovery
https://www.sciencedirect.com/science/article/pii/S2214993719300697?via%3Dihub


ELSEVIER
Sustainable Materials and Technologies
Volume 22, December 2019, e00124

Circular use of plastics-transformation of existing petrochemical clusters into thermochemical recycling plants with 100% plastics recovery

Henrik Thunman [1], Teresa Berdugo Vilches [1], Martin Seemann, Jelena Maric, Isabel Cañete Vela, Sébastien Pissot, Huong N.T. Nguyen [2]

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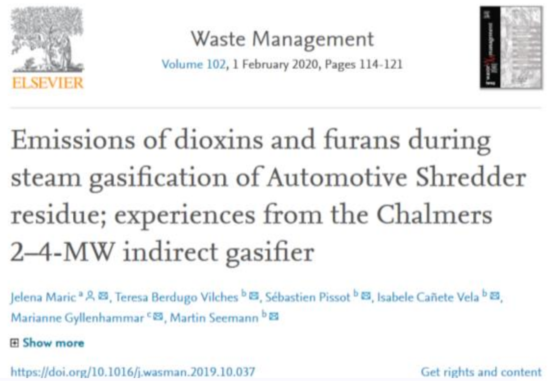
Emissions of dioxins and furans during steam gasification of Automobile Shredder Residue; experiences from the Chalmers 2-4MW indirect gasifier
https://www.sciencedirect.com/science/article/pii/S0956053X19306683?via%3Dihub


ELSEVIER
Waste Management
Volume 102, 1 February 2020, Pages 114-121

Emissions of dioxins and furans during steam gasification of Automotive Shredder residue; experiences from the Chalmers 2–4-MW indirect gasifier

Jelena Maric [a], Teresa Berdugo Vilches [b], Sébastien Pissot [b], Isabele Cañete Vela [b], Marianne Gyllenhammar [c], Martin Seemann [b]

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Valorization of Automoble Shredder Residue Using Indirect Gasification
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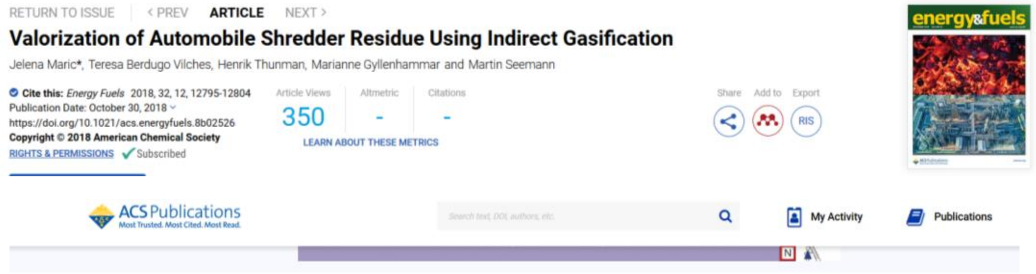
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Valorization of Automobile Shredder Residue Using Indirect Gasification

Jelena Maric*, Teresa Berdugo Vilches, Henrik Thunman, Marianne Gyllenhammar and Martin Seemann

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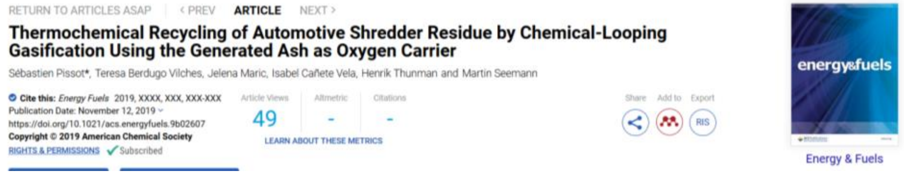
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Thermochemical Recycling of Automotive Shredder Residue by Chemical-Looping Gasification Using the Generated Ash as Oxygen Carrier

Sébastien Pissot*, Teresa Berdugo Vilches, Jelena Maric, Isabel Cañete Vela, Henrik Thunman and Martin Seemann

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