Economic and environmental assessment of chemical recycling via pyrolysis: A case study for engineering plastics

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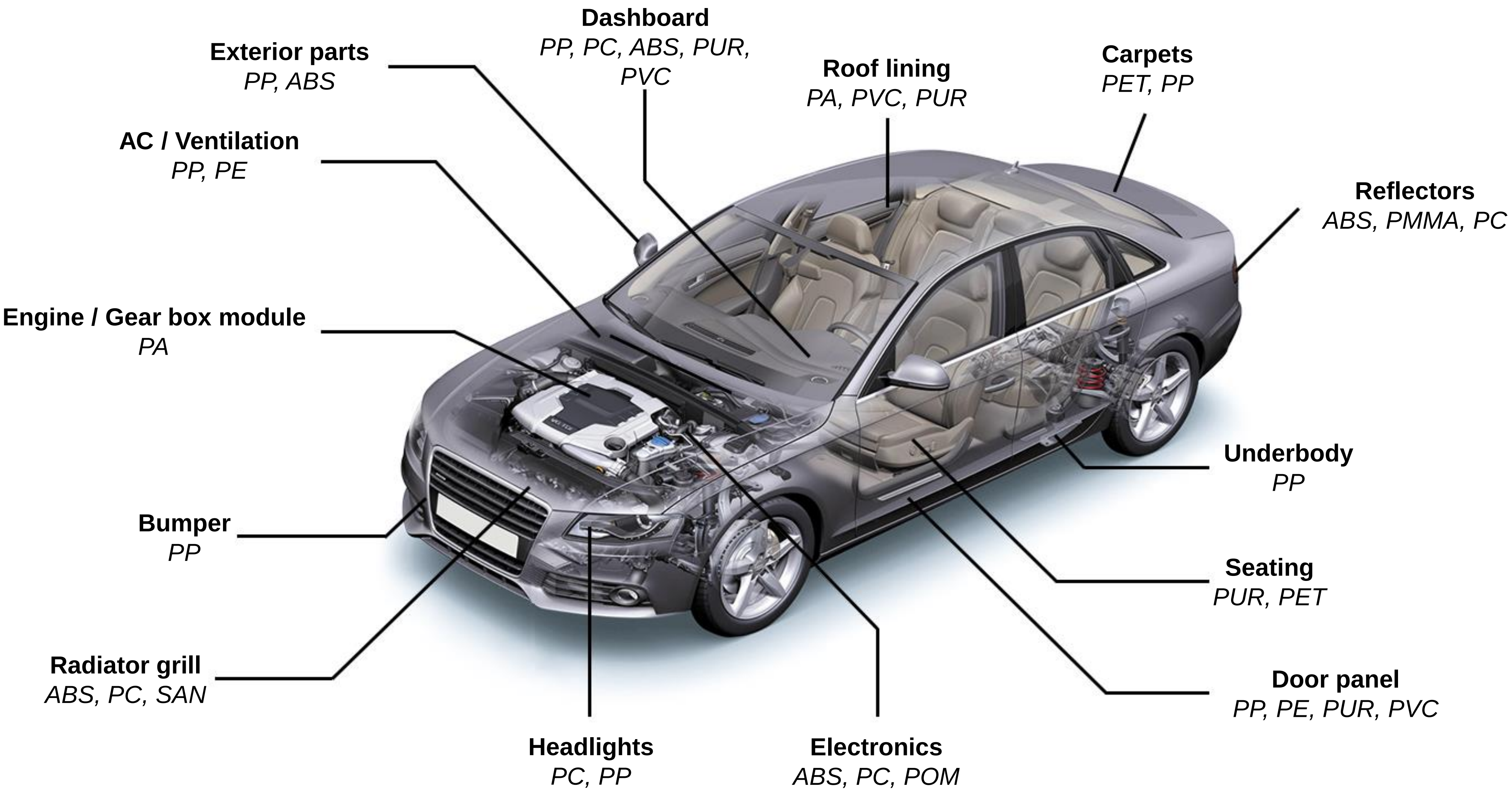
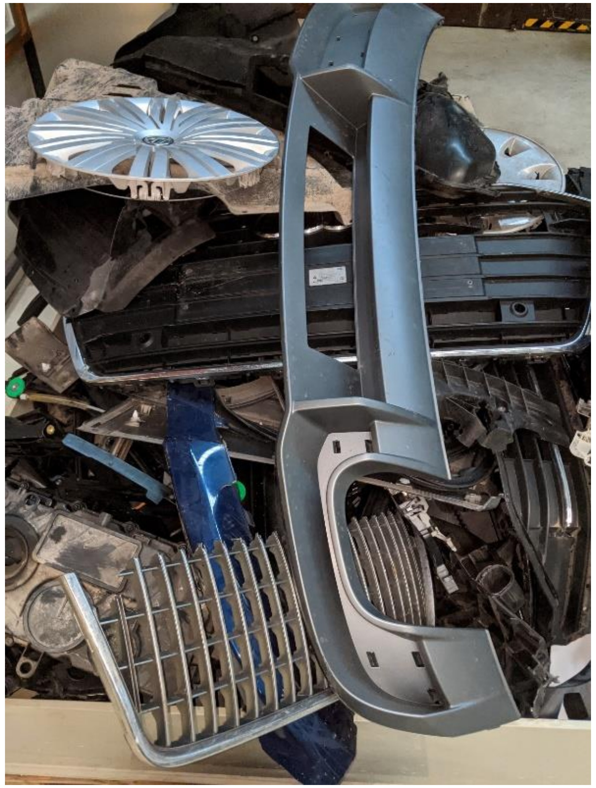
Engineering plastics in automotive applications



https://www.autoberufe.de//interaktionen/chemie-am-auto/it3/, accessed 18.09.2023

Automotive plastic waste from car workshops (APW)

Karlsruhe Institute of Technology



Chemical recycling might have the potential to produce new polymers with virgin polymer quality from plastic waste that cannot be recycled mechanically

Assessment of Automotive Plastic Waste recycling via pyrolysis

Karlsruhe Institute of Technology

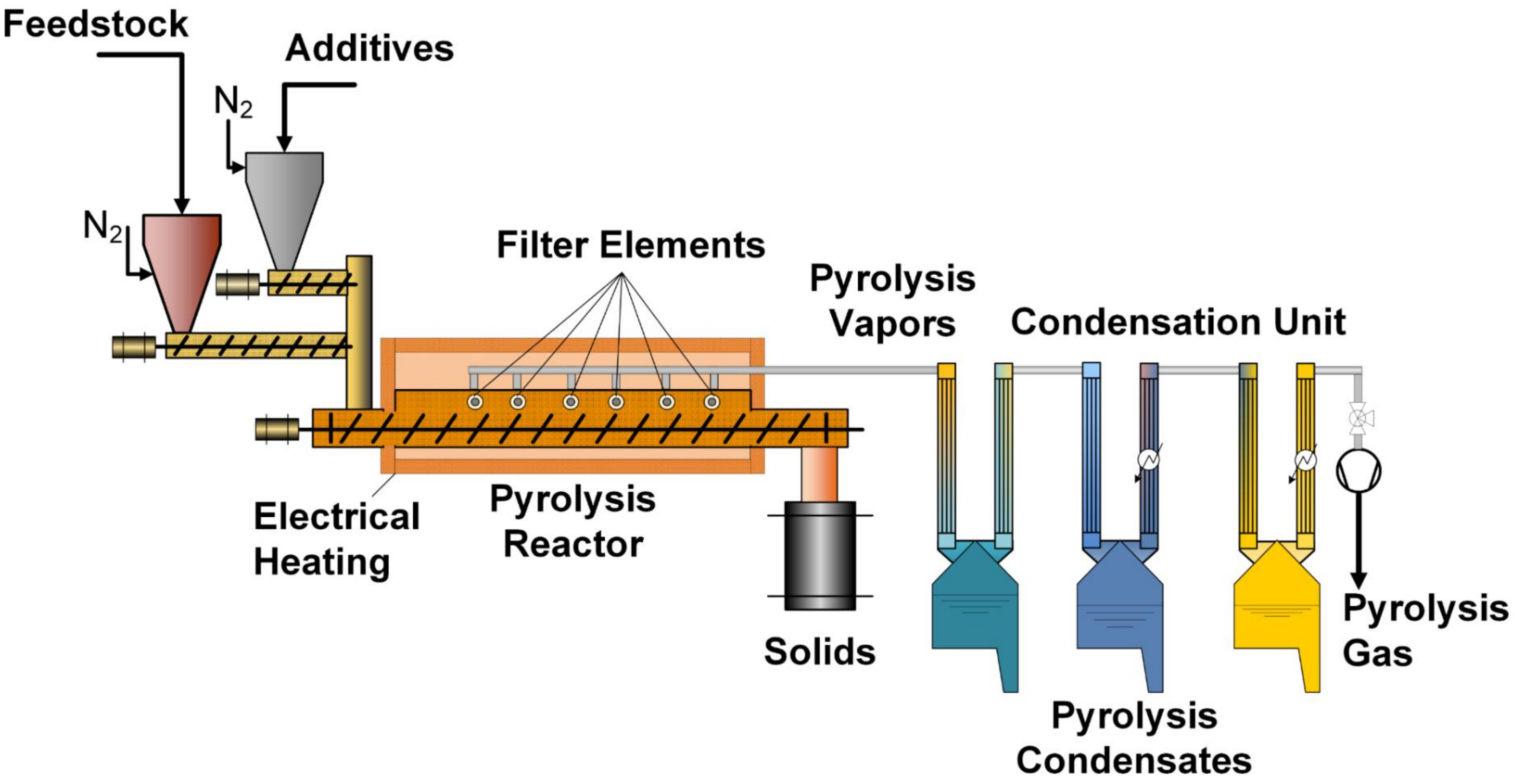
Technology

- Pyrolysis of complex mixture of engineering plastics
- Characterization of pyrolysis products
- Total and elemental mass balances of pyrolysis process

Techno-economic (TEA) and Life Cycle Assessment (LCA)

- Definition of process chain for chemical recycling of automotive plastic waste
- Balancing of entire process chain
- Calculation of costs and LCA indicators

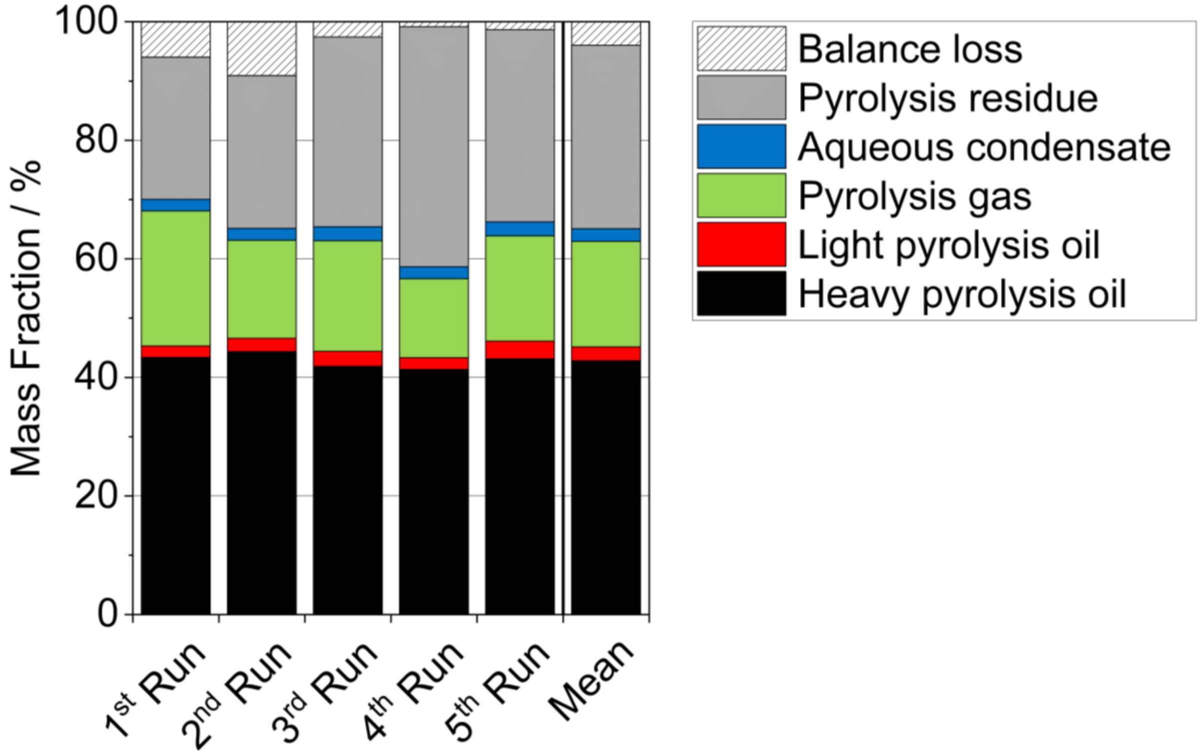
Feedstock flexible pyrolysis pilot plant



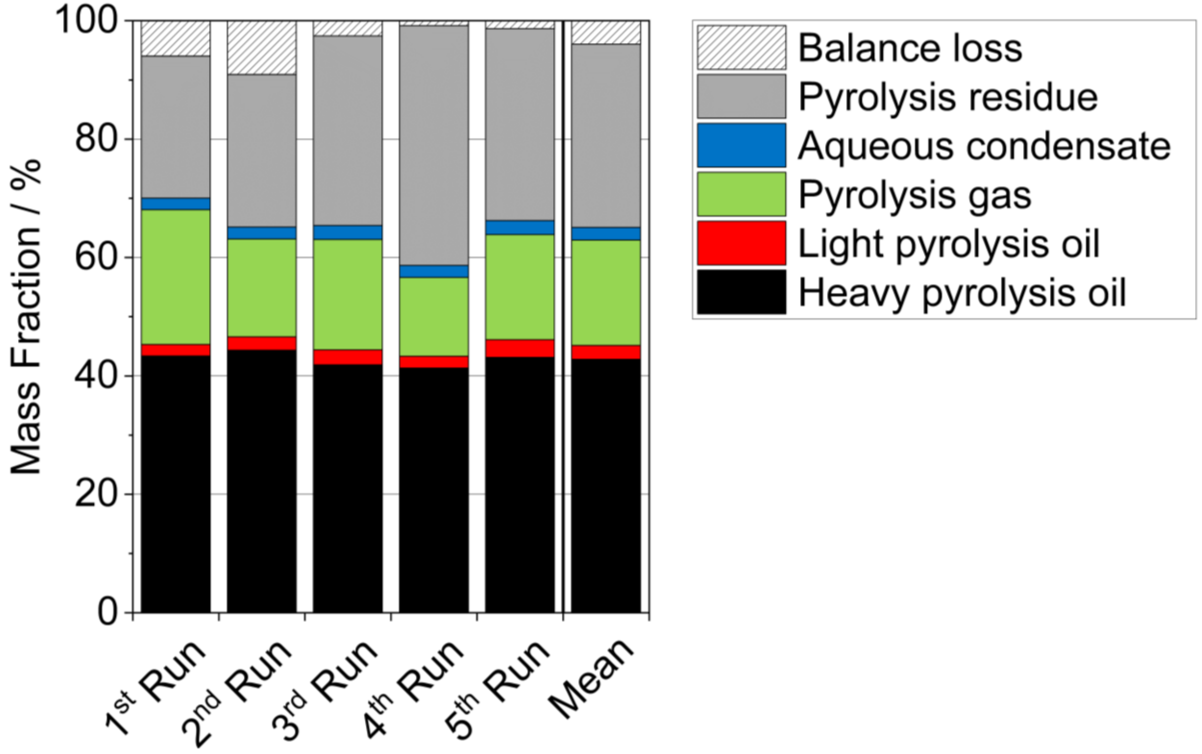
Throughput: 1 kg/h
Temperature: 450 °C

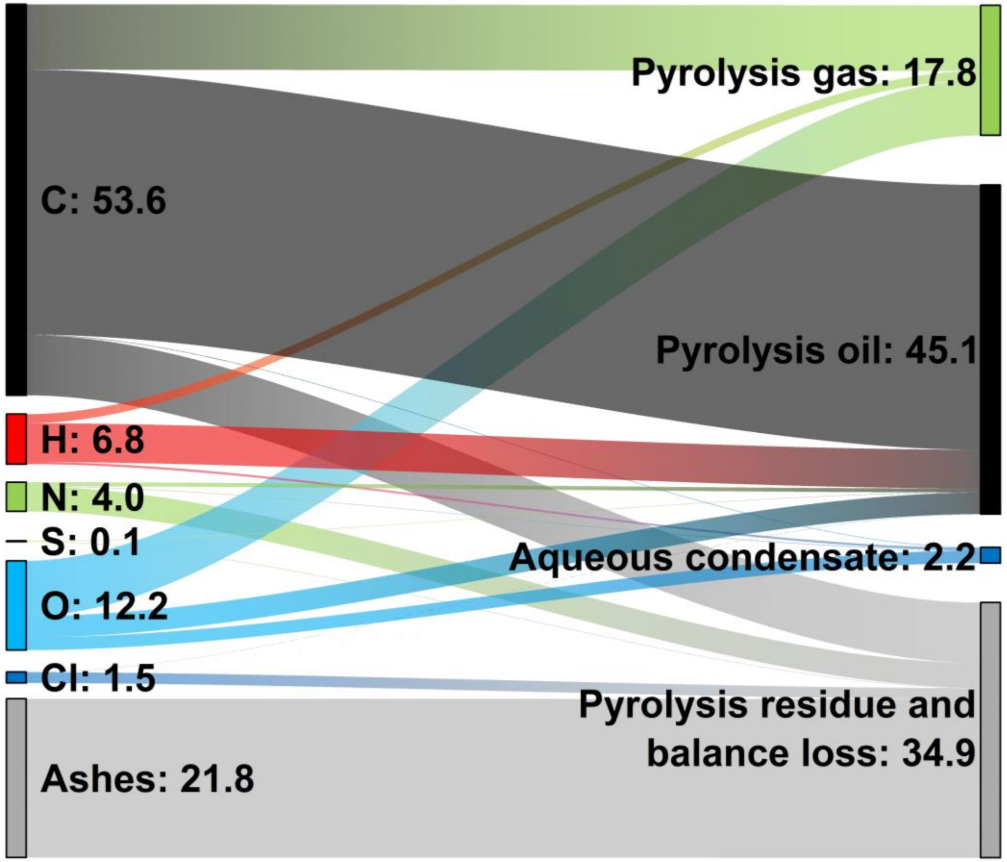
Moderator: Quartz sand
Residence time: 45 min

Pyrolysis mass and elemental balances



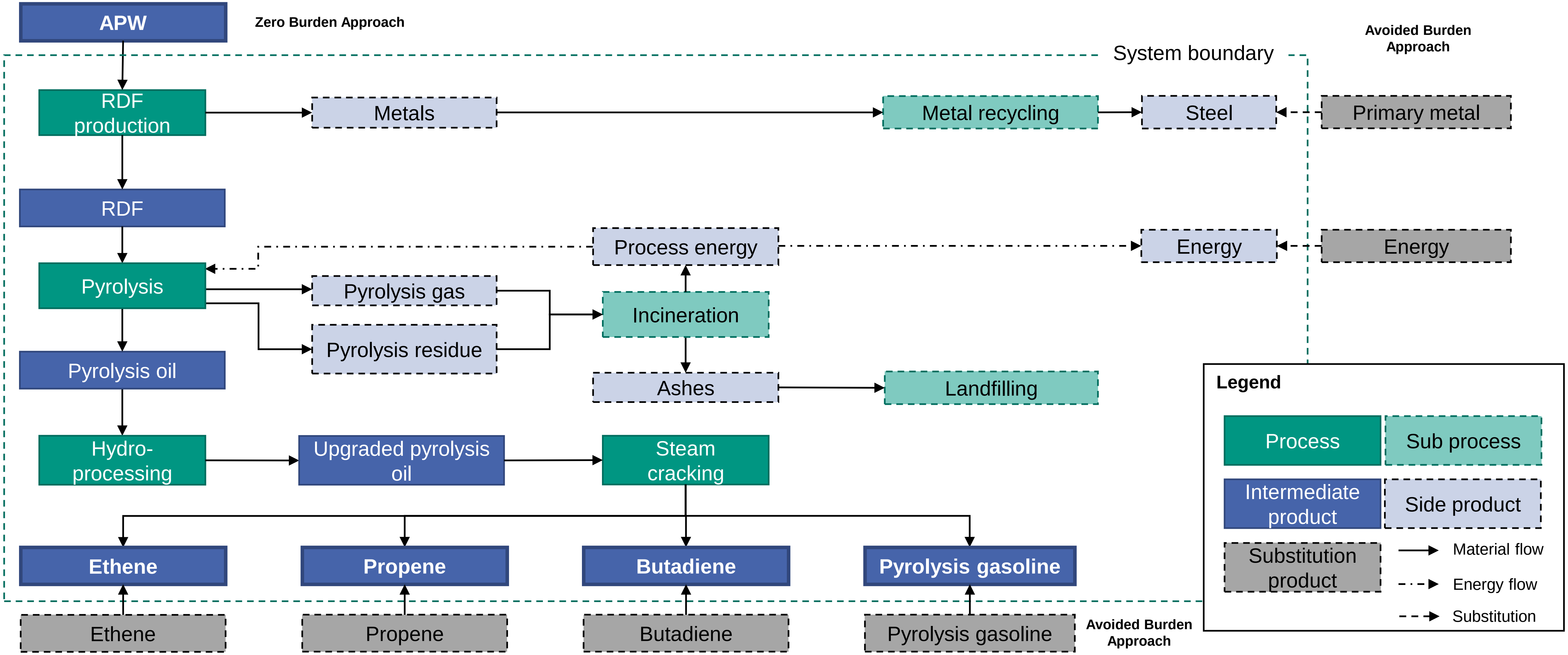
Pyrolysis mass and elemental balances





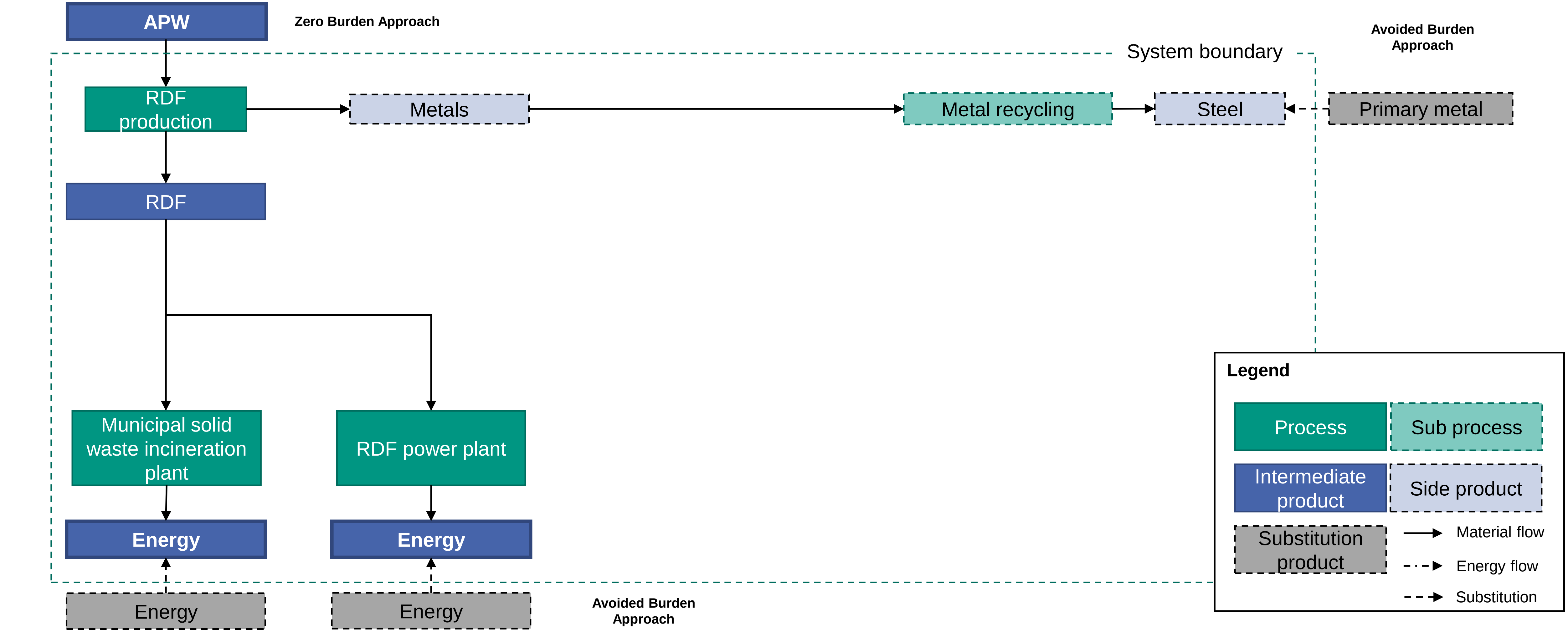
Pyrolysis of engineering plastics is feasible but upgrading of pyrolysis oil is required for use as steam cracker feedstock

Process chain and system boundaries



APW: Automotive plastic waste RDF: Refuse derived fuel

Reference system



APW: Automotive plastic waste

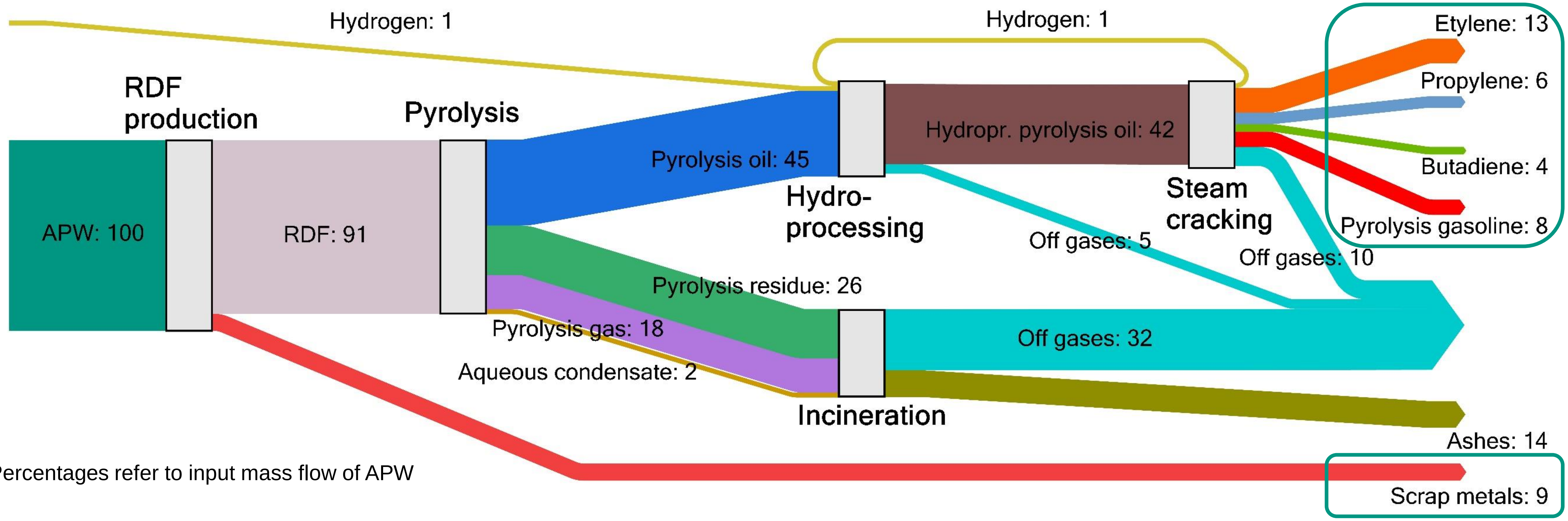
RDF: Refuse derived fuel

Assessment criteria for TEA and LCA

Assessment criteria	Unit	Description
ecological		
Climate Change	**kg CO_2e / kg waste**	Assessed based on GWP100 as defined by Kyoto-Protocol (IPCC 2013).
Carbon efficiency	**% carbon recovered**	Carbon recovery in the product compared to carbon contained in feedstock.
economic		
Costs	**€ / kg waste**	Depreciation of investment and OPEX

Stallkamp, C., Hennig, M. et al. (2023): Economic and environmental assessment of automotive plastic waste end-of-life options: Energy recovery versus chemical recycling. Journal of Industrial Ecology, jiec.13416. https://doi.org/10.1111/jiec.13416.

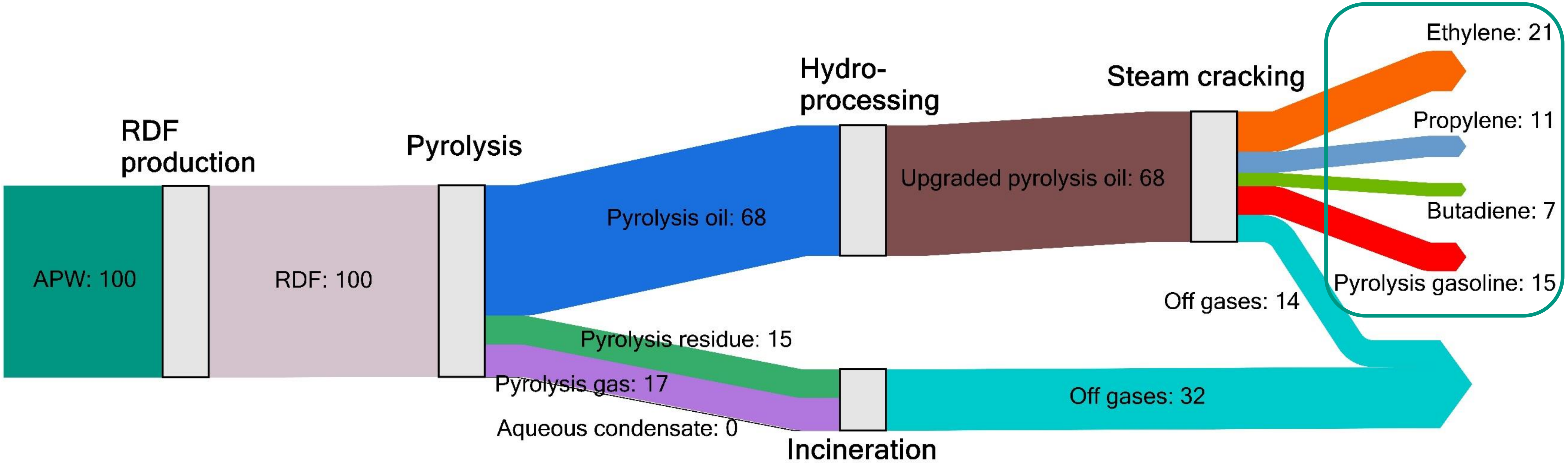
Mass balance of APW recycling via pyrolysis



Percentages refer to input mass flow of APW

31% of input material is recovered as High Value Chemical (HVC), 9% as scrap metals

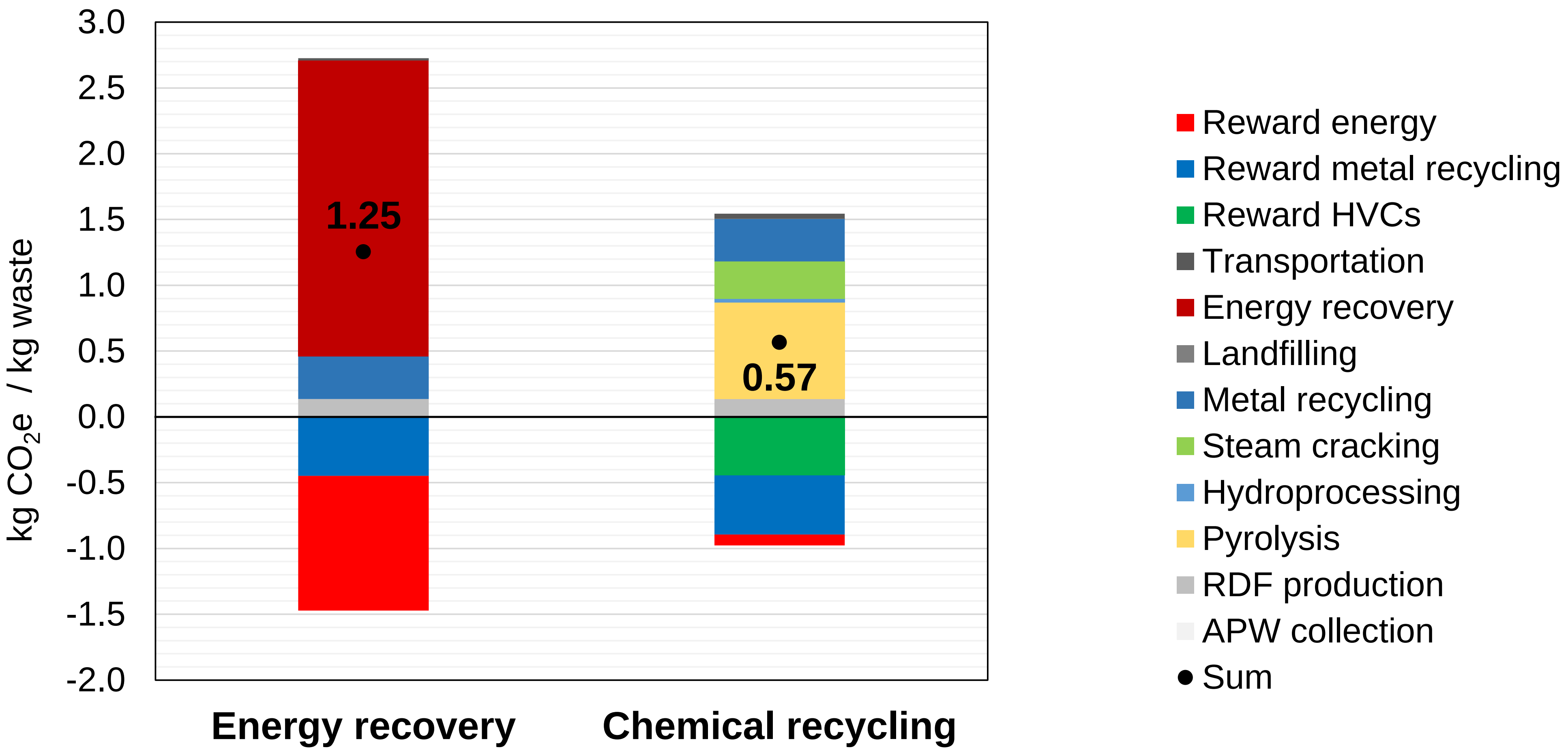
Carbon efficiency of APW recycling



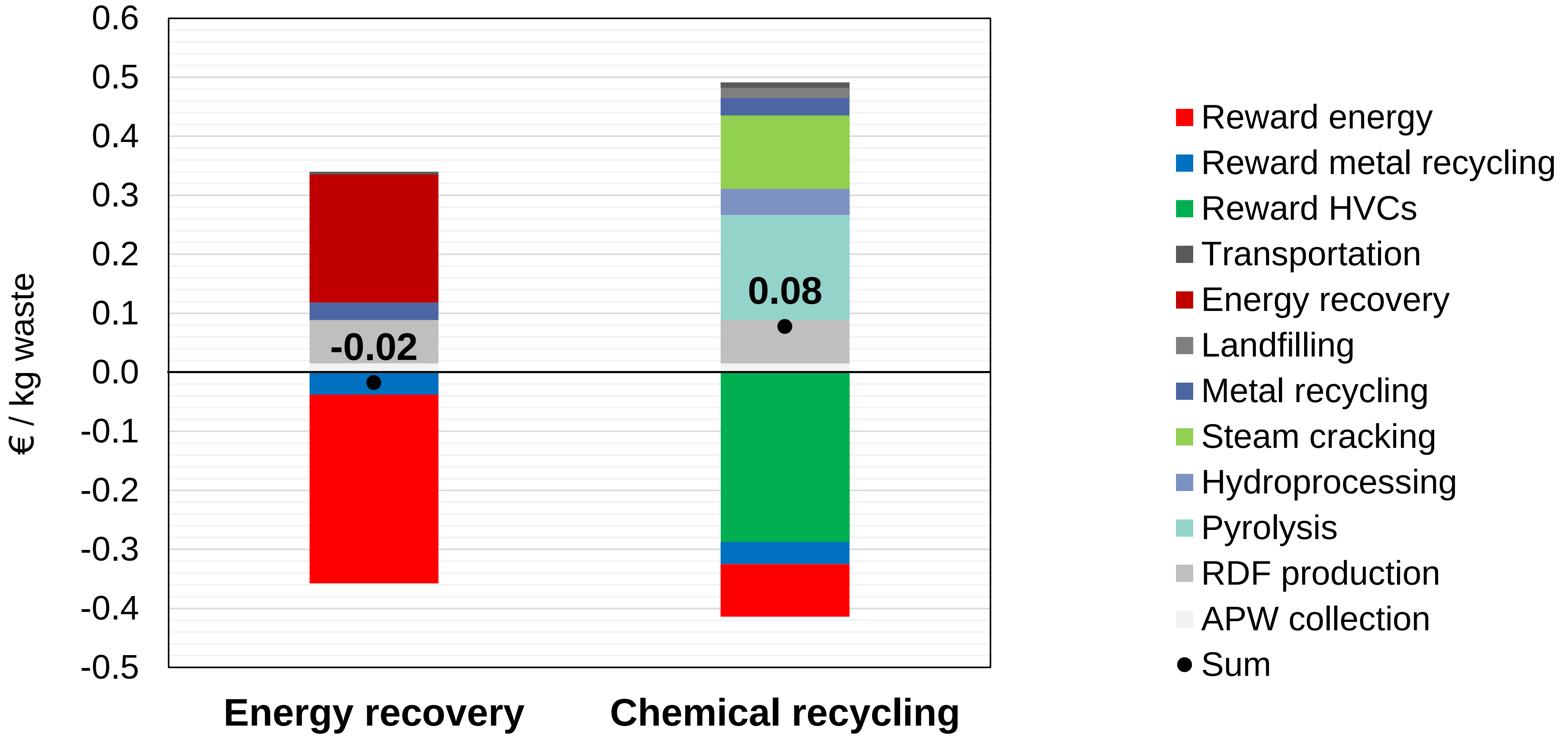
Percentages refer to input carbon mass flow of APW

Steam cracking of upgraded pyrolysis oil results in carbon recovery > 50 %

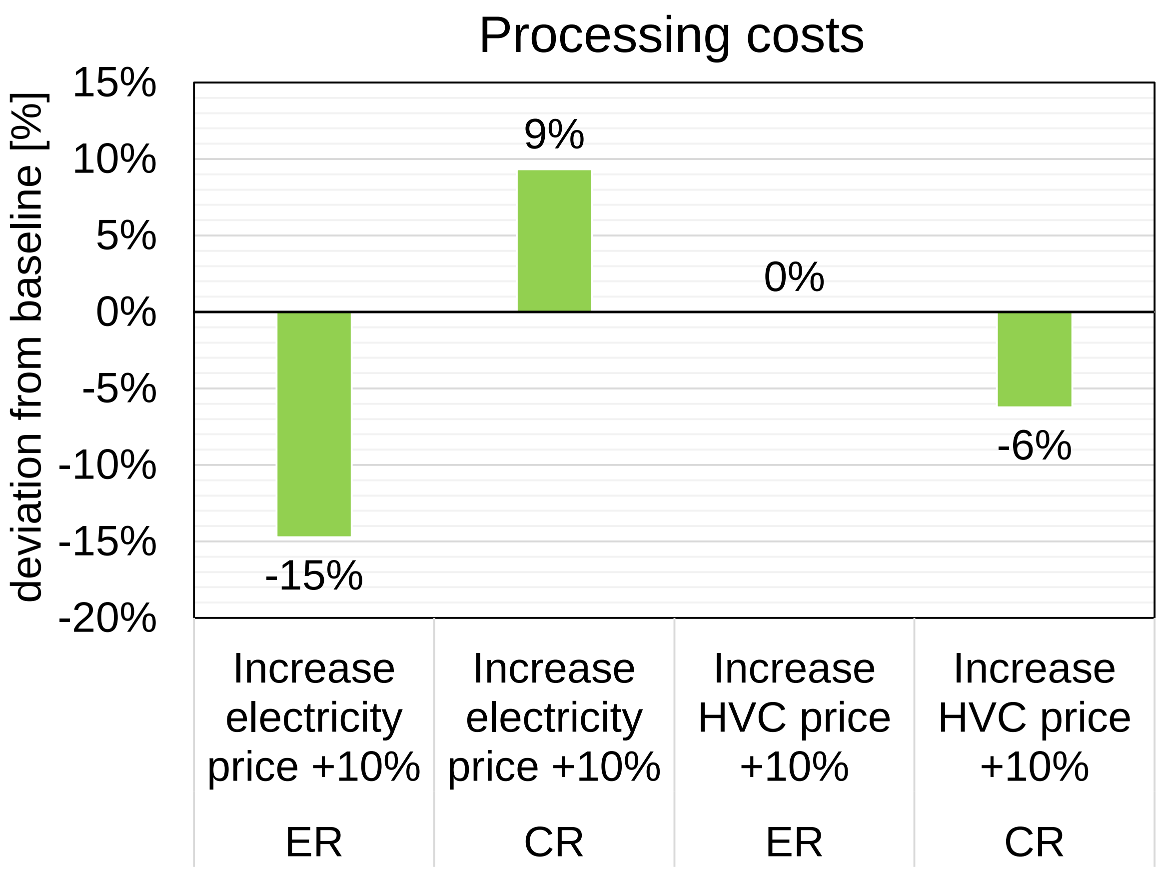
Climate change impact comparison

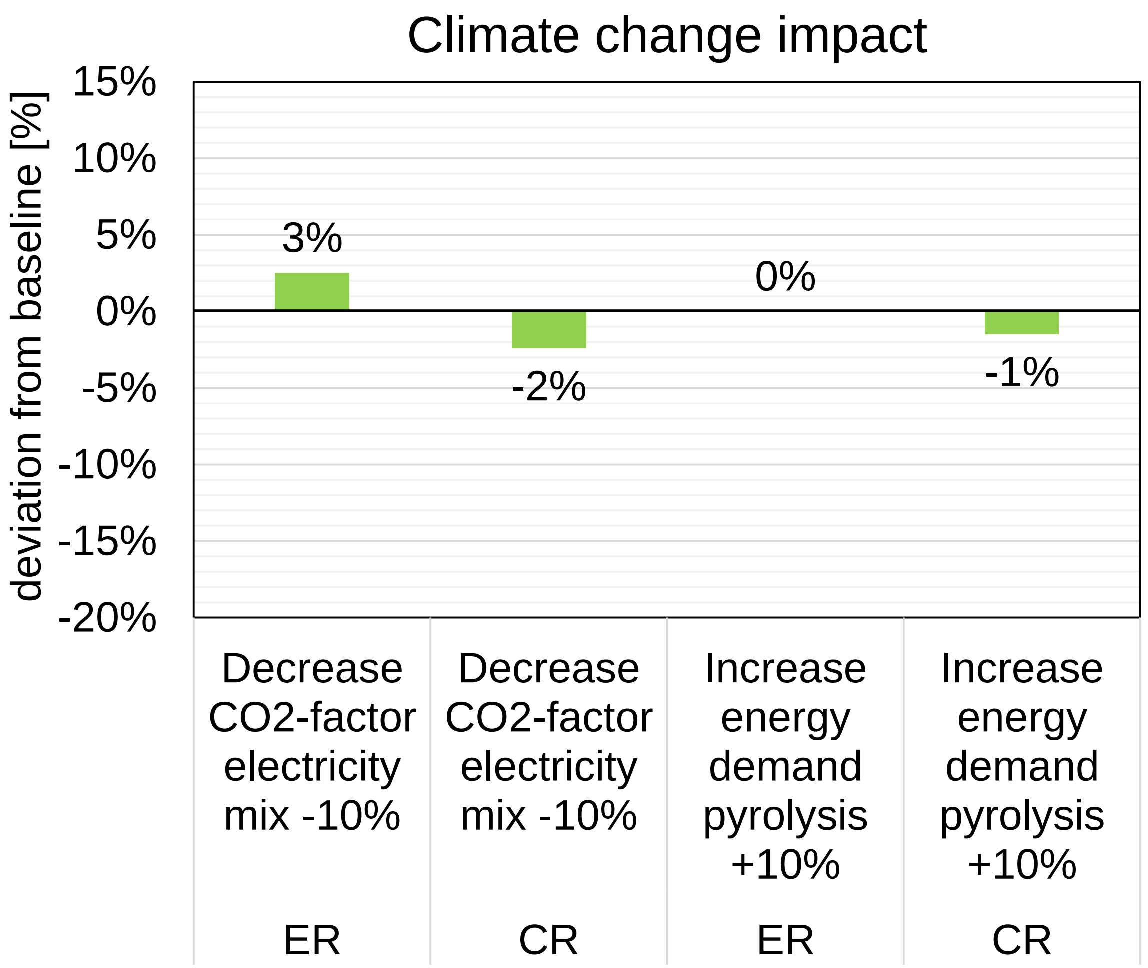


Economic comparison



Sensitivity analysis





ER: Energy recovery CR: Chemical recycling

Case study conclusions

Technology

- Pyrolysis of APW is feasible
- APW pyrolysis oil requires upgrading for use as steam cracker feedstock

Environment

- Chemical recycling of engineering plastics is beneficial in terms of climate change impact

Economy

- High energy prices favor energy recovery due to higher revenues

Thank you for your attention!

…and the financial support of THINKTANK Industrielle Ressourcenstrategien and AUDI AG and the provision of waste samples by Volkswagen Original Teile Logistik GmbH