Copernicus Institute of Sustainable Development

Project partners:

Towards Carbon Circularity

GHG Emissions and Carbon Efficiency Assessment of Dutch DKR-350 Pyrolysis

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Background

This research aimed to evaluate the life cycle GHG emissions of Dutch **DKR-350** (**a low-quality mixed-plastics sorting residue)** recycled via innovative **non-catalytic pyrolysis** technology. The pyrolysis oil, with properties resembling feed-cracking naphtha, is a potential precursor in plastic manufacturing. We also assessed the carbon efficiency, a pivotal circularity indicator of pyrolysis' ability to close the carbon loop.

Methods

Two DKR-350 samples were analysed, **unwashed** and **washed** (in hot water with a detergent). They were pyrolysed in a pilot-scale fluidized-bed reactor.

The LCA was carried out from two perspectives, based on how the primary function of pyrolysis can be perceived:

1. **Waste management perspective:** the primary function was to waste-manage DKR-350; results were compared to DKR-350 incineration.
2. **Naphtha production perspective:** the primary function was to produce naphtha; results are compared to fossil naphtha production in the refinery.

The geographical and temporal scopes were determined for **the Netherlands** in **2020**. We employed an LCA cradle-to-gate approach with cut-off (i.e. the impact of the DKR-350's previous lifecycle was excluded).

Conclusions and recommendations

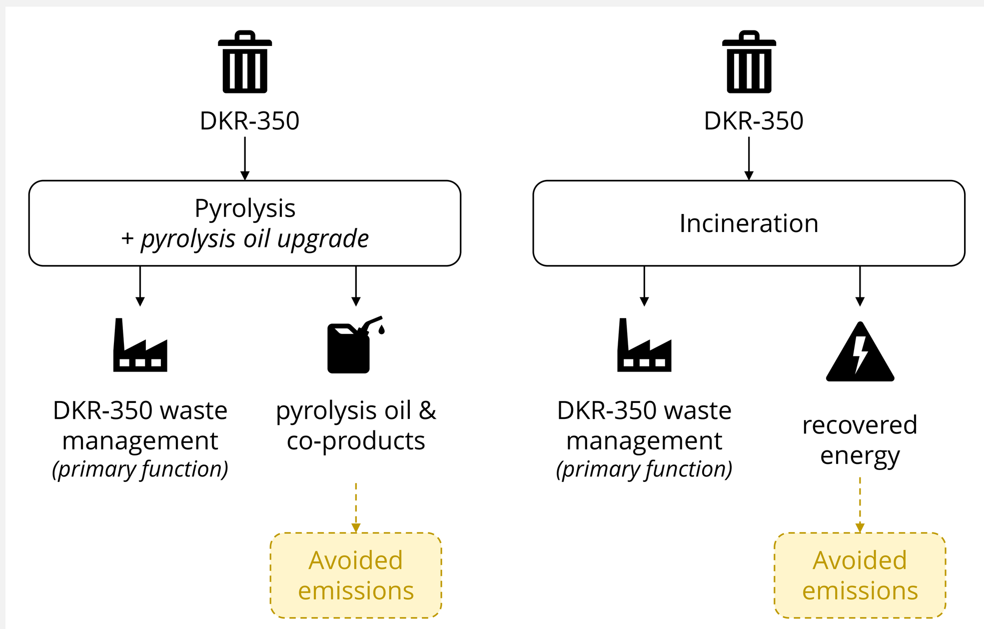
- Our analysis showed **high sensitivity of the results**; we recommend that future LCA studies of multifunctional systems include a goal-oriented approach in their analysis
- **Washing** of DKR-350 **did not** significantly **improve** pyrolysis **performance** in terms of GHG emissions
- **Pyrolysis** as a waste management technology **provides significant GHG emission savings** compared to incineration
- **Carbon efficiency** of the pyrolysis system reaches up to **55%**; we recommend including indirect carbon in any comprehensive circularity and carbon efficiency assessments on plastics circularity

Acknowledgement

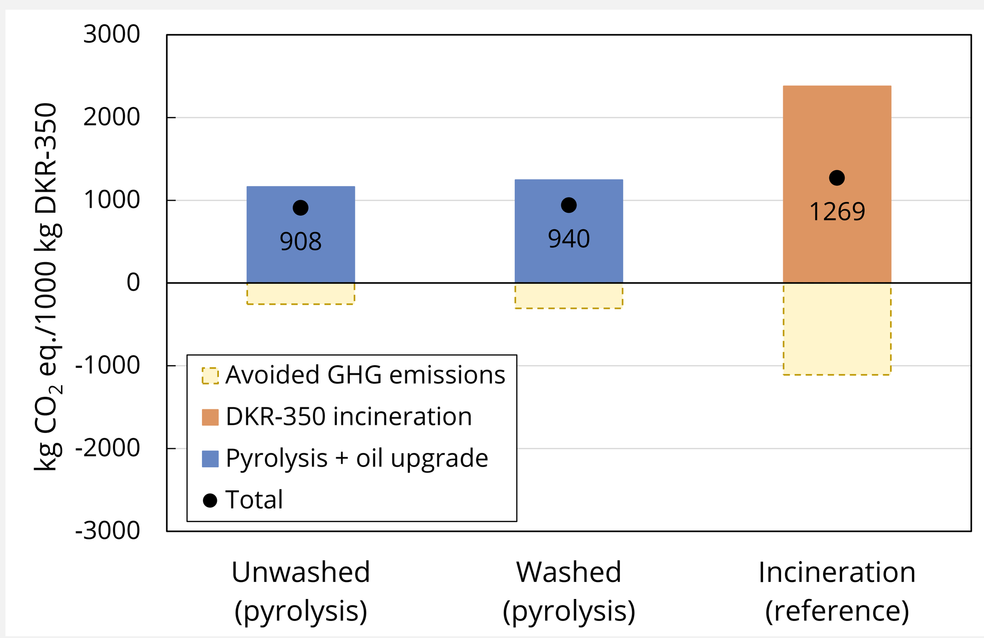
This research was co-funded with a subsidy from the Topsector Energy by the Ministry of Economic Affairs and Climate Policy of the Netherlands. Furthermore, the research was conducted within the project **Towards Improved Circularity of Poly-olefin Based Packaging** (https://ispt.eu/projects/towards-improved-circularity-of-polyolefin-based-packaging/).

Figure 1: Waste management perspective

Functional unit: waste management of 1000 kg DKR-350



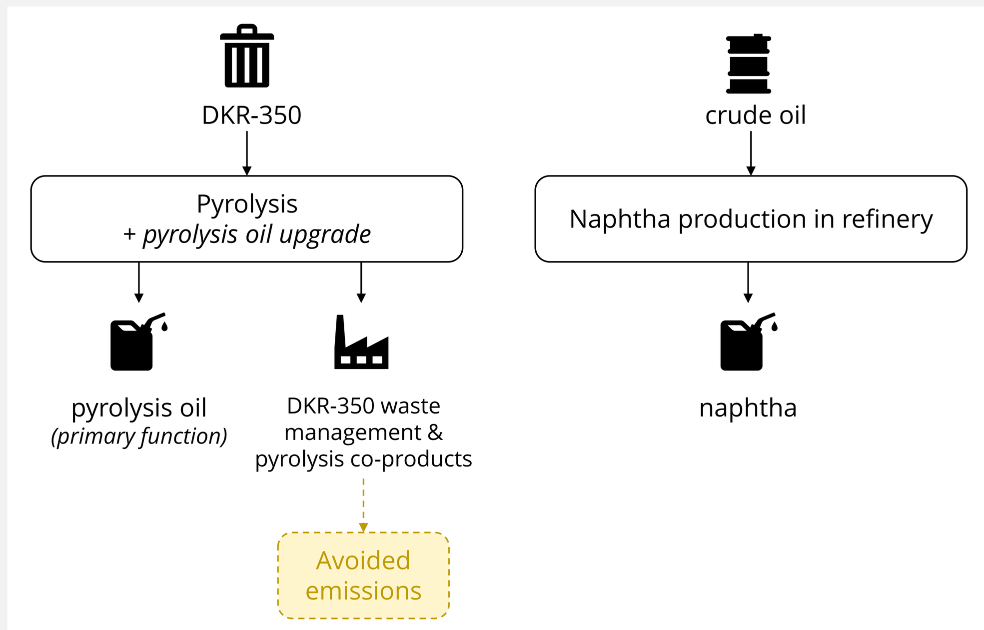
(a) System boundaries



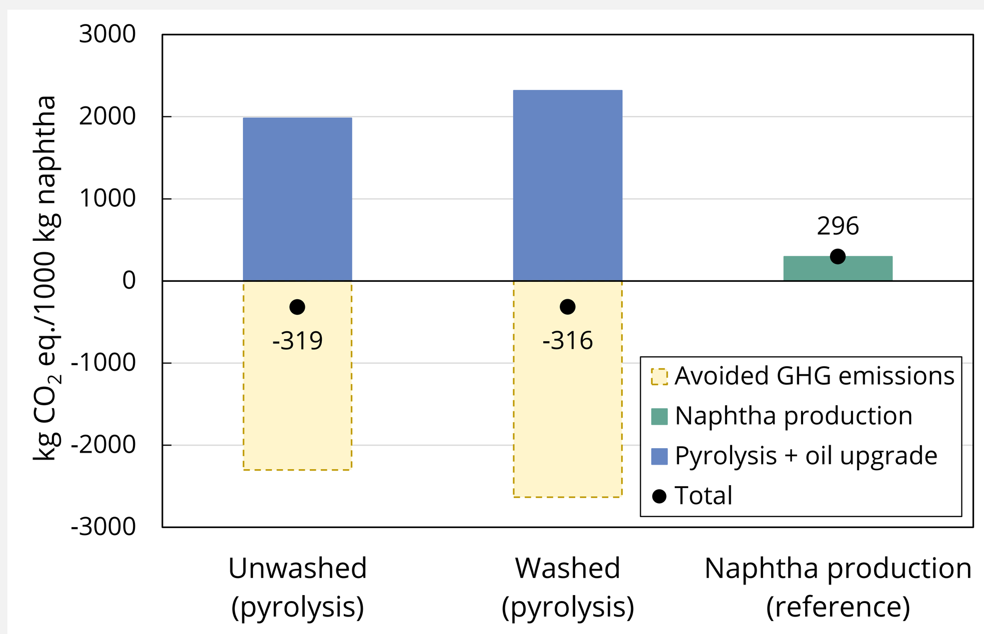
(b) Cradle-to-gate lifecycle GHG emissions

Figure 2: Naphtha production perspective

Functional unit: production of 1000 kg naphtha



(a) System boundaries

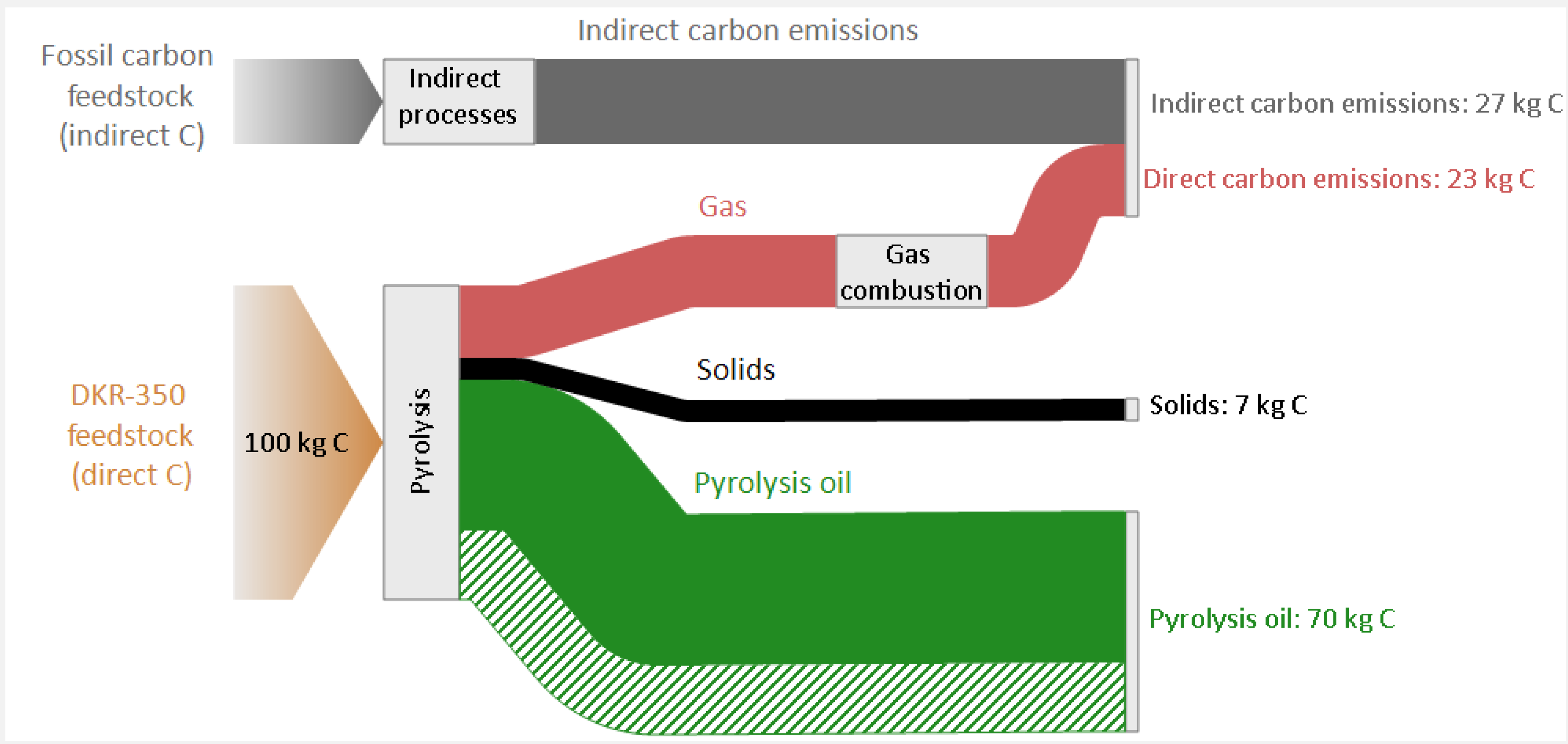


(b) Cradle-to-gate lifecycle GHG emissions

Figure 3: Carbon efficiency of the pyrolysis system (unwashed case)

Carbon efficiency (η_C) represents a share of carbon recovered in pyrolysis oil relative to the sum of direct and indirect carbon. Indirect carbon flow represents carbon embedded in fossil fuels utilised during the indirect processes, predominantly for electricity generation. It is calculated based on the amount of airborne fossil CO_2 emissions caused by these processes.

$$\eta_C\ [\%] = \frac{m_{C,oil}\ [kg]}{m_{C,feedstock}\ [kg] + m_{C,ind.proc.}\ [kg]} * 100$$



Carbon flows normalised to 100 kg C input to the pyrolysis reactor. The green dashed flow represents an uncertain carbon flow in the pyrolysis oil (i.e. uncollected oil fraction from the reactor during the pilot-scale trials).

38 – 55 %
carbon efficiency

The overall carbon efficiency of the system is estimated to be 38-55%, denoting the proportion of carbon recovered in the pyrolysis oil. It is crucial to note that this percentage does not signify the circularity level of the pyrolysis system, as the conversion of pyrolysis oil back to plastic polymer was not included in the assessment.

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