srh

Universität Rostock — Traditio et Innovatio

Imperial College London

10th International conference on Sustainable Solid Waste Management

Chania 2023

Experimental investigation of products from single-use and multilayered waste plastics

<u>Uduak Bassey</u>, Alex Bowles, Geoff Fowler, Abasi-ofon Tom, Gesa Beck, Satyanarayana Narra, Michael Nelles, Michael Hartmann

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Universität Rostock Traditio et Innovatio

Imperial College London

Thermal treatment options for single-use, multilayered and composite waste plastics in Africa

Uduak Bassey [a,b,*], Khadija Sarquah [b,a], Michael Hartmann [a], Abasi-ofon Tom [c], Gesa Beck [a], Edward Antwi [b], Satyanarayana Narra [b], Michael Nelles [b]

[a] Berlin School of Technology, SRH Berlin University of Applied Sciences, 10587, Berlin, Germany
[b] Department of Waste and Resource Management, University of Rostock, 18051, Rostock, Germany
[c] Department of Chemical Engineering, University of Port-Harcourt, Rivers state, Nigeria

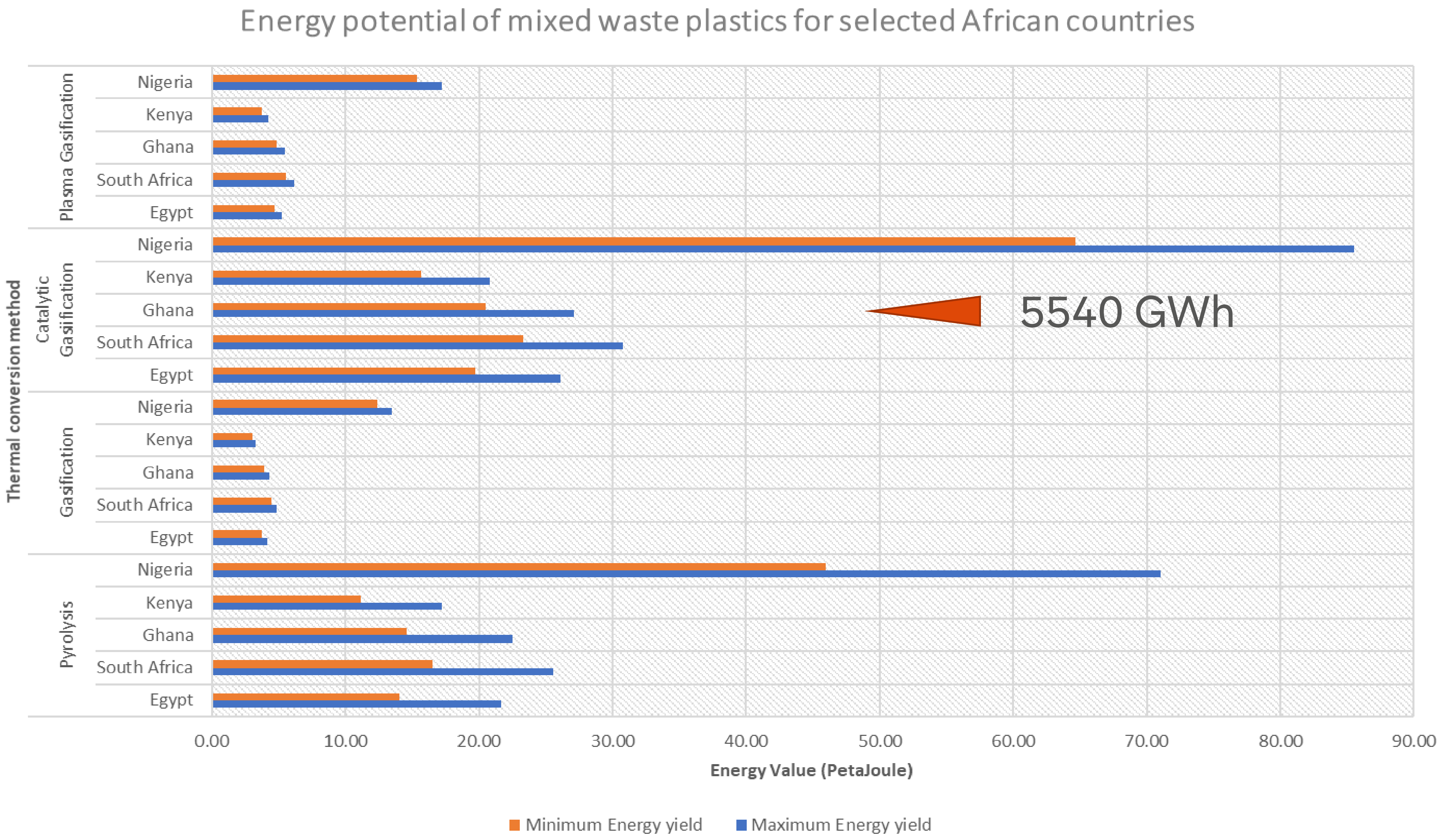
A R T I C L E I N F O

Handling Editor: Petar Sabev Varbanov

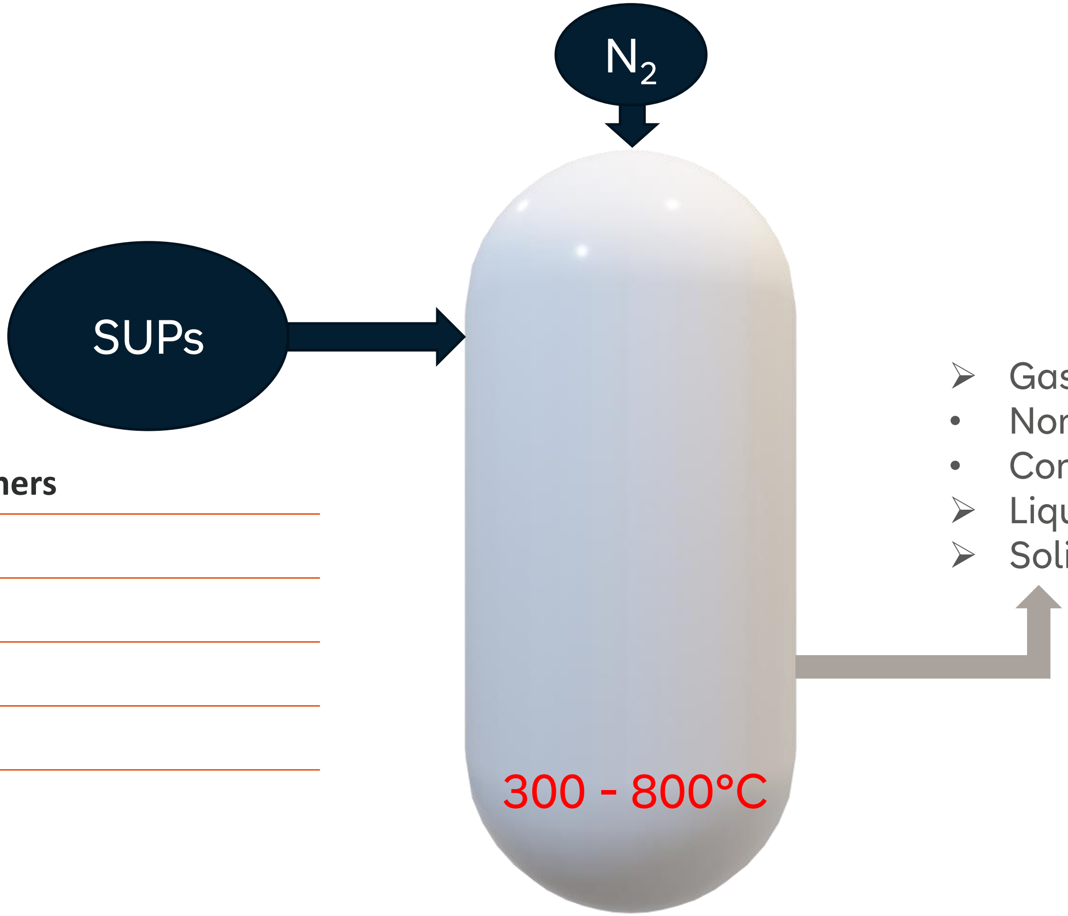
Keywords:
Energy recovery
Waste plastics
Pyrolysis
Gasification
Waste-to-Energy
Thermal treatment

A B S T R A C T

This review highlights the current level of waste plastics valorization through thermal treatment and its potential for African countries. Improved thermal treatment options are needed to convert the over 40% of mismanaged waste plastics in Africa to generate electrical and chemical energy. The values of measured and calculated energy yields from high-quality data are compared for treatment options such as pyrolysis, gasification, incineration, catalytic and plasma gasification. The investigation revealed that, for chemical energy production, catalytic gasification offers the best valuable product yield for single-use plastics with a promising liquid output of up to 80% with a low heating value (LHV) of 44 MJ/kg, gas output 6–7% with heating value of 48 MJ/m^3, and solid output of 10–20%. The liquid and gas products obtained at this quality could be used as fuel in a conventional gas/diesel engine for electricity generation. For the treatment of multi-layered and composite waste plastics, plasma gasification offers the best energy recovery approach with a potential of producing syngas with LHV of 10.8 MJ/m^3 and consisting of H_2 and CO weight fraction of 62.5% and 34%, respectively. The feasible waste plastics treatment options are presented based on waste plastics profiles in selected regions of Africa.


Energy potential of mixed waste plastics for selected African countries
Thermal conversion method
Plasma Gasification
Catalytic Gasification
Gasification
Pyrolysis
Nigeria
Kenya
Ghana
South Africa
Egypt
5540 GWh
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Energy Value (PetaJoule)
Minimum Energy yield
Maximum Energy yield

Pyrolysis of waste plastics



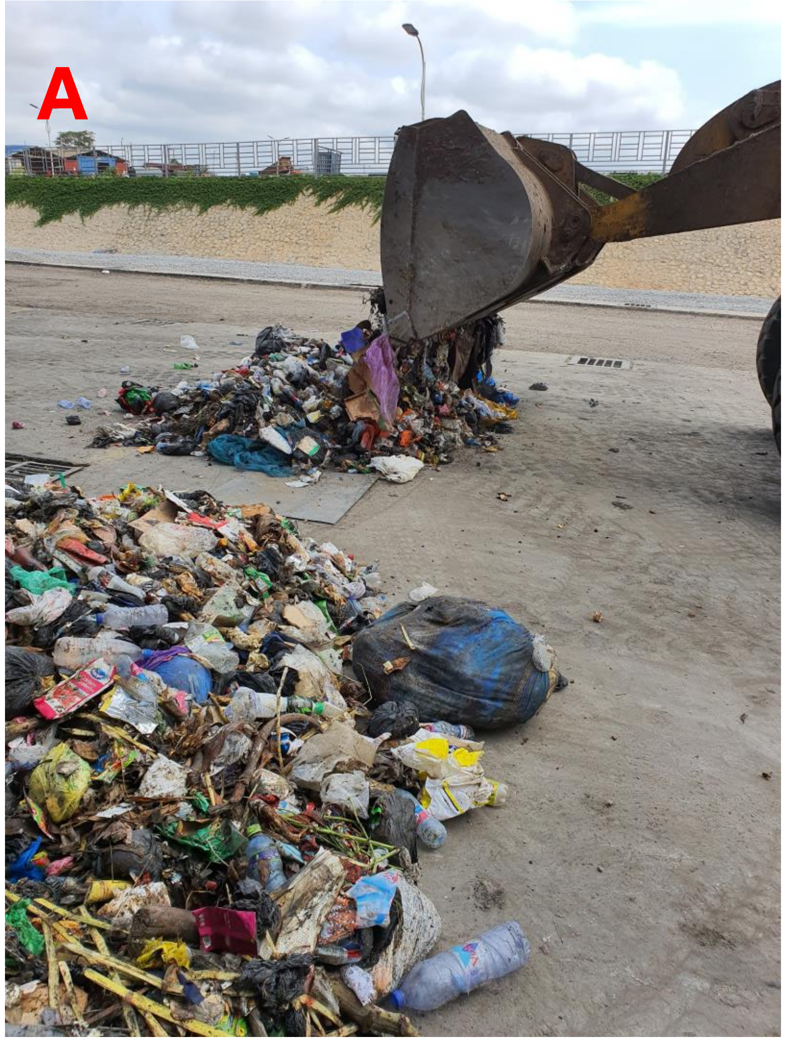
Polymers
PP
PE
PVC
PS
PET

- ➢ Gases (5 – 20 wt.%)
  - Non-condensable
  - Condensable
- ➢ Liquids (60 – 93 wt.%)
- ➢ Solids (5 – 20 wt.%)

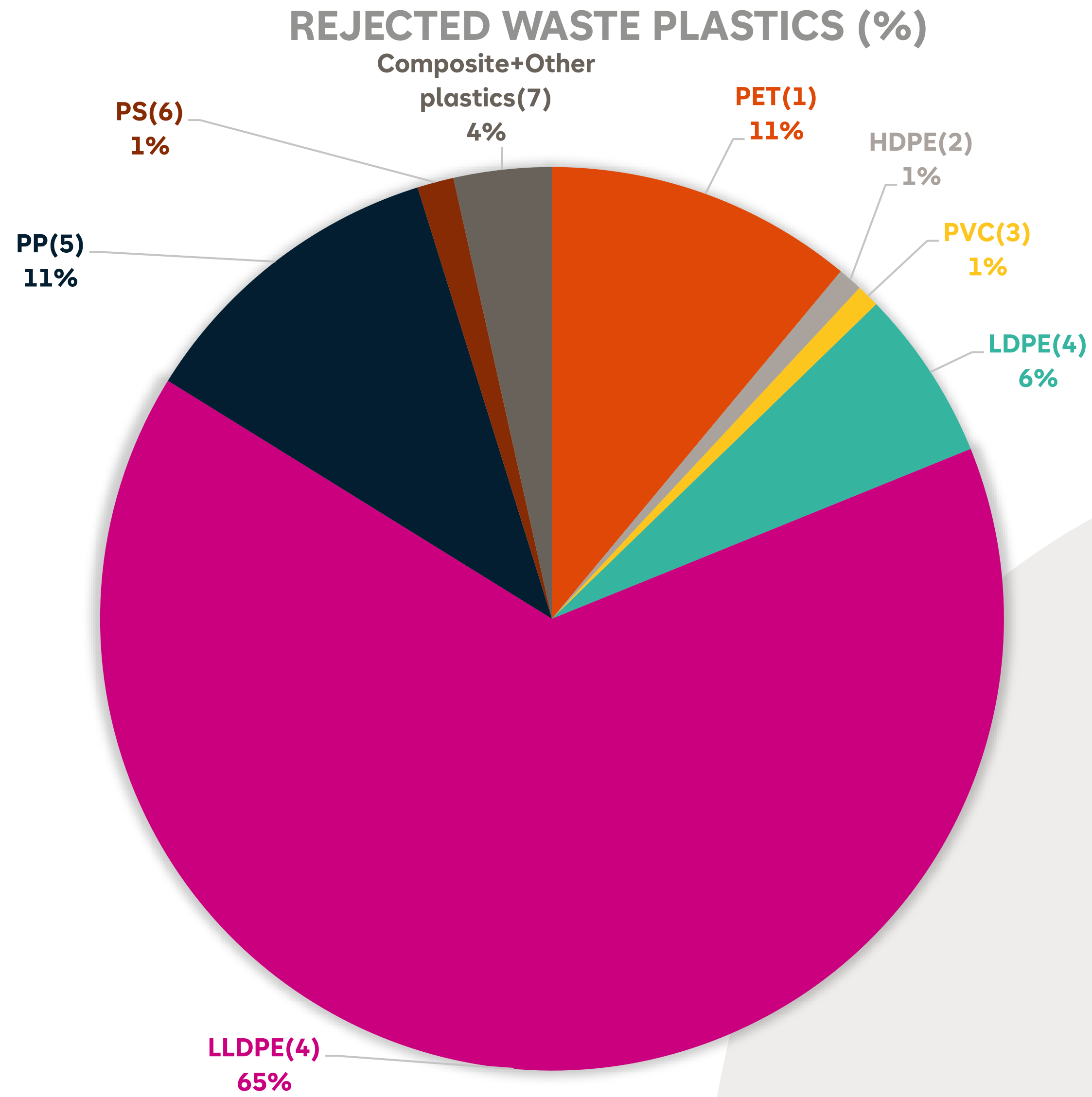
Fuels 36 - 48 MJ/kg

Chemicals

Feedstock sampling



Feedstock characterisation



energies

MDPI

Universität Rostock Traditio et Innovatio

Imperial College London

Article

Characterization of Municipal Solid Waste and Assessment of Its Potential for Refuse-Derived Fuel (RDF) Valorization

Khadija Sarquah [1,2,*], Satyanarayana Narra [1,3], Gesa Beck [2], Uduak Bassey [1,2], Edward Antwi [1], Michael Hartmann [2], Nana Sarfo Agyemang Derkyi [4], Edward A. Awafo [4] and Michael Nelles [1,3]

1 Department of Waste and Resource Management, University of Rostock, 18051 Rostock, Germany
2 Berlin School of Technology, SRH Berlin University of Applied Sciences, 10587 Berlin, Germany
3 German Biomass Research Centre (DBFZ), 04347 Leipzig, Germany
4 School of Engineering, University of Energy and Natural Resources, Sunyani P.O. Box 214, Ghana
* Correspondence: khadija.sarquah@uni-rostock.de

Abstract: Reuse and recycling are preferred strategies in waste management to ensure the high position of waste resources in the waste management hierarchy. However, challenges are still pronounced in many developing countries, where disposal as a final solution is prevalent, particularly for municipal solid waste. On the other hand, refuse-derived fuel as a means of energy recovery provides a sustainable option for managing mixed, contaminated and residual municipal solid waste (MSW). This study provides one of the earliest assessments of refuse-derived fuel (RDF) from MSW in Ghana through a case study in the cities of Accra and Kumasi. The residual/reject fractions (RFs) of MSW material recovery were characterized for thermochemical energy purposes. The studied materials had the potential to be used as RDF. The combustible portions from the residual fractions formed good alternative fuel, RDF, under the class I, II-III classification of the EN 15359:2011 standards. The RDF from only combustible mixed materials such as plastics, paper and wood recorded a significant increase in the lower heating value (28.66–30.24 MJ/kg) to the mass RF, with the presence of organics (19.73 to 23.75 MJ/kg). The chlorine and heavy metal content met the limits set by various standards. An annual RDF production of 12 to 57 kilotons is possible from the two cities. This can offset 10–30% of the present industrial coal consumption, to about 180 kiloton/yr CO_2 eq emissions and a net cost saving of USD 8.7 million per year. The market for RDF as an industrial alternative fuel is developing in Ghana and similar jurisdictions in this context. Therefore, this study provides insights into the potential for RDF in integrated waste management system implementation for socioeconomic and environmental benefits. This supports efforts towards achieving the Sustainable Development Goals (SDGs) and a circular economy.

Keywords: refuse-derived fuel (RDF); energy recovery; municipal solid waste; co-combustion; alternative fuel; thermochemical valorization

Citation: Sarquah, K.; Narra, S.; Beck, G.; Bassey, U.; Antwi, E.; Hartmann, M.; Derkyi, N.S.A.; Awafo, E.A.; Nelles, M. Characterization of Municipal Solid Waste and Assessment of Its Potential for Refuse-Derived Fuel (RDF) Valorization. *Energies* **2023**, *16*, 200. https://doi.org/10.3390/en16010200

Proximate and elemental analysis of feedstock

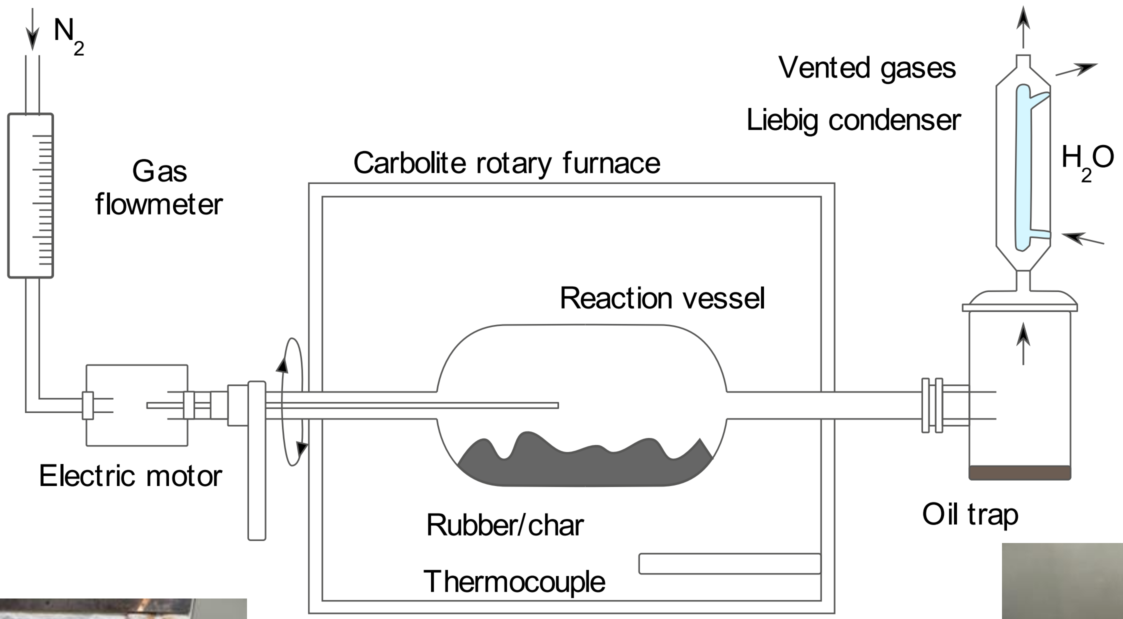
	S1 (own study)	S2	S3 [8]	S4 [9]	S5 [10]
Moisture content (wt.%)			0.02	0	
Proximate analysis, (wt.%)					
Volatile matter			99.85	99.30	88.54
Fixed carbon			0	0	9.37
Ash			0.15	0.7	2.09
Ultimate analysis (wt.%)					
Carbon	86.09		85.81	86.42	61.87
Hydrogen	13.32		13.86	12.28	4.35
Nitrogen	0.483		0.12	0.72	0
Sulphur	0.1		0.06	0.17	0
Oxygen			0	0	33.78
Density (kg/m^3) (own study)					
Loose bulk density (@15mm particle size	72.57	88.13	66.75	245.76	211,5

Universität Rostock Traditio et Innovatio

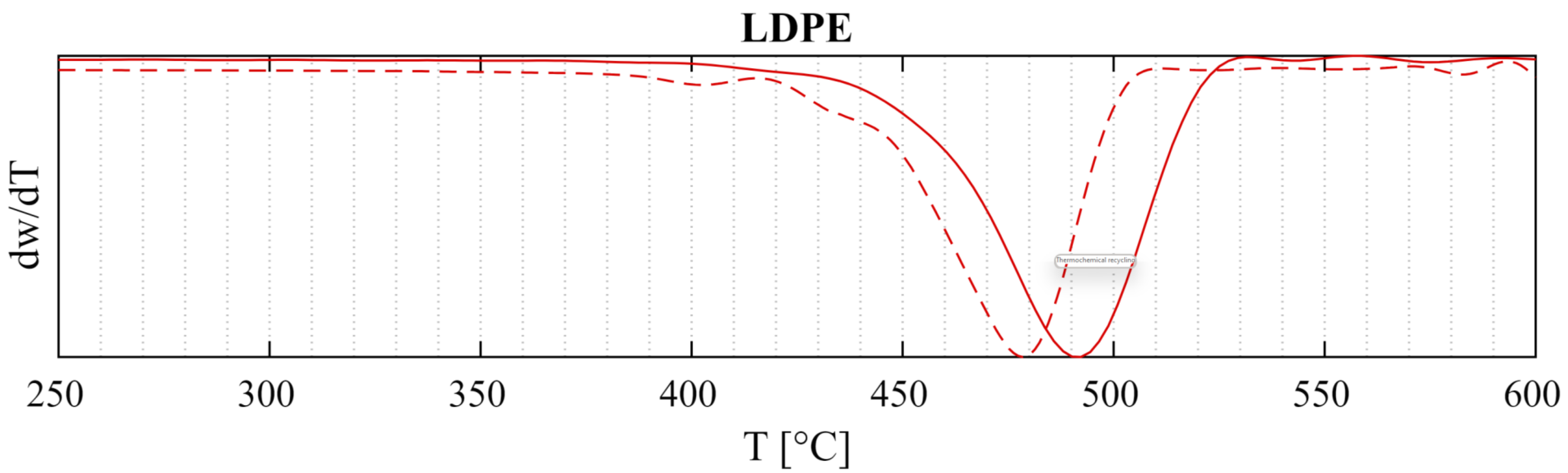
Imperial College London

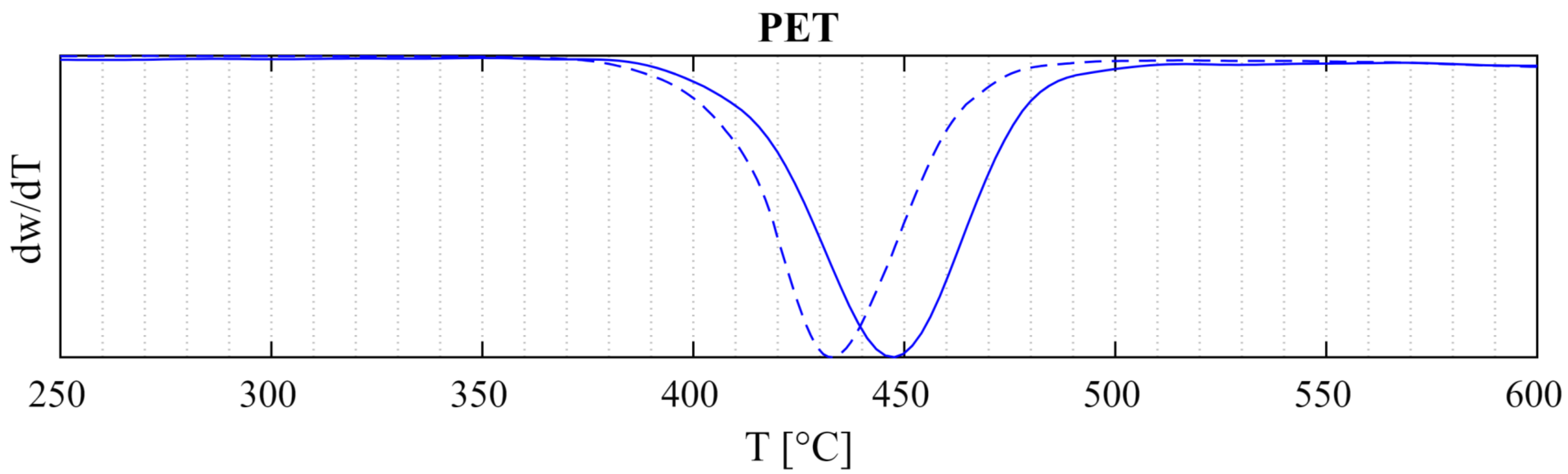
S1	Mixed single use plastics
S2	PE+PP (50/50)
S3	LDPE
S4	PP
S5	PET

Experimental setup



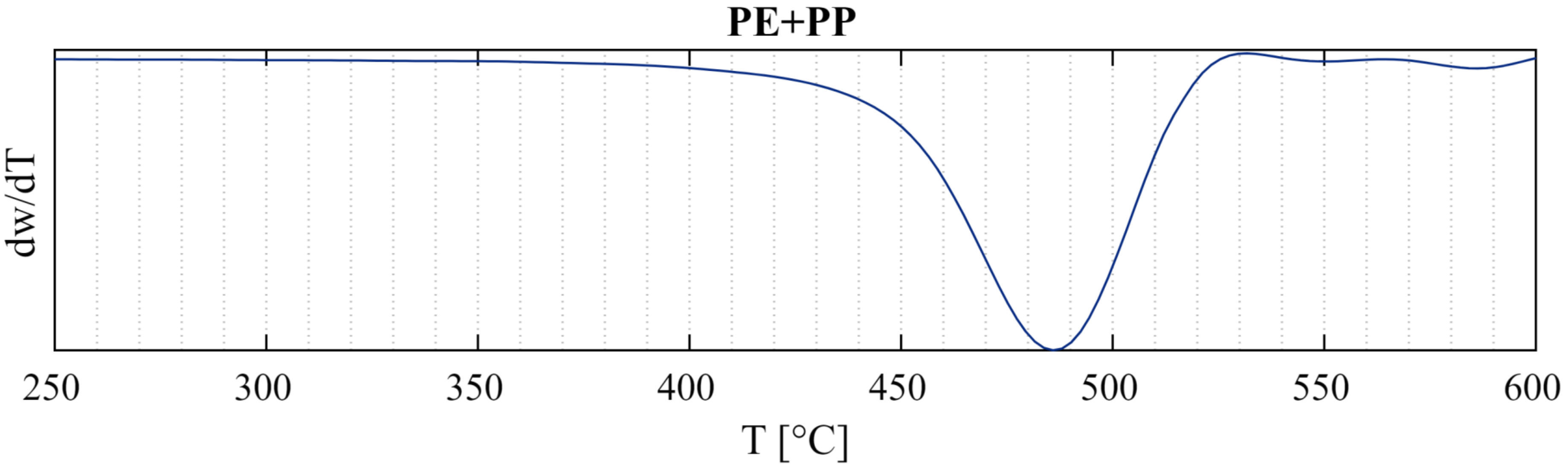
DTG of waste plastic feedstocks

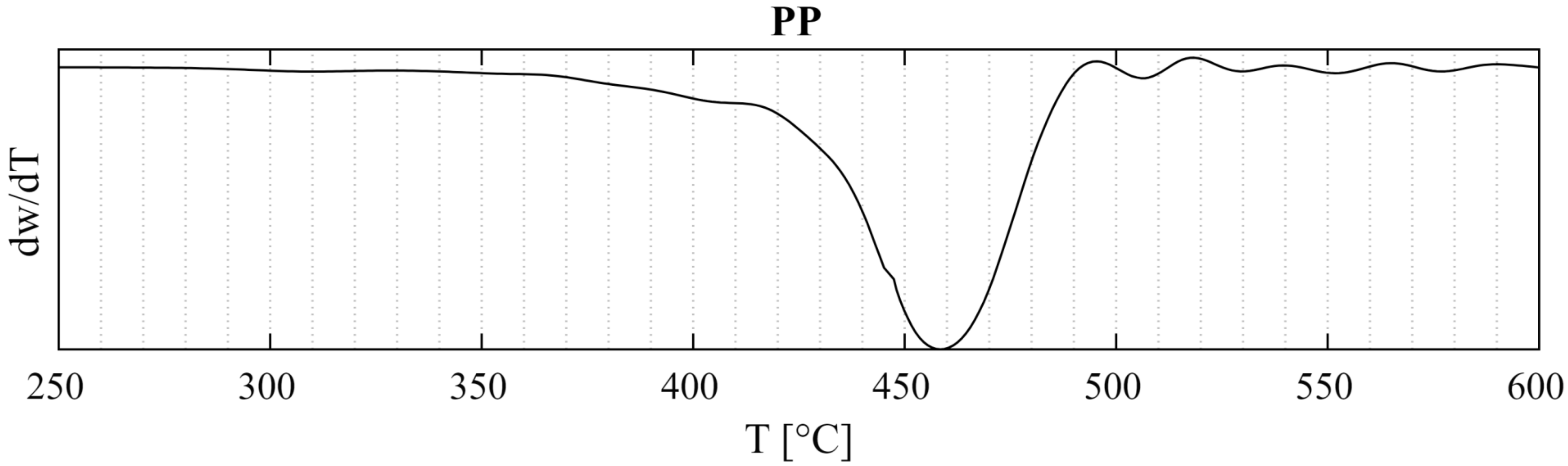




10°C/min --------
20°C/min ————

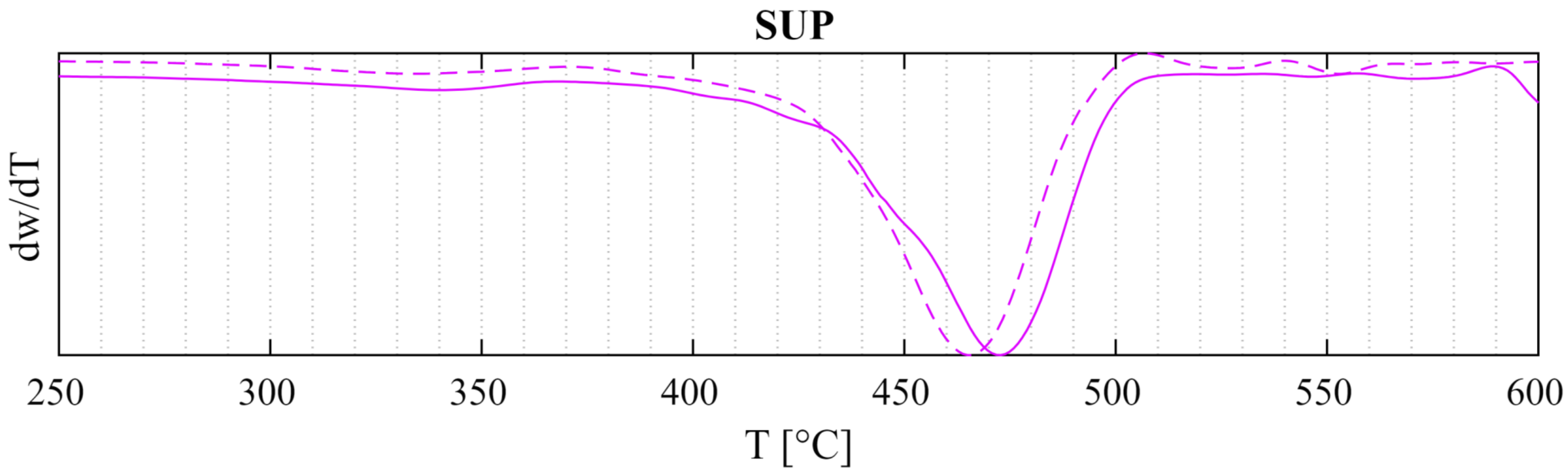
DTG of waste plastic feedstocks





10°C/min --------
20°C/min ————

DTG of waste plastic feedstocks



10°C/min --------
20°C/min ————

Experimental plan

Universität Rostock

Traditio et Innovatio

Aim

To investigate all the products obtainable from thermally treating single-use and multi-layered waste plastics

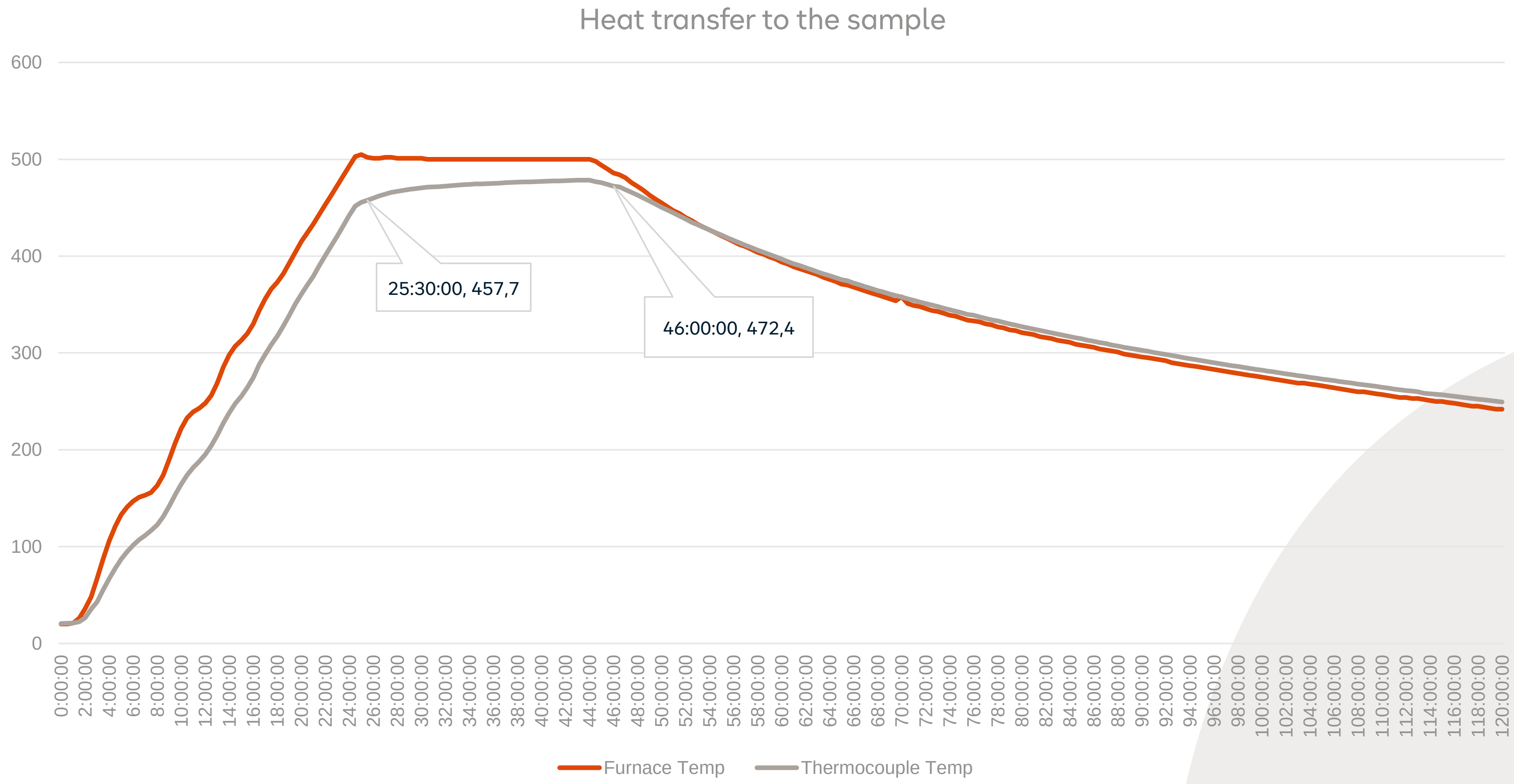
To identify and define the valuable products that are free of toxins

To analyze the input energy and exergy of the conversion processes

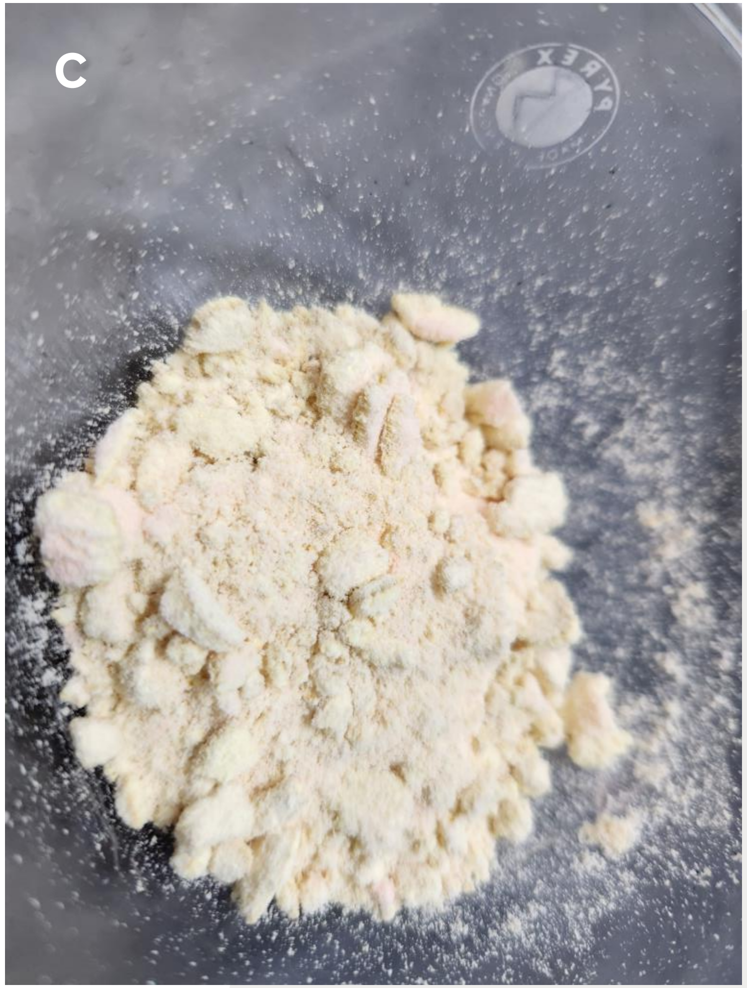
Pyrolysis

Method

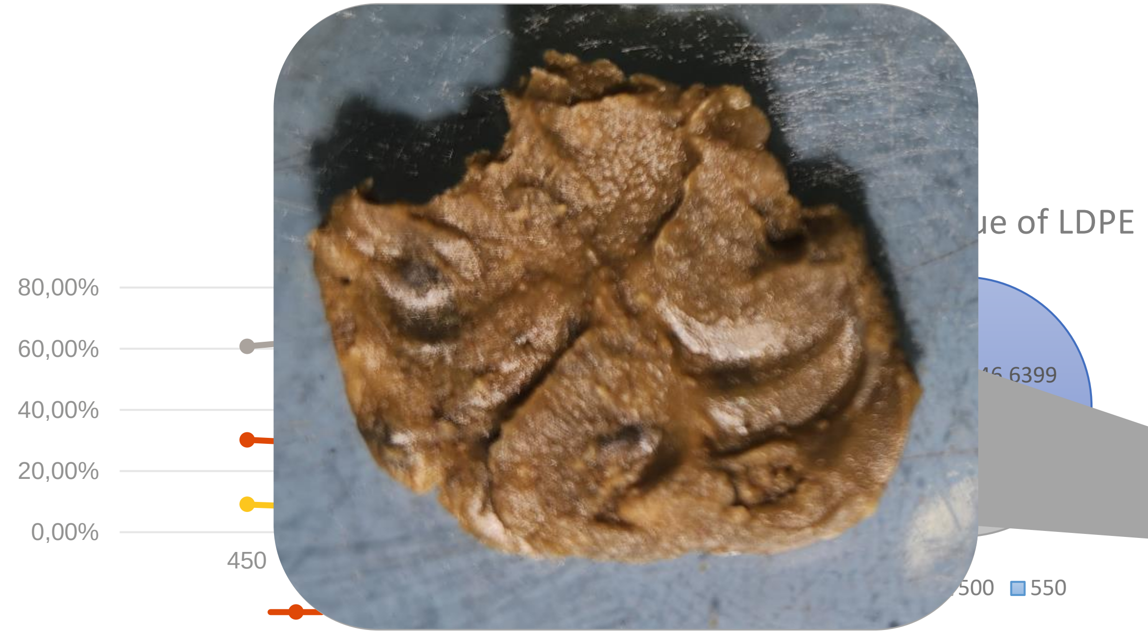
Effect of residence time on Vr

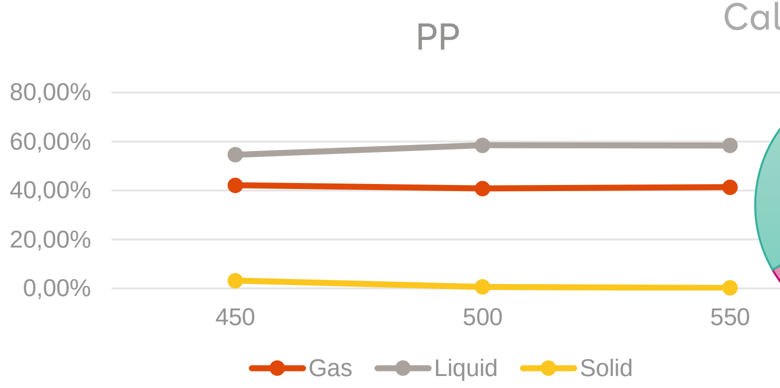


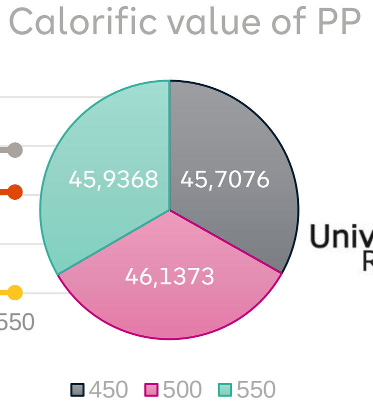
Effect of Nitrogen flow rate in slow pyrolysis using a tube furnace

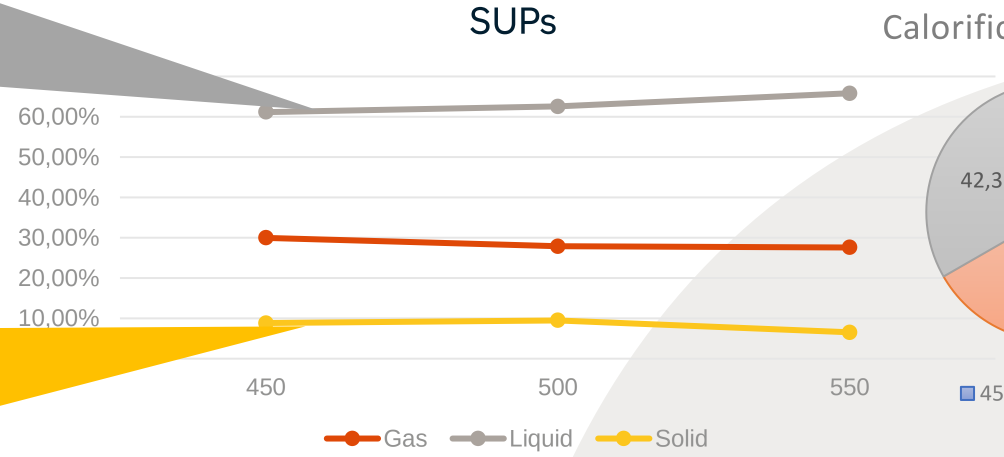


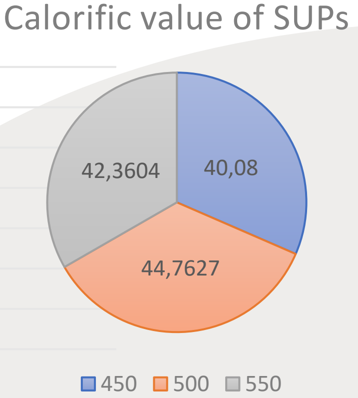
Effect of temperature on product yield

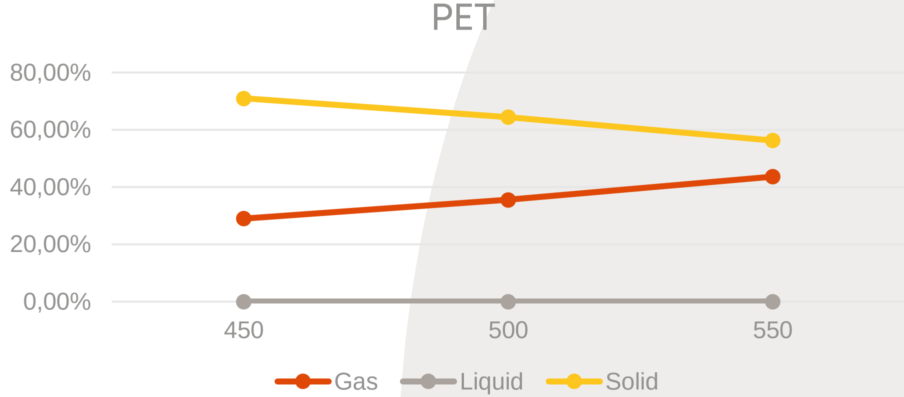




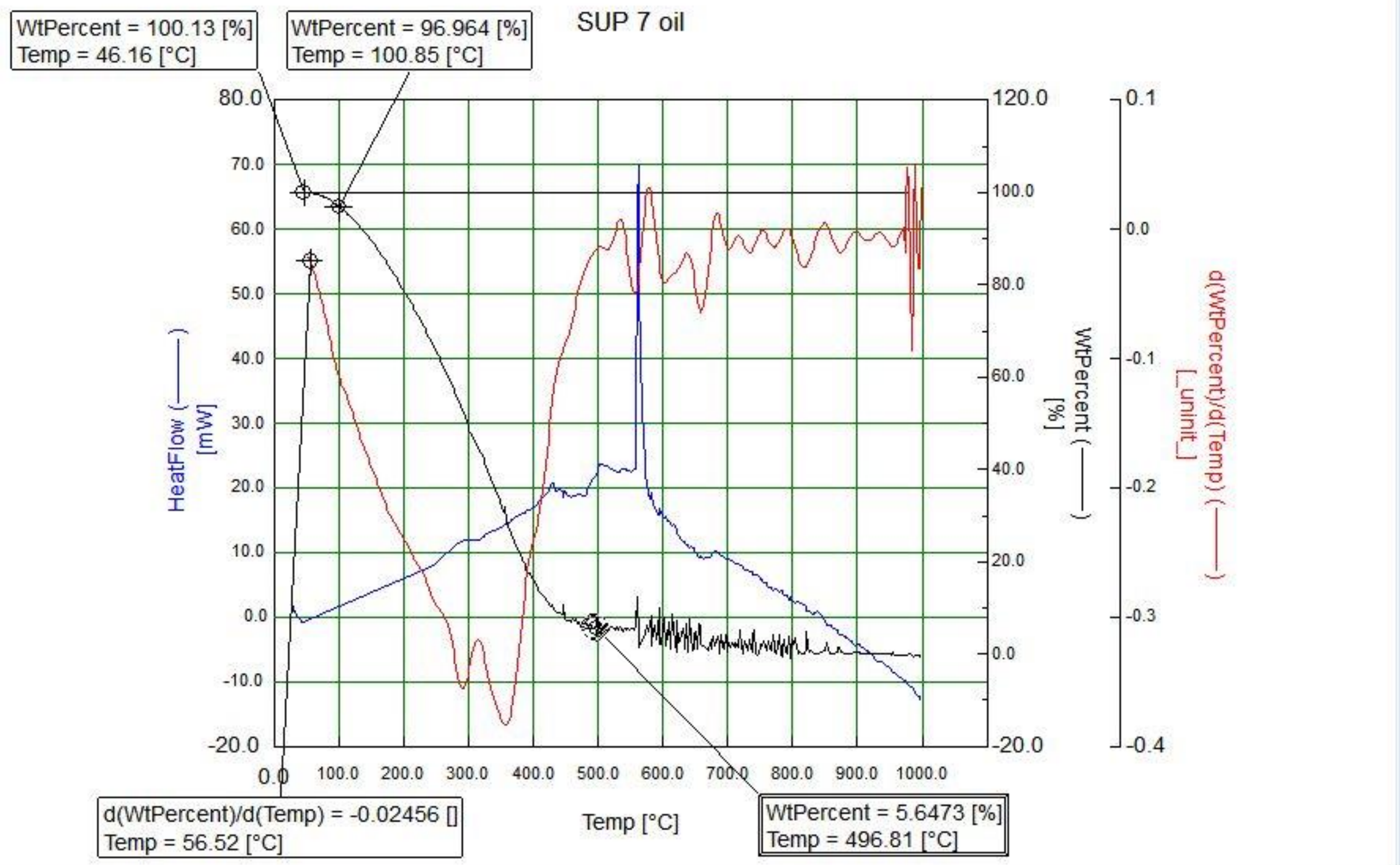




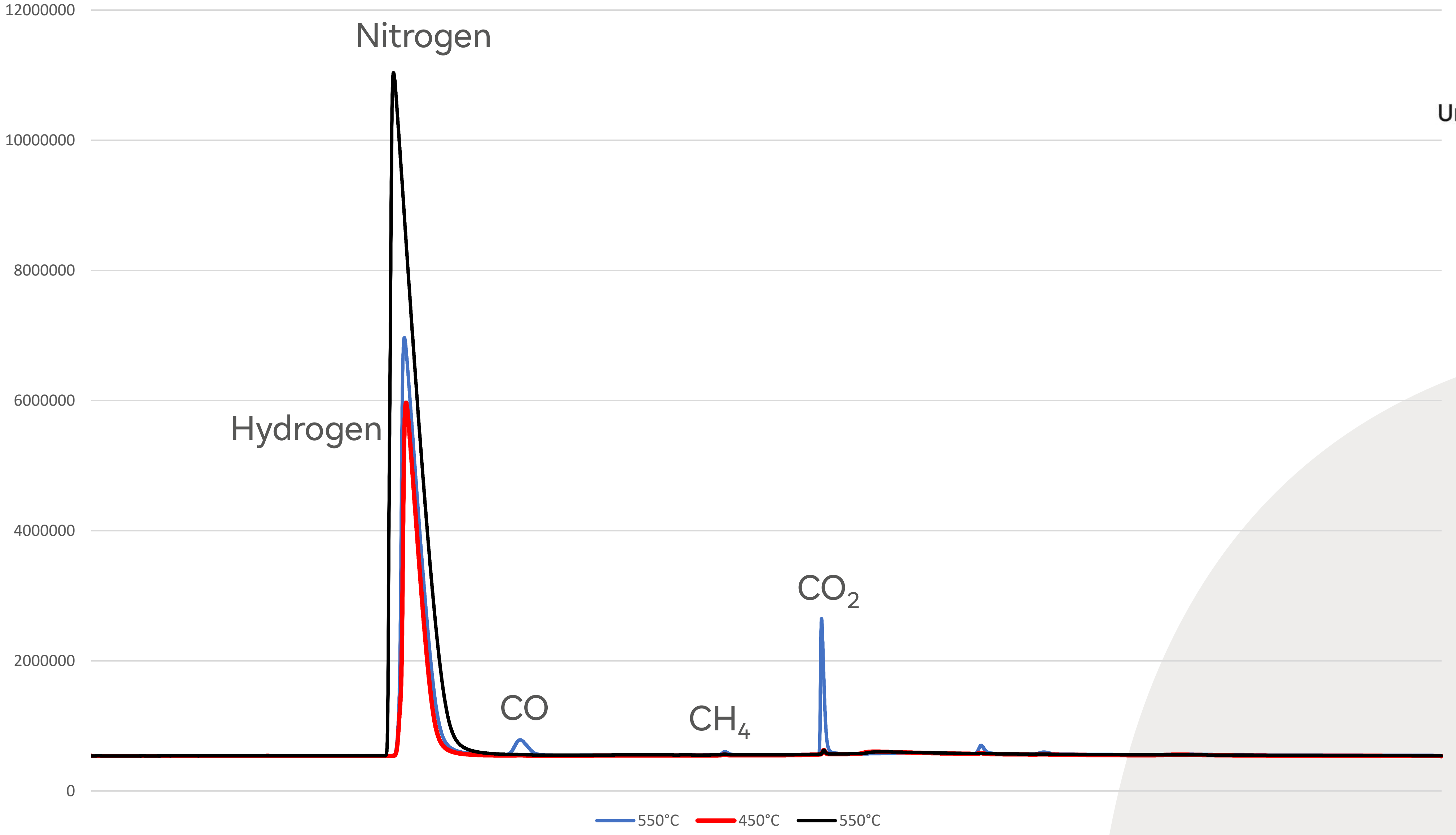




DTG of oil/wax of SUP



Effect of HHT on the quality of gaseous products



Findings

- ❑ Slow pyrolysis is not optimal for SUPs
- ❑ Varying residence time may not be critical when SUPs are pyrolyzed in a tube furnace
- ❑ Bulk density of the feedstock is an important property to be considered when varying gas flow rate (in tube reactor)

Prospects

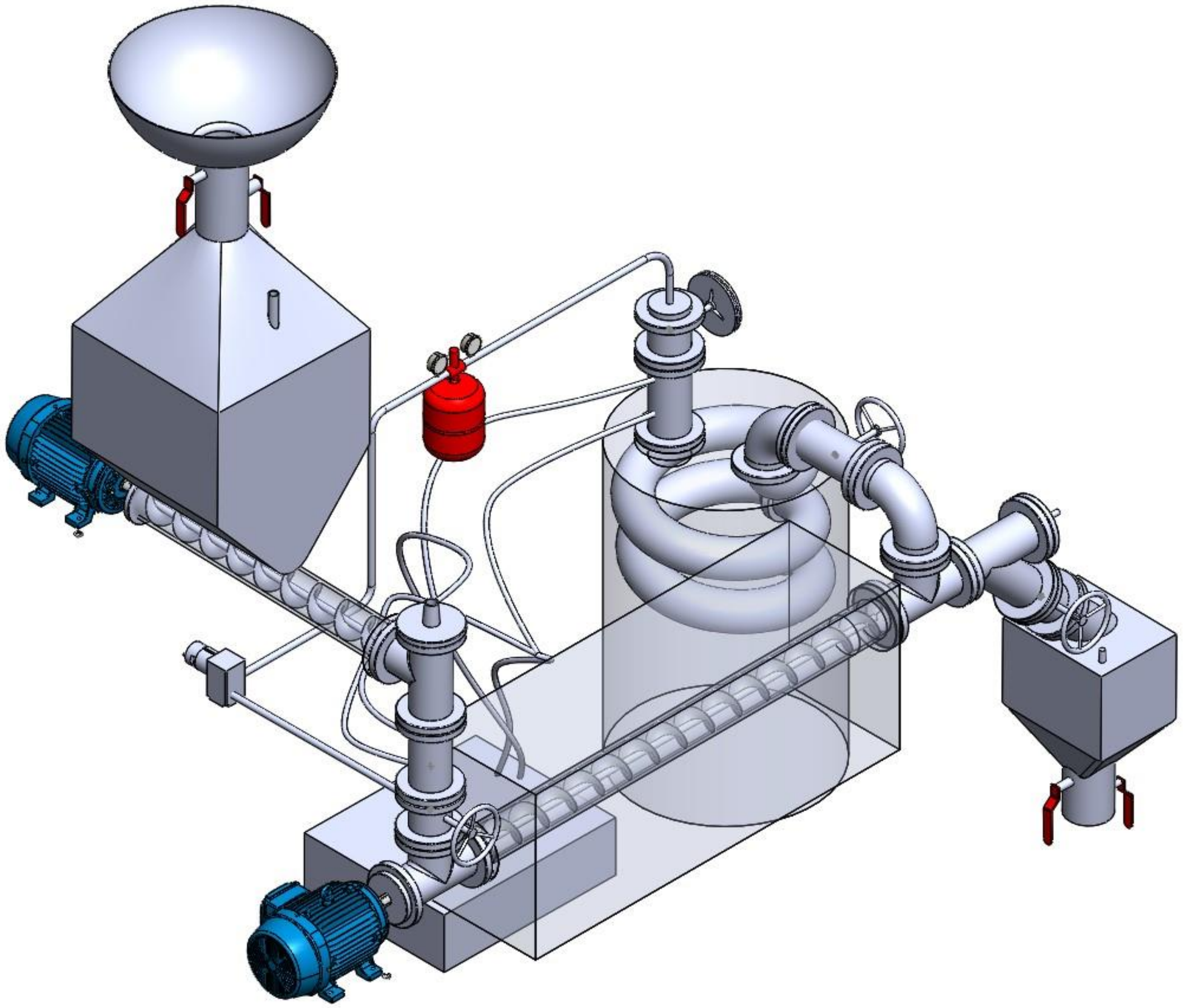
- ❑ Further analysis of the gaseous products to identify the valuable compounds
- ❑ Critical analysis of the liquid fraction
- ❑ Analysis and assessment of the char fraction
- ❑ Fast pyrolysis investigation using a continuous reactor
- ❑ Parameter optimization

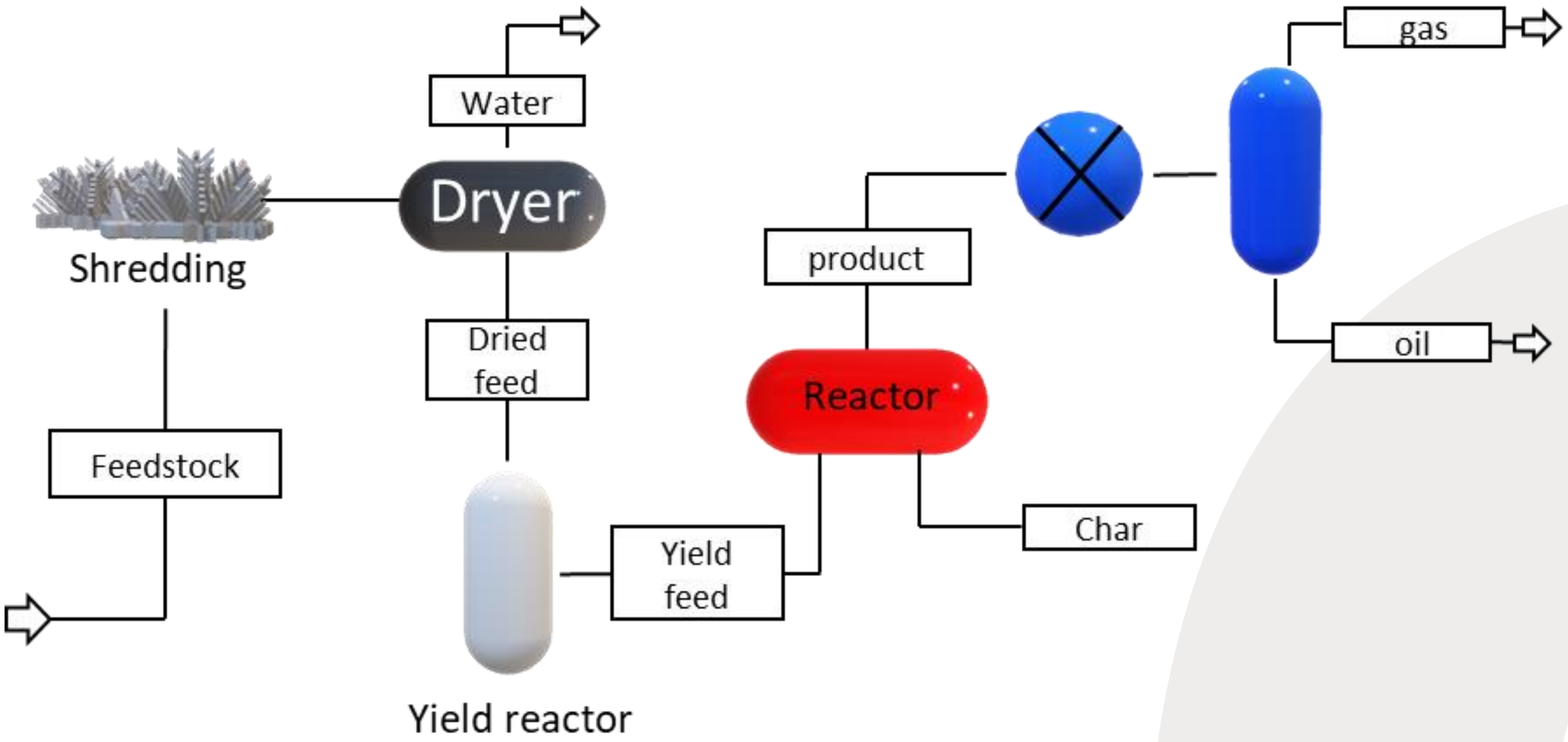
Thank you for your attention!

Uduak Bassey
Berlin School of Technology
SRH Berlin University of Applied Sciences
10587 Berlin
T +49 5095 4375-2
uduak.bassey@srh.de
www.srh.de

This research was supported by the German Federal Ministry of Education and Research within the project "Waste to Energy: Hybrid Energy from Waste as Sustainable Solution for Ghana" (03SF0591E).

Prospects




Water
Dryer
Shredding
Dried
feed
Feedstock
Yield
feed
Yield reactor
product
Reactor
Char
gas
oil