FACULTY OF BIOSCIENCE ENGINEERING

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GREEN CHEMISTRY AND TECHNOLOGY
LABORATORY FOR CIRCULAR PROCESS ENGINEERING

SEPARATION OF SHORT CARBON-CHAIN PRECURSOR MOLECULES FROM POST-CONSUMER PLASTIC PYROLYSIS OIL USING FRACTIONAL DISTILLATION

Waheed Zeb / June 17, 2022

Waheed Zeb[1], Martijn Roosen[1], Pieter Knockaert[1], Joël Hogie[1], Uros Kresovic[3], Kevin Van Geem[2], Steven De Meester[1]

[1]Laboratory for Circular Process Engineering (LCPE), Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University, B-8500 Kortrijk, Belgium
[2]Laboratory for Chemical Technology (LCT), Department of Materials, Textiles and Chemical Engineering, Faculty of Engineering & Architecture, Ghent University, B-9052 Zwijnaarde, Belgium
[3]Indaver N.V. Belgium, B-2800 Mechelen, Belgium

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Introduction

Post consumer waste plastic

Recycling (feed stock quality)

Mechanical Recycling

Effective, proven at industrial scale

Challenges: Thermal degradation, loss of properties due to impurities, additives and residues

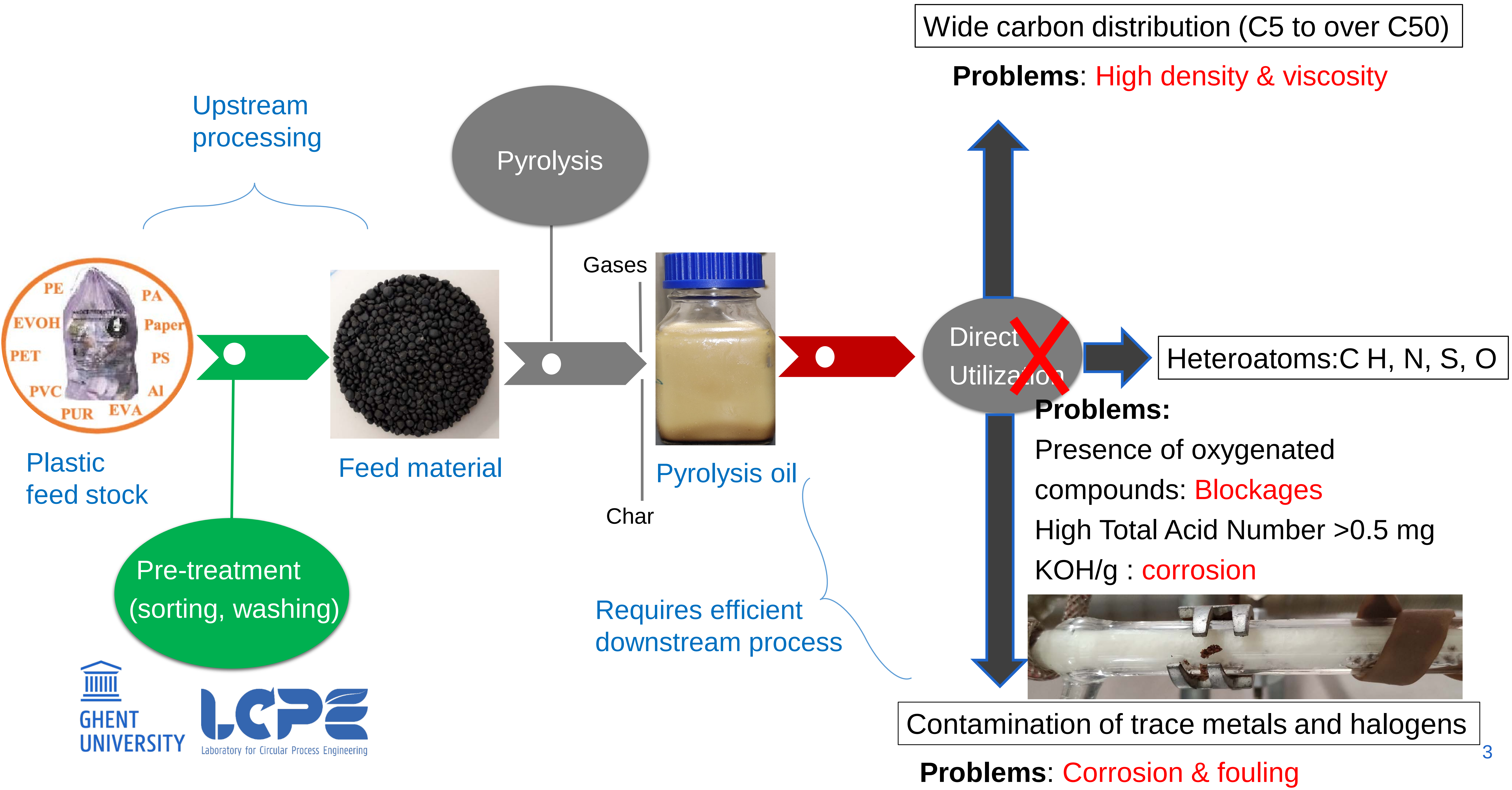
Chemical Recycling

Alternative to mechanical recycling: Wide range & mix polymers can be treated

Thermochemical process (Pyrolysis)

Roosen et al., 2020, Detailed Analysis of the Composition of Selected Plastic Packaging Waste Products and Its Implications for Mechanical and Thermochemical Recycling., Environ. Sci. Technol.54, 20, 13282–13293

Thermochemical recycling



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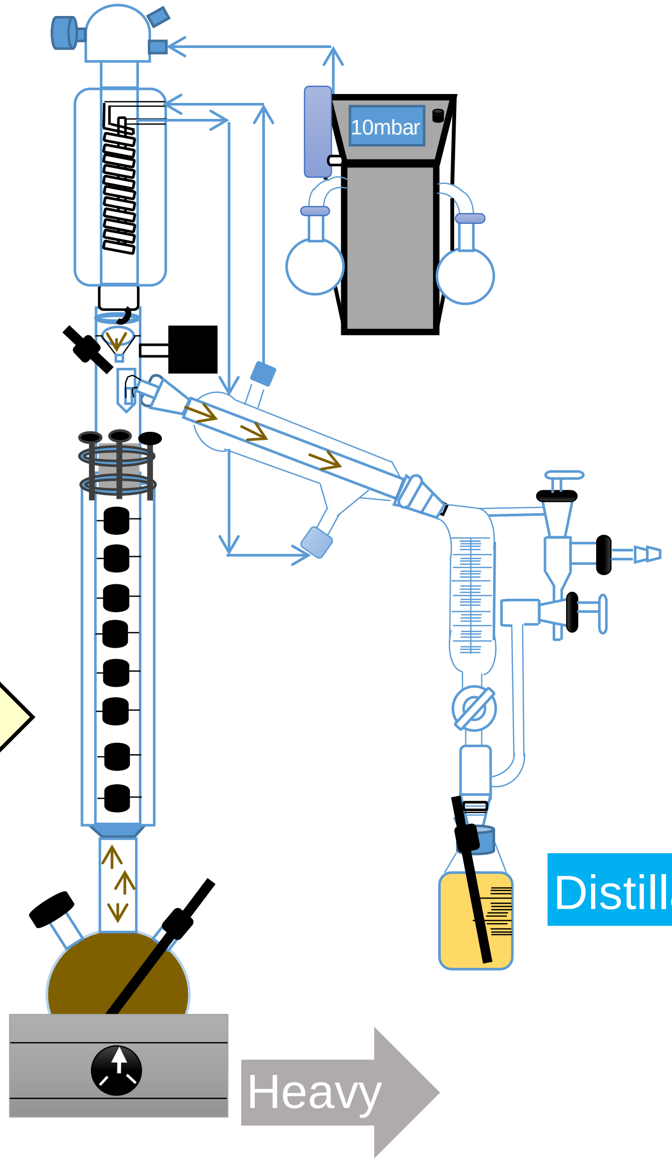
Downstream process

Pyrolysis oil

FEED



Distillates

Routes of valorization of pyrolysis

Distillated fractions types & quality depends on target applications

- Fuel production
  Gasoline & Diesel like fractions
- Steam cracking
  Monomer production

Broad carbon distribution 5 & 10 carbon number

- Isolation of molecules for chemicals preparation

Requires short carbon distribution & purity

Distillation is considered as 1st logical downstream process for treatment of pyrolysis oil.

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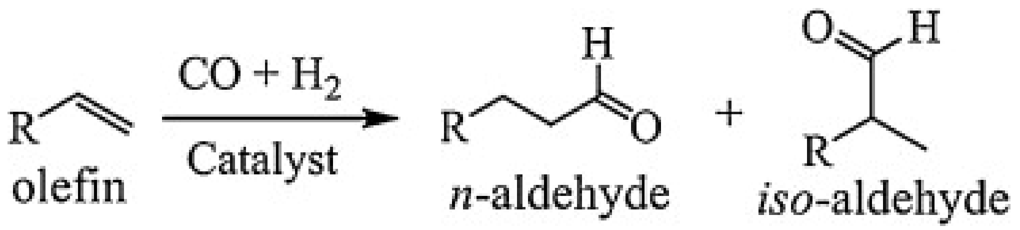
Isolation of molecules by fractional distillation

- Pyrolysis of polyolefins results in the formation of unsaturated Alkenes
- [2] 44 % olefins are present in the pyrolysis oil



[3] Liner aldehydes are important for solvents, fine and specialty chemical industry.

However, commercial application of hydroformylation reaction is restricted to the lower carbon chain alkenes due to the solubility and mass transfer

Hydroformylation

Requires short carbon distribution

How shorter carbon chain distribution can be obtained by fractional distillation?

Is distillation removes trace contaminations from pyrolysis oil?

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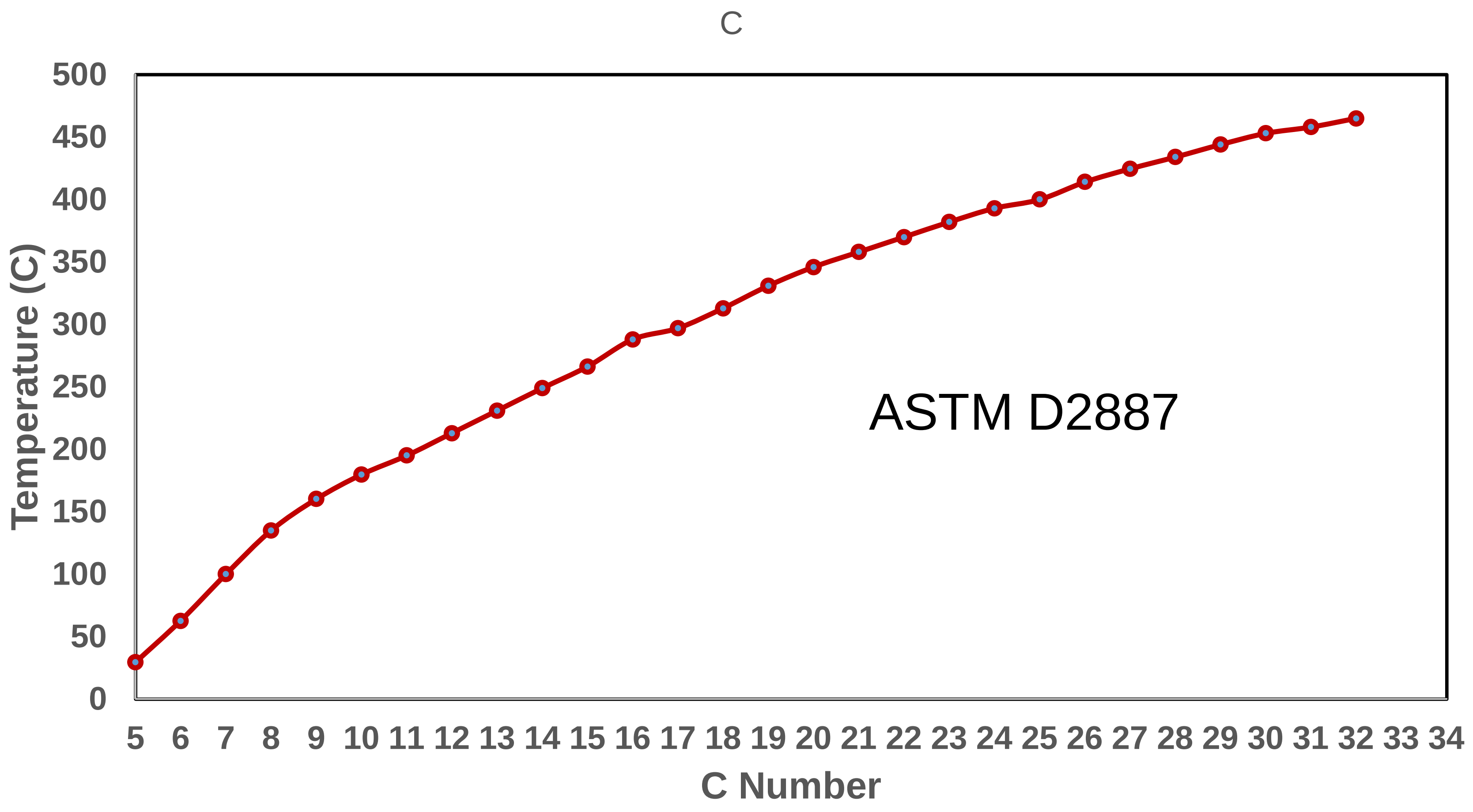
[2] Kusenberg et al., 2022,. A comprehensive experimental investigation of plastic waste pyrolysis oil quality and its dependence on the plastic, waste composition Fuel Processing Technology, 227,107090.
[3] Sharma et al, 2015,. Aqueous phase catalytic hydroformylation reactions of alkenes. Catalysis Today, 247, 70-81.

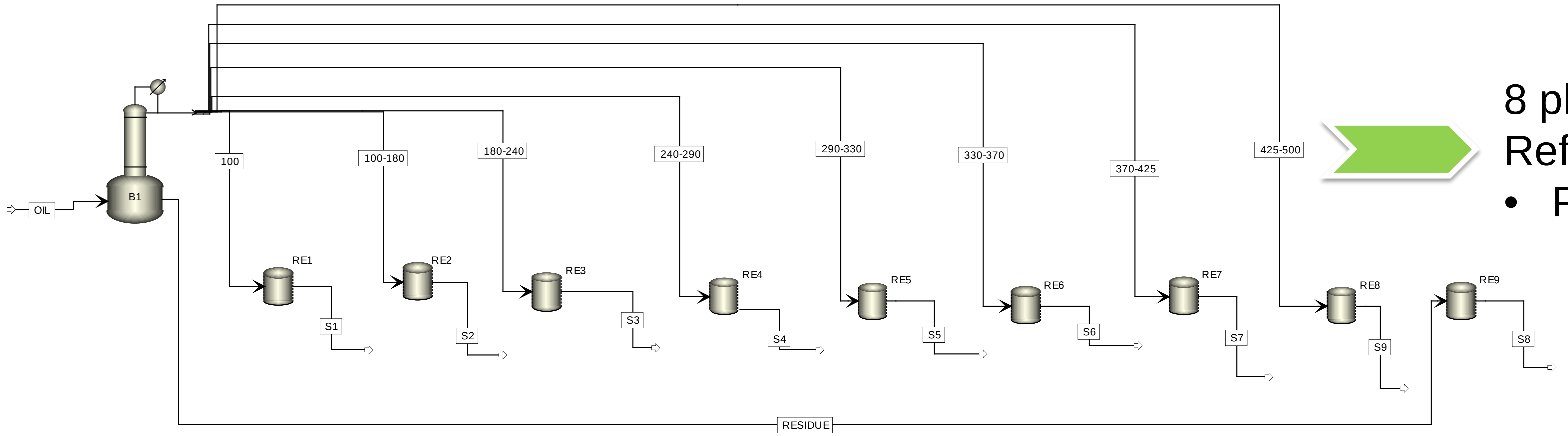
Methodology

GC analysis of pyrolysis oil



Final distillation temperature for each C number

Preliminary Aspen simulation using bulk properties and GC analysis for process conditions & minimum carbon distribution



8 plates ASTM,
Reflux ratio=2 , ASTM D2892

- Pure fraction= **3 carbons**

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Process conditions for distillation of each carbon cut

Fractions	Pressure (mbar)	Chiller temperature (°C)	Distillation temperature (°C)	Atmospheric equivalent temperature (°C)
C_5-C_7	Atmospheric	-20	100	100
C_8-C_{10}	Atmospheric	20	180	180
C_{11}-C_{13}	10±2	20	106	240
C_{14}-C_{16}	10±2	20	146.2	290
C_{17}-C_{19}	10±2	80	180	330
C_{20}-C_{22}	10±2	80	206	369

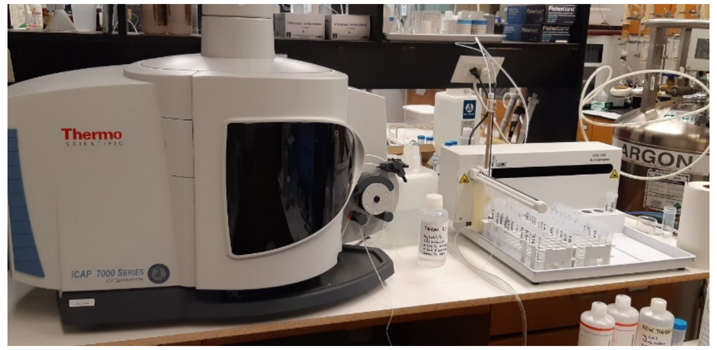
Analysis

GCMS

Qualitative

SVM 3001 Anton par

Bulk properties
(Density & Viscosity)



ICP-OES

Trace contamination

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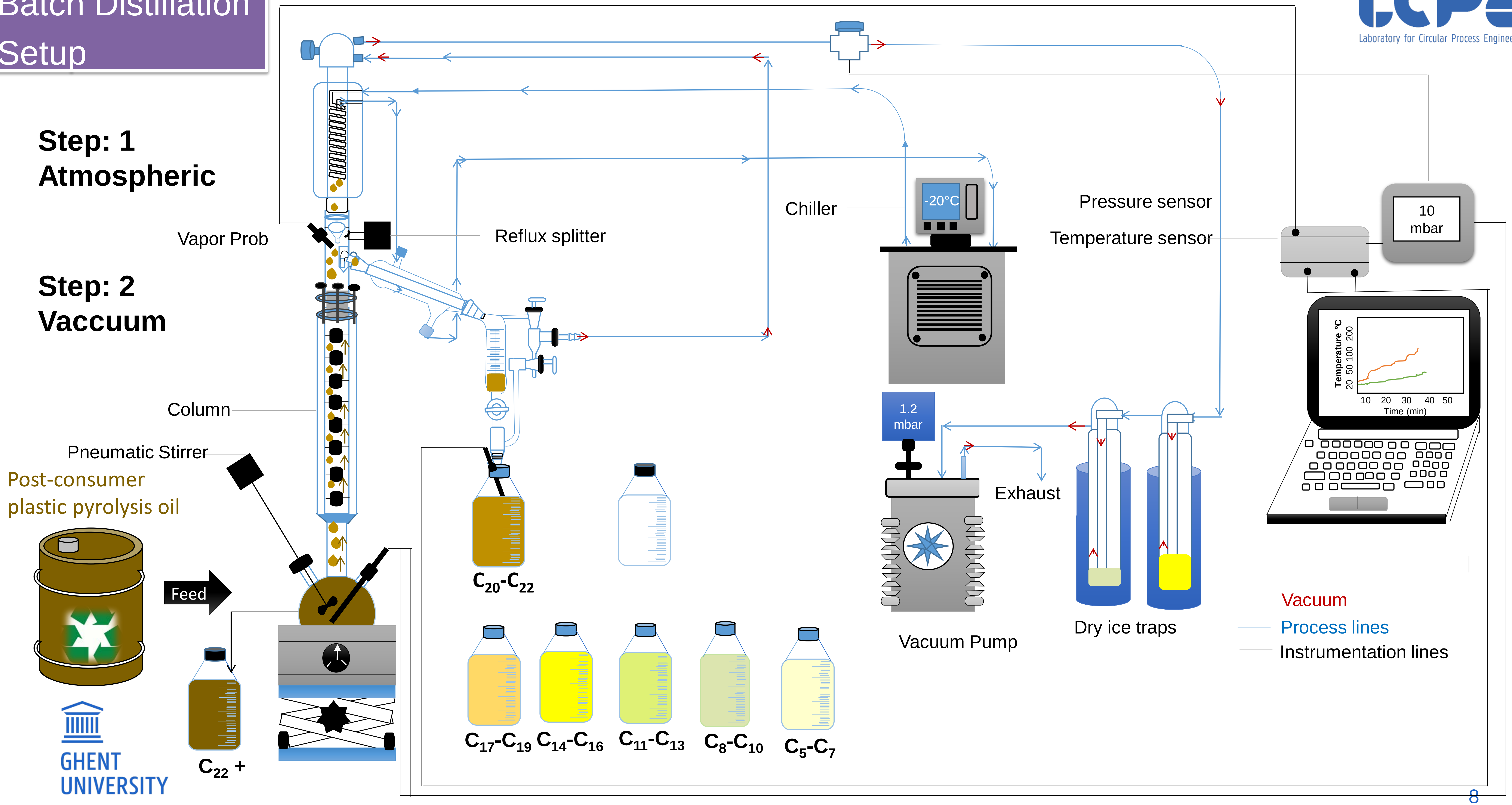
Batch Distillation Setup

Step: 1
Atmospheric

Step: 2
Vaccuum



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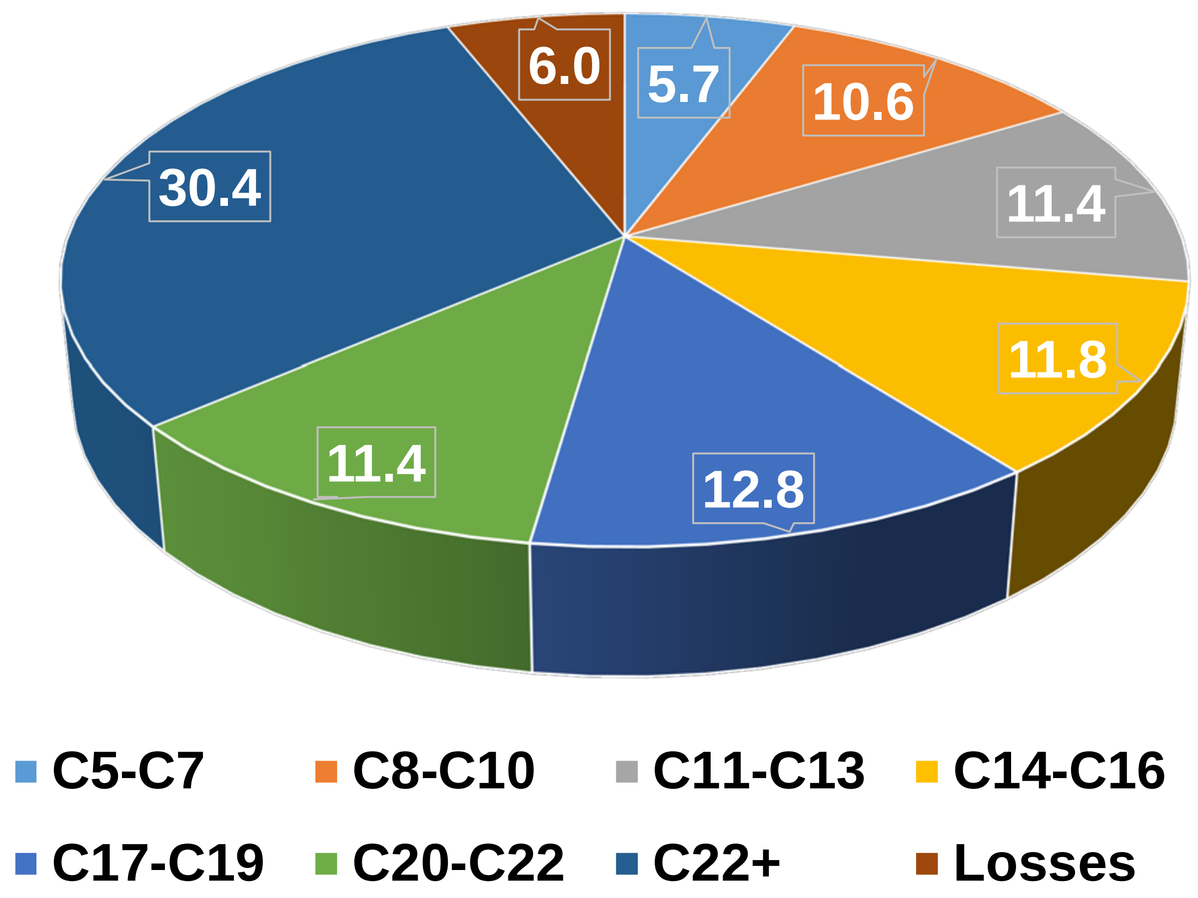
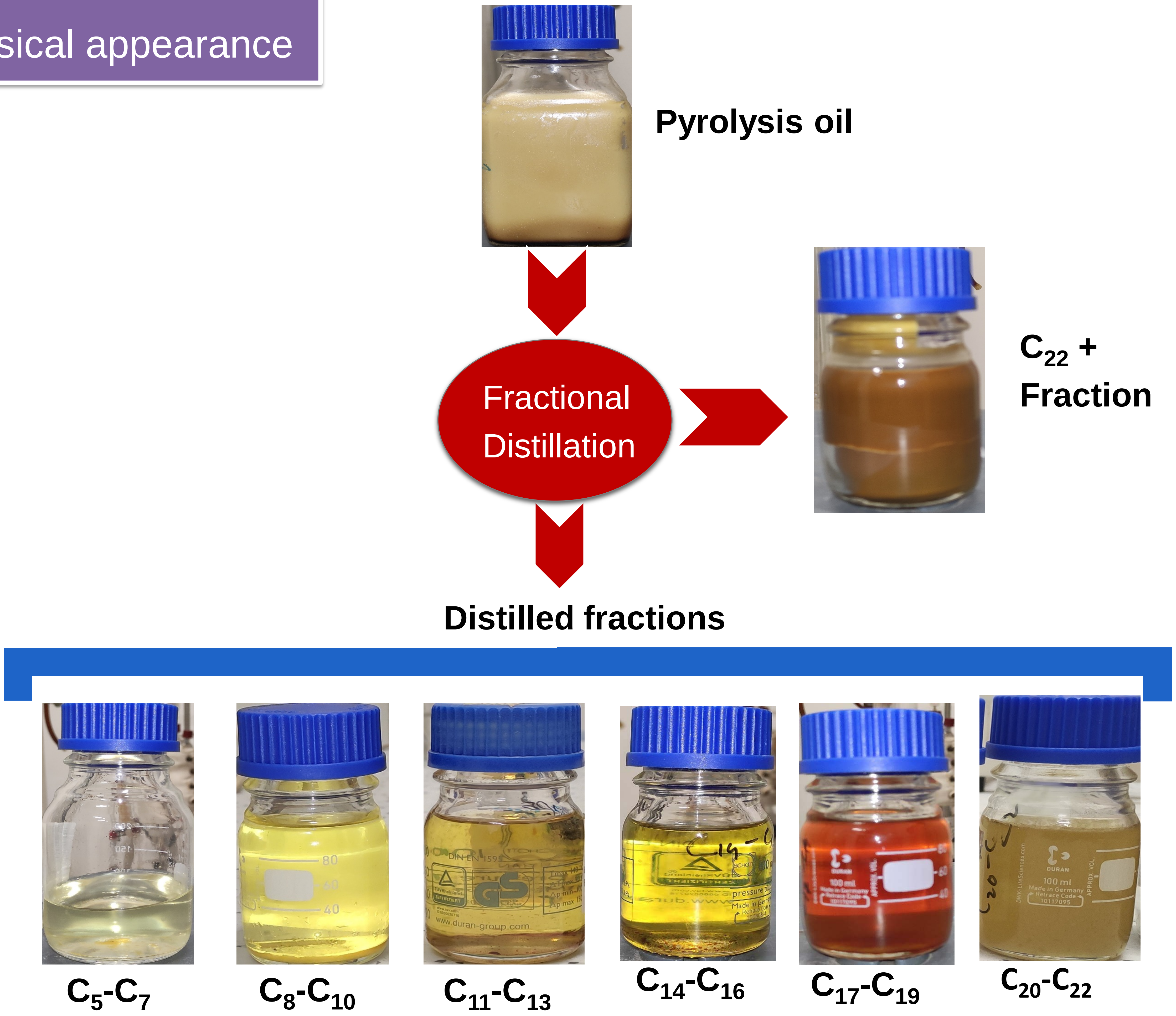
Overview of distillation recovery & physical appearance

Distillation recovery PE (%)





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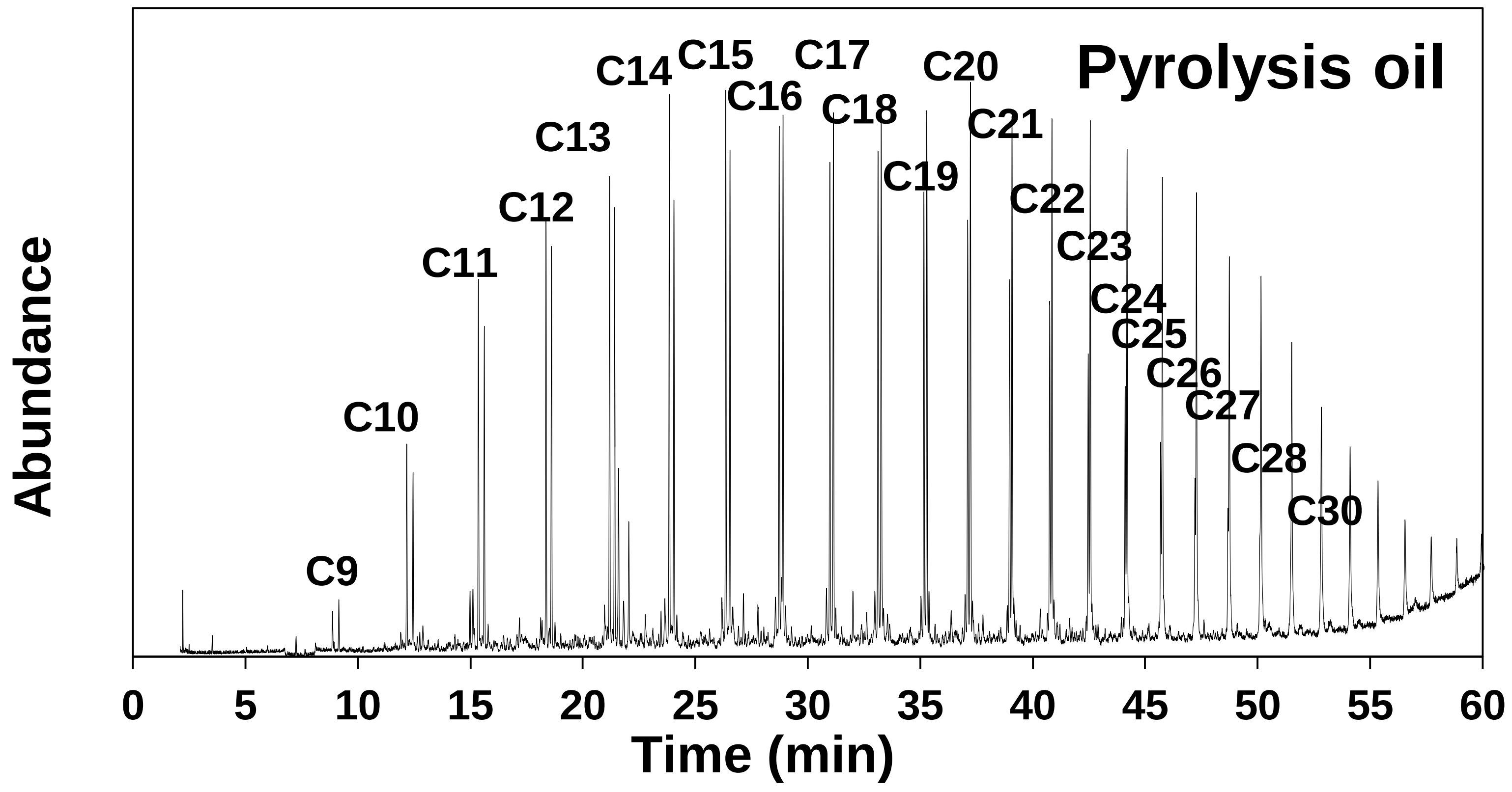
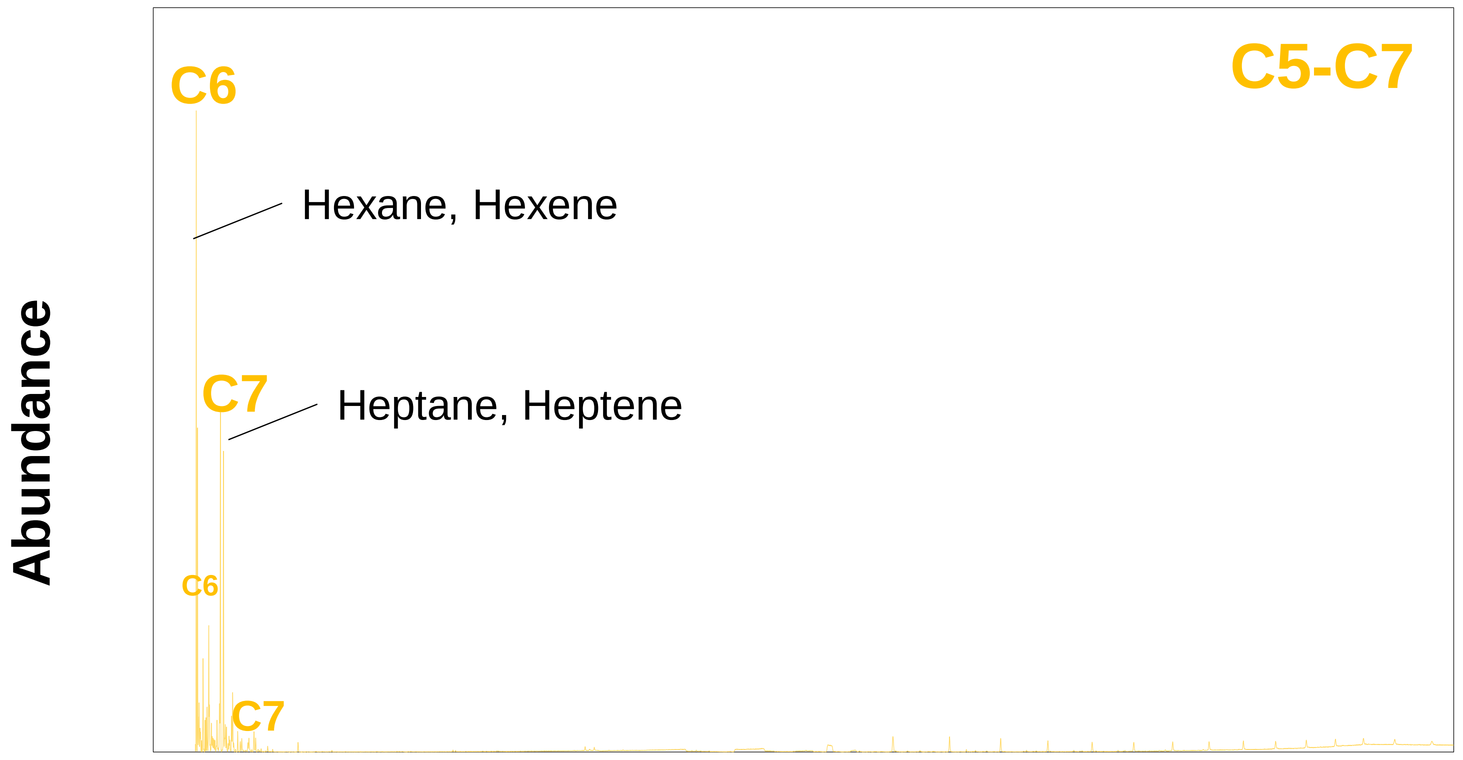
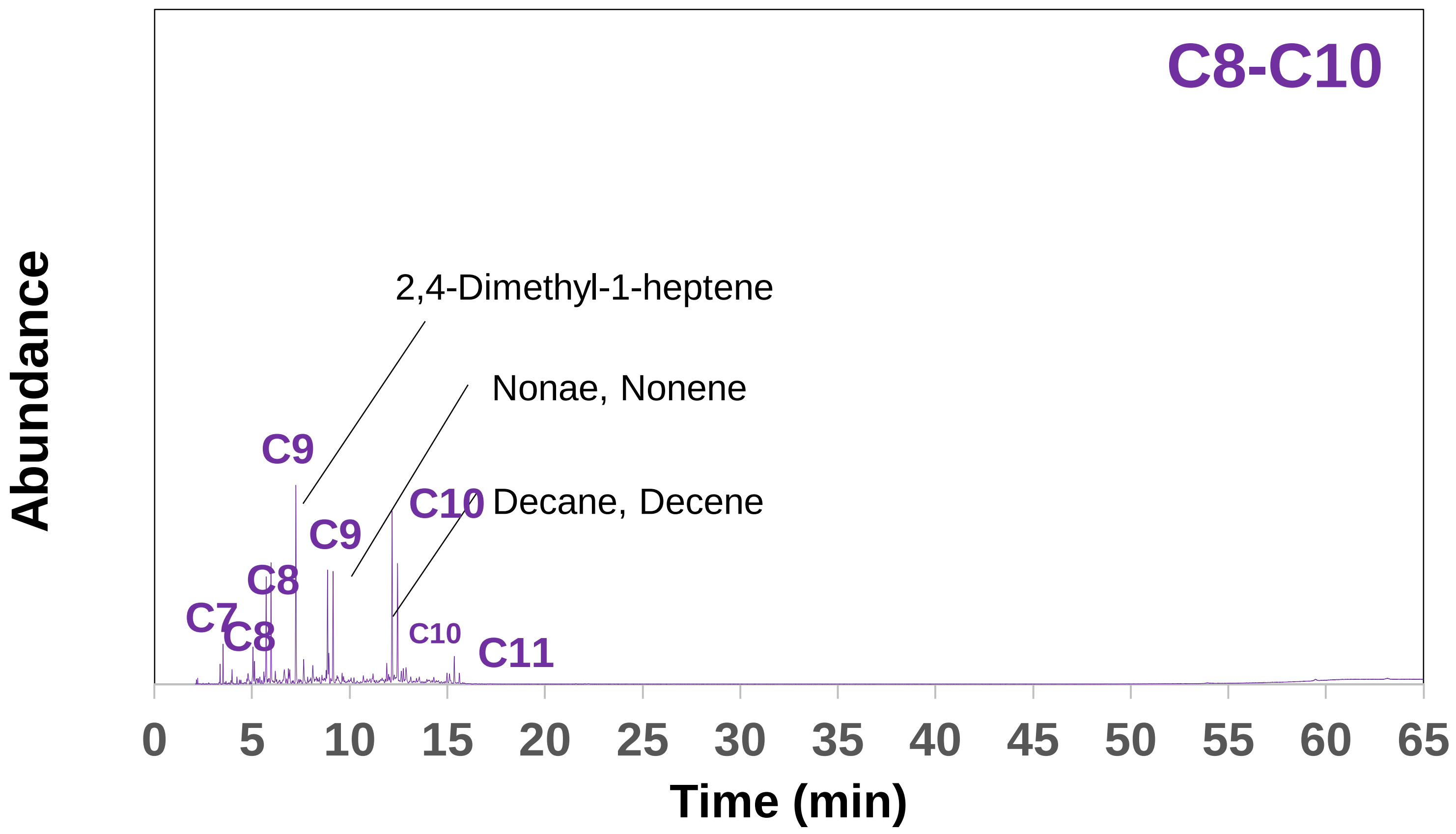
GCMS analysis of pyrolysis oil and fractions







Pure fractions of 3 carbon numbers were obtained using distillation 8 plates & 2 reflux ratio

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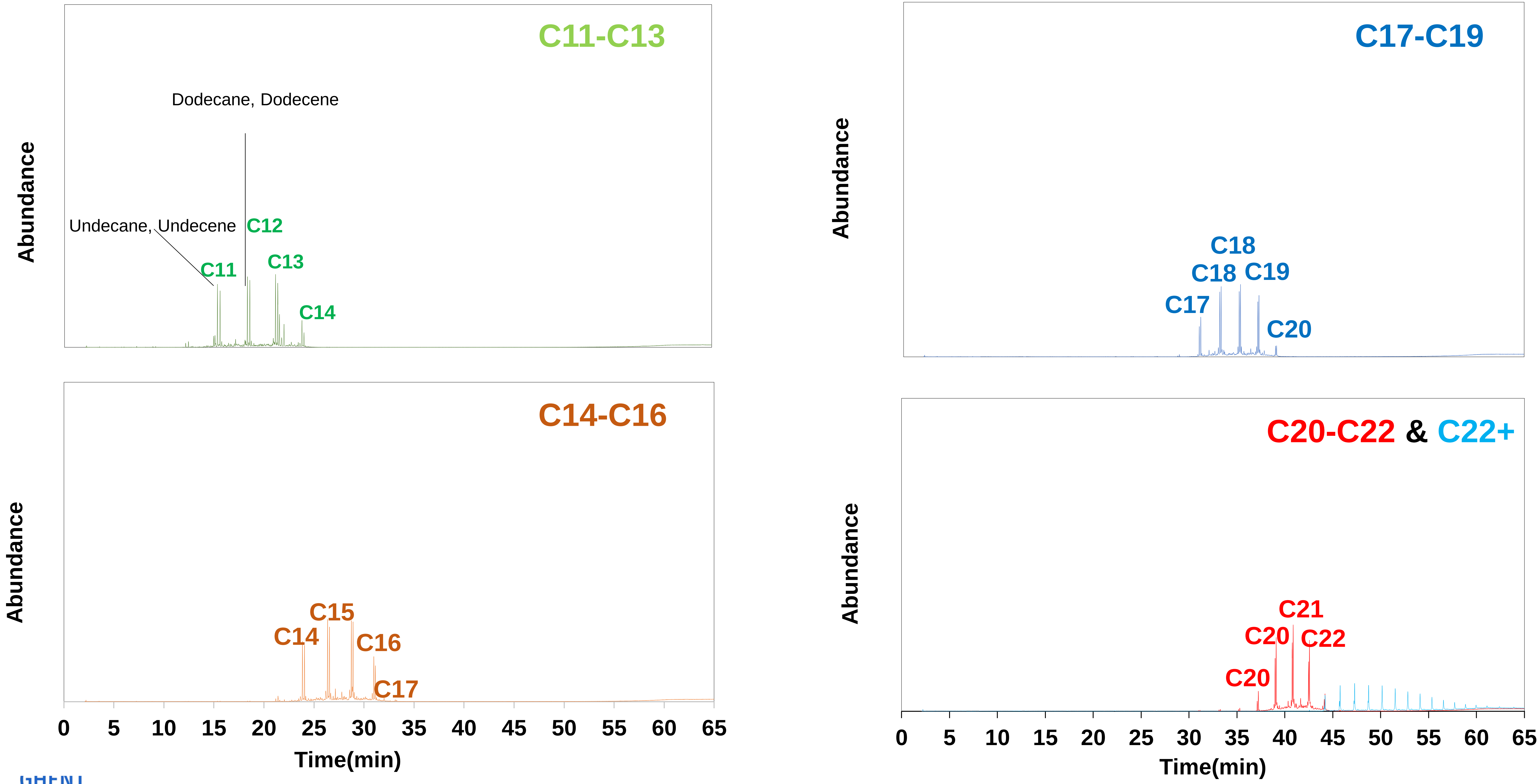

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Overview of improvements in physical properties and contaminations

Parameters	Pyrolysis oil	C_5-C_7	C_8-C_{10}	C_{11}-C_{13}	C_{14}-C_{16}	C_{17}-C_{19}	C_{20}-C_{22}	C_{22+}	
Physical property									
Density (g/cm3)	0.821	0.655	0.690	0.723	0.780	0.792	0.804	0.860	
Viscosity (mm2/sec)	a	0.442	0.726	2.09	2.38	4.39	7.069	a	
Trace contaminations									**LOD**
Al (ppm)	280	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	31.9
Fe (ppm)	130	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	4.2
Na (ppm)	146	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	25.2
Zn (ppm)	17.7	4.2	3.6	3.1	1.8	1.6	<LOD	<LOD	0.2
Pb (ppm)	3.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.6
Mg (ppm)	7.6	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.8

a Wax at measurement temperature

- Properties (i:e density, viscosity) improved
- The level of contaminations decreased

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Conclusion

- Fractional distillation improves bulk properties of fractions
- A pure fraction of minimum of three carbon number can be obtained by fractional distillation with reflux ratio of 2 and 8 theoretical plates
- Fractional distillation resulted in removal of trace metal contamination

Future work

- Quantitative analysis of distilled fractions
- Further improvements for removal of trace contaminations in lower detection limits
- Removal of acidic compounds

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Thank you

Waheed Zeb

University of Gent, Belgium
Email: Waheed.zeb@UGent.be
https://www.ugent.be/bw/gct/en/research/greentech/research/chemtech

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