UPGRADING OF BIO-BASED OILS TO FUELS

TOPSOE

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AGENDA

1	TOPSOE
2	CATALYTIC PYROLYSIS
3	FRACTIONATION
4	PYROLYSIS OIL
5	OUTLOOK

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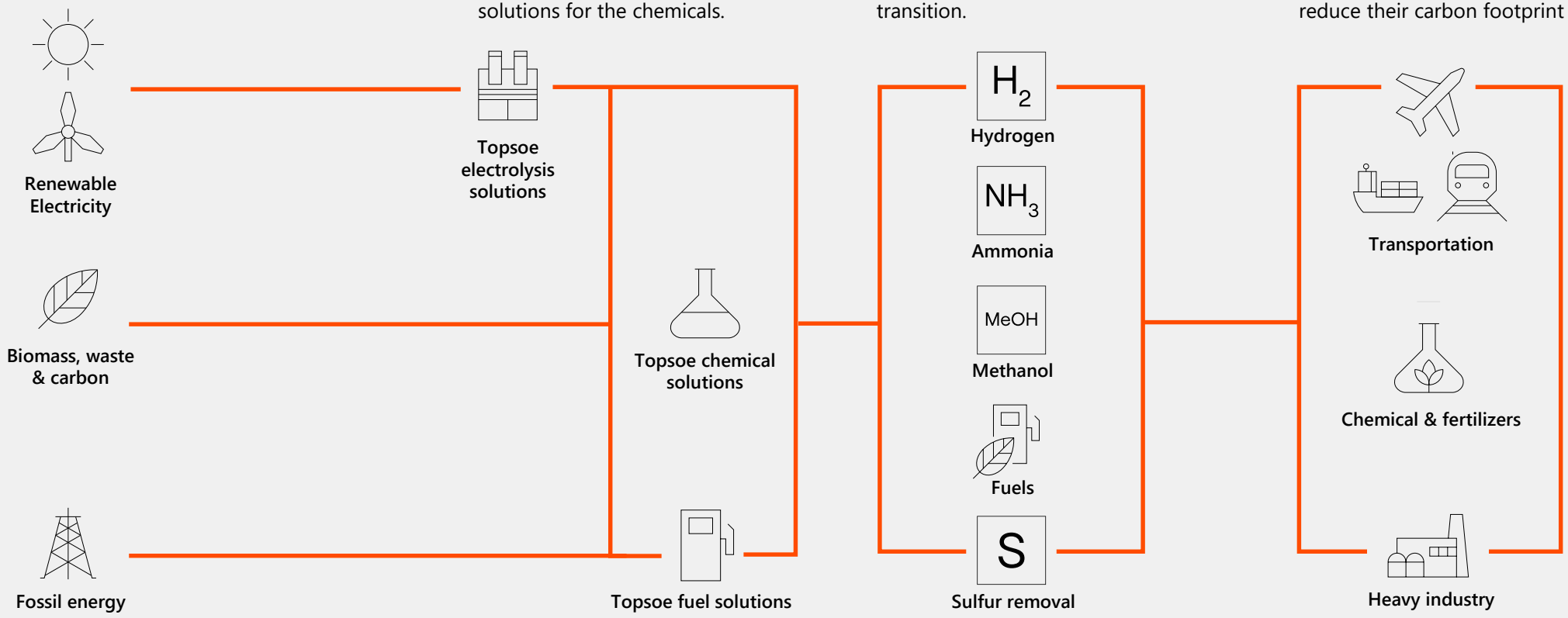
TOPSOE SOLUTIONS ACCELERATE THE ENERGY TRANSITION

ENERGY SOURCES
Fuels and chemicals can be produced from various ways of both renewable and fossil feedstocks.

SOLUTIONS
Topsoe helps customers on their decarbonization journey through advanced energy solutions, such as Power-to-X, renewable fuels and blue solutions for the chemicals.

CHEMICALS AND FUELS
For our customers, the output is more efficient processes or renewable feedstocks, that significantly can lower the carbon footprint, and thereby supporting them in their energy transition.

UTILIZATION
The societal benefits of these end-products come, among other things, in the shape of a cleaner transportation sector and hard-to abate sectors such as steel, cement, and mining, who can reduce their carbon footprint

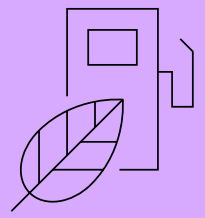


TOPSOE AT A GLANCE

Topsoe is a leading developer and provider of solutions and technologies to produce fuels and chemicals essential to the energy transition. For more than 80 years, we have been perfecting chemistry to help industries produce more efficiently. Today, it is our ambition to lead the global transition of heavy industry and transport to a zero-carbon future.

#1

In renewable diesel



#1

In ammonia

9%

Of revenue invested in R&D

6,225

In revenue

(DKK million)

903

EBIT before special items

(DKK million)

2,133

employees

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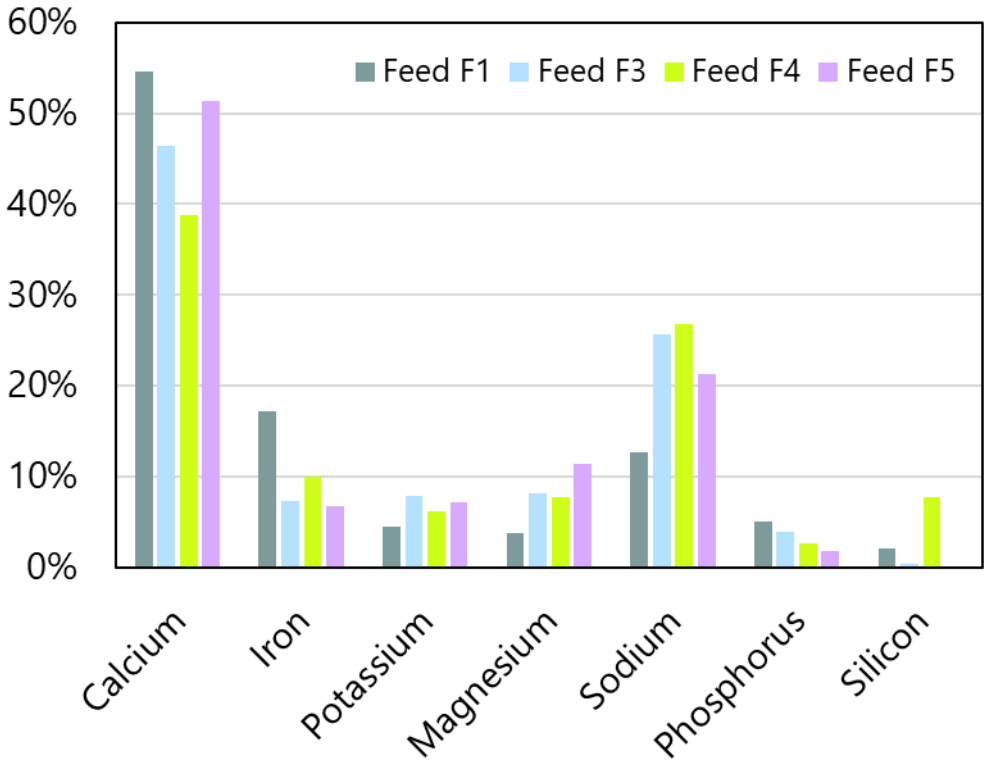
CATALYTIC PYROLYSIS
FEED PROPERTIES

Physical properties

	F1	F3	F4	F5
S, wt ppm	27	108	102	58
N, wt ppm	708	987	767	-
H, wt%	8.30	7.28	7.02	6.49
O, wt%	17	26	28	29
Water, wt%	8.0	9.4	9.9	10.4
Inorganics, wt ppm	34	40	41	185

Distribution of inorganics



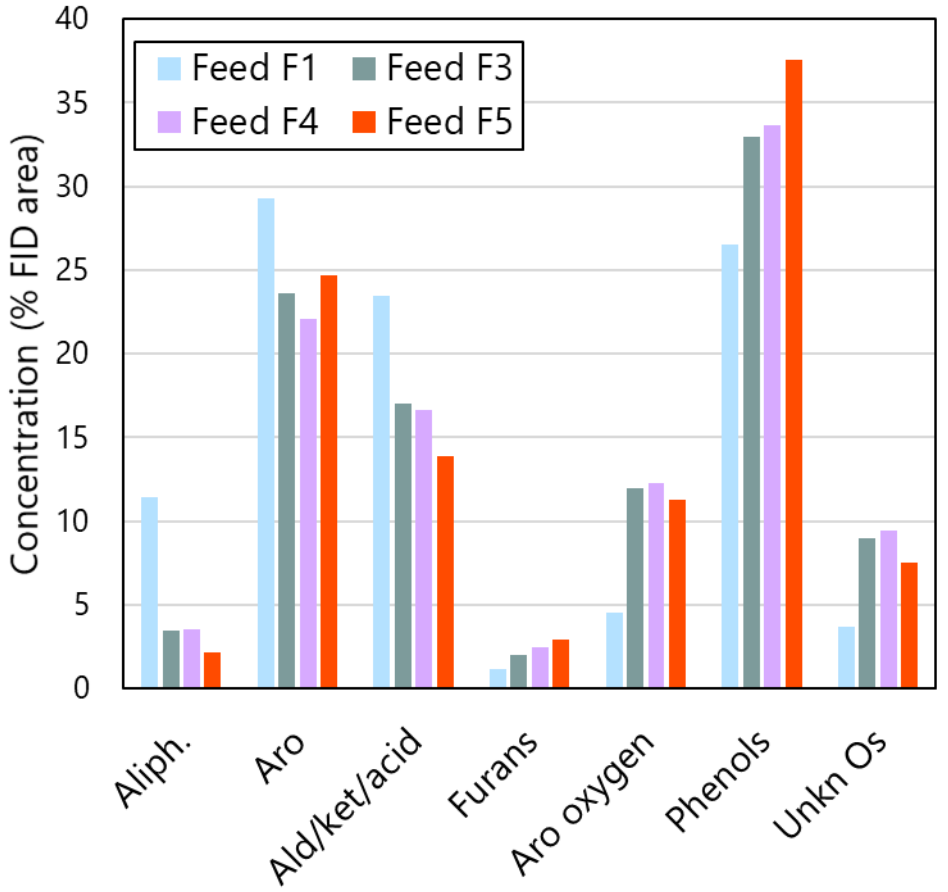
Sustainable Energy Fuels, 2021,**5**, 4668-4679

CATALYTIC PYROLYSIS
DETAILED CHARACTERIZATION

13C-NMR (relative % carbon total)

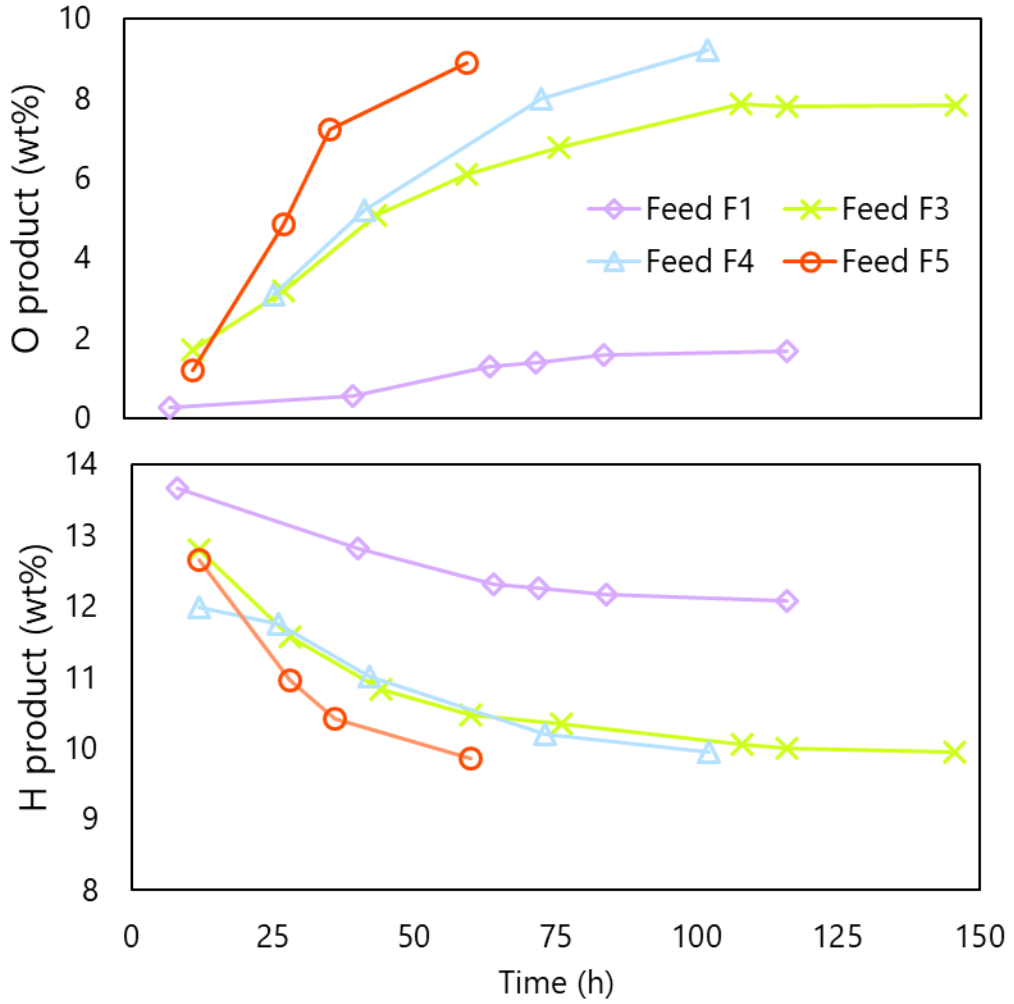
	F1	F3	F4	F5
Aliphatic	31.8	32.8	38.5	23.0
Methoxy in phenolics	3.3	4.1	4.3	2.0
Anhydrosugers, alcohols, ethers	0.5	4.1	4.3	18.4
Aromatic C-H bonds	27.0	27.1	22.1	24.0
Aromatic C-C bonds	25.6	19.8	16.0	17.4
Aromatic C-OH bonds	7.9	8.9	11.9	12.1
C=O (acids and derivatives)	2.0	2.0	1.9	2.2
C=O (carbonyls)	1.9	1.2	1.0	1.0

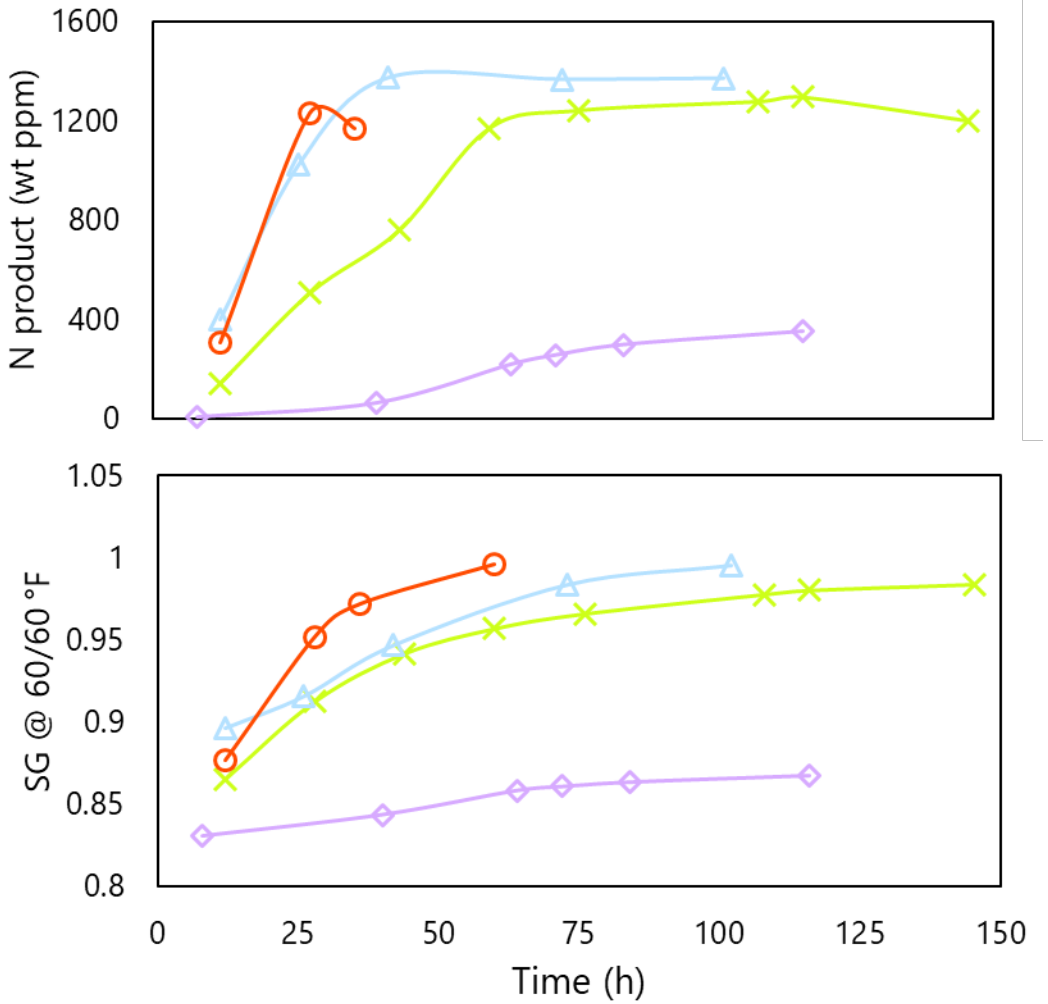
GC×GC-MS/FID



Sustainable Energy Fuels, 2021,**5**, 4668-4679

CATALYTIC PYROLYSIS
THE FEED PROPERTIES HAVE A LARGE IMPACT ON THE DEACTIVATION RATE





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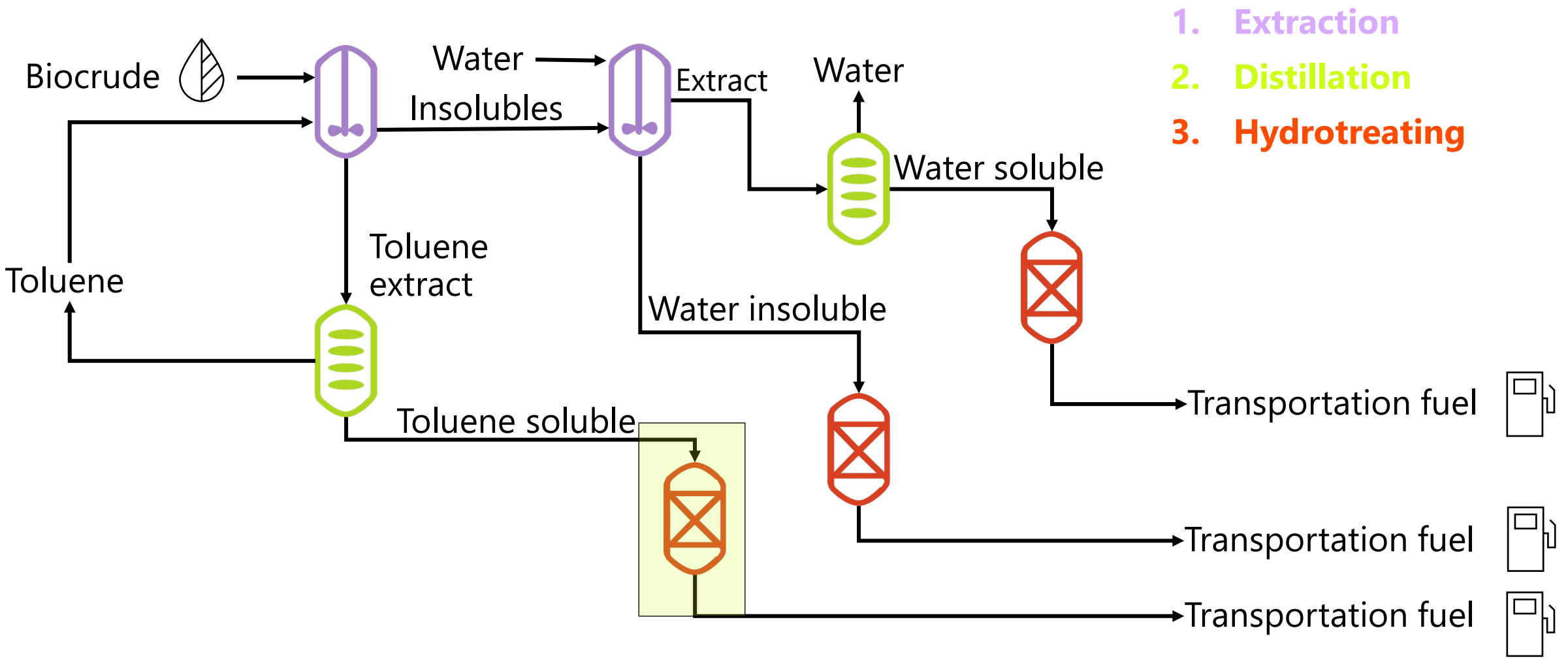
FRACTIONATION

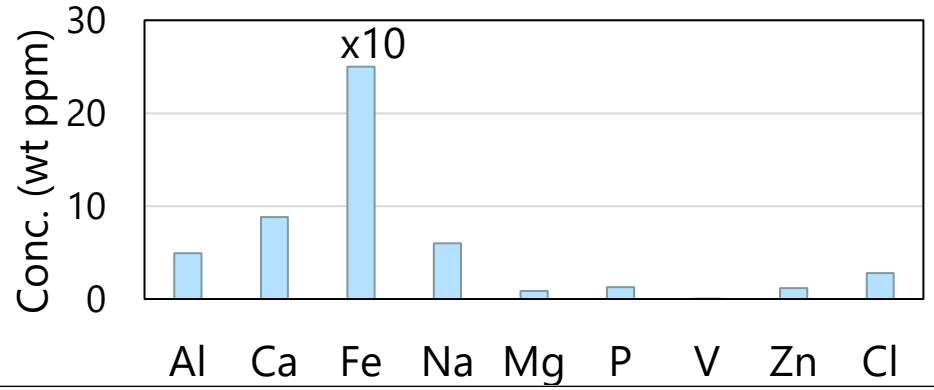


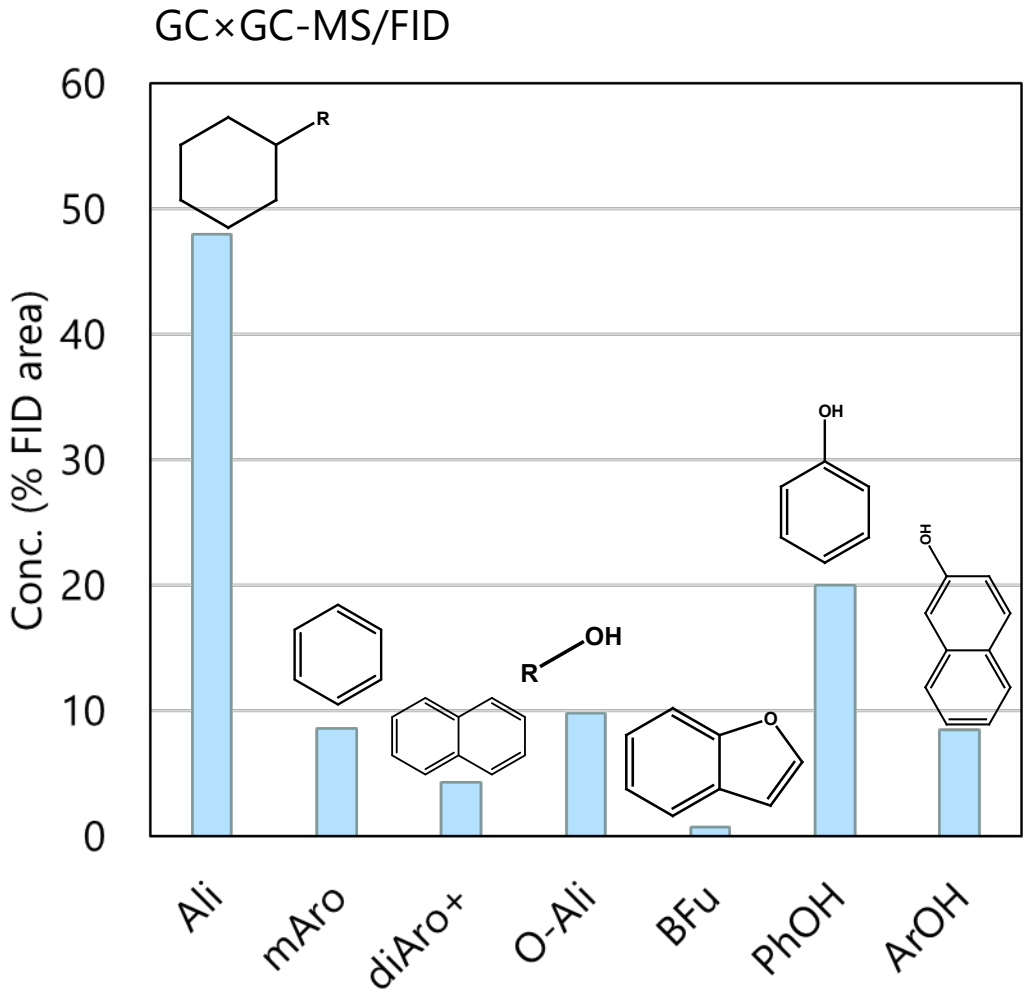
Green Chem., 2019,**21**, 2257-2265

FRACTIONATION - HYDROTREATMENT OF TOLUENE EXTRACTED BIOCRUDE

FEED PROPERTIES

Analysis	Value	Unit
H	6.78	wt%
N	431	wt ppm
S	62	wt ppm
O	22.3	wt%
Water	1.47	wt%
TAN	26.5	mg KOH/g
SG 60/60°F	1.1688	





FRACTIONATION - HYDROTREATMENT OF TOLUENE EXTRACTED BIOCRUDE
TEST CONDITIONS AND MASS BALANCES

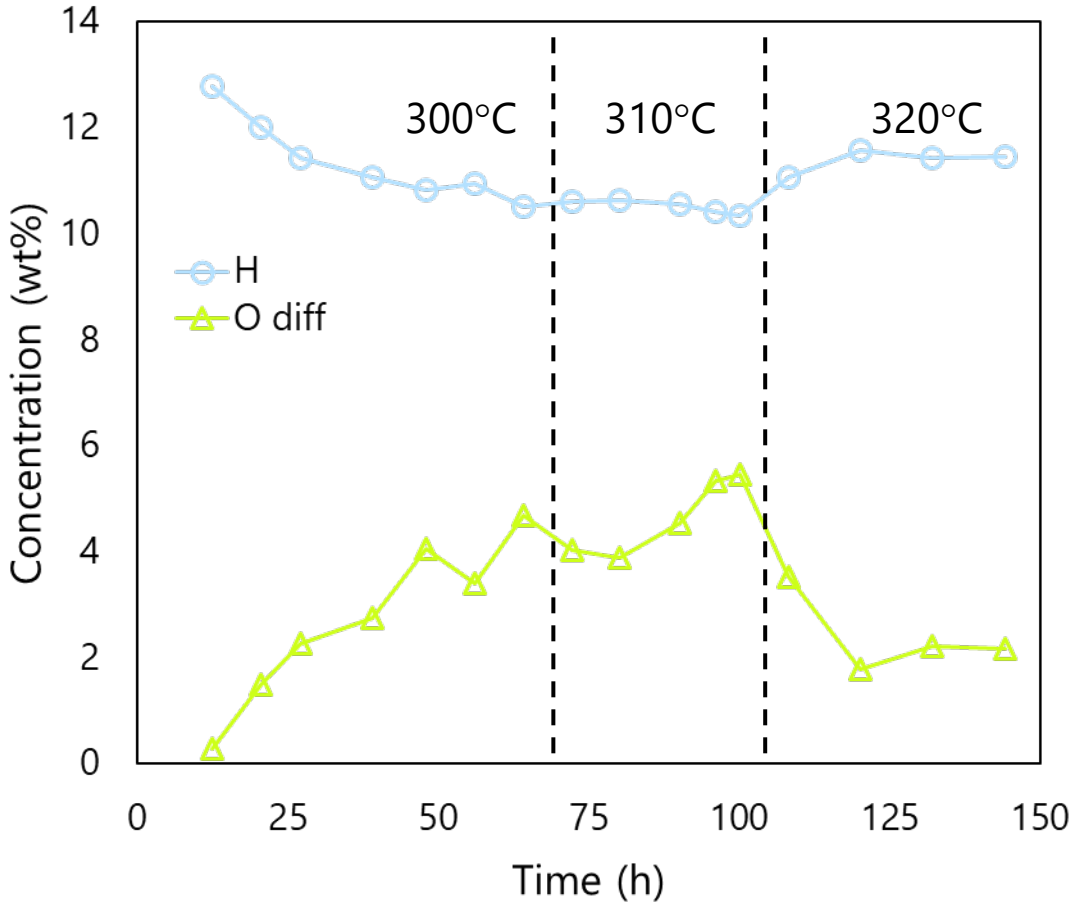
Test conditions

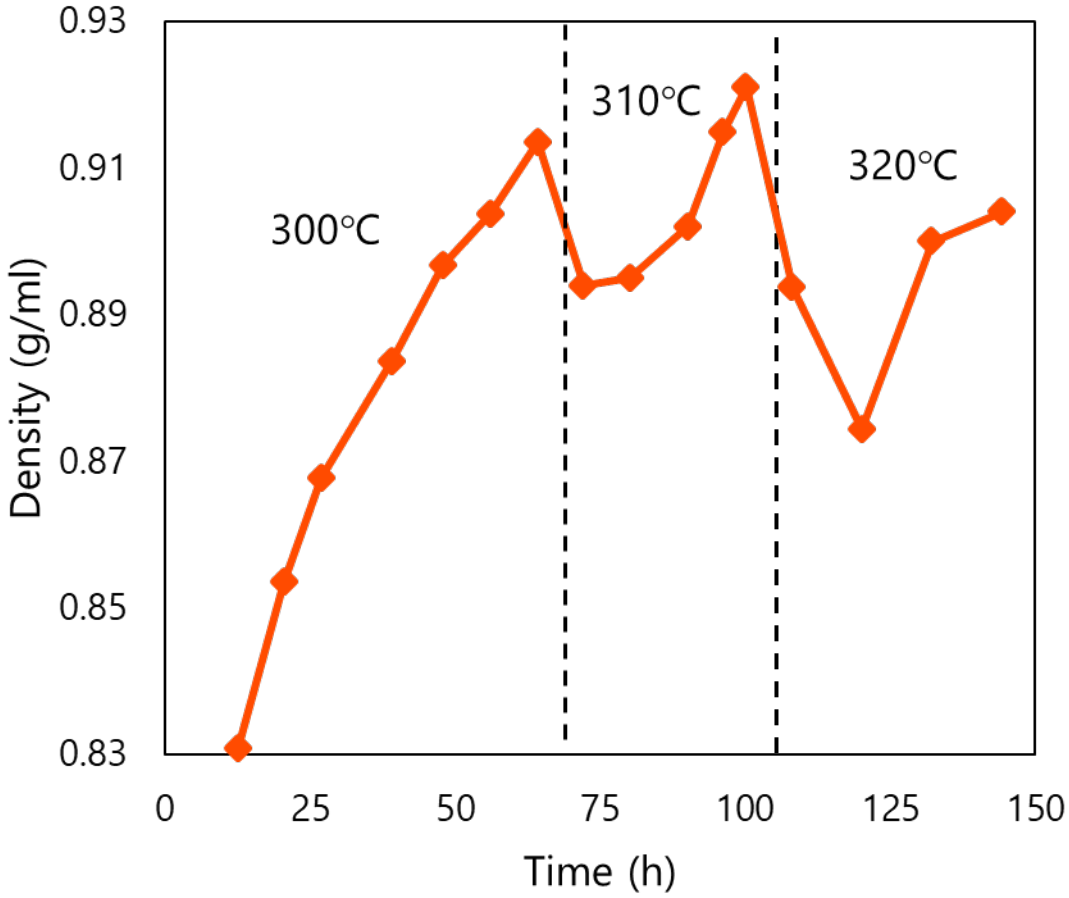
Pressure	139 bar
Avg. Temperature	300 °C
LHSV	0.35 h^{-1}
H_2/oil ratio	3300 Nl/l

Mass balance

Parameters	MB1 (6.5 h)	MB2 (8 h)	MB2 (10 h)	Average
Mass yield of product oil, wt.%	76.6	77.4	77.3	77.10
Carbon yield of product oil, %	98.7	99.02	99.9	99.21
Mass yield of aqueous fraction, wt.%	19.1	17.39	17.8	18.10
Carbon yield of aqueous fraction, %	0.3	0.27	0.28	0.28
Product Gas yield, wt.%	2.0	1.97	1.66	1.88
Carbon yield of product gas, %	1.8	1.93	1.57	1.77
H_2 consumed, g of H_2/g of dry bio-oil	0.071	0.088	0.087	0.082
Mass Balance, %	97.1	96.15	96.13	96.46
Carbon Balance, %	100.8	101.22	101.72	101.25

FRACTIONATION - HYDROTREATMENT OF TOLUENE EXTRACTED BIOCRUDE





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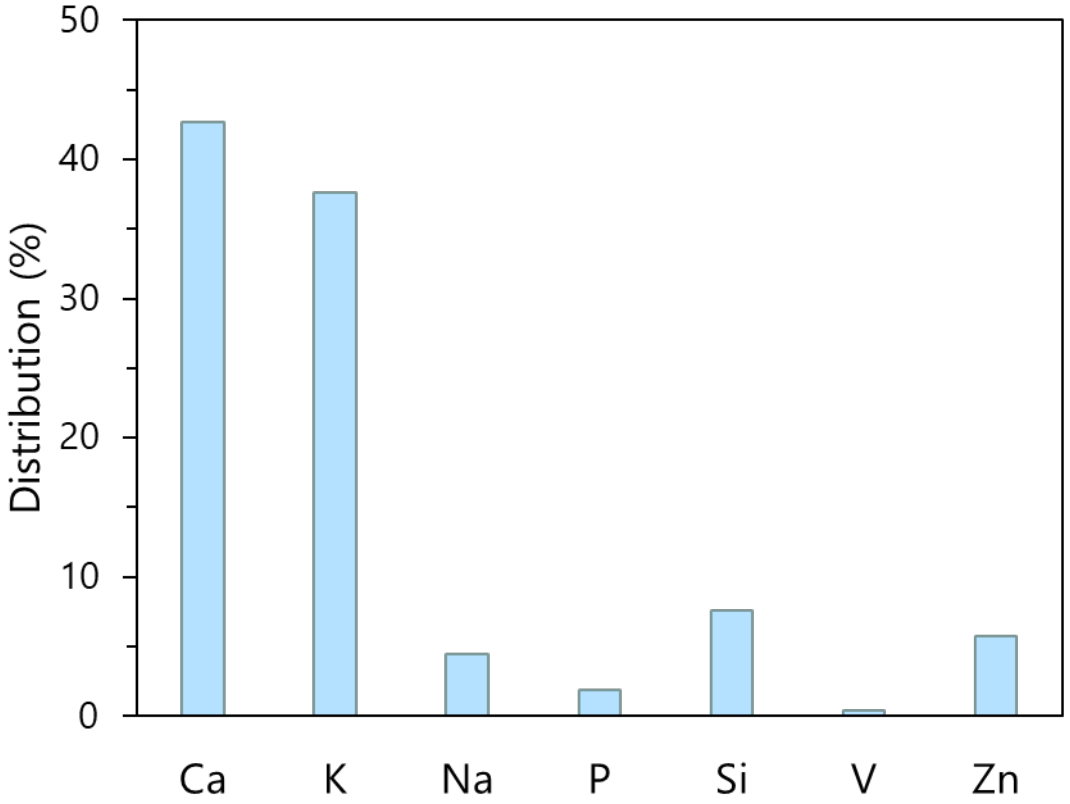
PYROLYSIS OIL
CHARACTERISATION – PHYSICAL PROPERTIES

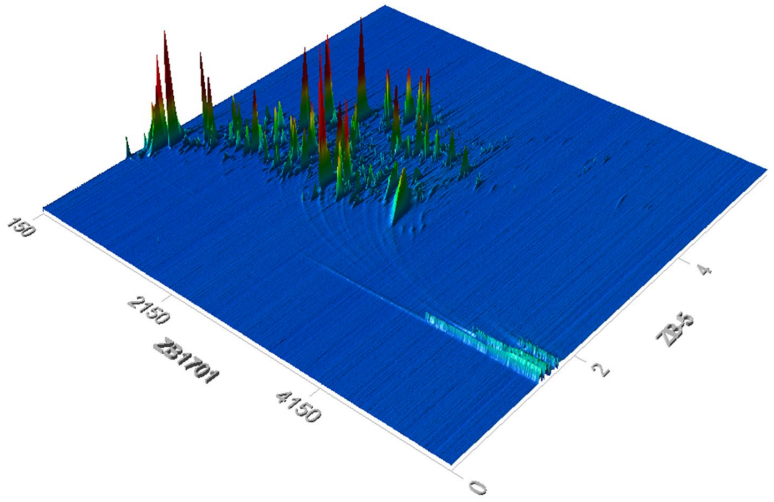
Feed properties

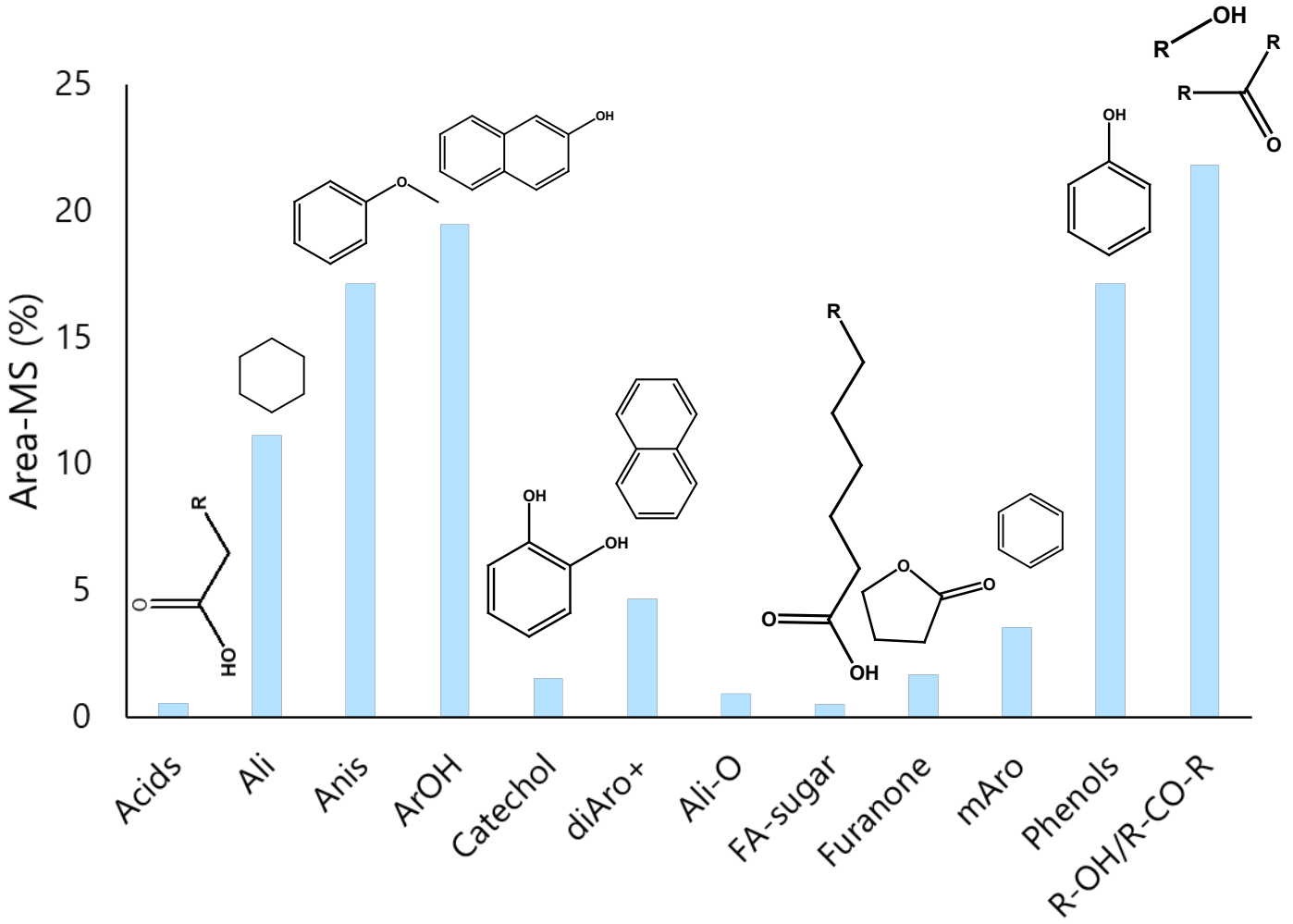
Analysis	Value	Unit
N	416	wt ppm
S	63	wt ppm
H	7.6	wt %
H	7.79	wt %
O	46	wt %
SG 60/60°F	1.1997	
Viscosity at 30°C	53.8	cSt
Total acid no.	79.7	mgKOH/g
Water	21.3	wt %
Carbon Residue	19.57	wt %
Carbonyls	5.0	mol/kg
Inorganics	69	wt ppm

Distribution of inorganics

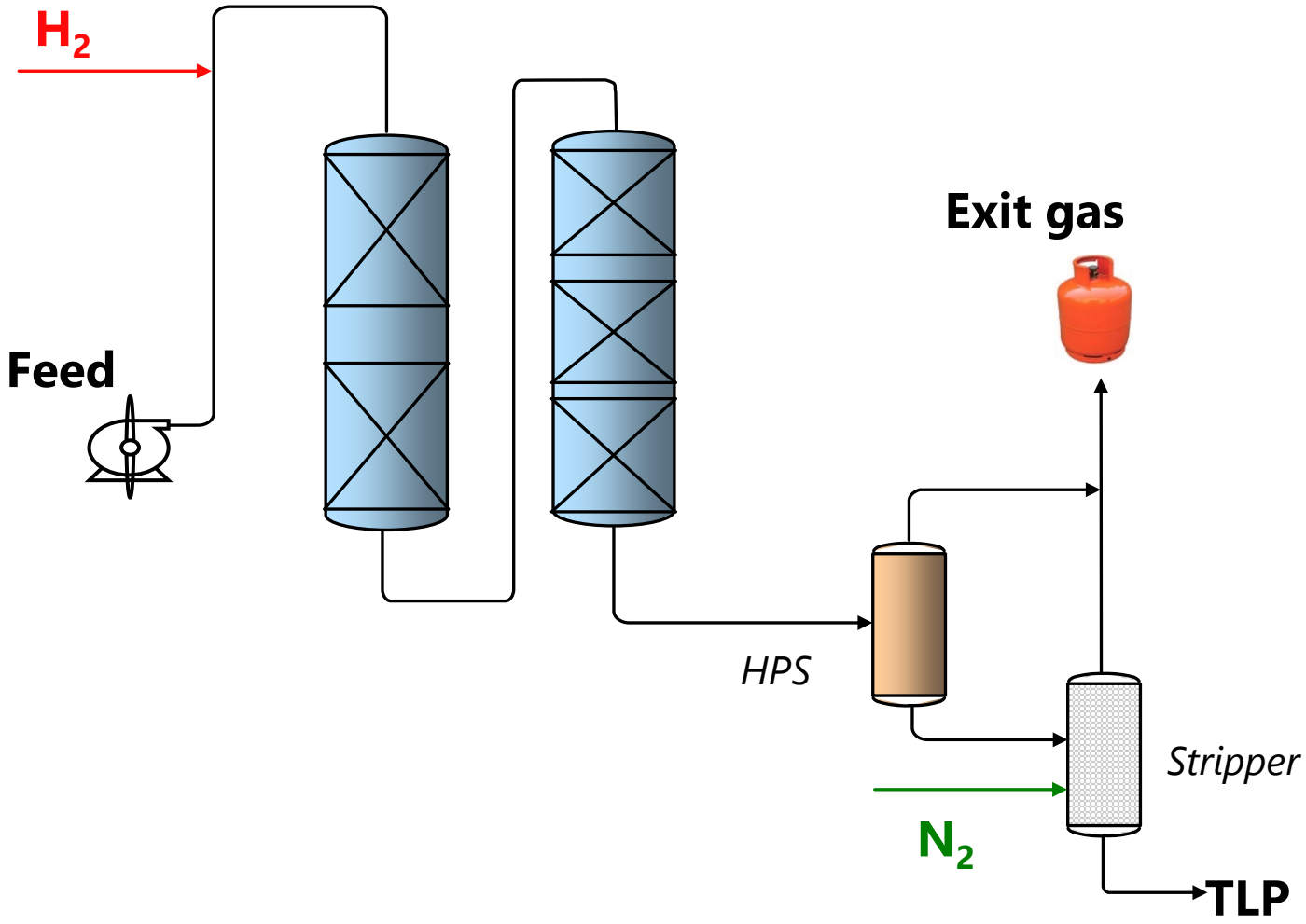


PYROLYSIS OIL
CHARACTERISATION - GC×GC-MS

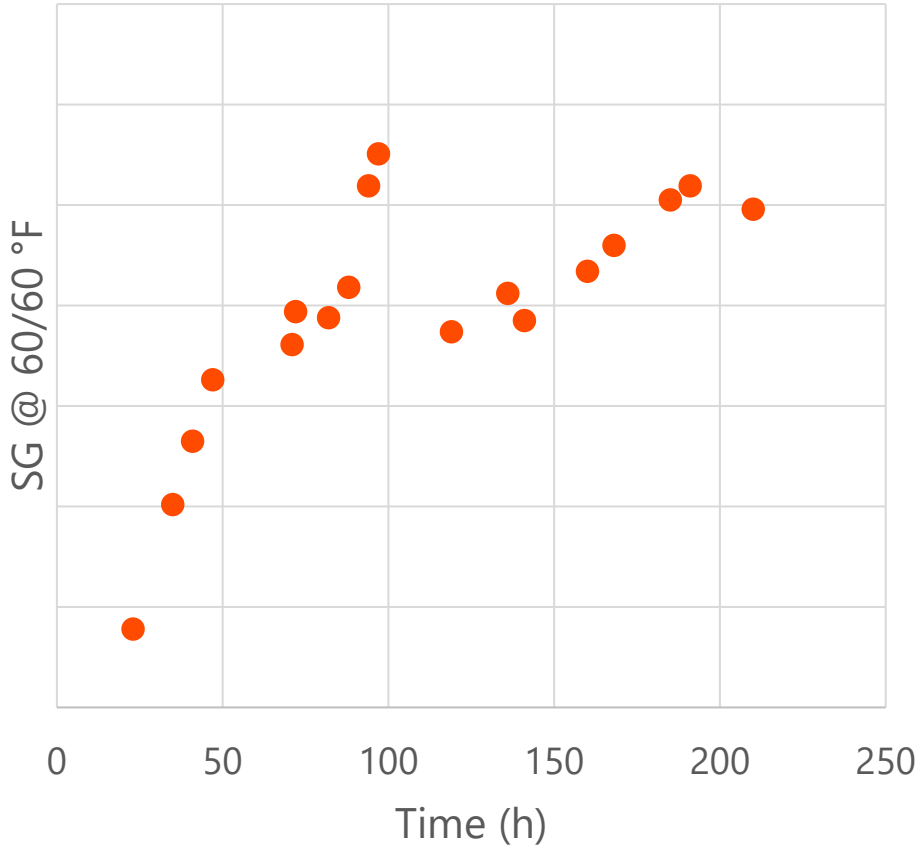


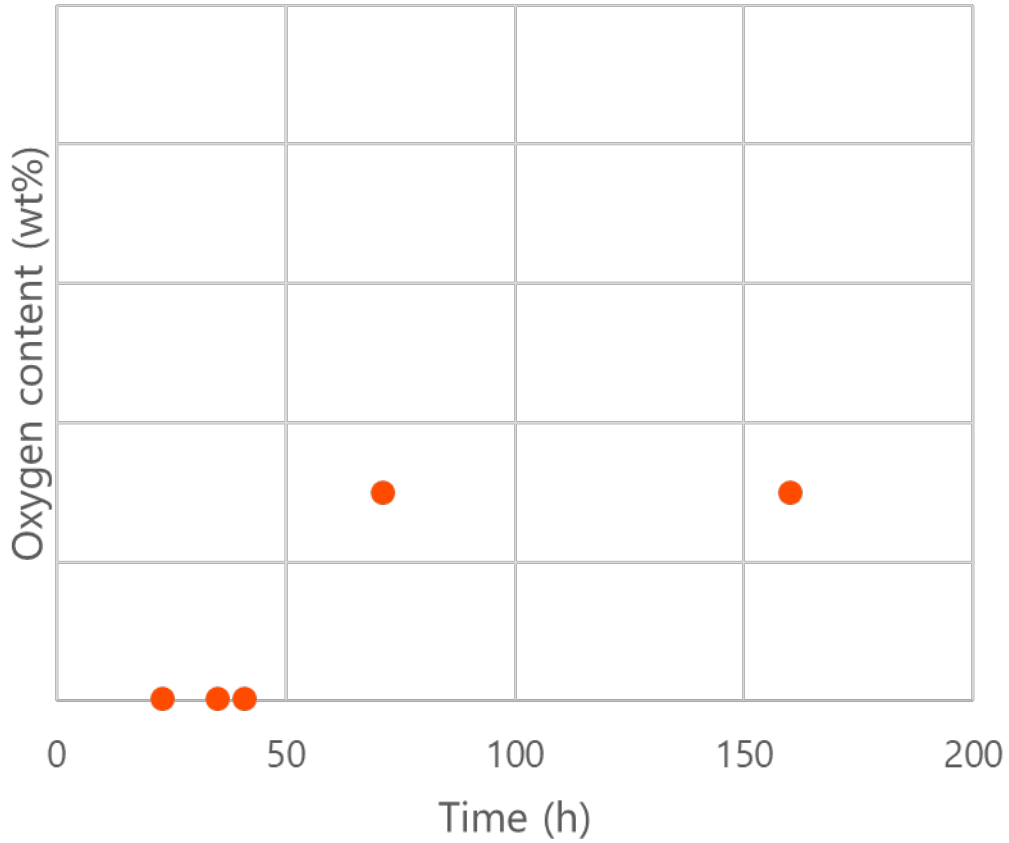


PYROLYSIS OIL
TOPSOE PILOT PLANT



PYROLYSIS OIL
HYDROTREATING RESULTS





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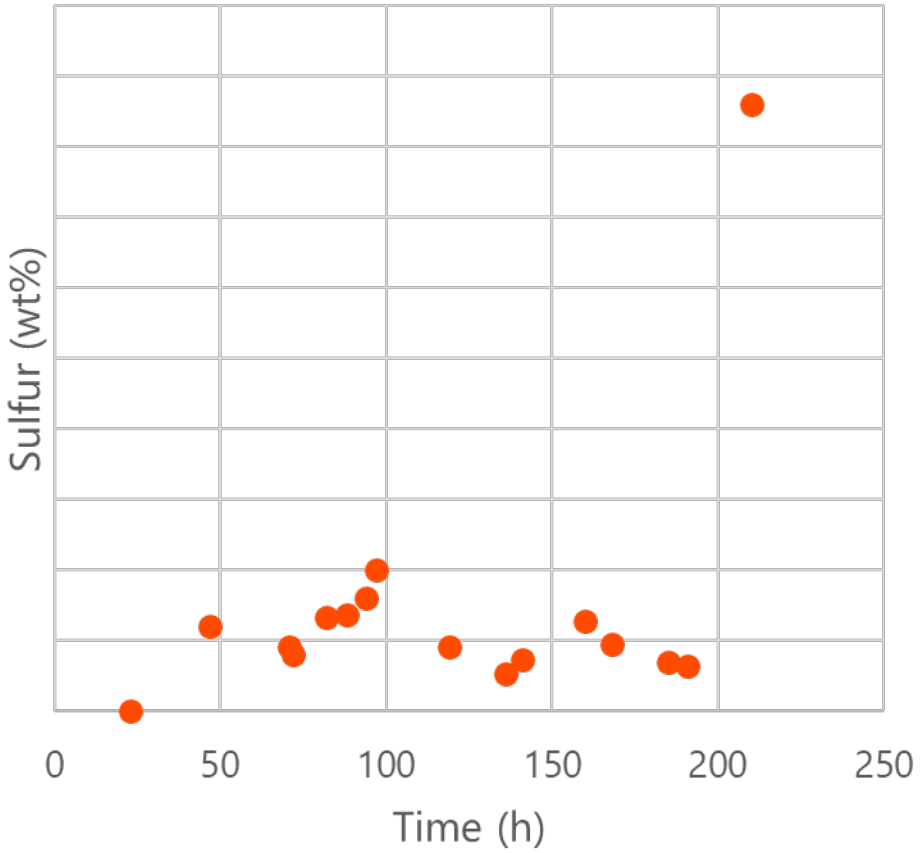
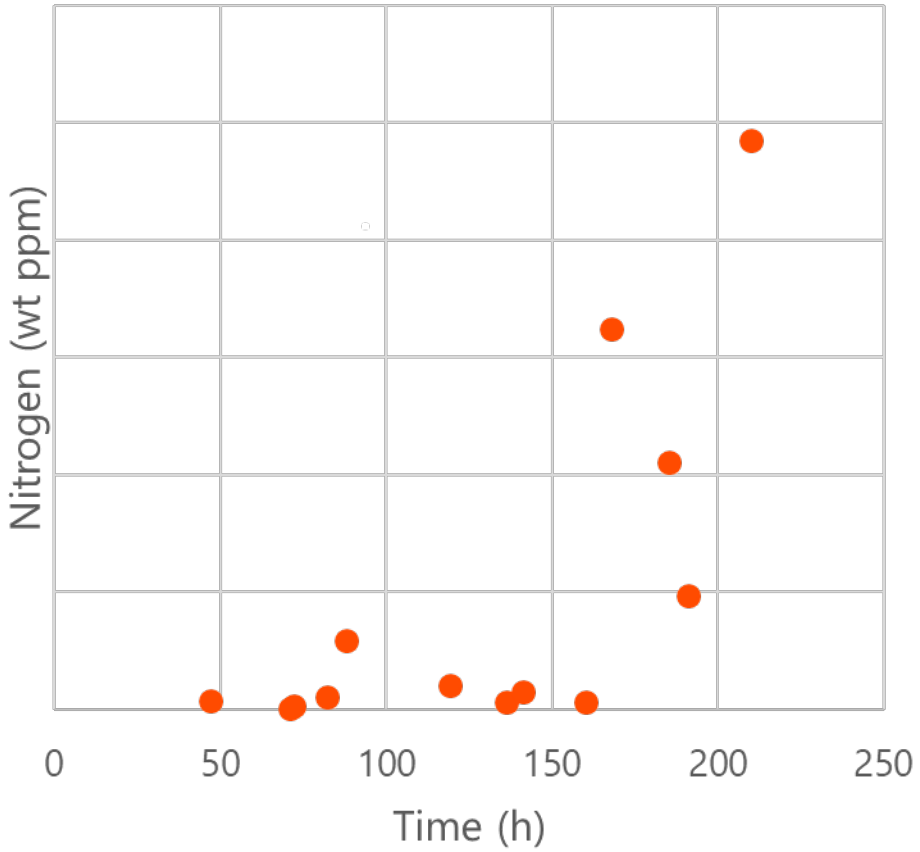


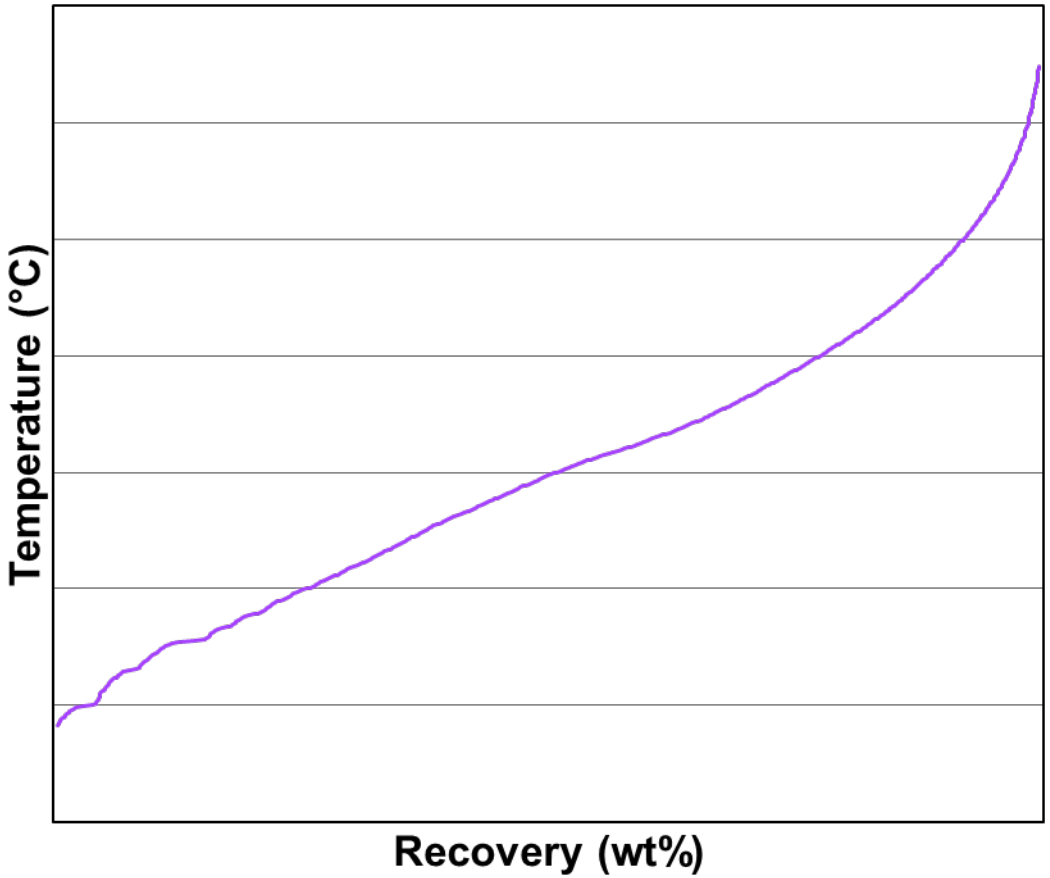


PYROLYSIS OIL
PRODUCT COMPOSITION

Product properties

Analysis	Value	Unit
Hydrogen	13.04	wt%
Sulfur	13	wt ppm
Nitrogen	1.2	wt ppm
Oxygen	6	wt%
Monoaromatics	7.17	wt%
Diaromatics	0.23	wt%
Tri+aromatics	0.09	wt%

Boiling point curve



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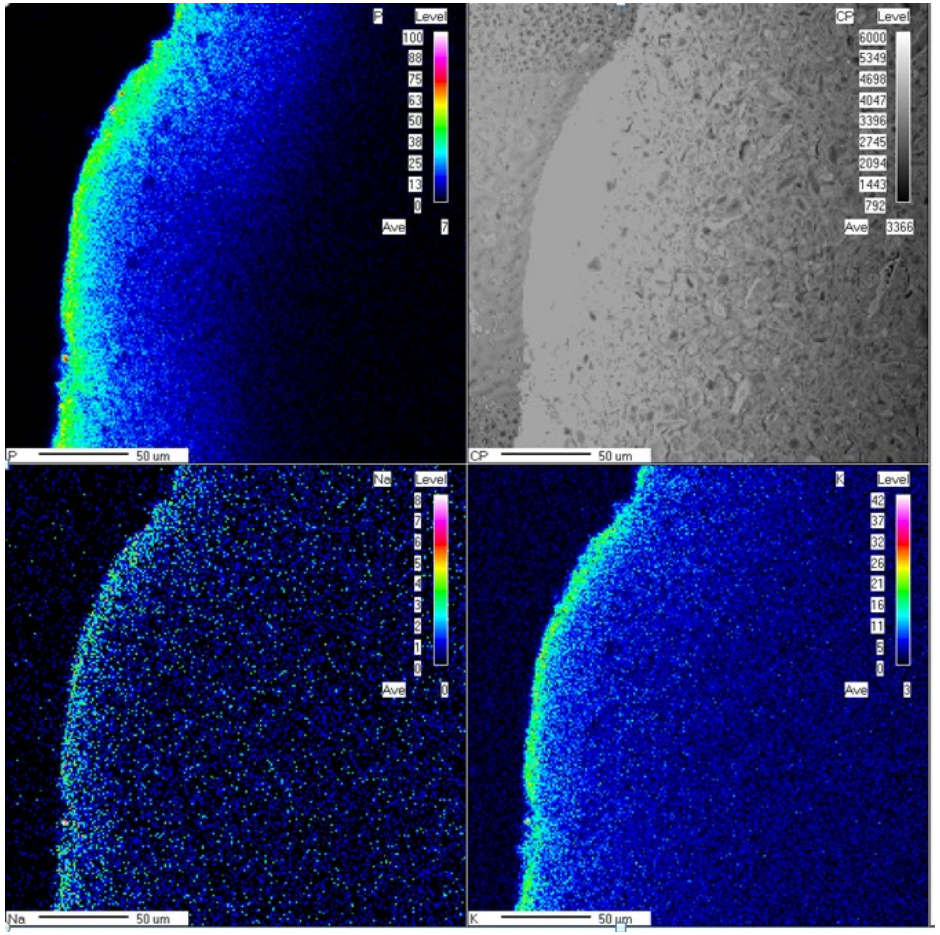
REFINERY INTEGRATION

CHALLENGES WHEN INTRODUCING A BIO-CRUDE INTO A REFINERY

- High oxygen content – low hydrogen content
  - Not miscible with fossil feedstock
  - Thermally unstable
  - Extremely high hydrogen consumption
- High concentration of impurities/catalyst poisons
  - Short catalyst life time –> inhibiting amounts of guard bed catalyst
  - dP problems
- High acidity
  - Material selection



REFINERY INTEGRATION
POSSIBILITY

PRE-TREAT BIO-CRUDE IN A STAND ALONE HYDROTREATER[1]

- May run at very low LHSV and high pressure
- All catalyst poisons removed
- Stabilizes bio-crude

CO-PROCESS LIGHT GAS OIL WITH PARTLY DEOXYGENATED PYROLYSIS OIL[2]

[1]Mante, O.D. et al. Integration of catalytic fast pyrolysis and hydroprocessing: A pathway to refinery intermediates and "drop-in" fuels from biomass, Green Chemistry, Volume 18, Issue 22, 2016, Pages 6123-6135

[2] Gabrielsen J., Upgrading of Catalytic Fast Pyrolysis Oils From Pine Tree, Lignofuels 2017, Helsinki Finland

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QUESTIONS?

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TOPSOE