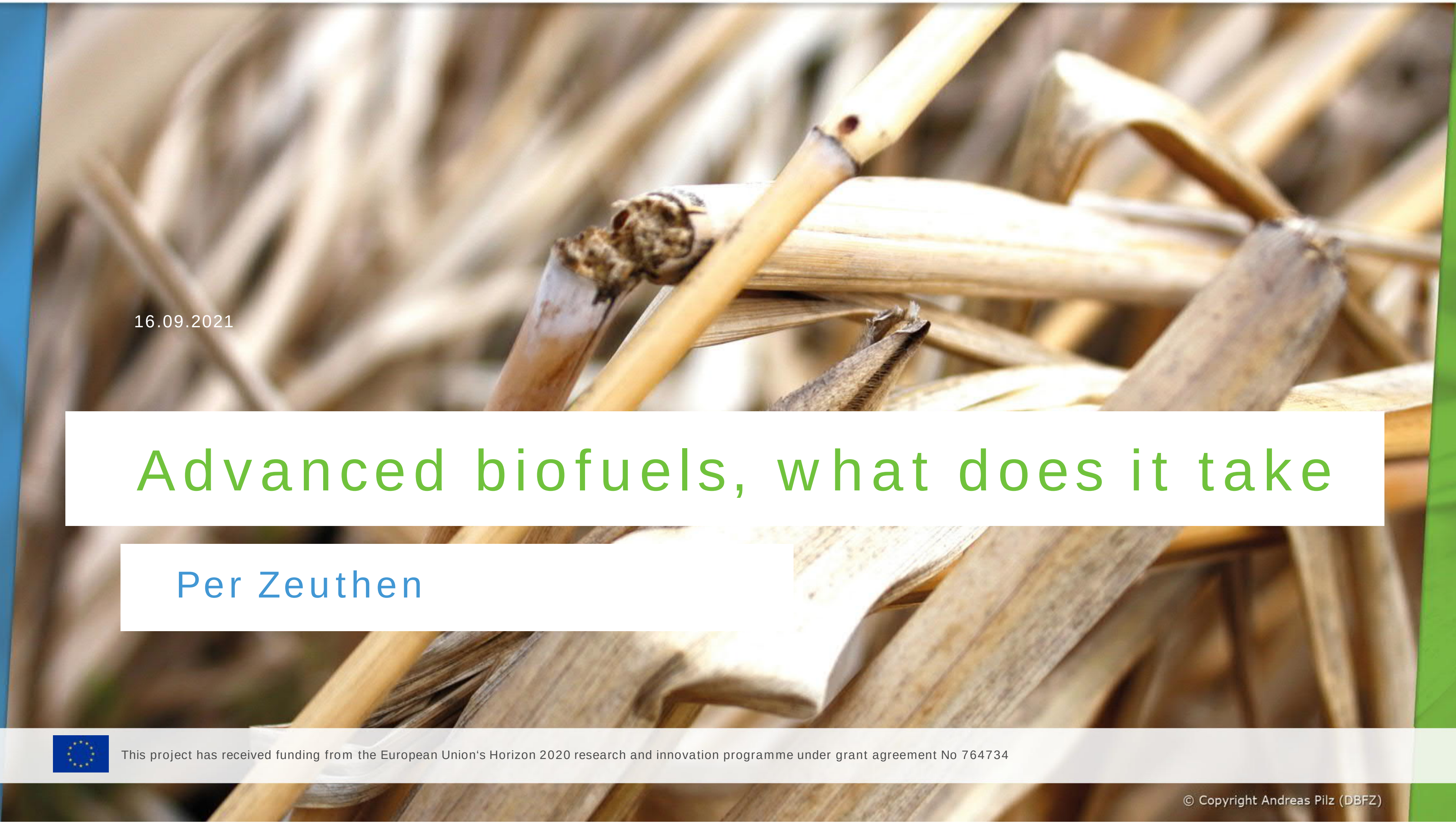
HyFlexFuel



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Advanced biofuels, what does it take

Per Zeuthen

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Types of renewable feedstocks

Limited amount of feedstock available

1st Generation

Virgin Oils

Rapeseed oil
Palm oil
Sunflower oil
Soybean oil

2nd Generation

Waste oils and fats

Used Cooking Oils (UCO)
Animal Fats
Palm Oil Mill Effluent (POME)
Palm Fatty Acid Distillate (PFAD)
Spent Bleaching Earth Oil (SBEO)
Palm Kernel Oil (PKO)
Distillers Corn Oil (DCO)
Crude tall oil (CTO)

3rd Generation

Solid Waste

Agricultural residue
Sewage sludge
Forestry residue
Organic fraction of MSW
Mixed plastic waste
Micro or macro algae

Low ILUC crops
Carinata
Castor
Miscanthus

Overview of methods for production of next generation renewables

	Fast pyrolysis	Catalytic pyrolysis	Gasification + Fischer Tropsch	Hydrothermal liquefaction
Operating temperature	450-550 °C	400-550 °C	700-1500 °C	250-450 °C
Operating pressure	1 barg	1 barg (up to 35 barg H_2)	1-70 barg	100-350 barg
Carbon recovery in liquid product (after HDO to 0 % O)	50-70 % (34-48 %)	10-45 % (9-40 %)	25-45 %	75 % 43 %
Product oxygen	35-45 wt %	10-35 wt %	5-15 wt%	10-20 wt %
GHG reduction	60-112 %	69-94 %	61-91 %	>70 %
Complexity	Low	Medium/High	High	High
Suitable feedstock	Dry biomass, plastic	Dry biomass, plastic	Dry biomass, plastic	Suited for sewage sludge, algae, woody biomass, plastic
Challenges	Difficult to upgrade	Low oil yield	Cleaning and conditioning of syngas before FT	Upgradability of feedstocks to confirm. High-temperature pumps and water handling

Overview of methods for production of next generation renewables

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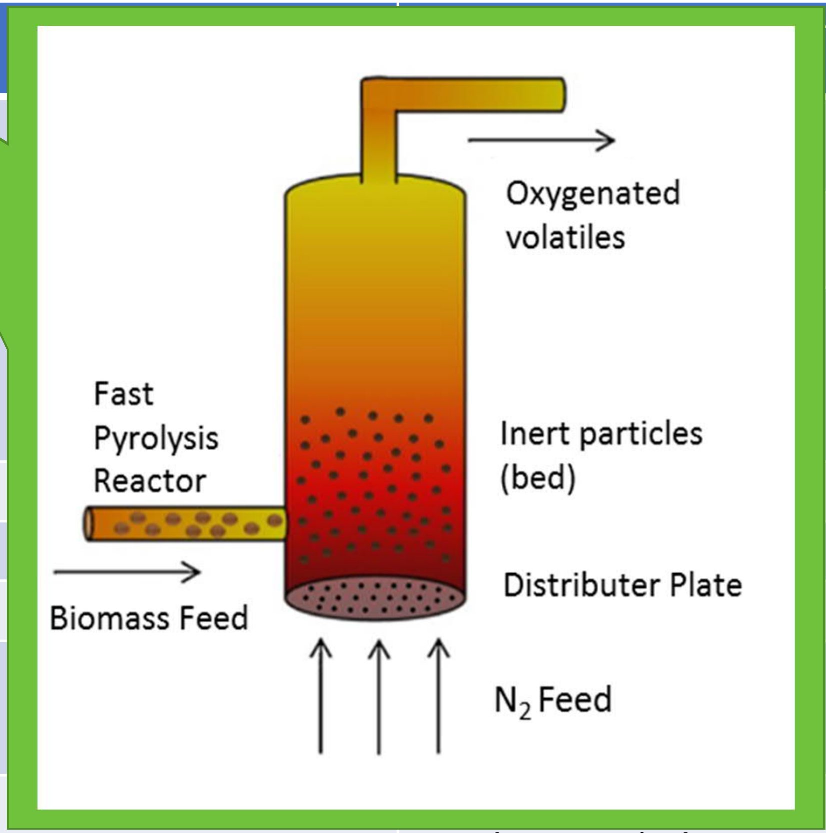

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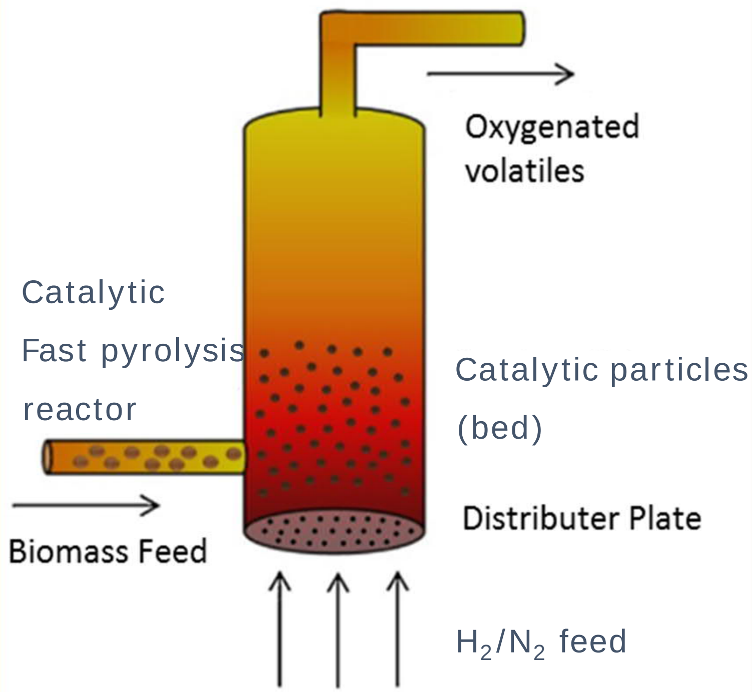
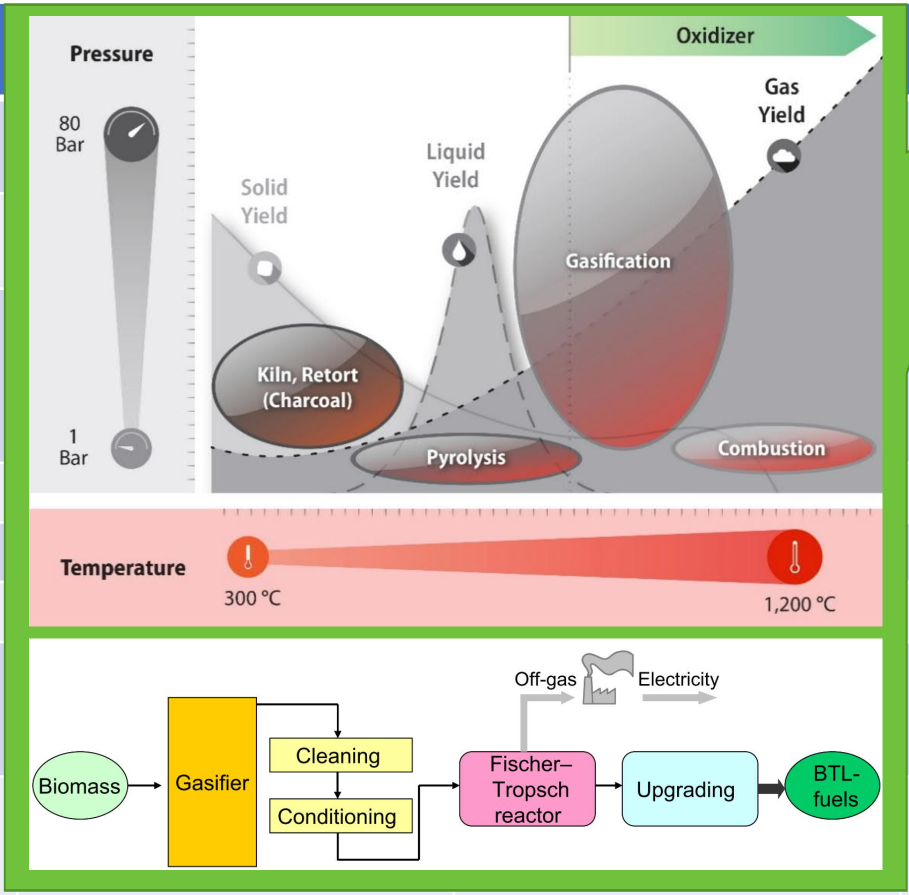


Oxygen is removed as CO, CO_2 or H_2O

Overview of methods for production of next generation renewables



	Gasification + Fischer Tropsch	Hydrothermal liquefaction
Operating temperature	700-1500 °C	250-450 °C
Operating pressure	1-70 barg	100-350 barg
Carbon recovery in liquid product (after HDO to 0 % O)	25-45 %	75 % 43 %
Product oxygen	5-15 wt%	10-20 wt %
GHG reduction	61-91 %	>70 %
Complexity	High	High
Suitable feedstock	Dry biomass, plastic	Suited for sewage sludge, algae, woody biomass, plastic
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Overview of methods for production of next generation renewables

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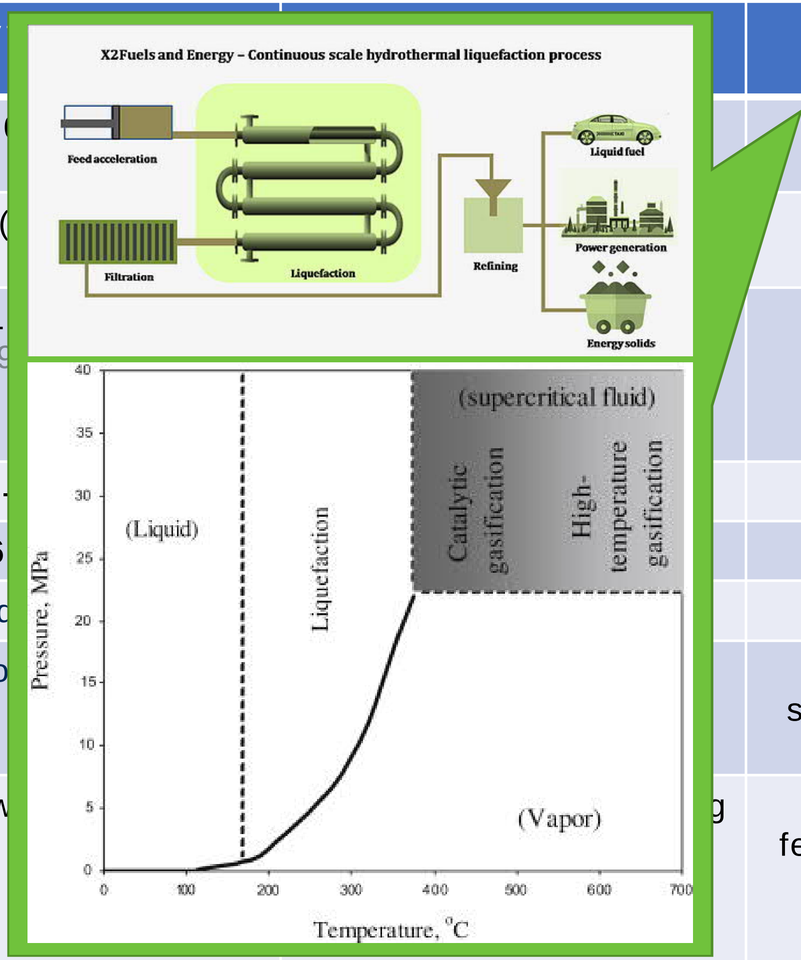


Biofuel properties

Examples of advanced biofuels

Property	Unit	Pyrolysis	Catalytic pyrolysis	Catalytic Hydro-pyrolysis	HTL	Vegetable oil	Diesel
H	wt%	5.5-7.2	6.5-8	9.6-12	8-11	11-12	13
O	wt%	30-50	10-35	0.5-20	7-12	10-12	0
S	wt%	<0.1	<0.1	<0.03	0.02-1.2	<0.01	0.001-0.05
N	wt%	<0.2	<0.06	<0.01	0.05-7	<0.01	<0.001
Viscosity (40-50°C)	cSt	13-100	250	1-9	100-1200	30-45	1.9-4.5
Density (15-40°C)	g/ml	1.1-1.3	1-1.1	0.82-1.0	0.94-1.3	0.9	0.82-0.85
TAN	mg KOH/g	60-100	6-30	0-14	30-100	0-25	0
Impurities	wt ppm	50-800	100-1000	0-10	200-1500	5-200	0

Pretreatment is necessary

The properties of biofuels reflect the biomass

Examples of biomass compositions

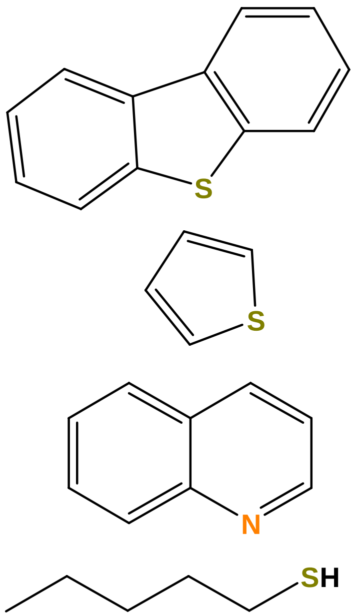
Property	Unit	Sewage sludge	Algae	Wheat straw (DK)	Beech wood	Oak wood
H	wt% daf	7.5	7.2	6.4	5.8	6.1
O	wt% daf	31	43	43	45	42
S	wt% daf	2	1	0.2	-	0.05
N	wt% daf	7.2	3.3	0.5	0.1	0.4
Ash	wt% db	53.5	22.5	7.2	0.64	2.4

daf: dry ash free basis
db: dry basis

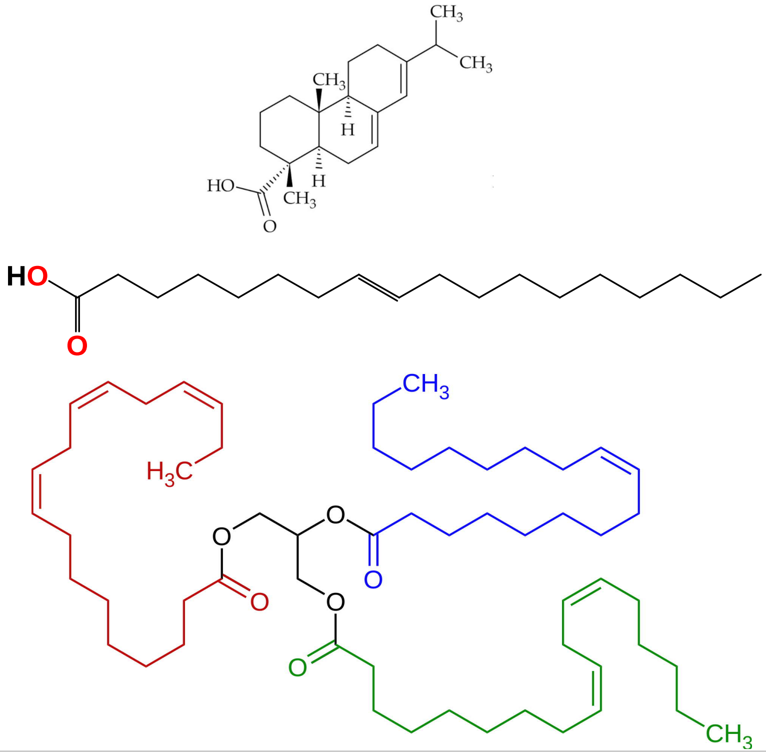
The impurities and N content in biofuels depend on the biomass

New feedstocks = new chemistry

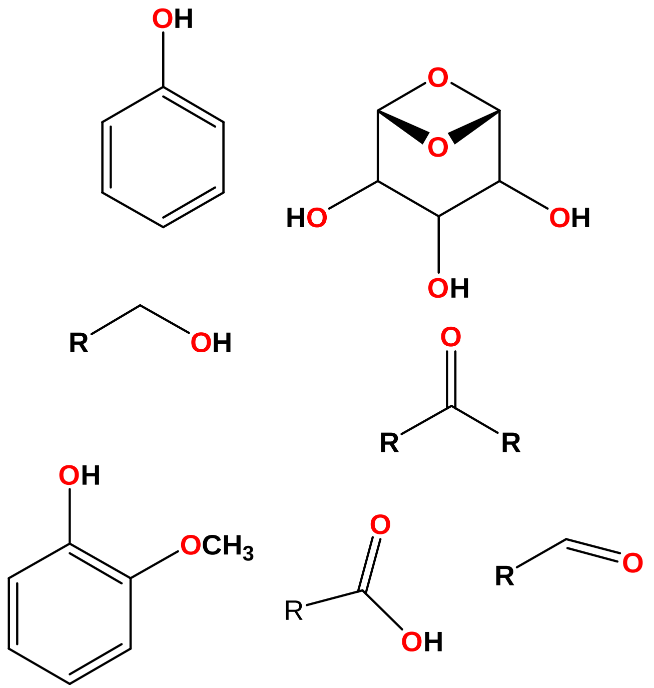
Fossil crude



1st & 2nd generation renewables



3rd generation renewables



Upgrading biocrudes may create challenges

- Low miscibility
- Instability at room conditions
- Polymerization tendency with increasing temperature
- Coking tendency
- High hydrogen consumption
- High level of contaminants depending on the feedstock (Fe, P, Si, Na, etc.) that may cause deactivation and pressure drops

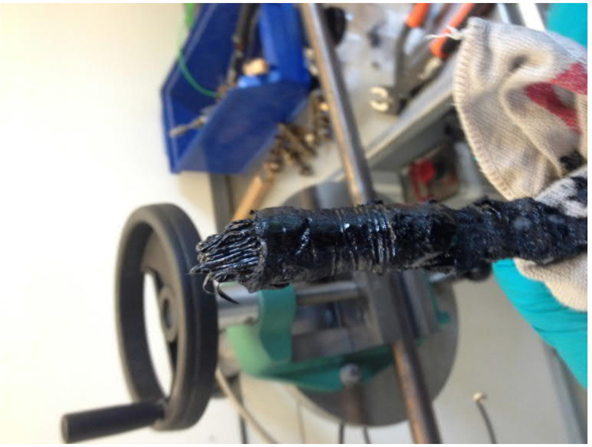
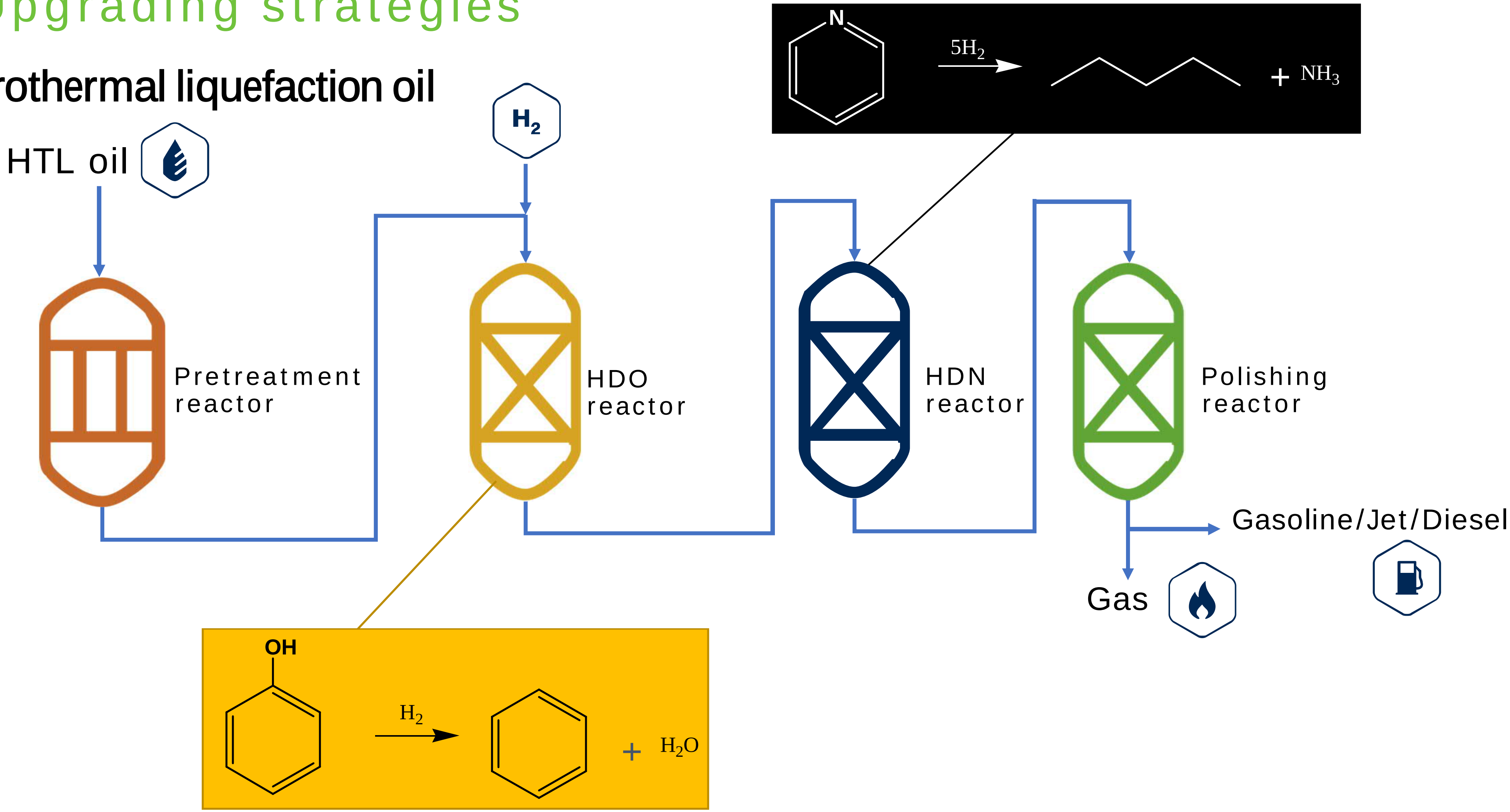


Figure: Polymerization of biocrude observed in a pilot plant unit

Upgrading strategies

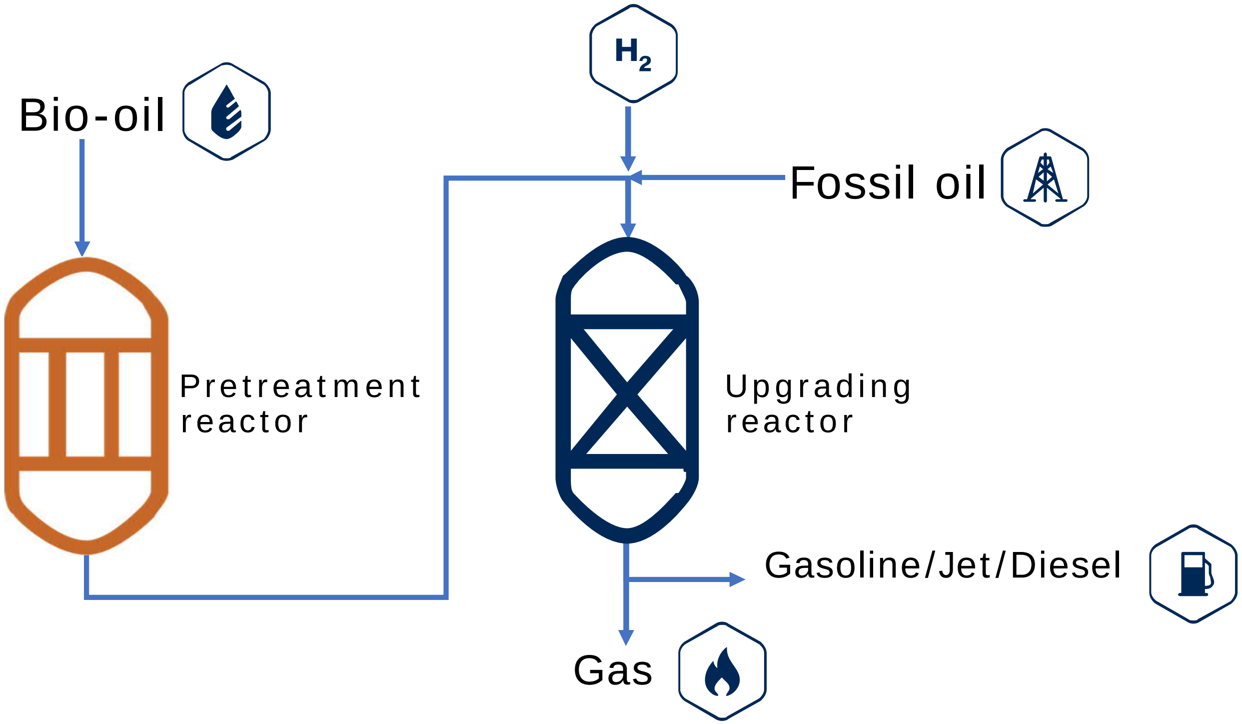
Upgrading strategies

Hydrothermal liquefaction oil



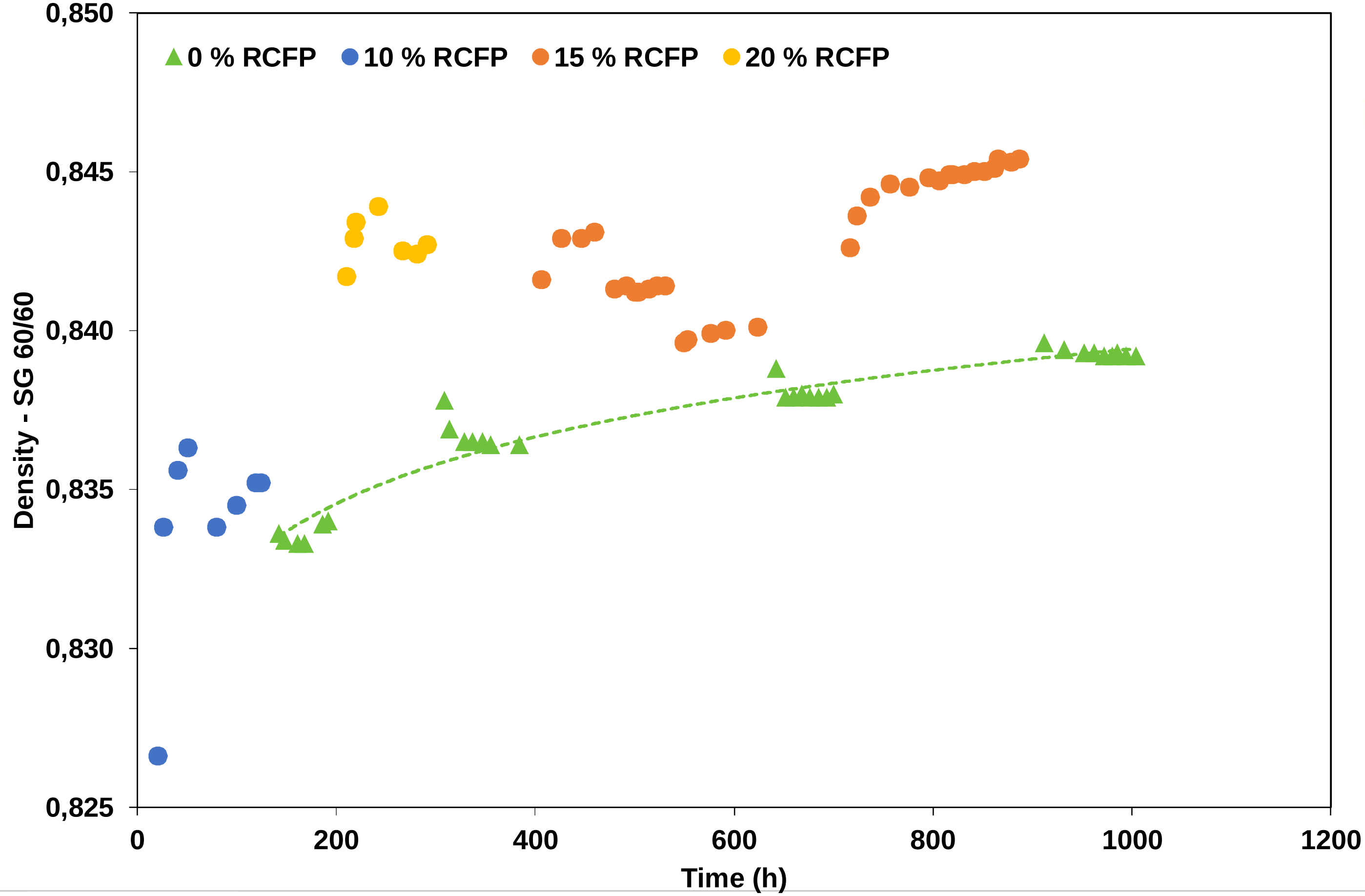
Upgrading strategies

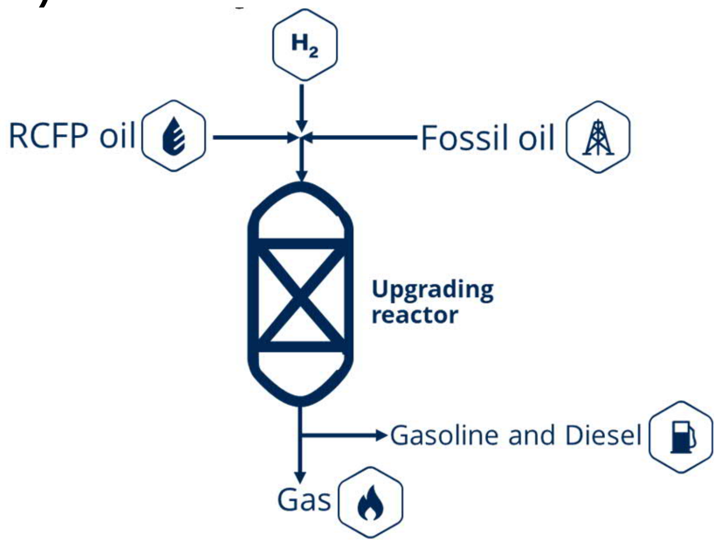
Co-feeding



Co-feeding strategies

Results from co-feeding of reactive catalytic fast pyrolysis (RCFP) oil with fossil oil





Estimated H_2 consumption for different feedstock

Property	Unit	Pyrolysis	Catalytic pyrolysis	Catalytic hydropyrolysis	HTL	Vegetable oil
H	wt%	6	9	10	11	11.5
O	wt%	40	15	1.8	7	11
S	wt%	<0.1	<0.1	<0.03	1.2	0.0002
N	wt%	<0.2	<0.06	<0.01	7	0.0001
Estimated H_2 consumption	Nl/l	800-1000	600-800	200-300	500-800	350

Take-home message

- The bio-oil composition depends on the type of conversion process and biomass
- Biomass derived oils are very different from fossil oil
- The upgrading strategy depends on the type of bio-oil
- Co-feeding of biomass derived oils with fossil oil is possible

Thank you!

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