Comparative Fast Pyrolysis of Agricultural Residues for Use in Biorefineries

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ECI Bioenergy-II:

Fuels and Chemicals from Renewable Resources

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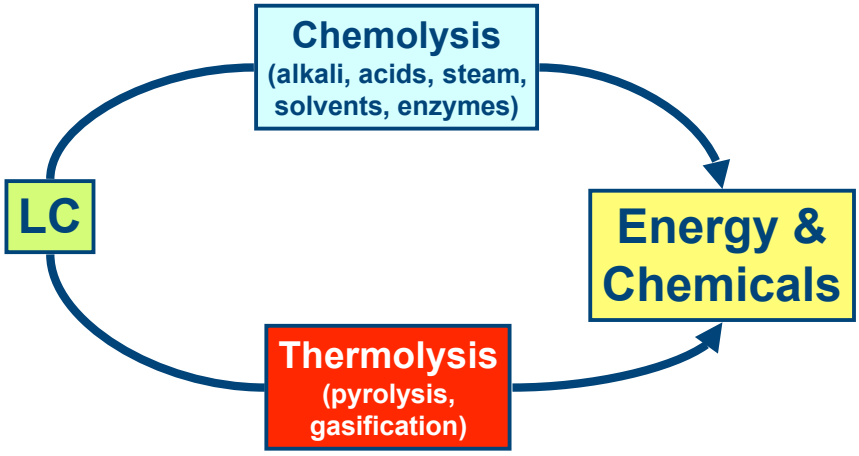
vTI HTB

Outline

- Background
- Bio crude oil (BCO) properties & applications
- BCO technologies
- Experimental results
- Outlook

From Lignocelluloses to Energy & Chemicals



Biorefinery Concepts

- General
  - Use of lignocelluloses (LC): wood, residues (e.g. straw, bagasse)
  - no competion with food
  - restricted accessibility of biopolymers => pretreatment =>conversion

- Classic approach
  - **limited feedstock** selectivity (conditioning)
  - (pretreatment necessary with **pressure processes**, e.g. organosolv, steam)
  - separation & cleaning
  - Use **only after conversion** or modification (degradation to monomers, functionalisation, polymerisation)

- Thermochemical approach
  - **broad selection of raw LC** materials (e.g. straw, bark, DDGS, shells, etc.)
  - simple thermal treatment by fast-pyrolysis at **atmospheric pressure**
  - **decentral conversion - central refining** (separation & cleaning)
  - **Direct or indirect** use after modificationen

The Approach

LC Materials

↓

„Homogenization“
thermo-chemical
conversion by
fast-pyrolysis into
Bio-Oil + Coke

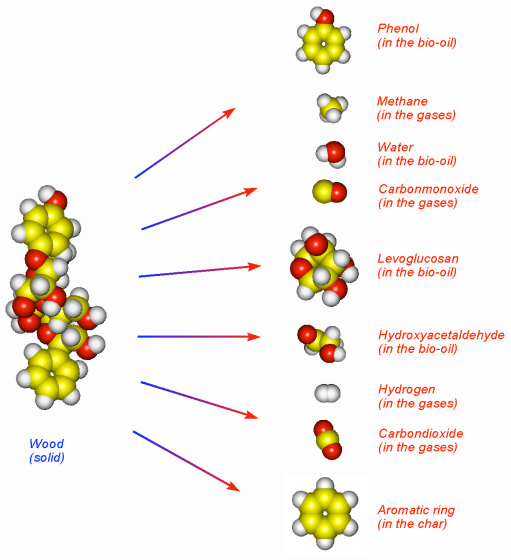
↓

Generation of Energy & Chemicals

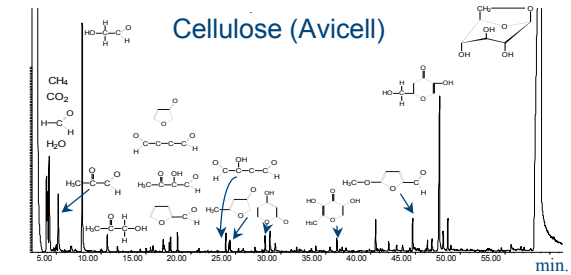
Fast Pyrolysis Principle

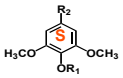
- Fast chemical degradation due to rapid heating in the absence of oxygen
- Process characteristics:
  - Temperature 500 °C
  - Pressure 1 bar
  - Particle size < 5 mm
  - t vapours < 2 s
- The main product is a liquid: Bio-Oil or Bio Crude Oil (BCO; approx. 70 wt.%)

Prins, W., 2007



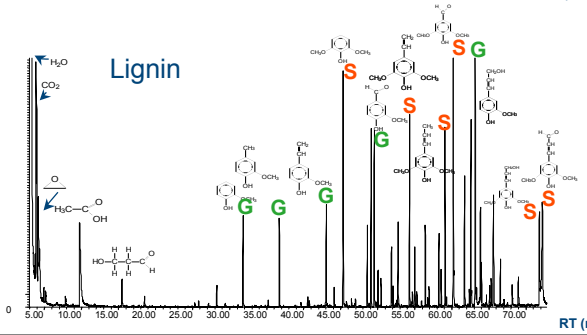
Products of Fast Pyrolysis from Py-GC/MS





syringyl

guaiacyl



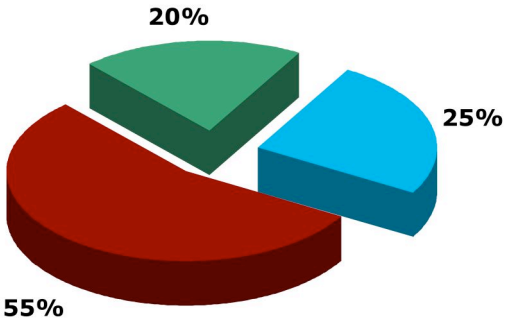
BCO Properties

Analysis	Pyrolysis liquids	Light fuel oil (Tempera 15)
Water, wt %	20-30	0.025
Solids, wt %	0.01-1	0
Ash, wt %	0.01-0.2	0.01
Nitrogen, wt %	0-0.4	0
Sulfur, wt %	0-0.05	0.2
Stability	Unstable	Stable
Viscosity (40 °C), cSt	15-35	3.0-7.5
Density (15 °C), kg/dm ^{3}	1.10-1.30	0.89
Flash point, °C	40-110	60
Pour point, °C	-9- -36	-15
LHV, MJ/kg	13-18	40.3
pH	2-3	Neutral
Distillability	Not distillable	160-400 °C

1 MJ Feedstock 1 MJ Product

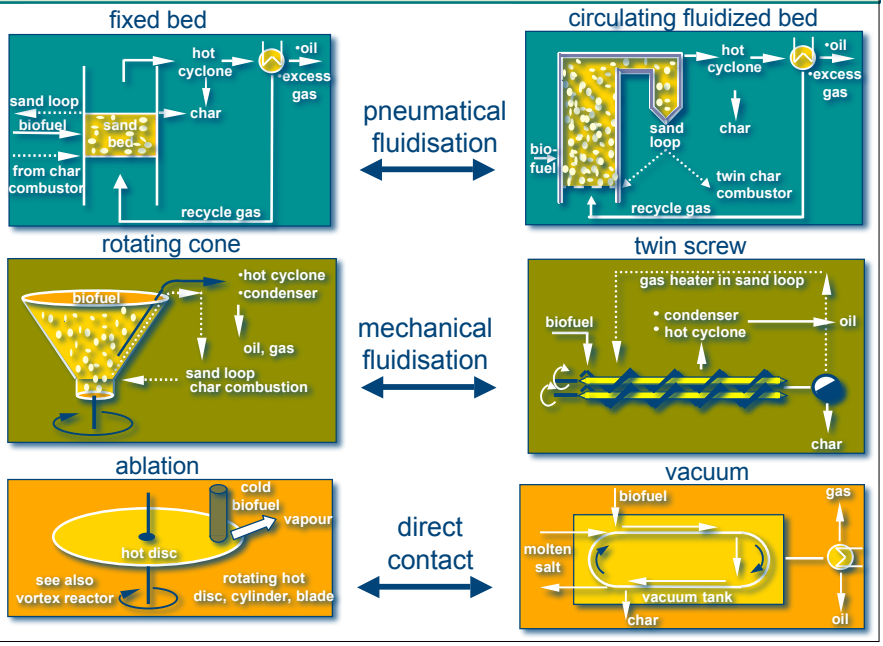
Prins, W., 2007

Overall Composition of Fast Pyrolysis Liquids

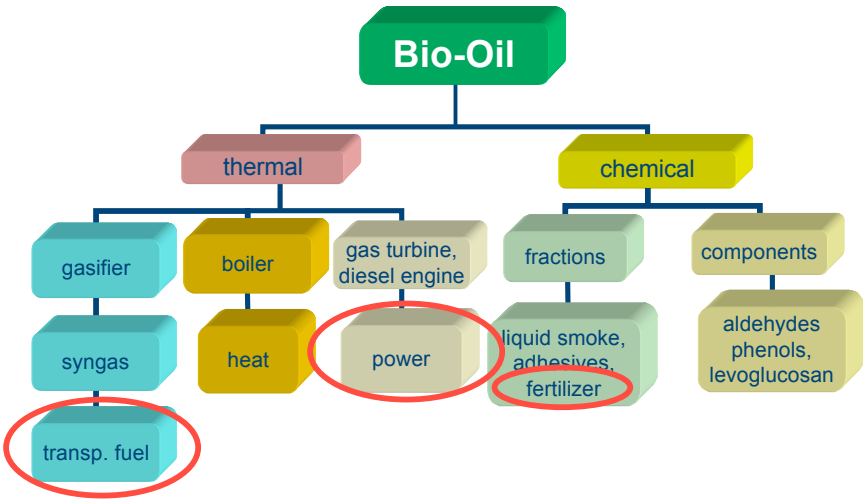


Monomers Oligomers (pyrolytic lignin) Water

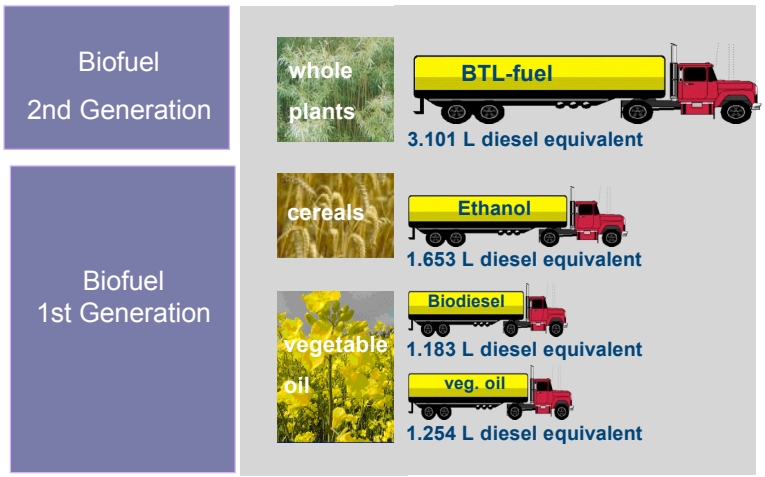
Reactor Designs for Fast Pyrolysis



Utilization Pathways for Pyrolysis Liquids

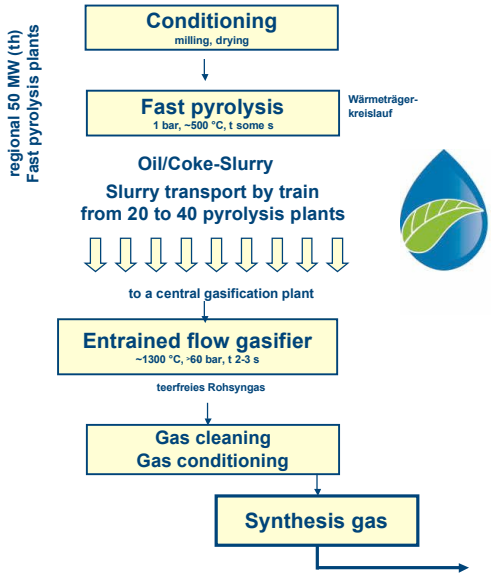


Productivity of Biofuels (yields/ha)



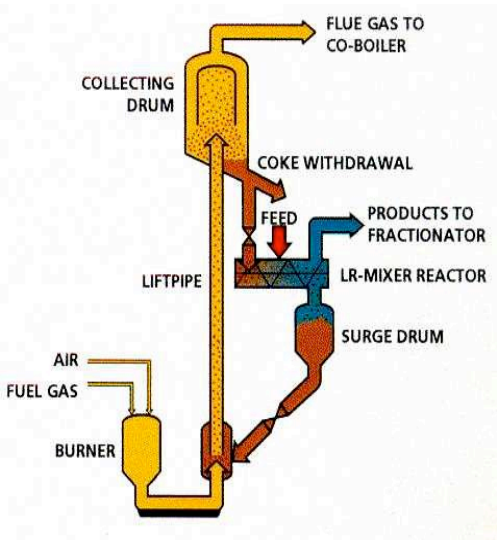
source: VW

The FZK BioLiq-Concept

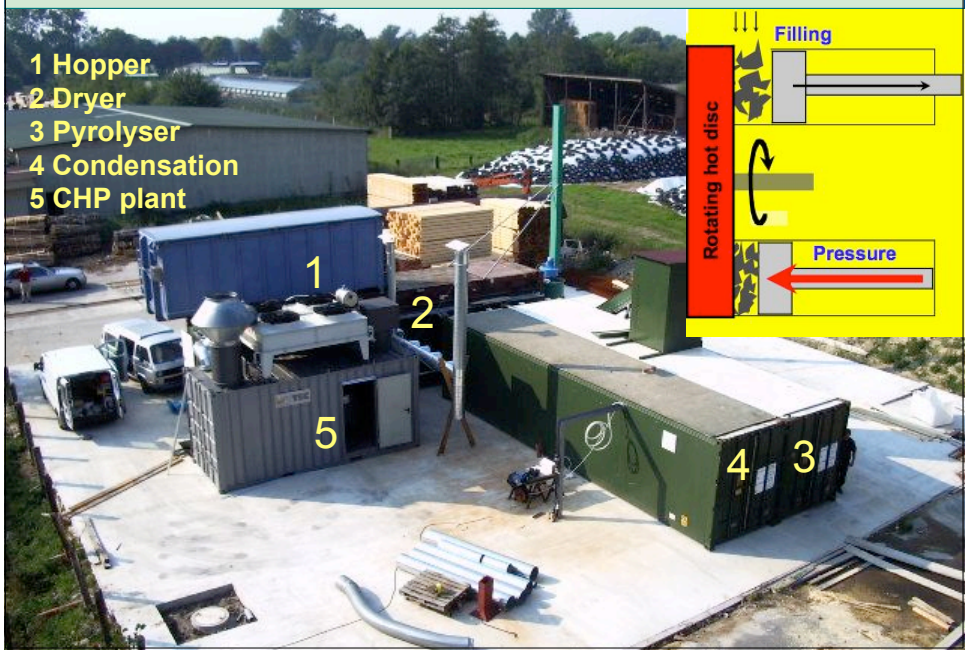


bioliq
Biomass to Liquid Karlsruhe

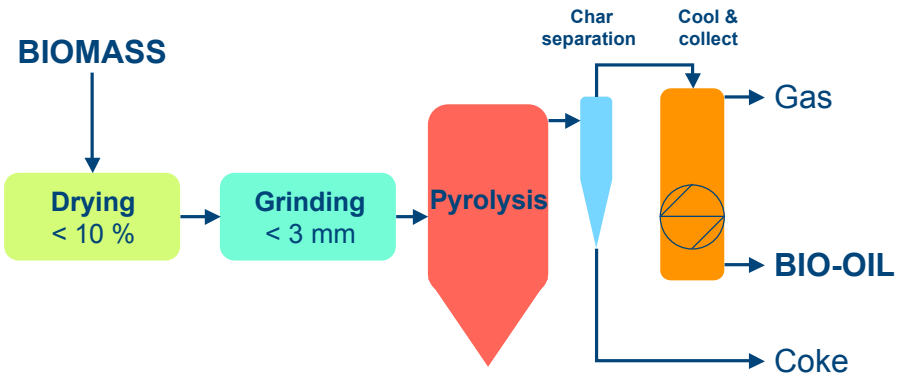
BCO + Char Gasification => FZK-BIOLIQ => MeOH



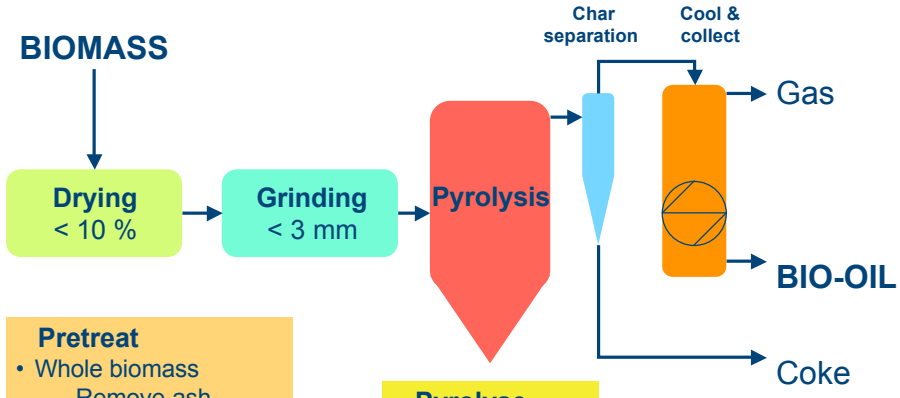
BTO-Pilot Plant in Bülkau



Conceptual Pyrolysis Process



Process Modifications

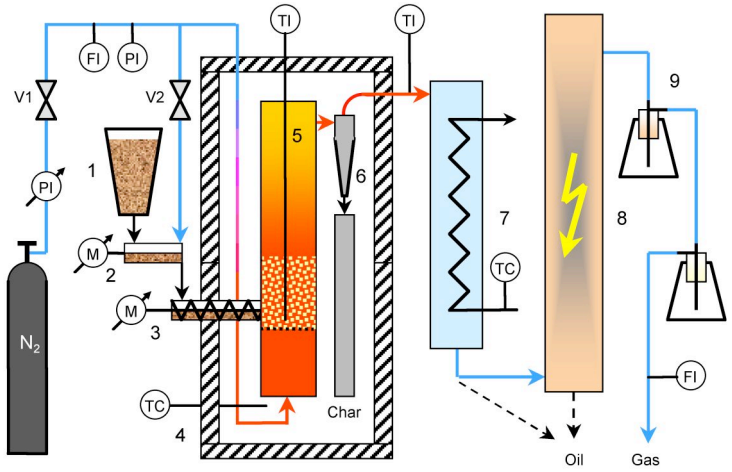


Pretreat
- Whole biomass
  - Remove ash
  - Add catalyst
- Separate bio-polymers into cellulose and lignin
  - Pulping
  - Biorefineries

Pyrolyse
- Vary parameters
  - Temperature
  - Time
  - Pressure
  - Atmosphere
- Add catalysts

Upgrade
- Physically
  - Staged condens.
- Chemically
  - React, derivatize
  - De-oxygenate
  - Gasify to syngas

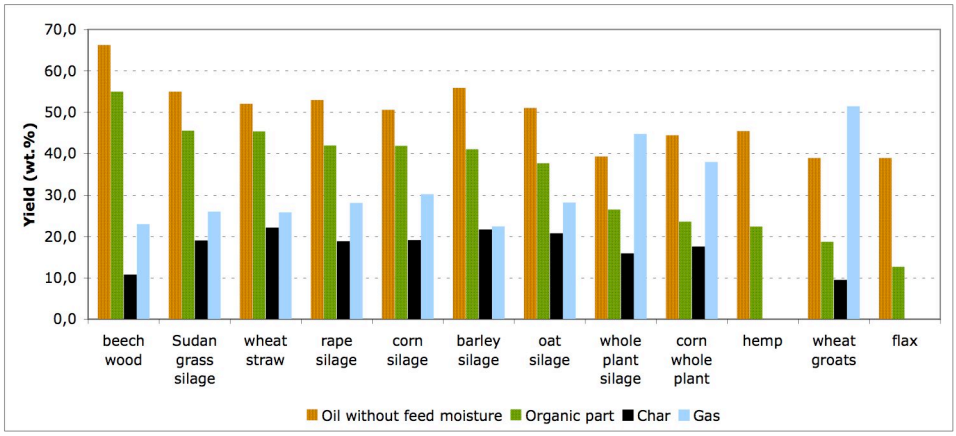
Laboratory Fluidized Bed Reactor



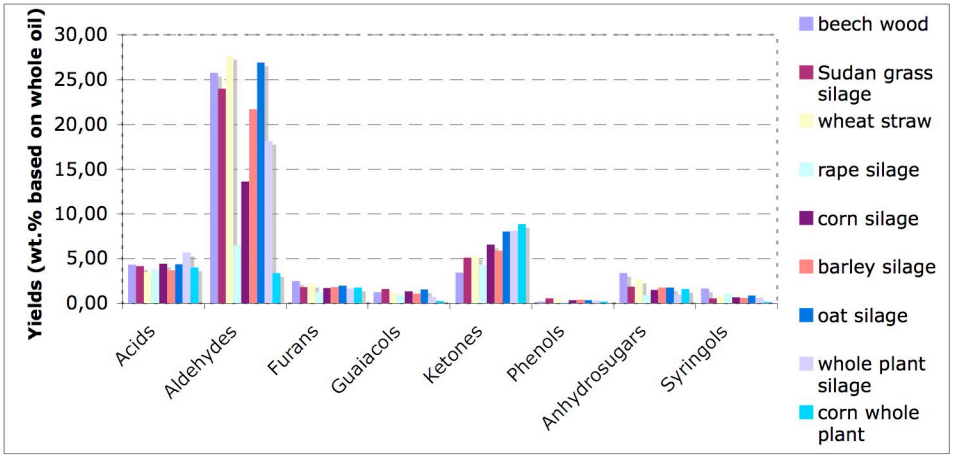
1 Hopper
2 Vibrator
3 Feeding screw
4 Heating and Insulation
5 Fluidized bed reactor
6 Cyclone and char pot
7 Intensive cooler
8 Electrostatic filter
9 Cotton wool filter

Laboratory Fluidized Bed Reactor

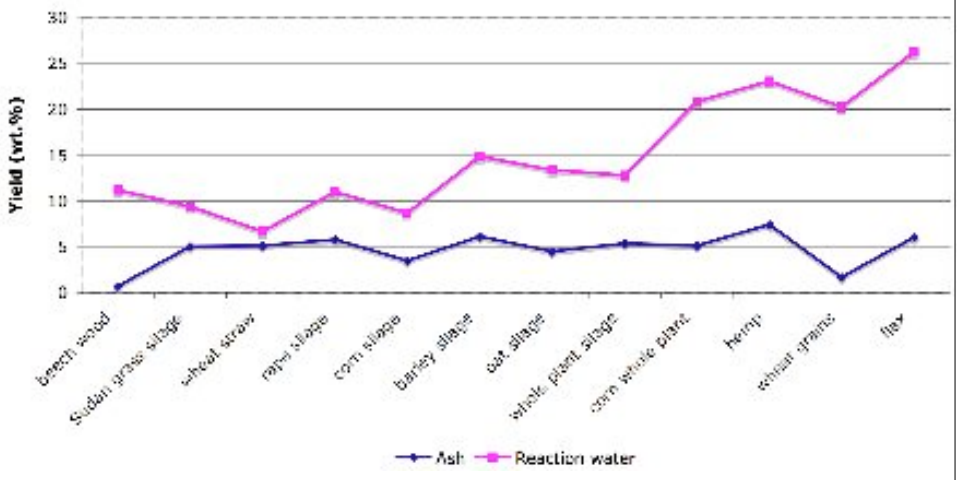
Yields of Products Based on Dry Feedstock



Distribution of Main Chemical Groups in Bio-Oils



Ash Content vs. Reaction Water

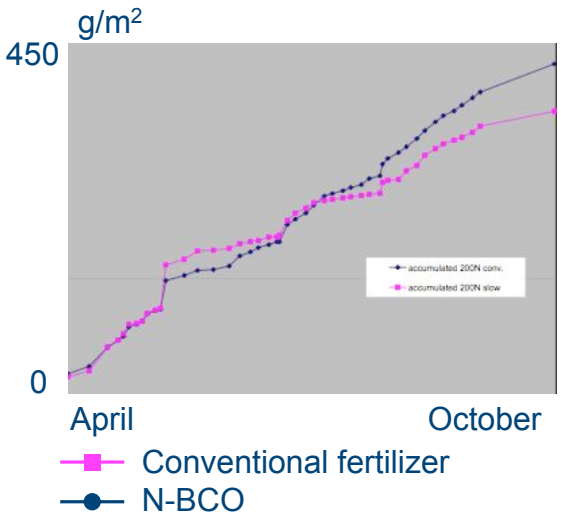


Compilation of Pyrolysis Behavior and Phase Separation

Material	Feeding	Behaviour in LFBU	Oil Phases
Beech wood	+++	++	single
Rape silage	--	++	single
Sudan grass silage	+++	+++	single
Wheat straw	+	+++	multiple
Wheat groats	++	--	multiple
Barley silage	+	+++	multiple
Oat silage	-	+	multiple
Corn whole plant	+	---	multiple
Corn silage	++	+++	multiple
Whole plant silage	++	++	multiple
Hemp/Flax press cakes	++	--	multiple

N-modified BCO

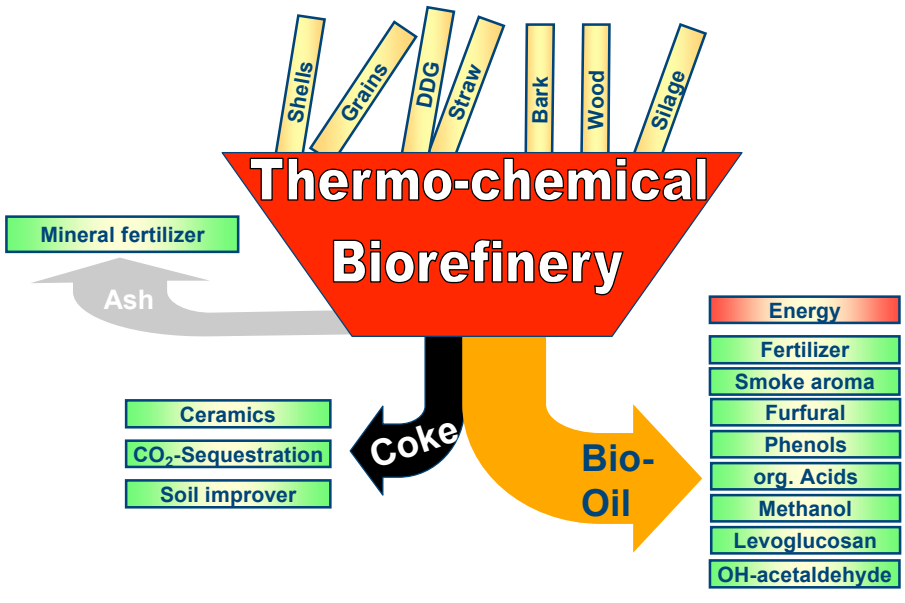
N-modified BCO



The Potential Role of Fast Pyrolysis

- Part of a **ethanol-based bio-refinery** based on residue pyrolysis for fuel and/or chemicals
- Incorporation into a gasification and chemicals/fuel **synthesis plant**
- **Stand-alone facilities** with distributed production and centralized processing and refining
- **Part of a petroleum refinery** with distributed production and centralized processing

„Zero-waste“ Concept




Thank You!