An integrated lignin biorefinery: Scaling-up lignin depolymerization technology for biofuels and chemicals

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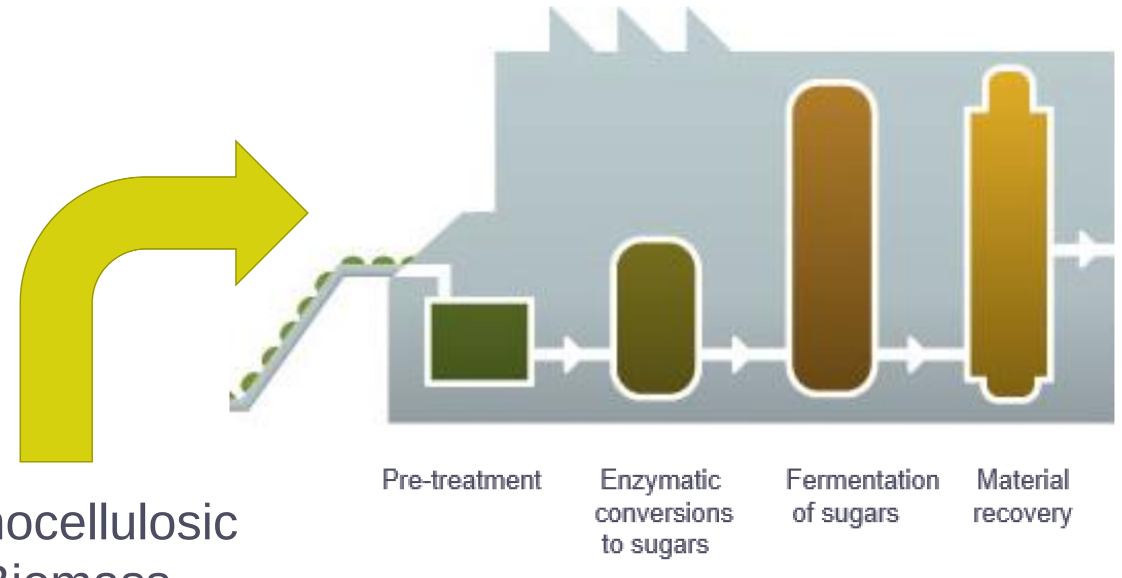
Lignin RICHES (Resins Chemicals Fuels)

Lignin is one of the major components of lignocellulosic biomass, constituting 15-30 % of the weight and approximately 40 % of the energy content depending on the source. Currently the lignin produced in 2G bio-ethanol plants is mainly used for on-side energy production. At Eindhoven University of Technology a method was explored to depolymerize lignin in super critical ethanol with cheap non-noble catalysts to produce a mixture of monomeric aromatics. The product might be applied directly as a bio marine fuel, or as a source for chemical building blocks (Resins), octane boosters or biofuels when blended with gasolines. The primary goal for pilot activities is to produce Lignin Crude Oil (LCO) from lignin with a viscosity spec < 800 cSt at 40 °C, on a ton scale and to collect information for designing a demo plant with the aim of having an economically viable process.

2G Bio-ethanol plants



Lignocellulosic Biomass

Lignin

Ethanol

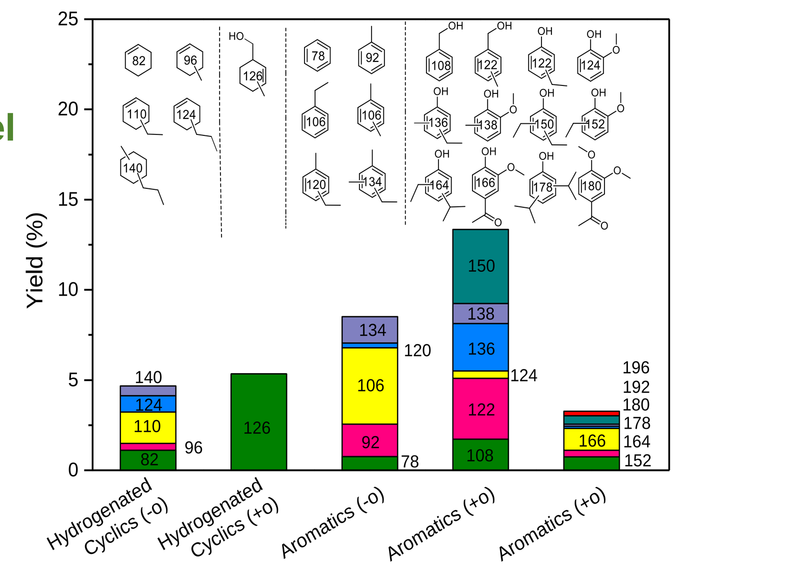
TU/e technology

Catalytic Depolymerization
scETOH + catalyst CuMgAlOx

▪Sulfur-free marine fuel
▪Fuel boosters

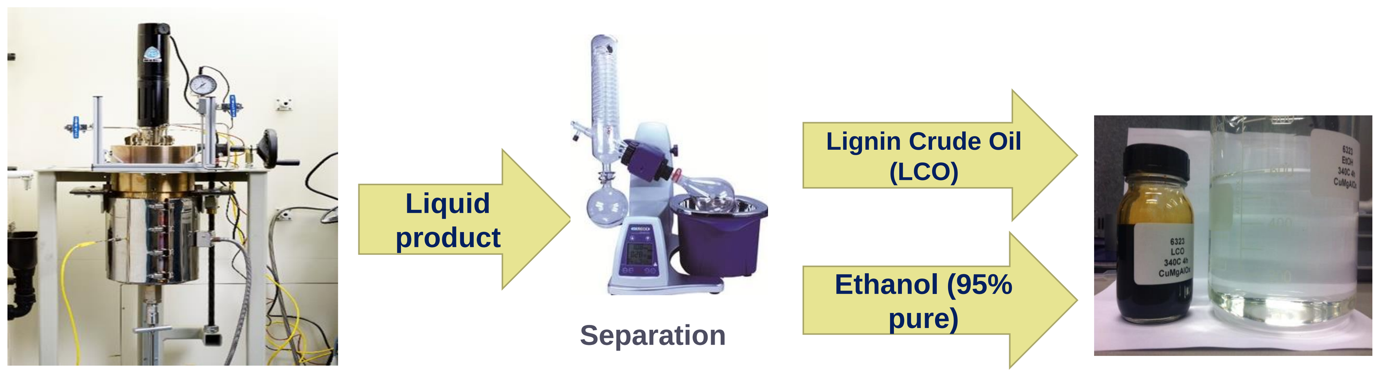
Lignin Crude Oil

▪Resins
▪Phenols



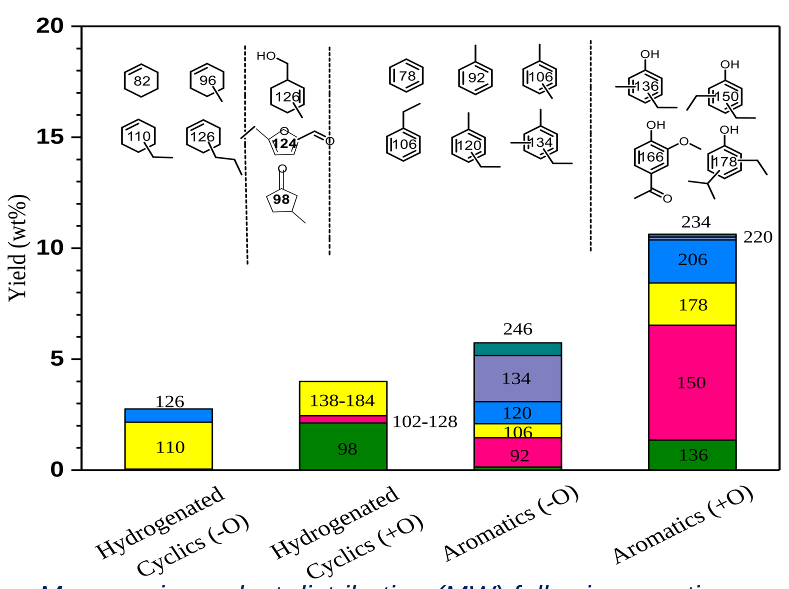
Monomeric product distribution (MW) following reaction at 340 °C/ 4h with 1:40 lignin:EtOH ratio, in 50 ml autoclave reactor

Scale-up reactions

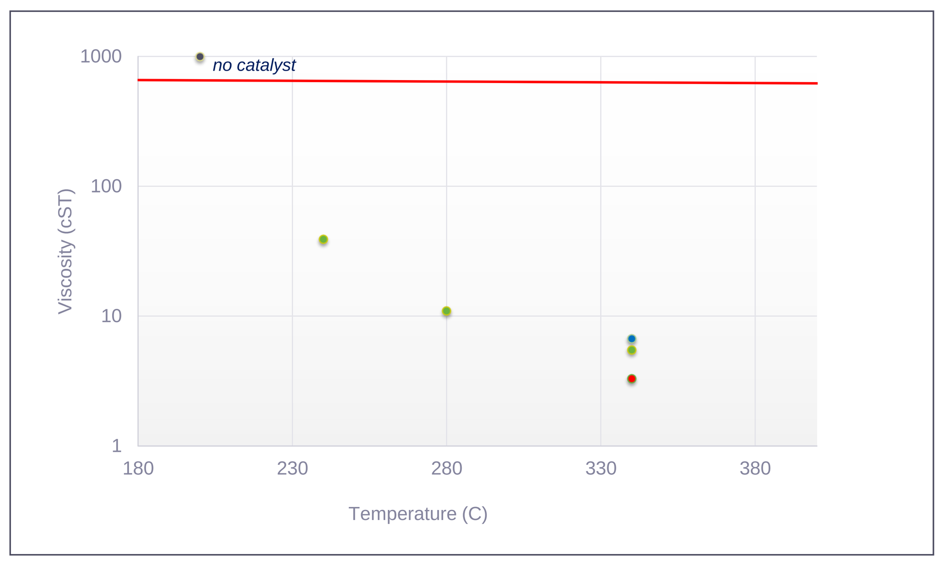


Temp [°C]	Lignin:EtOH ratio (w/v)	Monomer Yield (wt%)	LCO viscosity @40°C (cST)	Ethanol conversion (wt%)
200 (no cat)	1:40	1	>1000	4
240	1:40	1	39	12
280	1:40	3	11	21
340	1:40	11	5,5	53
340	1:30	14	3,3	46
340	1:20	25	6,7	47

Conditions: Lignin (20-50 g) , CuMgAlOx (10-25g), Ethanol (800-1200 ml), Lignin:EtOH ratio : **1:40 -1:10**
4L Autoclave reactor, t=4h



Monomeric product distribution (MW) following reaction at 340 °C with 1:20 ratio, in a 4L reactor



Kinematic viscosity of LCO over different reaction temperatures (red line: maximum viscosity limit)

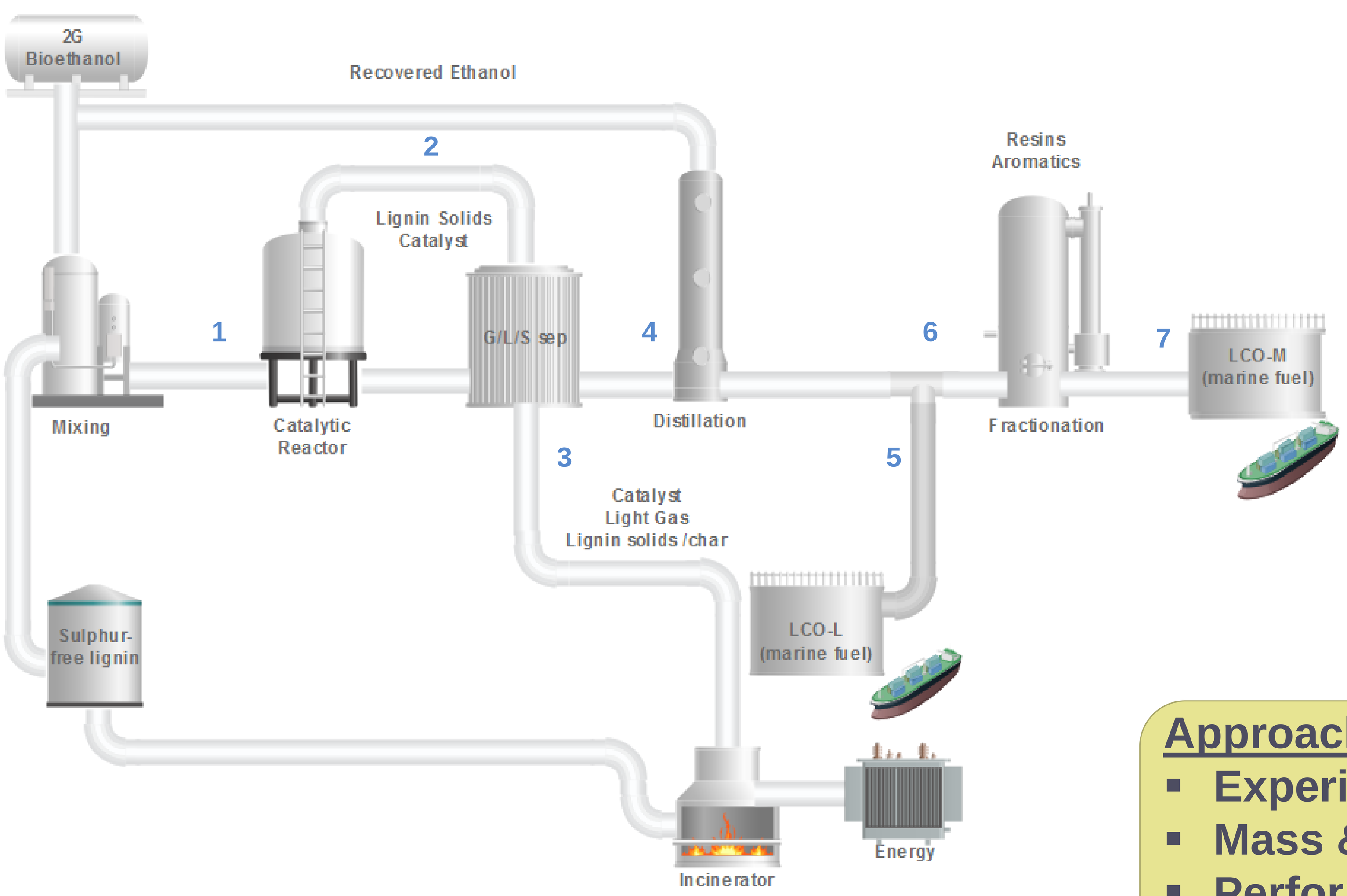
	Elemental analysis					GHV	Viscosity
	Oxygen(%)	Carbon(%)	Hydrogen(%)	Nitrogen(%)	Sulphur(%)	GJ/tn	cST
LCO 1:20	15,5	73,4	10,3	0,8	0	38,1	6,7

- **High monomer yield is important for the LCO fractionation process (resins and phenols)**
- **Gross Heating Value (GHV) and viscosity specifications are crucial for marine fuel application**
- **Ethanol conversion products are contributing to decreasing the LCO viscosity to very low levels**

Piloting

Process steps

1. Feed lignin / ethanol to catalytic reactor
2. Re-use catalyst / unconverted lignin
3. Burn catalyst / gas products / char for energy production
4. Liquid stream for separation process
5. Lignin Crude Oil production directly for low viscosity marine fuel (LCO-L)
6. Downstream process of LCO for resins application
7. More concentrated LCO for marine fuel application (LCO-M)



Design Challenges

- ❖ Process complexity
- ❖ Batch vs continuous
- ❖ Operating window
- ❖ Lignin / catalyst loading
- ❖ Ethanol conversion
- ❖ Reactor design
- ❖ Catalyst regeneration
- ❖ Separation steps
- ❖ Ethanol concentration in LCO
- ❖ Ethanol losses in the process

Approach

- **Experimental data ⟺ input for process design**
- **Mass & energy balances for all process streams**
- **Perform techno-economical study**
- **Optimize the most feasible process routes**

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