Catalytic Hydrothermal Conversion of Wet Biomass Feedstocks and Upgrading – Process Design and Optimization

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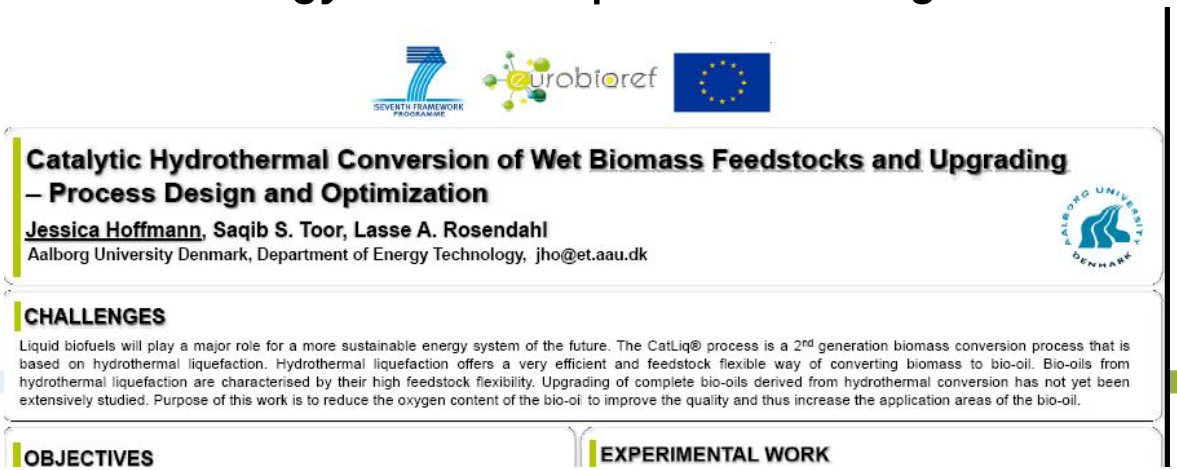
Challenges

- Bio-oil from hydrothermal liquefaction process and wet biomass feedstocks
  - High pressure process (250 bar)
  - Medium temperature process (280°C-370°C)
  - Heterogenous and homogenous catalyst
  - LHV of about 30-35 MJ/kg
  - Feedstock flexible
  - Oxygen content of about 5-20 wt.-%
  - Energy efficient process design



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CHALLENGES

Liquid biofuels will play a major role for a more sustainable energy system of the future. The CatLiq® process is a 2nd generation biomass conversion process that is based on hydrothermal liquefaction. Hydrothermal liquefaction offers a very efficient and feedstock flexible way of converting biomass to bio-oil. Bio-oils from hydrothermal liquefaction are characterised by their high feedstock flexibility. Upgrading of complete bio-oils derived from hydrothermal conversion has not yet been extensively studied. Purpose of this work is to reduce the oxygen content of the bio-oil to improve the quality and thus increase the application areas of the bio-oil.

OBJECTIVES

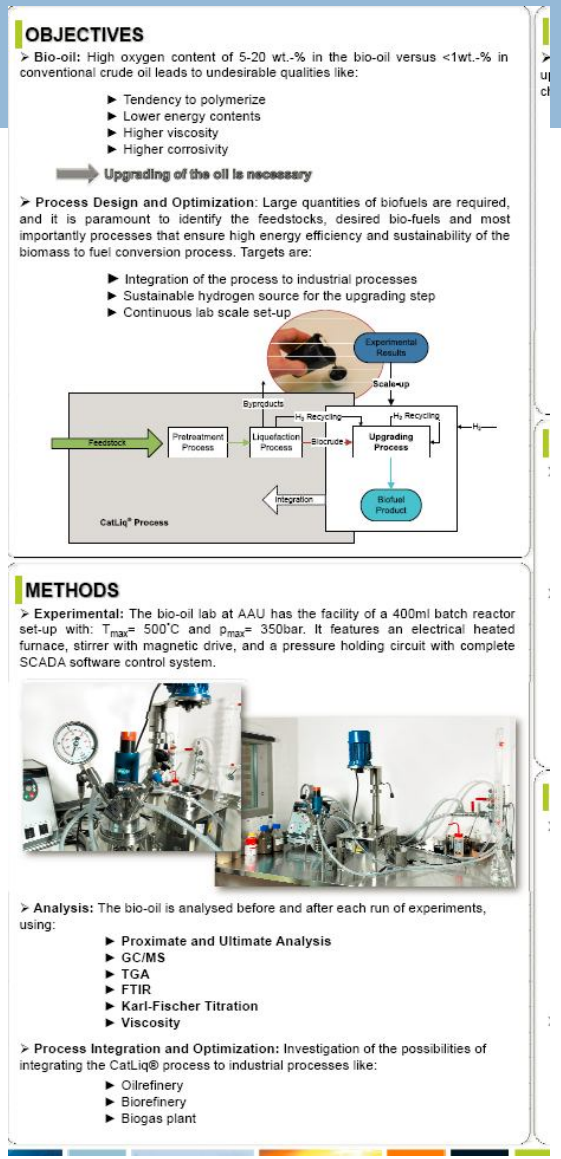
EXPERIMENTAL WORK

Objectives/Methods

- Use of the bio-oil as transportation fuel
  - Lower negative properties
  - Lower the oxygen content

  → Hydrodeoxygenation of the oil through hydrotreating

- Develop an Energy Efficient Process
  - Process integration of the upgrading step and integration of the conversion and upgrading process to (existing) industrial processes (e.g. Biogas plant)



OBJECTIVES

➢ **Bio-oil:** High oxygen content of 5-20 wt.-% in the bio-oil versus <1wt.-% in conventional crude oil leads to undesirable qualities like:

- ► Tendency to polymerize
- ► Lower energy contents
- ► Higher viscosity
- ► Higher corrosivity

Upgrading of the oil is necessary

➢ **Process Design and Optimization**: Large quantities of biofuels are required, and it is paramount to identify the feedstocks, desired bio-fuels and most importantly processes that ensure high energy efficiency and sustainability of the biomass to fuel conversion process. Targets are:

- ► Integration of the process to industrial processes
- ► Sustainable hydrogen source for the upgrading step
- ► Continuous lab scale set-up

METHODS

➢ **Experimental:** The bio-oil lab at AAU has the facility of a 400ml batch reactor set-up with: T_{max}= 500°C and p_{max}= 350bar. It features an electrical heated furnace, stirrer with magnetic drive, and a pressure holding circuit with complete SCADA software control system.

➢ **Analysis:** The bio-oil is analysed before and after each run of experiments, using:

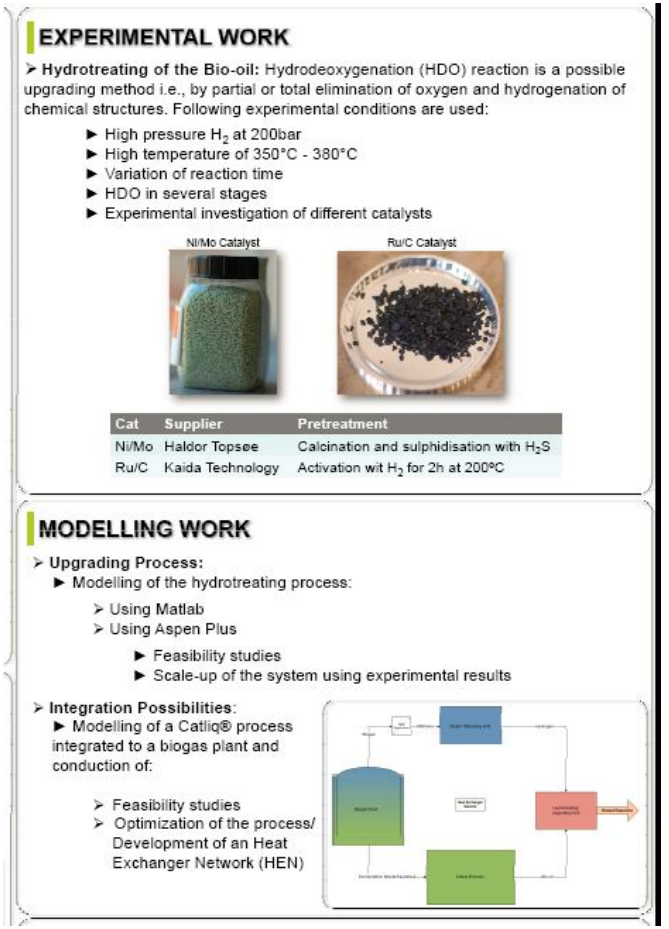
- ► **Proximate and Ultimate Analysis**
- ► **GC/MS**
- ► **TGA**
- ► **FTIR**
- ► **Karl-Fischer Titration**
- ► **Viscosity**

➢ **Process Integration and Optimization:** Investigation of the possibilities of integrating the CatLiq® process to industrial processes like:

- ► Oilrefinery
- ► Biorefinery
- ► Biogas plant

Methods

- Experimental hydrodeoxygenation studies
  - Batch reactor set-up
  - NiMo and Ru/C Catalyst
- Process Modelling
  - Matlab and Aspen Plus
  - Development of HEN in Gams



EXPERIMENTAL WORK

➢ **Hydrotreating of the Bio-oil:** Hydrodeoxygenation (HDO) reaction is a possible upgrading method i.e., by partial or total elimination of oxygen and hydrogenation of chemical structures. Following experimental conditions are used:

- ► High pressure H_2 at 200bar
- ► High temperature of 350°C - 380°C
- ► Variation of reaction time
- ► HDO in several stages
- ► Experimental investigation of different catalysts

Ni/Mo Catalyst

Ru/C Catalyst

Cat	Supplier	Pretreatment
Ni/Mo	Haldor Topsøe	Calcination and sulphidisation with H_2S
Ru/C	Kaida Technology	Activation wit H_2 for 2h at 200°C

MODELLING WORK

➢ **Upgrading Process:**

- ► Modelling of the hydrotreating process:
  - ➢ Using Matlab
  - ➢ Using Aspen Plus
    - ► Feasibility studies
    - ► Scale-up of the system using experimental results

➢ **Integration Possibilities:**

- ► Modelling of a Catliq® process integrated to a biogas plant and conduction of:
  - ➢ Feasibility studies
  - ➢ Optimization of the process/ Development of an Heat Exchanger Network (HEN)

Thank you and enjoy!