Transportation Fuels and Other High Value Products via Biomass Fast Pyrolysis

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Several routes to fuels and chemicals employing fast pyrolysis

1. Thermal fast pyrolysis and hydrotreatment of bio-oil
2. Bio-oil gasification and synthesis
3. Bio-oil co-refining with mineral oils
4. Catalytic fast pyrolysis (hydrotreatment of bio-oil)
5. Fractionation and upgrading of bio-oil groups selectively
Strategy based on phased implementation

1. Industrial demonstration of biomass fast pyrolysis fuel oil
2. Development of upgrading technologies
3. Phased construction of biofuel production capacity

- Due to smaller initial investments
  - Reduced risk for investors
  - More potential investors
Fast Pyrolysis for Bio-Fuel Oil - Scale-Up

**EARLY FAST PYROLYSIS BENCH-SCALE**
- Canada, USA
- IEA Bioenergy Assessments

**FIRST EUROPEAN PILOTS 1994-2000**
- Two Canadian, one Finnish technology
- Continuous operation verified
- Operated by European utilities

**SCALE-UP 2004 - 2015**
- ENSYN in Canada
- BTG in Malaysia
- Valmet 2008
- Fortum Demonstration 2014
- BTG Demonstration 2015

Timeline:
- 1985
- 1990
- 1995
- 2000
- 2005
- 2010
- 2015
- 2020
- 2025

Countries and Technologies:
- UNION FENOSA, SPAIN
- ENEL, BASTARDO, ITALY
- VALMET, TAMPERE, FINLAND
- FORTUM, PORVOO, FINLAND
- Fortum Demonstration - Joensuu, Finland

IEA Bioenergy Collaboration

IEA Bioenergy Assessments
Fast pyrolysis (FP) and hydrotreatment (HDO) of bio-oil
FP Bio-Oil HDO - First patent filed 1987*

- Pioneering work at PNNL
- PNNL active continuously – a recognized authority on the field
- VTT is collaborating with PNNL
  - Tekes/US DoE funded work**
  - US DoE funded projects***
  - Researcher and sample exchange

***Elliott D.C., Production and Upgrading of Infrastructure Compatible Bio-Oil with VTT. DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review March 25, 2015
Thermal fast pyrolysis – gasification (distributed)
The Karlsruhe bioliq® Process

Integrated Processes to Produce Synthetic Fuels and Bulk Chemical Products from Dry Residual Biomass

http://www.bioliq.de/english/177.php
Co-gasification of black-liquor and FP bio-oil - The incremental investment compared to upgrade recovery boiler

*MeOH selling price 984 €/ton and no taxes considered
Co-refining fast pyrolysis bio-oil in mineral oil refineries

VTT, U of Twente, Shell GSI, CNRS, ARKEMA, BTG, UHPT, Metabolic Explorer, Innventia, U of Groningen, Helsinki U of Technology, TI, Slovenian Institute of Chemistry, Boreskov Institute of Catalysis, ALMA, Albemarle, CHIMAR, Technical U of Eindhoven

http://www.biocoup.com/


FCC co-refining addressed by Albemarle, Grace, UOP, Shell GSI, Petrobras, Ensyn, Fibria, et al

- Typically hydrotreated fast pyrolysis bio-oils co-refined


FCC demonstration-scale unit

- Petrobras first to claim successful co-refining of non-hydrotreated FP bio-oil in a FCC.
- The catalyst inventory was 450 kg, and the total feed rate was controlled at 150 kg/h.
- However, a high amount of phenolic compounds was also detected in the naphtha produced.

A Pinho et al., Co-processing raw bio-oil and gasoil in an FCC Unit. Fuel Processing Technology 131 (2015) 159–166
Catalytic fast pyrolysis
Catalytic fast pyrolysis addressed by CERTH, Albemarle, Grace, UOP, KiOR et al

- Early development at the University of Waterloo (prof Scott et al)
- CERTH an early promoter of the technology
- Interest towards CFP increased considerably after KiOR 2007
- VTT demonstrated continuous operation with catalyst regeneration in pilot-scale 2013*
- KiOR failed in scale-up

VTT Fast Pyrolysis
Pilot 0.5 tpd

Catalytic reactor
Regenerator
Liquid recovery
Thermal and Catalytic Fast Pyrolysis to High Value Fuels

The unit is industrial
The unit is in pilot scale
The unit is at laboratory scale
The unit is largely untested
Production Cost as a Function of Plant Size

Thermal vs catalytic pyrolysis

Centralized vs de-centralized concepts
Brasilian industrial example: Production costs are reduced while the amount produced is increased
Fractionation and upgrading of bio-oil groups selectively
Thermal Fast Pyrolysis Bio-Oil Characteristics

Bio-Oils to Be Co-Refined at Oil Refineries

INTEGRATED PYROLYSIS

Wood → FP bio oil → HDO → FCC

Black-liquor crude oil

Refinery products

Chemicals
Conclusions
Summary

- Fast pyrolysis offers **several routes** for higher returns
- Potential for **distributed production** of bio-oil with centralized upgrading
- Potential for **phased implementation** of biofuels and chemicals, which reduces risks for investors (first intermediate products will be demonstrated, and other value chains will be based on previous experience)
- Hydrothermal liquefaction (HTL) of **kraft liquor** would complement the distributed biofuel concept
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Palkittu menetelmä perustuu pyrolyysi- ja leijupolttotehokkaiden yhdistämiseen. Sen ansiosta bioöljyn tuotantovolyymihin voidaan odottaa merkittävää lisääntymistä tulevina vuosikymmeninä.