Co-Processing for Refinery Integration of Biofuels Production

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An independent, Norwegian Research Institute
Process Technology: Micro to full Pilot

- High Throughput
- Micro-Structured
- CCS Full Pilot
- Tiller Sustainability Pilot Lab
- Refinery Mini Pilot
Background

- Need for rapid scale-up of production of biofuels to meet the current climate mitigation targets for transport sector
- The focus on drop-in fuels seen as a route to meet these targets based on using current transport infrastructure
- The integration with existing European refinery infrastructures could fulfil this potential through co-integration, co-processing, co-refining
  - Reduce the capital cost
  - Build on existing processes
  - Integrate with existing value chains
EU funded Projects research in Co-Processing

**Municipal Waste as feedstock toward co-processing in Refinery**

**Lignocellulose feedstock toward co-processing in Refinery**

**Gasification and Pyrolysis routes for Biofuels production**

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Co-processing Challenge: Oxygen Removal + Energy densification

Biomass

Bio crude

Fuel

Decreasing Oxygen Content

Decreasing Molecular weight

Complex solid Feedstock

Liquefaction Processes

Refinery Processes

Drop in Fuel

**4refinery Strategy**

**Diversity of Biomass**
- Wood
- Straw
- Eucalyptus

**Complementary Liquefaction technologies**
- Pyrolysis
- HTL

Integration with refinery
4refinery Strategy

Diversity of Biomass

Wood

Straw

Eucalyptus

Complementary Liquefaction technologies

Pyrolysis

HTL

Integration with refinery

Public Acceptance

Business Case
Supply chain & market assessment – Feedstock

- Biomass supply chains are relatively immature at present - vary by feedstock and region.
- Common challenges:
  - The large amounts of biomass needed lead to expensive transportation costs.
  - Introducing variability (source location) into the process complicates supply chain logistics and affects the quality and yield of the conversion process.
  - Local assessment of feedstock availability needs to be performed on case by case basis to determine true level of feedstock availability.

CONTENT
- Supply chain structure
- Supply chain security
- Supply chain costs

OBJECTIVES
- Estimate feedstock costs and sensitivities
- Define supply chain logistics (to identify potential suppliers/partners, and infrastructure requirements)

OUTCOME
- Sustainable technical potential of harvesting residues in the EU in 2030 (dry mass)
Integration to existing Refineries

4refinery - Scenarios for integration of bio-liquids in existing REFINERY processes

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Alternative routes of bio-liquids in refinery

- Two primary conversion processes
  - Pyrolysis
  - HydroThermal Liquifaction (HTL)

- Four refining processes
  - Co-Fluidized Catalytic Cracking (Co-FCC)
  - Co-HydroTreating (Co-HT)
  - Co-HydroDeOxygenation (HDO)
  - HydroTreating (HT)

- Final products
  - Gasoline
  - Diesel
  - LPG
Upgrading: Optimising Oxygen for integration

**Pyrolysis Liquid**

- C<sub>daf</sub>: 57.4 wt.%
- H<sub>daf</sub>: 6.1 wt.
- O<sub>daf</sub>: 36.5 wt.
- H<sub>2</sub>O: 22.5 wt.

**Stabilisation**

- 350 kg water
- 150 kg gas
- 150 kg water

- Catalyst: Picula NiCuMo5P

**Partial Deoxygenation**

- Optimisation: H<sub>2</sub>

**Stabilized Deoxygenationed Oil**

- C<sub>daf</sub>: 86.1 wt.
- H<sub>daf</sub>: 12.5 wt.
- O<sub>daf</sub>: 1.2 wt.
- H<sub>2</sub>O: 0.2 wt.
Techno-Economic Evaluation building MODELS for range of alternatives for Refinery integration
Techno-Economic Evaluation building MODELS for range of alternatives for Refinery integration

Stabilization model

Deoxygenation model

FCC models

Hydrotreater models

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Feedstock/Location: Final selection of value chains

- **Forest residue:**
  - Northern Europe
  - Baltics
- **Eucalyptus:**
  - Southwestern Europe (Spain)
- **Straw:**
  - Central Europe
  - Denmark

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**4refinery - Scenarios FOR integration of bio-liquids in existing REFINERY processes**

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## Scenario analysis:
### Ranking of Technical and Economic feasibility

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Post-treatment</th>
<th>Final refining</th>
<th>Raw material</th>
<th>Location</th>
<th>Technical feasibility</th>
<th>Economic feasibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrolysis</td>
<td>Stabilisation</td>
<td>co-FCC</td>
<td>Forest residue</td>
<td>Baltics</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Forest residue</td>
<td>Northern Europe</td>
<td>++</td>
<td>++</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Eucalyptus</td>
<td>Spain</td>
<td>+</td>
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<td></td>
<td></td>
<td></td>
<td>Straw</td>
<td>Central Europe</td>
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<td>+++</td>
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<td></td>
<td></td>
<td></td>
<td>Straw</td>
<td>Denmark</td>
<td>---</td>
<td>+</td>
</tr>
<tr>
<td>Stabilisation/Deoxygenation</td>
<td>co-FCC</td>
<td>Forest residue</td>
<td>Baltics</td>
<td>++</td>
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<td>co-FCC</td>
<td>Forest residue</td>
<td>Northern Europe</td>
<td>+++</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>co-HT</td>
<td>Forest residue</td>
<td>Baltics</td>
<td>-</td>
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<tr>
<td></td>
<td>co-HT</td>
<td>Forest residue</td>
<td>Northern Europe</td>
<td>-</td>
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<tr>
<td></td>
<td>co-HDO</td>
<td>Forest residue</td>
<td>Baltics</td>
<td>+++</td>
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<tr>
<td>HTL</td>
<td>-</td>
<td>HT</td>
<td>Forest residue</td>
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</tbody>
</table>

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### Evaluating Business Cases for scenarios

<table>
<thead>
<tr>
<th>Business Case</th>
<th>Raw Material</th>
<th>De-centralised Pre-processing</th>
<th>Refinery Processing</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCC-1</td>
<td>Forest Residue</td>
<td>Fast Pyrolysis N plant(s)</td>
<td>FCC</td>
<td>Gasoline</td>
</tr>
<tr>
<td>HTL-1</td>
<td>Forest Residue</td>
<td>HTL 1 plant</td>
<td>HT</td>
<td>Diesel</td>
</tr>
<tr>
<td>HT-1</td>
<td>Forest Residue</td>
<td>Fast Pyrolysis N plant(s)</td>
<td>UPGR 1 plant</td>
<td>HT</td>
</tr>
</tbody>
</table>
Overall Conclusions (1)

- There is significant potential to make use of existing EU refineries.

- HTL less mature than FP – Still technical challenges to be tackled in the near-future.

- Co-HT less mature than co-FCC - but there are significant mid-to-long-term opportunities for co-HT:
  - The aviation and shipping industries present a longer-term market for co-processed fuels.
  - Support and initiative focused on SAF and sustainable shipping.
Overall Conclusions (2)

- Lignocellulosic biomass supply chains are relatively immature at present, though vary by feedstock and region.
  - EU has high feedstock potential but local level feedstock assessments will be needed to determine the true level of feedstock availability
  - Decentralised primary conversion steps can simplify the supply chain
- Competitive pricing is the main factor for the market integration of co-processed fuels

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Public acceptance - Overall Findings

- The public is in general found to be **supportive of biofuels**, although public knowledge and understanding of biofuels is found to be limited.

- Thus, **public opinion is vulnerable to dominant discourses and media frames** and can be **swayed** by these.

- **Knowledge is found to be a key element in the shaping of public opinion**, and awareness of unintended consequences of biofuel implementation diminishes public support.

- Some **potential drawbacks** related to biofuels, such as land requirements, iLUC (indirect land use change), and biodiversity impacts, **seem to be seldom understood by the public**, which raises the **importance of knowledge** increase and a **factual transparency** of these critical aspects.

- This becomes increasingly important as large scale production of biofuels are developed.

- Balanced and transparent reporting of involved risks and benefits will be key to continued **public support** and a **stable investment-environment**.
Final developments: Toolbox for scenario analysis

- Based on database and models developed in the 4Refinery Project
- To be accessible for scenario analysis
Acknowledgements to 4Refinery Consortium

Process Model and Techno-Economis

- Sustainability
- Liquefaction Processes
- Bio-crude
- Refinery Processing Technologies
- Advanced Biofuel

Public Acceptance
Business Models

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Thank you for your attention!

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