Using energy systems analysis to compare cross-dimensional performance of biofuel production

Bio4Energy researchers meeting
16 October 2018, Umeå

Elisabeth Wetterlund, Energy Engineering, LTU
Comparing long and short term biofuel production pathways

- Swedish Energy Agency priorities
  - Short-term: refinery based
  - Long-term: gasification and/or biochemical
  - Existing infrastructure vs. efficiency

- Project funded by f3 and Energy Agency
  - Bio4Energy (LTU), IVL, RISE, Preem
# Biofuel production pathways

<table>
<thead>
<tr>
<th>Liquefaction – hydrotreatment</th>
<th>Gasification – catalytic synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kraft lignin</strong></td>
<td></td>
</tr>
<tr>
<td>Case 1. MSL-HDO</td>
<td>Case 2. BLG</td>
</tr>
<tr>
<td>Lignin separation, depolymerisation, hydrotreatment</td>
<td>Black liquor gasification, catalytic synthesis</td>
</tr>
<tr>
<td><strong>Forest residues</strong></td>
<td></td>
</tr>
<tr>
<td>Case 3.</td>
<td>Case 4. BMG</td>
</tr>
<tr>
<td>Forest residues pyrolsysis, oil upgrading</td>
<td>Forest residues gasification, catalytic synthesis</td>
</tr>
<tr>
<td>a) HDO based, <strong>3a Pyr-HDO</strong></td>
<td></td>
</tr>
<tr>
<td>b) FCC based, <strong>3b Pyr-FCC</strong></td>
<td></td>
</tr>
<tr>
<td>c) Hydropyrolys, <strong>3c Hydropyr</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Gasoline, diesel</strong></td>
<td><strong>Methanol</strong></td>
</tr>
</tbody>
</table>

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**Note:**
- **MSL-HDO:** Milled softwood lignin hydrodeoxygenation
- **BLG:** Black liquor gasification
- **HDO:** Hydrodeoxygenation
- **FCC:** Fluid Catalytic Cracking
- **Pyr:** Pyrolysis
- **Hydropyr:** Hydropyrolys
- **HDO based, Pyr-HDO:** Hydrodeoxygenation based on pyrolysate
- **FCC based, Pyr-FCC:** Fluid Catalytic Cracking based on pyrolysate
- **Hydropyr:** Hydropyrolys based on pyrolysate
Approach

Best available data → "Grey box" modelling integrated prod. → Mass and energy balances → OPEX estimation

Energy market scenarios → Investment margin

Profitability assessment → Investment requirement

CAPEX estimations → RED (Renewable Energy Directive) System expansion

Product yield and system efficiency → Production potential → Technological maturity

Feedstock potentials → TRL estimations
Approach

- Best available data
  - "Grey box" modelling integrated prod.
    - Mass and energy balances
      - OPEX estimation
        - Investment margin
          - Energy market scenarios
            - Profitability assessment
              - Investment requirement
                - CAPEX estimations
                  - RED (Renewable Energy Directive) System expansion
                    - Product yield and system efficiency
                      - Production potential
                        - Technological maturity
                          - CROSS-DIMENSIONAL PERFORMANCE
                            - Investment requirement
                              - Feedstock potentials
                                - TRL estimations
Profitability assessment
1) production cost estimation

- Methanol/ethanol ~810 SEK/MWh
- HVO ~710 SEK/MWh

Specific investment margin

Biomass
Catalysts and chemicals
Electricty
Hydrogen
Fuel oil
Fossil Production

Total Prod. Costs
Profitability assessment
2) investment cost estimations

Andersson et al [10]
Jones et al [74]
Dutta et al [100]
Benjaminsson et al [69]
Jones et al [74]
Tan et al [31]
Meerman and Larson [103]
Hannula and Kurkela [86]
Udengaard et al [85]

BLG Pyr-HDO Pyr-HDO Pyr-FCC Pyr-FCC HydroPyr HydroPyr BMG BMG

Specific Investment Margin
Annual Spec. Invst. Cost

N\textsuperscript{th} of a kind (NOAK)

Recent CAPEX data from Biozin project (IH2)
~3500 MSEK for 120,000 m\textsuperscript{3}/y
Profitability assessment

2) investment cost estimations

First of a kind (FOAK)

- Anheden et al [32]/Tews et al [99]
  - MSL-HDO, 34 MW
- Andersson et al [9]
  - BLG, 110 MW
- Meerman and Larson [103]
  - HydroPyr, 493 MW

recent CAPEX data from Biozin project (IH2)
~3500 MSEK for 120,000 m³/y
Carbon footprint

Calculated according to RED (Renewable Energy Directive)

70% reduction

- Fuel oil
- Wood chips
- Hydrogen
- Electricity
- Total

1 MSL-HDO  2 BLG  3a Pyr-HDO  3b Pyr-FCC  3c Hydropyr  4 BMG
Production potential – in Sweden

<table>
<thead>
<tr>
<th>Process</th>
<th>TWh biofuel per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MSL-HDO</td>
<td>10</td>
</tr>
<tr>
<td>2 BLG</td>
<td>25</td>
</tr>
<tr>
<td>3a Pyr-HDO</td>
<td>15</td>
</tr>
<tr>
<td>3b Pyr-FCC</td>
<td>10</td>
</tr>
<tr>
<td>3c Hydropyr</td>
<td>25</td>
</tr>
<tr>
<td>4 BMG</td>
<td>30</td>
</tr>
</tbody>
</table>

- FCC capacity limiting
- Black liquor limiting
- Forest residues limiting

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Technology maturity

Weighted average TRL

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<tr>
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<th>Pyr-HDO</th>
<th>Pyr-FCC</th>
<th>Hydropyr</th>
<th>BMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>4</td>
<td>9</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>4</td>
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"Weakest link" TRL

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<tr>
<td>1a</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3c</td>
<td>4</td>
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# Cross-dimensional performance

<table>
<thead>
<tr>
<th></th>
<th>Energy efficiency</th>
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<th>Technology maturity</th>
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</table>
| **1 MSL-HDO**  
Lignin depol. + HDO  
→ petrol/diesel | +            | +            | +                     | 0               | 0               | -                   |
| **2 BLG**  
Black liquor gasification  
→ methanol | +            | +            | 0/-                   | +               | +               | +                   |
| **3a Pyr-HDO**  
Fast pyrolysis + HDO  
→ petrol/diesel | 0            | -            | -                     | +               | -               | 0                   |
| **3b Pyr-FCC**  
Fast pyrolysis + FCC-co-proc.  
→ petrol/diesel | -            | -            | +                     | -               | +               | +                   |
| **3c Hydropyr**  
Hydropyrolysis IH2  
→ petrol/diesel | 0            | +            | +                     | +               | +               | 0                   |
| **4 BMG**  
Forest residue gasification  
→ methanol | 0            | +            | +                     | +               | +               | +                   |
## Cross-dimensional performance

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<td>+</td>
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**ONGOING PROJECT**

<table>
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<tr>
<th>F3/EM</th>
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<td>Bio4Energy/LTU, RISE, Södra Cell, Smurfit Kappa, SunCarbon, Preem</td>
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**BIO4ENERGY**
Renewable fuels and systems – Program conference
”Flera filer mot framtidens drivmedel”

• Energimyndigheten + f3
• Stockholm, 22 November 2018
• Including ”pitch and match” session
Want to know more?


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