Techno-economic comparisons between the various PtL technologies
Fischer-Tropsch- vs. Methanol-Route

Steffen Voß, Stefan Bube, Martin Kaltschmitt
Motivation

• All PtL products require a synthesis step
• Syntheses enable the use of a wide variety of input materials for conversion into a wide variety of products
• In particular, high production potentials can be unlocked through PtX
• Todays focus is on carbon-based energy carrier
• Fischer-Tropsch and methanol-based production currently widely discussed
Overall Process Route

CO₂ + H₂O → CO₂ + H₂

Alkanes, Alkenes, Waxes

CO₂ + H₂ → CO₂ + H₂

Power-to-Fischer-Tropsch crude

Fischer-Tropsch Synthesis

E-Syncrude

Hydrocracking

Hydrogenation

Fractionation

Fischer-Tropsch Fuel

Hydrotreatment

Power-to-Methanol (PtM)

MeOH-Synthesis

E-Methanol

Dehydration

Oligomerization

Hydrogenation

Fractionation

Methanol-based fuel production

Short chain olefins

Long chain olefins

Paraffin
Overall Process Route

- Both production paths can be based on PtL approaches
  - Basis: Electricity, Water, CO₂
- FT route the direct formation of paraffins from synthesis gas takes place
- Synthesis (PtM) and paraffin formation takes place separately in methanol route
Process Route – Fischer-Tropsch

- High-temperature RWGS used for CO generation from CO₂
  \[ \text{CO}_2 + \text{H}_2 \rightleftharpoons \text{CO} + \text{H}_2\text{O} \quad \Delta H^0_R = 42 \text{ kJ/mol} \]
- Cobalt-catalyzed low-temperature synthesis requires \( \text{H}_2: \text{CO} \)-based syngas

\[
\begin{align*}
n \text{CO} + (2n + 1) \text{H}_2 & \rightarrow C_n\text{H}_{2n+2} + n \text{H}_2\text{O}
\end{align*}
\]

- Hydrotreatment of FT syncrude necessary
Process Route – Methanol

Methanol production

\[
\begin{align*}
\text{CO}_2 + 3\text{H}_2 & \rightleftharpoons \text{CH}_3\text{OH} + \text{H}_2\text{O} & \Delta H^\circ_{298K} &= -49 \text{ kJ/mol} \\
\text{CO}_2 + \text{H}_2 & \rightleftharpoons \text{CO} + \text{H}_2\text{O} & \Delta H^\circ_{298K} &= 42 \text{ kJ/mol} \\
\text{CO} + 2\text{H}_2 & \rightleftharpoons \text{CH}_3\text{OH} & \Delta H^\circ_{298K} &= -91 \text{ kJ/mol}
\end{align*}
\]

Methanol → Short chain olefins → Long chain olefins → Alkanes

Dehydration
- Methanol-to-Olefins; state-of-the-art for ethene and propene production

Oligomerization
- Coupling of shorter olefins to longer olefins

Hydrogenation & Fractionation
- Typical processes
Qualitatively Techno-Economic Comparison

- FT route tends to be deployable at shorter notice
- FT-Syncrude can be refined with conventional refinery technology
- Methanol route not yet regulatory applicable for a jet fuel product
- Potentially higher jet fuel selectivities and more flexible production concept in the methanol route
- With high contribution of electricity costs to total production costs leads potentially economically advantageous

<table>
<thead>
<tr>
<th></th>
<th>FT</th>
<th>MeOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity demand</td>
<td>+</td>
<td>+(+++)</td>
</tr>
<tr>
<td>Target product selectivity</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>TRL</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Feedstock availability</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Infrastructure and handling</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Flexible operation</td>
<td>0</td>
<td>++</td>
</tr>
</tbody>
</table>

+++: strongly advantageous
+: advantageous
0: neutral
-: disadvantageous
--: strongly disadvantageous

TRL: Technology Readiness Level