Decarbonising today’s methanol operations to meet tomorrow’s demands

Iain Roberts, Technology Manager – Low Carbon Solutions
Johnson Matthey
Agenda

01 Drivers for methanol decarbonisation

02 CLEANPACE™ Methanol

03 Decarbonising and debottlenecking

04 Key takeaways
01 Drivers for methanol decarbonisation

02 CLEANPACE Methanol

03 Decarbonising and debottlenecking

04 Key takeaways
Drivers for methanol decarbonisation
- drivers are increasing with opportunities for industry leaders

<table>
<thead>
<tr>
<th>Europe</th>
<th>North America</th>
<th>MEA</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High CO₂ prices – forecast to exceed €100/te before 2030</td>
<td>• US – tax credits for carbon capture (45Q)</td>
<td>• National strategies e.g.</td>
<td>• ESG goals: desire to do the right thing and demonstrate corporate responsibility to stakeholders</td>
</tr>
<tr>
<td>• EU Innovation Fund: over €38bn to invest up to 2030</td>
<td>• Canada – ETS CO₂ price will be CAN$170/t in 2030</td>
<td>• Saudi Arabia and Bahrain net zero 2060</td>
<td>• Price premium for low carbon products and market demand, e.g. maritime fuel</td>
</tr>
<tr>
<td>• Expansion of EU ETS to include maritime sector – demand for low carbon fuel</td>
<td>• US and Canada – government funding available for CCUS projects</td>
<td>• Oman and UAE net zero 2050</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• EU Carbon Border Adjustment Mechanism (CBAM) - adds cost to exports to EU from 2026</td>
<td></td>
</tr>
</tbody>
</table>
Agenda

01 Drivers for methanol decarbonisation
02 CLEANPACE Methanol
03 Decarbonising and debottlenecking
04 Key takeaways
CLEANPACE Methanol
- a differentiated carbon capture solution for methanol plants

Key features of our solution:

A pre-combustion CO₂ capture solution, combining JM’s demonstrated ADVANCED REFORMING™ experience with proven 3rd party CO₂ capture to reduce cost and technology risk

Optional:
- Steam export
- Syngas or H₂ export
JM’s **ADVANCED REFORMING** unit

**Concept**

- Offgases and NG trim fuel converted to a high hydrogen content fuel and CO₂ captured
- The low carbon fuel is used for SMR firing (+ other FHRs)
- End of pipe solution
- Minimal changes to existing MeOH plant
Benefit of CLEANPACE Methanol is high performance at low CapEx - exceptional capture rate, for multiple plants, with low-risk

- **Lower CapEx and plot space requirement** than post combustion capture
- **Economy of scale** shared CapEx with a common unit serving multiple plants
- **Flexible location** to ease implementation into an existing plant site
- **up to 95%** CO₂ emission reduction
- Using only **well proven** technologies at scale
- Can be combined with **capacity expansion** to support increased methanol demand
<table>
<thead>
<tr>
<th>Agenda</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
</tr>
<tr>
<td>02</td>
</tr>
<tr>
<td>03</td>
</tr>
<tr>
<td>04</td>
</tr>
</tbody>
</table>
Decarbonising and debottlenecking - through CLEANPACE Methanol

- The SMR is often the restriction to capacity expansion
  - CO₂ co-feed could achieve up to ~20% expansion (using excess H₂ from SMR)
- Studies(1) show debottlenecking with extra syngas, could achieve 30% expansion
  - The extra syngas can be provided by the CLEANPACE unit

Thus decarbonisation AND capacity expansion, can be achieved

---

1. E.g. IMTOF 2019 - IMC's efficiency enhancement project exceeding the target
Case study
- using syngas from CLEANPACE unit to achieve 30% debottleneck

➢ TWO CASES ANALYSED

1) CLEANPACE only
2) CLEANPACE + 30% debottleneck

➢ For Case 2, the following modifications are assumed:
  • Once through converter
  • Parallel distillation

➢ BASIS

• 3000 MTPD (from natural gas)
• Middle East – no carbon tax
• Scope 1 = 0.8 teCO₂/teMeOH
• CLEANPACE CO₂ capture = 90%
• 50% export to EU => CBAM impact
• No premium for low carbon methanol
• Sales margin $200/teMeOH
Case study results

Basis: US $ / Natural gas 1.5 $/MMBTU / Power 0.05 $/kWh / CO₂ T&S $15/teCO₂

<table>
<thead>
<tr>
<th></th>
<th>Case 1 Decarbonisation</th>
<th>Case 2 Decarbonisation + Debottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ tax – CBAM ($/teCO₂)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>CO₂ to storage (kte/year)</td>
<td>720</td>
<td>720</td>
</tr>
<tr>
<td>Additional MeOH product (kte/year)</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>Incremental OpEx - CLEANPACE ($m/year)</td>
<td>-21</td>
<td>-27</td>
</tr>
<tr>
<td>CO₂ transport and storage cost ($m/year)</td>
<td>-11</td>
<td>-11</td>
</tr>
<tr>
<td>Avoided CO₂ tax - CBAM ($m/year)</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>54</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Incremental product margin ($m/year)</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Net annual cash flow ($m/year)</td>
<td>4</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>94</td>
</tr>
<tr>
<td>CapEx – ISBL + OSBL ($m)</td>
<td>220</td>
<td>350</td>
</tr>
<tr>
<td>NPV (13 year @ 9% discount rate) ($m)</td>
<td>-179</td>
<td>-8</td>
</tr>
<tr>
<td></td>
<td>-82</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>186</td>
</tr>
</tbody>
</table>
01 Drivers for methanol decarbonisation

02 CLEANPACE Methanol

03 Decarbonising and debottlenecking

04 Key takeaways
Key take aways
- for your decarbonisation journey

**CLEANPACE** Methanol is a new solution to decarbonise existing methanol plants, based on well proven technologies.

Business case for decarbonisation improves with time, as emitting CO$_2$ becomes more expensive.

There can be a positive business case **today**, when decarbonisation is combined with capacity expansion.
Thank you

Iain Roberts, Technology Manager – LCS
Sebastiaan van Haandel, Business Development Manager – LCS
Johnson Matthey