Methanol, from electrons to engines

Eelco Dekker, Chief EU Representative
Methanol Institute
Turin, June 6th, 2018
01 Who we are
A global industry association

- First formed in 1989, the Methanol Institute (MI) serves as the trade association for the global methanol industry.

- MI represents the world’s leading methanol producers, distributors and technology companies from offices around the world.

MI provides value to its members by:
- Ensuring safe handling of methanol and its derivatives
- Promoting methanol growth by furthering methanol as an essential chemical commodity and an emerging source of clean and renewable energy
- Influencing global regulatory and public policy initiatives that impact the methanol industry
2018 members
02 Trends drive change
As renewable energy increases, so does curtailment
And combustion engines remain dominant
• Power to Methanol
• Methanol fuel
03 Converting electricity to fuel
The key to Power-to-X is hydrogen
PtX and CCU are similar but not the same

1. Convert electricity to hydrogen
   - electricity → electrolysis → hydrogen

2. Convert hydrogen to fuel
   - gaseous
     - hydrogen
   - liquid
     - ammonia
     - methane
     - formic acid
     - methanol
     - butanol
     - FT diesel
     - gasoline
     - a.o.
Different shades of green

hydrogen

CO₂
The practical side of energy storage

One cubic meter of e-Methanol contains the same amount of energy as the battery capacity of 222 BMW i3’s*

*Storage capacity BMW i3 = 21.6 kWh
Methanol process requires less hydrogen

Power-to-Methanol

\[ \text{CO}_2 + 3\text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O} \]

64 w% CH\textsubscript{3}OH
36 w% H\textsubscript{2}O

1/3 difference in hydrogen

Power-to-Methane

\[ \text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \]

30 w% CH\textsubscript{4}
70 w% H\textsubscript{2}O
Increasing carbon conversion yield

C₂H₅OH
1 t/h

CO₂
1 t/h
Increasing carbon conversion yield

Ethanol production

$\text{C}_2\text{H}_5\text{OH}$
$1 \text{ t/h}$

$\text{CO}_2$
$1 \text{ t/h}$

$\text{H}_2\text{O}$ steam
$0.41 \text{ t/h}$

Methanol synthesis

$<0.7 \text{ ton CH}_3\text{OH}$ per hour

Electrolysis

$\text{H}_2$
$0.14 \text{ t/h}$

$\text{O}_2$
$1.09 \text{ t/h}$

Steam generation

$\text{H}_2\text{O}$
$1.23 \text{ t/h}$
04 Methanol fuels
Oil displacement drives growth

Source: IHS
Different stage of the life cycle

sales

DME
OME
MD95
M100
GEM
Turbines
Generators

introduction
growth
mature
decline

boilers
marine
fuel cell
cook stoves

MTBE
biodiesel
M15
M3

WWW.METHANOL.ORG
Three main segments for methanol fuels

- Gasoline blends
- Diesel substitution
- Hydrogen carrier
Methanol fuel benefits

- High octane
- Lower emissions
- Existing infrastructure
- Renewable pathways
Comparing apples to apples

<table>
<thead>
<tr>
<th>Hazard pictograms (CPL)</th>
<th>METHANOL</th>
<th>DIESEL</th>
<th>GASOLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image" alt="CPL" /></td>
<td><img src="image" alt="CPL" /></td>
<td><img src="image" alt="CPL" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signal word: (CPL)</th>
<th>METHANOL</th>
<th>DIESEL</th>
<th>GASOLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danger</td>
<td></td>
<td></td>
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</table>

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<tr>
<th>Hazard statements (CPL)</th>
<th>METHANOL</th>
<th>DIESEL</th>
<th>GASOLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>H315: Toxic if swallowed.</td>
<td>H315: May be fatal if swallowed and enters airways.</td>
<td>H315: Causes skin irritation.</td>
<td></td>
</tr>
<tr>
<td>H335: Toxic if inhaled.</td>
<td>H335: May be fatal if inhaled.</td>
<td>H335: May cause cancer.</td>
<td></td>
</tr>
<tr>
<td>H411: Causes damage to organs.</td>
<td>H417: May cause damage to organs through prolonged or repeated exposure.</td>
<td>H411: Causes skin damage.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Precautionary statements (CLP)</th>
<th>METHANOL</th>
<th>DIESEL</th>
<th>GASOLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P311: Avoid breathing the spray.</td>
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<td>P311: Avoid breathing the spray.</td>
<td></td>
</tr>
<tr>
<td>P335: If in eyes: flush with plenty of water for several minutes.</td>
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<td></td>
</tr>
<tr>
<td>P361: Skin contact: wash with soap and water.</td>
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<td></td>
</tr>
<tr>
<td>P366: Do NOT give anything by mouth.</td>
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<td>P366: Do NOT give anything by mouth.</td>
<td></td>
</tr>
<tr>
<td>P405: Avoid release to the environment.</td>
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<td>P405: Avoid release to the environment.</td>
<td></td>
</tr>
<tr>
<td>P413: Do NOT incinerate.</td>
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<td></td>
</tr>
<tr>
<td>P510: Dispose of contents/container in accordance with local/national/international regulation.</td>
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Methanol Fuels and Fire Safety

Vehicle Fire Risk
In 1986, there were 500,000 vehicle fires and 1,400 vehicle fire fatalities in the United States. Gasoline was the first material to ignite in 180,000 of these fires and many of the other fires ultimately involved gasoline. Gasoline-ignited fires in 1986 involving cars, buses, or trucks resulted in 760 deaths, 4,100 serious injuries, and $215 million in property damage.

Projections indicate that casualties would drop dramatically if methanol were substituted for gasoline as the country’s primary automotive fuel. Looking just at vehicle fires in which gasoline is the first material to ignite, a switch to methanol could save an estimated 720 lives, prevent nearly 3,900 serious injuries, and eliminate property losses of millions of dollars a year.

Methanol’s fire safety advantage over gasoline stems from several physical and chemical properties (see figures on page 3):
- LOWER VOLATILITY (Figure 1)
  Methanol does not evaporate or form vapor as readily as gasoline does. Under the same conditions, exposed gasoline will emit two to four times more vapor than will exposed methanol.
- HIGHER FLAMMABILITY REQUIREMENT (Figure 2)
  Methanol vapor must be four times more concentrated in air than gasoline vapor for ignition to occur.
- LOWER VAPOR DENSITY
  Gasoline vapor is two to five times denser than air, so it tends to travel along the ground to ignition sources. Methanol vapor is only slightly denser than air and disperses more rapidly to non-combustible concentrations.
- LOWER HEAT RELEASE RATE
  Methanol burns 25 percent as fast as gasoline and methanol fires release heat at only one-eighth the rate of gasoline fires.

These properties together make methanol inherently more difficult to ignite than gasoline and less likely to cause deadly or damaging fires if it does ignite. Methanol is the fuel of choice for Indianapolis-type race cars, in part because of its superior fire safety characteristics.

Table 6-1

<table>
<thead>
<tr>
<th>Flammability</th>
<th>M100</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Occurrence</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Open &amp; Restricted Areas</td>
<td>8 (2-4)</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative Hazard of Fire</th>
<th>Fire Severity</th>
<th>Fire Stability</th>
<th>Flammability</th>
</tr>
</thead>
<tbody>
<tr>
<td>M100</td>
<td>3</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Gasoline</td>
<td>10</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
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<thead>
<tr>
<th>Toxicity</th>
<th>Inhalation-Low Conc.</th>
<th>Inhalation-High Conc.</th>
<th>Skin Contact</th>
</tr>
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<tbody>
<tr>
<td>M100</td>
<td>3</td>
<td>10</td>
<td>9</td>
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<td>Gasoline</td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

Table adapted from Machiele, 1998; a 1-No concern, 2 to 3 = Low Level concern, 4 to 6 = moderate concern, 7 to 8 = high-level concern, 9 to 10 = extreme hazard. Numbers in parenthesis reflect hazard reductions resulting from design changes. Number in parenthesis incorporates the lowered likelihood of ingestion due to the presence of additives.

Source: Malcolm Pirnie, Inc., Technical Memorandum
Methanol has lower fire risk

Methanol
- evaporates slowly
- needs lots of vapour to burn
- confined fire zone; fires less likely

Gasoline
- evaporates fast
- needs little vapour to burn
- broad fire zone; fires more likely
Putting things in perspective

LC50 - Lethal dose for fish

Gasoline \(^{[1]}\)
8.2 mg/l

Diesel \(^{[2]}\)
65 mg/l

Methanol
15.400 mg/l

Sources:
\(^{[1]}\) Petrobras/StatOil ASA, Safety Data Sheet, ECHA registration dossier Gasoline
\(^{[2]}\) ECHA, European Chemical Agency, registration dossier Diesel
\(^{[3]}\) ECHA, European Chemical Agency, registration dossier Methanol
Moving forward
Reaching out to the automotive industry

Growing supply of low carbon methanol pathways

Methanol is part of the solution

Reaching out to automotive industry to address challenges and find solutions
06 Contacts
MSF maintains a presence in over 60 countries. Many of these countries MSF has targeted for methanol poisoning outreach programs, MSF has existing operations, to include:

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- Back up
PtX and CCU are similar but not the same

**GAS**
- H₂: Hydrogen
- N₂: Ammonia
- CO₂: Methane

**LIQUID**
- Formic acid
- Methanol
- Butanol
- FT diesel
- Gasoline
- ‘Hybrid’