03 METHANOL PRODUCTION
Conventional Methanol Production

Natural Gas → Reformer

Steam($H_2O$) → Fuel Gas

Reformer → Natural Gas (fuel)

Synthesis gas

CO + $H_2$

CO$_2$ + $H_2$

Methanol Converter

$H_2$ Purge

To Burners

To $H_2$ consumers

Methanol/Water

$CH_3OH/H_2O$

Distillation

Methanol

Water

Reformer

Distillation tower
Methanol Production – Coal Gasification

Source: Johnson Matthey
Methanol Production Bridge to Sustainability

• Methanol is a “future proof” molecule that can be made from conventional fossil sources and emerging renewable feedstocks.

• Expansion of energy markets for methanol builds demand for sustainably-sourced and locally-produced methanol.
Several Renewable Production Pathways Exist

Conventional Production

$CH_4$  $\rightarrow$  Refomer  $\rightarrow$  Reactor  $\rightarrow$  Distillation  $\rightarrow$  $CH_3OH$

Option 1: New Life for Old Assets

Option 2: $CO_2$ Recovery & Utilization

Option 3: Back to Basics

Option 4: Liquid Electricity
New Life for Old Assets

Option 1
bio-methane

[Diagram showing process: reformer, $H_2$, CO, CO$_2$, reactor, distillation, bio-methanol]
Option 1

BioMCN – Biomethane to Biomethanol
CO₂ Recovery & Utilization

Option 1

flue gas

CO₂

methane

reformer

H₂

CO

CO₂

reactor

methanol

distillation
500 MTPD of CO₂ is recovered from the flue gas using MHI’s proprietary KS–1™ solvent and injected in synthesis loop for boosting Methanol production.

- The capacity of Methanol Plant has increased by 300 MTPD with addition of CO₂ in synthesis gas mixture as excess H₂ is available for the methanol reaction.
- Thus, QAFAC’s Methanol Plant became Self–sufficient for raw material (CO₂).
CO₂ Recovery & Utilization

MHI's Flue Gas CO₂ Recovery Process

- Flue Gas Outlet
- CO₂ Purity 99.9%
- Cooling Tower Deep FGD
- Pre-treated Flue Gas
- Reboiler
- Steam
- C:W.
Back to Basics

Waste wood
Black liquor
MSW

H₂
CO
CO₂

Gasifier

Crude bio-methanol

Distillation

Bio-methanol

Option 3
Option 3

Enerkem – Waste to Methanol

World’s first commercial MSW-to-biofuels and chemicals facility

ENERKEM ALBERTA BIOFUELS

Capacity: 38 million litres per year
(i.e. 1 X standard Enerkem system)

Feedstock: 25-year agreement with City of Edmonton for 100,000 dry tonnes of MSW per year

Products: Biomethanol, cellulosic ethanol
Option 3

Chemrec - From Black Liquor to Methanol to bio-DME

- DME production capacity: 4 tons / d
- Pipe installation: ~ 10,000 m
- Hand valves & on/off valves: ~ 1,400 pieces
- Instruments: ~ 450 pieces
- Vessels: ~ 30 pieces
- Heat exchangers: ~ 25 pieces
- Process Plant Foot Print: 20 x 30 m
- Investment cost (excl gasification): ~ 22 million €

European Project BioDME
7th Framework Programme
Liquid Electricity

Option 4

electricity → electrolyzer → CO₂ capture → H₂ → CO₂ → reactor → distillation → e-methanol
Option 4

CRI Power - CO$_2$ to Methanol

Renewable Methanol Plant

Carbon Recycling International
Option 4

Pathway to Storing Renewable Electricity

- Converting intermittent renewable power into ‘liquid electricity’ is an alternative option to e-mobility, while reducing CO₂
- The amount of energy stored in one cubic meter of methanol equals the storage capacity of 222 battery-electric BMW i3’s

Source: BSE engineering

*Storage capacity BMW i3 = 21,6 kWh
NEW MARKETS
# Methanol Fuel Examples Around the World

<table>
<thead>
<tr>
<th>Application</th>
<th>Current Methanol Demand (2015E, -000-Tons)</th>
<th>Potential Market Demand (-000- Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative Fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Gasoline</td>
<td>11,571</td>
<td>40,000-50,000</td>
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<tr>
<td>- Biodiesel</td>
<td>1,197</td>
<td>25,000-40,000</td>
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<tr>
<td>- DME</td>
<td>4,970</td>
<td>10,000-15,000</td>
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<tr>
<td>- Power Generation &amp; Others</td>
<td>&gt;1</td>
<td>40,000-60,000</td>
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<tr>
<td>Fuel Cells</td>
<td>8</td>
<td>3,000-8,000</td>
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<tr>
<td>Methanol-to-Olefins</td>
<td>16,683</td>
<td>30,000-40,000</td>
</tr>
<tr>
<td>Methanol-to-Gasoline</td>
<td>250</td>
<td>15,000-35,000</td>
</tr>
</tbody>
</table>
Methanol in Gas Powered Turbines

In 2011, Israel Electric Corp (IEC) & Dor performed trial conversion at Caesara power plant located in valley in Eilat.

Previously used diesel-fuelled turbine for peak power. Limited to 300 hours of operation annually; no pipeline natural gas access.

June 2014 commercial operation of 100% methanol-fuelled Pratt & Whitney FT4C Twin Pack 50 MW gas turbine.
Dor Findings

• Low-cost fuel system retrofits to methanol, with this initial project costing $5 million.
• Yields significant NOx, SO2, and particulates emission reduction, without affecting performance.
• Unit now permitted to operate for 2,000 hours per year.
• Methanol consumption is 30 tons per hour.
• This technology (first of its type in the world) can be adopted in many other places (mainly Islands) where due to no natural gas supply, are currently using polluting fuels.
Methanol in Cooking Stove Applications

- Traditional cooking fuels (wood/charcoal, dung, kerosene, paraffin, diesel, coal, LPG) can emit significant CO2 and harmful particulates, potential fire hazards.
- Nigeria (kerosene stoves), South Africa (paraffin), China (coal).
- Project Gaia pilot project and studies in Nigeria since 2005.
- Distributed fuel already in canister: no handling of fuel by beneficiaries; results very successful.
Methanol in Cooking Stove Applications

Methanol-powered cookstoves

Wasted, Flared Methane Gas
Captured & Converted to Methanol
Methanol Distribution & Canister Refill Depot
Canister Distribution Model
Safe Storage
Clean Cooking

Project Gaia
Methanol in Cooking Stove Applications

China is Leading the World

• Methanol for cooking applications in China since 1983

• Potential for large amounts of methanol needed for future cooking applications in China.

• Use of alcohol in cooking fuels could reduce annual direct coal burning by 3,172 MW and CO$_2$ emissions decrease of 8.25 billion tons.
TWO TYPES OF FUEL CELLS

Direct Methanol Fuel Cells (DMFCs):
- Subcategory of proton exchange fuel cells
- Liquid MEOH used as the fuel.
- Easy to transport, energy-dense/stable
- Low efficiency
- Good for portable power
- Waste: CO$_2$ & water vapor

Reformed Methanol Fuel Cells (RMFC) / Indirect Methanol Fuel Cells (IMFCs):
- Methanol reformed to hydrogen gas before being fed into fuel cell.
- Higher efficiency, smaller cell stacks, better operation/storage at low temps.
- Heat mgt/insulation systems required

Methanol important in fuel cells as an environmentally-friendly hydrogen carrier fuel
Primary Applications for Fuel Cells

**Charging/Replacement of batteries**
- Forklifts (Oorja Protronics)
- Camper vans (SFC Energy)

**Provision of off-grid or grid-support power**
- Backup power supply to telecoms towers
- Remote communities
- Desalination plants
- Off-grid mining
Major Global Methanol Fuel Cell Producers

- Ballard Power Systems (Canada)
- Horizon Fuel Cell Technologies (Singapore)
- Oorja Protonics (United States)
- Panasonic (United States)
- SFC Energy (Germany)
- Toshiba (Japan)
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