Monetizing Gas-to-Gasoline™

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Presentation Contents

- Gas-to-Gasoline Approach
- Air Liquide Methanol and ExxonMobil MTG Technology
- G2G™ Plant - Economics (Example Calculation)
Gas-to-Gasoline Technology Approach

- Referenced technologies - Costs and performance well understood
- Two proven technologies, one competitive solution

65 plants licensed
5 plants natural gas to methanol of the same size and technology in operation

2 plants operated:
- New Zealand 14,500 bbl/d (1985-97)
- JAMG China 2,500 bbl/d demonstration plant (2009-14)
- JAMG China (2 trains - 25,000 bbl/d) under construction

Feedstock options for G2G™
Technology Summary, Methanol & MTG

Natural Gas
- 151.9 MMSCFD
- 1,009.5 BTU/SCF (HHV)

ASU

Lurgi Syngas Plant

Lurgi Methanol Plant

MTG Plant

16,100 bpd Gasoline

LPG (internally consumed)

Off sites and Utilities (common)

Methanol
- 5,000 mtpd

Gasoline
- 1,009.5 BTU/SCF (HHV)

Air Liquide Technologies

ExxonMobil Technologies
Air Liquide Lurgi™ Methanol Technology Suite

LP Synthesis  MegaMethanol  GigaMethanol

1-Stage Synthesis  2-Stage Synthesis

pure SMR  Combined Reforming  HP ATR

capacity (mtpd)
0  2,500  5,000  7,500  10,000
Air Liquide’s Lurgi MegaMethanol™

**Air** → **Air-Separation** → **Oxygen**

**Natural Gas** → **Desulphurization** → **Autothermal Reforming 40 bar** → **Steam Reforming**

**Syngas Compressor** → **Steam System**

- Steam driven:
  - ASU compression
  - Syngas compressor
  - MeOH distillation

**Water Cooled MeOH Reactor** → **Gas Cooled MeOH Reactor** → **Interstage Condensation** → **Methanol Distillation** → **Pure Methanol**

**Overall consumption of 28.5 MMBTU per t of MeOH**

**Proven and most efficient process for large capacities**

5 operating references at 5,000 tpd MeOH
Air Liquide’s Lurgi Water Cooled Reactor

Process
- Extremely Quick Transfer of Reaction Heat
- Even distribution of cooling surface
- Low temperature difference between reaction gas and steam
- High steam pressure possible
- Methanol Yield up to 1.8 kg MeOH/l Catalyst

Operation
- Easy Start-up by Direct Steam Heating
- Overheating of Catalyst Impossible
- Thermosiphon Circulation. No Pumps
- Safe and Robust

Cooling Surface: 90 m²/m³ catalyst
Air Liquide’s ATR Design

- CFD / Burner
- Refractory
- Mature Design + Safe and Reliable Operation
- Operational Experience
- Catalyst

Contours of Static Temperature (K)

FLUENT model, swirl, aug

Contour 2741 2030 1526 1196 974 863 703 442 332
Recent Air Liquide Methanol Licenses

- **2014**
  - BASF
    - 1,650,000 tpy Natural Gas
  - Yuhuang Chemical Inc
    - 1,650,000 tpy Natural Gas
  - Natgasoline
    - 1,650,000 tpy Natural Gas
  - Zeogas
    - 1,650,000 tpy Natural Gas
- **2017**
  - Confidential
    - 1,650,000 tpy Natural Gas
  - Petroleos Brasileiros
    - 800,000 tpy Natural Gas
- **2012**
  - Confidential
    - 300,000 tpy Natural Gas

- **2018**
  - Chinacoal
    - 1,000,000 tpy Coal Gas
  - Guangxi Huayi
    - 1,000,000 tpy Coal Gas
  - Shanxi Changqing
    - 1,000,000 tpy Coal Gas
  - Guanzxi Huayi
    - 1,000,000 tpy Coal Gas
  - Sinopec/Wanbei Group
    - 1,800,000 tpy Coal Gas
  - Shenhua SNCG CTL
    - 1,000,000 tpy Coal Gas
- **2019**
  - Confidential
    - 300,000 tpy Natural Gas
  - Guangxi Huayi
    - 1,000,000 tpy Coal Gas

**Total MeOH License (number / capacity): 65 / 52 million tons/a**
ExxonMobil MTG Process (Reactor Section)

- Methanol is vaporized by heat from the MTG reaction and fed into a DME reactor.
- DME reactor effluent is mixed with recycle gas & fed to the MTG reactors.
- Recycle gas controls reactor temperatures.
- MTG reactor effluent is cooled by the methanol feed, recycle gas & air or water.
- Condensed effluent is separated into gasoline, water and gas.
- Raw gasoline is pumped to a recovery section.
Raw Gasoline Recovery Section

- Raw MTG gasoline is fed to de-ethanizer and stabilizer columns to remove fuel gas and LPG fractions from the gasoline.
- Stabilized gasoline is split into light and heavy gasoline fractions.
- Heavy gasoline is mildly hydro-treated to reduce Durene (1,2,4,5 tetra-methyl benzene) content.
- Treated heavy gasoline and light gasoline or blended into finished product.
High conversion efficiency, sulfur-free gasoline

<table>
<thead>
<tr>
<th>MTG GASOLINE YIELDS</th>
<th>MTG GASOLINE PROPERTIES/COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent of Feed</td>
</tr>
<tr>
<td>Gas</td>
<td>1%</td>
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<tr>
<td>LPG</td>
<td>5%</td>
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<tr>
<td>Gasoline</td>
<td>38%</td>
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<tr>
<td>H₂O</td>
<td>56%</td>
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<tr>
<td></td>
<td>Octane, RON</td>
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<td>Octane, MON</td>
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<td></td>
<td>(R+M)/2</td>
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<tr>
<td></td>
<td>Paraffins, vol%</td>
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<td></td>
<td>Olefins, vol%</td>
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<tr>
<td></td>
<td>Naphthenes, vol%</td>
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<td></td>
<td>Aromatics, vol%</td>
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<td></td>
<td>Benzene, vol%</td>
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<td>Sulfur</td>
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The New Zealand SynFuels plant started up in 1985. The plant was operated until 1997.
In 2009, Jincheng Anthracite Mining Group in Shanxi Province China started the first 2nd Generation MTG Plant: 100 KTA Gasoline

World’s first coal-to-liquids plant using MTG
Second grassroots MTG plant in construction (JAMG II)

In 2011 Jincheng Anthracite Mining Group licensed to build a 1 MTA MTG complex – Under Construction
Latest MegaMethanol Reference - Natgasoline

- Customer: Natgasoline LLC
- Process: Lurgi MegaMethanol™
- Licensor: Air Liquide
- Plant Capacity: 5,000 mtpd
- Feedstock: Natural Gas
- Scope of Work: L, BE, DE, Prop Eqs.
- Start-Up Year: 2018
- Project Highlights: Largest MeOH plant in the US

Picture: Courtesy of Natgasoline LLC
G2G™ Production Cost

- Example calculation
- Assumptions:
  - Full process chain
  - Natural gas 2$/MMBTU
  - Variable costs include consumables such as catalysts and raw water
  - Fixed costs include estimated fixed labor and annual maintenance
  - Owners costs assumed at 15% of TIC
  - No contingencies, taxes & insurance
- No storage or sales cost considered
# Technology Supply

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<tr>
<th>Item</th>
<th>Responsible Party</th>
<th>Supporting Party</th>
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<tbody>
<tr>
<td>Global Marketing</td>
<td>Air Liquide</td>
<td>ExxonMobil</td>
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<td>NDAs (pre-license)</td>
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Thank you for your attention!

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- Lurgi Syngas Plant
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- Lurgi Methanol Plant: 5,000 mtpd Methanol
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- LPG (internally consumed)
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Air Liquide Technologies
ExxonMobil Technologies
BACKUP
Air Liquide’s Interstage Condensation

- Effluent from WCR “close” to equilibrium
- Condensation of MeOH and H2O increases distance to equilibrium
- Optimal utilization of catalyst and reactor volume in GCR
  - Overall space time yield: +66% vs. 1st version
  - Recycle ratio: −18% vs. 1st version
  - CAPEX neutral vs. original Lurgi MegaMethanol™
  - OPEX advantage
Feedstock - Abundant Gas in Many Regions

- Advantaged Feedstock
- Future Gas Development
- Demand for Distillates and Oxygenates
- Industry Modernization
- Advantaged Feedstock
- Environment protection
- Coal based development
Air Liquide’s Lurgi MegaMethanol™

Natural Gas

Desulphurization

Pre-Reforming -> Autothermal Reforming

Steam Reforming

Steam System

Air Separation

Air

Oxygen

Large syngas capacities enabled through oxygen technology

High reforming pressure, i.e. reduced line sizes

Small syngas / recycle compressors

Maximized energy efficiency

Best referenced technology at 5000 mtpd

Two-Step Synthesis

PSA

Methanol Distillation

Pure Methanol

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Air Liquide’s Lurgi MegaMethanol™: Highlights

- Well referenced
- Single gun burners
- Flexible pressures
- Max per pass conversion
- Optimized temperature control
- Min recycle ratio