The Status of DME Development in KOREA

Hoseo University
Chemical and Industrial Technology Center
Dep’t of Chemical Engineering
Director and Prof. Gye-Gyu Lim, Ph.D.

BPPT Conference Hall, Jakarta, Indonesia, 2013
History of DME Activities

- DME Manufacturing Technology Development (KOGAS)
  - LAB scale (’00~’03)
  - 50Kg/day DME Pilot Plant (’03~’05)
  - 10Ton/day DME Demo Plant (’04~’09)
    - ’04~’06: Safety standard study for DME fuel (KGSC)
    - ’04~’07: Basic property study for DME-LPG blending fuel (KGSC)
- DME Partnership Program
  - ’04~’07: Application technology development for DME fueled Power plant (KEPRI)
  - ’05~’08: DME fueled diesel engine for Bus (KIER)
- Demonstration and Model Business
  - ’07~’11: DME demonstration and model business (MKE, KOGAS, KGS, K-Petro, KDA, Korea LPGas)

Target
Commercial scale DME production plant development from Small-medium size gas fields

BPPT Conference Hall, Jakarta, Indonesia, 2013

KOGAS DME Technology

- Direct Synthesis (1step, KOGAS)
  - Syngas → Reforming → DME Reaction → DME
- Indirect synthesis (2 steps, TEC, Lurgi)
  - Syngas → Reformer, Combined SMR, Heat Exchange, Autothermal
  - Methanol synthesis
  - Dehydration

<table>
<thead>
<tr>
<th>Process Comparison</th>
<th>KOGAS Direct Process</th>
<th>Indirect Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Development Stage</td>
<td>10 Metric Tons/Day Demonstration Plant</td>
<td>30 Metric Tons/Day Plant</td>
</tr>
<tr>
<td>Process Type</td>
<td>One-Step or &quot;Direct&quot;</td>
<td>Two-Step or &quot;Indirect&quot;</td>
</tr>
<tr>
<td>Number of Reaction Steps</td>
<td>2 (Reformer → DME)</td>
<td>3 (Reformer → Methanol → DME)</td>
</tr>
<tr>
<td>Number of Major Equipment</td>
<td>80 plus ASU</td>
<td>90 plus ASU</td>
</tr>
<tr>
<td>Tolerance for High CO&lt;sub&gt;2&lt;/sub&gt; in NG Feed</td>
<td>Up to 20 mole% CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Not Known</td>
</tr>
<tr>
<td>Reforming</td>
<td>Tri-Reformer → Utilize High CO&lt;sub&gt;2&lt;/sub&gt;, NG Feed</td>
<td>Combined SMR, Heat Exchange, Autothermal</td>
</tr>
<tr>
<td>DME Production</td>
<td>Single Step from Syngas to DME → Less Complex Process</td>
<td>Syngas to MeOH followed by MeOH to DME</td>
</tr>
</tbody>
</table>

BPPT Conference Hall, Jakarta, Indonesia, 2013
KOGAS DME Process

- **KOGAS DME Technologies**
  - Syngas process: tri-reforming method (0-20% CO₂)
  - DME Process: fixed bed reactor with shell & tube

- Development status
  - 2003: Pilot plant Construction and Operation (50~100 kg/d) (1,457 ~ 2,914 MJ/d)
  - 2008: Demo plant Construction and Operation (10 ton/d) (291 GJ/d)
  - Establishment of catalyst recipe and reactor design for commercial plant

Reforming process
- Syngas Production Process
- DME Process
- DME Process (heat removal system)

Plant View
- Area: 6,000 M²
- Cap: 10 ton/d

DME Prospects (Market) in Korea

- **At present**: Cosmetics, Spray propellant, Intermediate of agricultural chemical, LPG blending.
- **In future**: Power generation, Transportation, Households & Commercial, etc.
  (Korea will use it for households & commercial, transportation fuel at 2013)

Future
- Emergency diesel generator
- Community energy supply system
- Fuel cell
- DME-FCV
- Industrial fuel
- Home-use
- DME station
- Diesel engine car
KOGAS Design Package for Commercialization

- **Capacity**
  - 3000TPA demo Plant
  - 300,000TPA Commercial Plant
  - 1,000,000TPA Commercial Plant

- **Site**
  - Incheon LNG Terminal in KOGAS
  - Sabah State in Malaysia: SOGIP (Sipitang Oil & Gas Industrial Park)
  - Subsea gas field in Malaysia / Australia

- **Design**
  - For Construction
  - Basic Engineering Package
  - Pre-FEED

- **Resource**
  - BOG of LNG terminal
  - PNG (Kimanis–Bintulu pipeline)
  - Subsea gas field

- **Process Simulation**

- **Layout**

Source: DSME-KOGAS promotional video

---

DME FPSO Design

- **Inlet facility**
- **Desulfurization**
- **Reforming**
- **Power Generation**
- **DME Synthesis**
- **Purification**
- **Offloading**
- **Air Separation Unit**
- **Steam Generation**

Source: DSME-KOGAS promotional video

DME Synthesis Section
Syngas/CO2 Recycle Section
DME Purification Section

BPPT Conference Hall, Jakarta, Indonesia, 2013
KOGAS DME Commercialization

Gas field $\rightarrow$ DME commercialization

- DME import until 2013, Expected 1.5 million tons on 2015
- Establishment of commercial technology optimization
- Secured gas field (2010)
- Licensing of core technology
- Development of core technology of DME FPSO
- Securing gas field in Indonesia, Vietnam etc
- Secure economic of non-economic gas field containing CO2
- Domestic supply and market expansion

CBM $\rightarrow$ DME commercialization

- Production of 10,000 ton from coal and CBM
- Resource development cooperation projects in Mongolia (2009~12)
- Secure resources from applied commercial technology
- Improvements of exploitation of Mongolia
- New growth green energy projects
- New growth businesses in KOGAS
- LPG and diesel alternative clean fuel supply
- Domestic supply and market expansion

Demonstration step in 2009, Penetration from model distribution until 2011
Basic Design Package for Plant(1)

Completion of Basic Design Package of 300,000 ton/yr DME production ('11.7)
- Development of Plant Engineering based on the KOGAS DME core technology (catalyst, reactor, process)

- Plant Capacity :
  - DME : 300,000 Ton/Yr
  - MeOH : 72,500 Ton/Yr
- Product purity :
  - DME 99.6 wt% / MeOH 98.0 wt%
- Storage Capacity :
  - DME 25,000 M³ x 2set (64 days)
  - MeOH 12,000 M³ x 1set (32 days)
- Locations :
  - Middle-east Asia (Saudi Arabia), Mozambique (Africa) Etc.

※ DME 300,000 ton/yr = 8,742,000 GJ/yr

Candidate location (Saudi Arabia)

Outline of DME Project in Nigeria

- Production Capacity : 300,000 tons X 2 trains of DME a year
- Technology : Patented technology developed by KOGAS
- Natural Gas Consumption : 540,000 tons of NG a year (for 25yrs. 1tcf)
  (Except utility fuel for boiler)
- CO₂ Consumption : 0-64,000 tons of CO₂ a year (vary as CO₂% contained)
- Plant Site : Close to gas line & Port, 300,000M² (74acre)
  (Onne FTZ, Bonny Island)
- Target Market : South Korea, India, Africa. Indonesia, EU, etc.
- Application : House Cooking Fuel, Vehicle engine/ Power Generation Fuel Chemicals (Spray Propellant, etc.)

※ Natural Gas 1tcf = 28,317,000 M³/d

BPPT Conference Hall, Jakarta, Indonesia, 2013
Installation site for DME plant in Nigeria

Outline of DME Project in Malaysia

- Production Capacity: 300,000 tons of DME a year
- Technology: Patented technology developed by KOGAS
- Natural Gas Consumption: 60mmcf/d of Natural gas (12,856 ton/d)
- Electricity: 60MW (supply from nearby electric power plant)
- Capital Requirement: up $333,000,000
- Plant Site: Close to gas line & Port, 150,000M² (37 acre) SOGIP (Sipitang Oil & Gas Industrial Park) of Sabah State
- Target Market: Malaysia, Indonesia, South Korea
- Application: House Cooking Fuel, Vehicle engine/ Power Generation Fuel, Chemicals (Spray Propellant, etc.)

※ DME 300,000 ton/yr = 8,742,000 GJ/yr, ※ Natural Gas 60mmscf/d = 771,351 ton/d
Installation site for DME plant in Malaysia

- New Natural Gas of Sabah State: 750mmcf/d (9,642,000 ton/d)
  - LNG Liquefaction etc.: 500mmcf/d (6,428,000 ton/d) (for Bintulu)
  - Oil & Gas Industry: 250mmcf/d (3,214,000 ton/d) (SOGIP)
    - Fertilizer (90mmcf/d), Power generation (90mmcf/d), LPG (10mmcf/d)
    - Unknown (60mmcf/d), DME (Sabah state project)
- Potential Fields & Locations
  - Sabah State of Malaysia, Sipitang Oil & Gas Industrial Park (SOGIP)

Project Economics (1)

<table>
<thead>
<tr>
<th>Economic Analysis – 300,000 ton/yr</th>
<th>Evaluation Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation Input Parameters</strong></td>
<td>Payback Time</td>
</tr>
<tr>
<td>Feed Gas Price</td>
<td>US$ 3.0/mmbtu</td>
</tr>
<tr>
<td>DME Production Cost</td>
<td>US$ 389/ton</td>
</tr>
<tr>
<td>DME Price (LPG Price)</td>
<td>US$ 650/ton (US$ 900/ton)</td>
</tr>
<tr>
<td>Investment Cost</td>
<td>US$ 383 million</td>
</tr>
<tr>
<td>Project lifespan</td>
<td>25 yrs</td>
</tr>
<tr>
<td>Finance rate</td>
<td>10 %</td>
</tr>
</tbody>
</table>

- LPG price: average price from 2010.10 to 2011.09 (Basis: C&F [cost & freight])
- PI*: Profitability index

* LPG price: average price from 2010.10 to 2011.09 [Basis: C&F (cost & freight)]
* PI: Profitability index
<table>
<thead>
<tr>
<th>Gas Cost</th>
<th>NG Cost per DME production</th>
<th>CAPEX</th>
<th>OPEX</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>OPEX(Tax &amp; Insurance)</td>
<td>OPEX(Transportation)</td>
</tr>
<tr>
<td>2.0</td>
<td>3.01</td>
<td>2.67</td>
<td>1.22</td>
<td>0.17</td>
</tr>
<tr>
<td>3.0</td>
<td>4.52</td>
<td>2.67</td>
<td>1.22</td>
<td>0.17</td>
</tr>
<tr>
<td>4.0</td>
<td>6.03</td>
<td>2.67</td>
<td>1.22</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Demonstration test for LPG replace(1)

- **Objective**
  - To make the regulation of DME-LPG blending fuel
  - To ensure the safety of facilities for user and gas supplier
  - To investigate the user satisfaction

- **Period**: 2010. 9 ~ 2011. 11

<table>
<thead>
<tr>
<th>LPG stations</th>
<th>Users(Household/medium size)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-Bang City Gas Industry (Kangreung City, Kangwon)</td>
<td>51 / 33 (84)</td>
<td></td>
</tr>
<tr>
<td>Youngjin Energy (Youngkwang City, Jeonnam)</td>
<td>48 / 37 (85)</td>
<td></td>
</tr>
<tr>
<td>Mokpo City Gas (Mokpo City, Jeonnam)</td>
<td>1 / 49 (50)</td>
<td></td>
</tr>
<tr>
<td>Chunil Gas (Pohang City, Kyungbuk)</td>
<td>2 / 14 (16)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>102 / 133 (235)</strong></td>
<td></td>
</tr>
</tbody>
</table>

Demonstration test for LPG replace(2)

**Supply flow of DME-LPG bled fuel**

- DME 20wt% from Incheon DME Plant (KOAGS)
- LPG 80wt% from Incheon LPG Terminal
- DME 20wt% + LPG 80wt% to Dongbang City Gas
- DME 20wt% + LPG 80wt% to Youngjin City Gas
- DME 20wt% + LPG 80wt% to Mokpo City Gas

- Households Use (102 Houses)
- Medium size Use (133 Cooks)
Demonstration test for LPG replace (3)

1. DME loading (KOGAS)
2. Propane loading (E1)
3. DME-LPG unloading (LPG station)

BPPT Conference Hall, Jakarta, Indonesia, 2013

Demonstration test for LPG replace (4)

Results of demonstration test

- To check the result of safety: No issue by using DME-LPG blend
- User satisfaction: 93% +
  - Satisfaction % of equal or better to compare with LPG
- If DME-LPG is cheaper than LPG, 80% of user will use DME-LPG blend

Set up regulations enabling use of DME-LPG blend on commercial business
- To prepare quality and safety standard of DME-LPG

**BPPT Conference Hall, Jakarta, Indonesia, 2013**

---

**DME – Alternative Fuel**

An enforcement ordinance of *Petroleum and Substitute Fuel Business Act*

Article No. 5 (Kinds of Alternative Fuels)

Biodiesel  Bioethanol  CTL  Orimulsion (Bitumen)  Emulsified Fuel  GTL  DME  Biogas  Etc.

Power generation  Cooking

* What level can DME be blended into LPG without affecting the performance of the common LPG vehicles?

100% DME  DME-LPG Mixtures  100% LPG


BPPT Conference Hall, Jakarta, Indonesia, 2013

---

**Determination of Optimum DME-LPG Blending Ratio**

LPG engine performance & emission test for DME level

Engine durability test (300 hr)

DME 5 mol%

Simulation test of LPG engine system (2 000 hr)

**BPPT Conference Hall, Jakarta, Indonesia, 2013**
**Project Schedule**

- **Target Mileage**
  - April 2010: 0 km
  - Oct. 2011: 60,000 km
  - Mileage: First year: 30,000 km
  - Second year: 60,000 km

- **Exhaust Emission, Fuel Economy** (per 10,000 km)
  - First year: 30,000 km

- **Cold Weather Performance Test** (per 30,000 km)
  - First year: 60,000 km

**Testing Procedures**

- Demo Plant: KOGAS
- Analysis of DME-LPG Blends
- Filling station: K-Petro
- DME(5 mol%) LPG Blending
- Gas Chromatography
- Mode Test
- Field Test: Total mileage: 60,000 km
- Distribution and filling

BPPT Conference Hall, Jakarta, Indonesia, 2013
### Specification of test vehicle

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG vehicle</td>
<td>![Car Images]</td>
</tr>
<tr>
<td>Fuel supply type</td>
<td>LPLi</td>
</tr>
<tr>
<td>Valve mechanism</td>
<td>DOHC</td>
</tr>
<tr>
<td>Displacement (cc)</td>
<td>1 998</td>
</tr>
<tr>
<td>Wheel base (mm)</td>
<td>2 700</td>
</tr>
<tr>
<td>Max. power (ps/rpm)</td>
<td>136/6 000</td>
</tr>
<tr>
<td>Max. torque (kg m/rpm)</td>
<td>18.9/4 250</td>
</tr>
</tbody>
</table>

BPPT Conference Hall, Jakarta, Indonesia, 2013

### Vehicle Performance Test

- **Fuel economy**
  - CVS-75(FTP-75) mode
  - HWFET mode (Highway fuel economy cycle)

- **Exhaust emissions**
  - CO, NMHC, NOX, CH4

- **Acceleration & Power**
  - 20 → 100 km/h

- **Cold Weather Performance Test**
  - Starting time and drivability at -15 °C

BPPT Conference Hall, Jakarta, Indonesia, 2013
### Draft of DME LPG Specification Standard for Autogas

#### LPG fuel spec. (in Korea) 1)

<table>
<thead>
<tr>
<th>Item</th>
<th>LPG No. 1 (for domestic)</th>
<th>LPG No. 2 (for automotive fuel)</th>
<th>Draft for DME-LPG blends</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>summer</td>
<td>winter</td>
<td>summer</td>
</tr>
<tr>
<td>C3 Hydrocarbon</td>
<td>&gt;90</td>
<td>≤10</td>
<td>25~35</td>
</tr>
<tr>
<td>C4 Hydrocarbon</td>
<td>-</td>
<td>≥85</td>
<td>-</td>
</tr>
<tr>
<td>DME</td>
<td>-</td>
<td>-</td>
<td>≤19.3</td>
</tr>
<tr>
<td>Butadiene</td>
<td>≤0.5</td>
<td>≤0.5</td>
<td>12)</td>
</tr>
<tr>
<td>Sulfur4) (mg/kg)</td>
<td>≤40</td>
<td>≤40</td>
<td>≤40</td>
</tr>
<tr>
<td>Vapor pressure (40 °C, MPa)</td>
<td>≤1.53</td>
<td>≤1.27</td>
<td>≤1.43</td>
</tr>
<tr>
<td>Density (15 °C, kg/m³)</td>
<td>-</td>
<td>500~620</td>
<td>-</td>
</tr>
<tr>
<td>Residue (mL)</td>
<td>≤0.05</td>
<td>≤0.05</td>
<td>≤0.05</td>
</tr>
<tr>
<td>Copper corrosion (40 °C, 1 h)</td>
<td>No. 1</td>
<td>No. 1</td>
<td>No. 1</td>
</tr>
<tr>
<td>Water</td>
<td>pass</td>
<td>-</td>
<td>≤0.04 wt%</td>
</tr>
</tbody>
</table>

2. From November to March
3. Including butadiene as well as other hydrocarbons (methanol, CO2, methyl formate etc.)
4. After adding odorant

BPPT Conference Hall, Jakarta, Indonesia, 2013

### Development of DME Vehicle

- Improvement of vehicle performance
  - Control logic
  - Engine calibration

#### Engine test
- DME engine test
- Experiment in main driving domain

#### Engine calibration/ECU mapping
- Engine map using modeling
- Development ECU for DME engine

#### Fuel feed system
- Improvement of drivability
  - Development of ECU
  - Fuel feed system
- Make-up of diesel/DME bi-fuel system

BPPT Conference Hall, Jakarta, Indonesia, 2013
활용기술 현황

DME 차량 개발
- 기존 LPG 차량에 DME-LPG 혼합연료 공급
- 순수 DME 차량 개발: DME 버스, 트럭

DME 버스
- 33인승 버스

승차정원: 33+1 (대우 BM090)
배기량: 8,071 cc
형식: 6기통, 터보 엔터클러
ENGINE: DEDBTIS
최대 출력: 225 PS/2,300 rpm
최대 토크: 90 Kg.m
최고 속도: 120km/h

Transportation

Agriculture

DME boiler performance test

Direct injection DME combustion Boiler

Boiler test system Diagram

DME application test
Gas boiler performance test

DME Burners
Thank you