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DME Activities & Prospects in Korea

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- DME Prospect (Market)
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KOGAS’s Activities on DME

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- Development of KOGAS DME Process
- KOGAS DME Commercialization
- Global DME business of KOGAS
DME Activities & Prospects in Korea
Government master plan of DME supply in Korea
(MKE, Ministry of Knowledge Economy)
’07. 7(1st Master plan), ’09. 11(2nd Master plan)

Domestic Supply of DME fuel in 2013

- 1st Demonstration step(’07~’09) : DME-LPG transport quality, household/ commercial, Charging Facility Safety Assessment → Establishment of regulation
- 2nd Demonstration step(’09~’11) : DME distribution project in domestic area
- Enlargement step(’11~’13) : Oversea construction, Import DME as a domestic fuel
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)
Household and Industrial use

- **Household**
  - Gas range used in the kitchen
  - Hot water boiler is used for under floor heating room and warm water

- **Industrial**
  - Industrial gas range used in restaurants

- **Spray Propellant**
  - DME is non toxic and then used as aerosol propellant for personal uses such as spray for hair dressing or wart removers.
DME-LPG blending test of KGS(I)

DME-LPG blending test facilities

Domestic DME-LPG Experimental System

Combustion Test

DME-LPG Test Facilities (Lab.)

Blending Test

Cylinder Test
DME-LPG blending test facilities

Boiler Test for DME-LPG fuel

Performance Test

Inner view of laboratory

Heat Exchanger System
DME Vehicles promotion activities in KOREA:

• From 2003, development of DME engine has been completed, the future development will be large scale DME truck as heavy duty truck

Development of DME vehicle

• KIER (Korea Institute of Energy Research): development of DME bus and truck with KOGAS and SK (2003~)

• KATECH (Korea Automotive Technology Institute): common rail diesel van vehicle converted to DME vehicle (2008)
Supply of DME-LPG blending (KOGAS)

Demonstration test of DME-LPG mixture

- DME-LPG blending fuel station
  - Mixture: DME 20wt% + LPG 80wt%
  - Distribution and supply: Domestic home and industry cooking user, LPG vehicles

- DME Station
  - Purity: over 99%, Fuel grade
  - Distribution and supply: Heavy Duty Truck, Diesel Bus (Substitute diesel fuel)
Less CO₂ emission than coal or oil fired power generation

Similar efficiency to gas fired power generation
- Generation efficiency in gas turbine: 39~40%

Demonstration is completed by KEPRI
- Retrofit fuel supply system
DME Domestic market (Korea)

- LPG-DME blend fuel market (for cooking and transportation fuels)
- Industrial Boiler (district heating)
- Diesel alternative Fuel (Bus, Truck)

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<tbody>
<tr>
<td>For family use-LPG DME(20%)</td>
<td>254</td>
<td>241</td>
<td>228</td>
<td>215</td>
<td>204</td>
<td>193</td>
<td>182</td>
<td>172</td>
<td>163</td>
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<tr>
<td>Transportation-LPG DME(5%)</td>
<td>265</td>
<td>275</td>
<td>286</td>
<td>297</td>
<td>309</td>
<td>321</td>
<td>334</td>
<td>347</td>
<td>360</td>
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<tr>
<td>Industrial Boiler (district heating)</td>
<td>99</td>
<td>94</td>
<td>90</td>
<td>86</td>
<td>82</td>
<td>78</td>
<td>75</td>
<td>71</td>
<td>68</td>
</tr>
<tr>
<td>Diesel alternative Fuel (Bus, Truck)</td>
<td>105</td>
<td>209</td>
<td>314</td>
<td>418</td>
<td>628</td>
<td>732</td>
<td>837</td>
<td>941</td>
<td>1,046</td>
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<tr>
<td>Total</td>
<td>723</td>
<td>819</td>
<td>918</td>
<td>1,017</td>
<td>1,222</td>
<td>1,324</td>
<td>1,427</td>
<td>1,532</td>
<td>1,637</td>
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</tbody>
</table>

(Unit : 1000ton)
Test of Business Model supplying DME-LPG fuel

- Specific Regulation for DME-LPG blending fuel (KGS AC211\textsuperscript{2009})
- To Check the Safety of the Equipment and Distribution Network in Korea
- To Supplement/Improve the Inadequate Problem
- Duration: 2009. 11 ~ 2011.11
- Start-up for DME-LPG Distribution: 2010. 8. 5

<table>
<thead>
<tr>
<th>Demonstration Field Tester</th>
<th>Site</th>
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<tbody>
<tr>
<td><strong>Filling Station Company</strong></td>
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</tr>
<tr>
<td>Dong-Bang City Gas Industry</td>
<td>Kangreung City, Kangwon Prov.</td>
</tr>
<tr>
<td>Youngjin Energy</td>
<td>Youngkwang City, Jeonnam Prov.</td>
</tr>
<tr>
<td>Mokpo City Gas</td>
<td>Mokpo City, Jeonnam Prov.</td>
</tr>
<tr>
<td>Chunil Gas</td>
<td>Pohang City, Kyungbuk Prov.</td>
</tr>
<tr>
<td><strong>Manufacture Company</strong></td>
<td></td>
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<tr>
<td>Korea Gas Corporation</td>
<td>Incheon</td>
</tr>
</tbody>
</table>
DME-LPG Supply Demonstration in Korea

Incheon DME Plant (KOGAS)

DME 20% + LPG 80%

Dongbang City Gas

Chunil City Gas

Youngjin City Gas

Mokpo City Gas

Households Use (200 Houses)

Industry Use (400 Cooks)

Incheon DME Plant (KOGAS)

DME 20%

LPG 80%

Incheon LPG Terminal

KOGAS R&D Division

DME Project
KOGAS’s Activities on DME
History of KOGAS 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~’10 : DME demonstration and model business (MOCIE)

Target: 3,000 ton/d DME production plant Construction from Small-medium size gas fields
Technical properties

- DME technology using various feed stocks like NG, CBM, Biogas, etc.
- Syngas process: tri-reforming using 20% CO₂ included in gas field
- DME Process: application of efficient heat removal system of fixed bed reactor with shell & tube

Development state

- 2003: Pilot plant Construction and Operation (50~100 kg/d)
- 2008: Demo plant Construction and Operation (10 ton/d)

→ Establishment of catalyst recipe and reactor design for commercial plant
Development of core technology

- Syngas Catalyst
- Methanol Catalyst
- DME Catalyst

- Optimum Process Simulation
- BEP Licensing
- Optimization technology

- Direct synthesis
- DME Purification
- CO₂ Recycle

- Tri-reformer
- Methanol reactor
- DME Synthesis Reactor
<table>
<thead>
<tr>
<th>Process</th>
<th>Conditions</th>
<th>Catalyst</th>
<th>Photo</th>
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</thead>
<tbody>
<tr>
<td>Desulfurization</td>
<td>350~400°C</td>
<td>ZnO/CaO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15~30atm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-reforming</td>
<td>350~400°C</td>
<td>Ni/CuO/MgO/Al₂O₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15~30atm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tri-reforming</td>
<td>950~1050°C</td>
<td>NiO-Mg/Ce-ZrO₂/Al₂O₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15~30atm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DME Synthesis</td>
<td>230~280°C</td>
<td>CuO/ZnO/Al₂O₃ + Additives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30~60atm</td>
<td></td>
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</tbody>
</table>
**KOGAS DME Commercialization**

**Gas field ➔ 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

**CBM ➔ DME commercialization**

- Production of 10,000 tons from coal and CBM
- Resource development cooperation projects in Mongolia (‘09~‘12)
  - Secure resources from applied commercial technology
  - Improvement of air pollution in Mongolia

**DME Technology**

- Development of core technology of DME FPSO
- Securing gas field in Indonesia, Vietnam etc
- Secure economic of non-economic gas field containing CO2

**Gas field ➔ DME FPSO technology**

- Securing gas field of oversea, utilizing domestic shipbuilding company

**Domestic supply and market expansion**

- New growth green energy projects
- New growth businesses in KOGAS
- LPG and diesel alternative clean fuel supply

Demonstration step in 2009, Penetration from model distribution until 2011
Implementation of KOGAS DME Project

(1) Establishment of Commercial Basic Design for KOGAS DME Project (‘11.7)
- Completion of Basic Design Package of 300,000 ton/yr DME production for KOGAS DME commercialization (Service company : KOGAS-tech)
  - Development of Plant Engineering base on the KOGAS DME core technology (catalyst, reactor, process)
  - BEP (Basic Engineering Package) for “first-of-a-kind” Technical Business Project of KOGAS
    - Coming out the results of Process Design Package (PDP), HMB, PFD, P&ID, Equipment, Electric, Instrumentation, Piping etc.

(2) Implementation of Feasibility Study for Commercial Project (‘11.8)
- The feasibility study was conducted by reviewing the technology, engineering and business documents provided by KOGAS (Service company : RES Group, Fluor)

<table>
<thead>
<tr>
<th>(Technical FS)</th>
<th>(Economic FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Assessment</td>
<td>Market Analysis</td>
</tr>
</tbody>
</table>

Reinforcement of Internal organization structure
Securing Natural Gas, PF and Establishment of JVC
Basic Design Package for Commercial Plant

- Plant Capacity: DME: 1,000 Ton/Day (300,000 Ton/Year)
  MeOH: 217 Ton/Day (72,500 Ton/Year)
- 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: Saudi Arabia (Middle-east Asia), Mozambique (Africa) Etc.

Candidate location (Saudi Arabia)

Commercial DME Plant Plot Plan
# Results of Economic Analysis

**Payback period:** 5 yrs, **IRR:** 21.3%

## Evaluation Input Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Feed Gas Price</td>
<td>US$ 2.0</td>
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<tr>
<td>DME Production Cost</td>
<td>US$ 320</td>
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<tr>
<td>DME Price <em>LPG Price</em></td>
<td>US$ 600 / US$ 900</td>
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<tr>
<td>Investment Cost</td>
<td>US$ 383 million</td>
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<tr>
<td>Project lifespan</td>
<td>25 yrs</td>
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<tr>
<td>Finance rate</td>
<td>10 %</td>
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</table>

## Evaluation Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payback Time</td>
<td>5 yrs</td>
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<tr>
<td>Pre-tax ROI</td>
<td>27.8 %</td>
</tr>
<tr>
<td>NPV</td>
<td>US$ 335 million</td>
</tr>
<tr>
<td>IRR</td>
<td>21.3 %</td>
</tr>
<tr>
<td>MIRR*</td>
<td>14.7 %</td>
</tr>
<tr>
<td>PI*</td>
<td>1.87</td>
</tr>
</tbody>
</table>

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* LPG price: average price from 2010.10 to 2011.09 (Basis: contract price)
* MIRR: Modified internal rate of return
* PI: Profitability index
Global DME business of KOGAS

Saudi Arabia
- 1000TPD (300,000TPY) DME Production MOU cooperation
  ('09.11) → Joint Study Agreement ('10.7)
  - Basic Design for Commercial Plant, Feasibility study, etc.
  - Uncertainty of the securing feedstock (Hold)

Mongolia
- Low grade coal, Construction and operation of 10~20 KTPA DME Plant ('09.9 ~ '12.12)
  → Supply of Ulaanbaatar and near area for the vehicle and household fuel

Mozambique
- MOU concerning the Gas Industry Corporation ('10.11)
  → Implementation of Feasibility Study ('11.12) and FID ('12.6)
  * Recently, KOGAS (10% stake) and ENI had discovered a natural gas deposit off the coast of Mozambique.

Australia
- Contract MOU for Preliminary Feasibility Study ('11. 7)
  → Offshore DME production by DME FPSO and fixed DME plant on Tassie Shoal
  * PFS have been conducted for analysis of economic and technical feasibility of producing DME on a commercial scale in Northern Australia.

etc
- Russia, Malaysia, Nigeria etc
  - DME Production From CBM, Flaring Gas Utilization
With CO₂ rich natural gas of above 1.0 TCF, DME plant of 1,000,000 ton per year will be built and operated.

Sales to domestic fuels and export to other nations

→ DME-LPG blending fuel & Diesel substitute

**Business Model**

- **Flared Gas**
- **DME Plant**: 100~1,000 ton/day
- **DME Station**: 20 ton lorry
- **End User**
Considerations for the outcome of commercial project:

- Securing a reliable feedstock supply at a reasonable price
- Fluctuation in competing energy price and policy (NG, LPG, Methanol, DME)
- Fluctuation in the procurement costs
- Political, legislative, and taxation changes, etc.