Outline

- Context and history
- Opportunities
  - Feedstocks
  - Markets
- Challenges
  - Commercial
  - Technical
  - Global
- IDA and global collaboration
- Conclusion

Supported with Presentations by Key Players at DME1

Not included in this slide set
DME

Butane Gas  DME

Source: CO-OP Eco Vehicles (Japan), DME1
Why DME?

- Multiple Markets
- Multiple Sources
- Ready technologies
- Green
- Economic viability
Methanol and DME: Twin Pillars

- DME Today: 0.15 million tpa specialty product business (aerosol propellant)
- Potential for very large fuel markets
- Manufacturing plants are very similar
- Capital cost differential small
- Co-production feasible
- Both can be versatile chemical feedstocks

DME can be manufactured from multi-feedstocks similar to methanol production ...

- Today: Current suppliers for propellant market include Akzo Nobel, DuPont, and Mitsubishi Gas Chemicals.
- Tomorrow: Future mega-plant technology providers include Haldor Topsoe, Lurgi, Toyo Engineering, Mitsubishi Gas Chemicals and JFE Holdings.

<table>
<thead>
<tr>
<th>Property</th>
<th>DME</th>
<th>Propane (Butane)</th>
<th>Methanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point (deg C)</td>
<td>-25</td>
<td>-42 (-0.5)</td>
<td>65</td>
</tr>
<tr>
<td>Vapor Pressure @ 20 deg C (bar)</td>
<td>5.1</td>
<td>8.4 (2.1)</td>
<td>0.3</td>
</tr>
<tr>
<td>Liquid Density (kg/m³)</td>
<td>670</td>
<td>500 (610)</td>
<td>790</td>
</tr>
<tr>
<td>Lower Heating Value (MJ/kg)</td>
<td>28</td>
<td>46 (46)</td>
<td>20</td>
</tr>
<tr>
<td>Auto Ignition Temp @ 1 atm (deg C)</td>
<td>235-350</td>
<td>470 (365)</td>
<td>465</td>
</tr>
<tr>
<td>Explosion/Flammability Limit in air (vol %)</td>
<td>3.4-17</td>
<td>2.1- 9.4 (1.9-8.4)</td>
<td>7.3-36</td>
</tr>
<tr>
<td>Octane, (R+M)/2</td>
<td>low</td>
<td>104</td>
<td>100</td>
</tr>
<tr>
<td>Cetane</td>
<td>55-60</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
## A brief history of DME

<table>
<thead>
<tr>
<th>Year</th>
<th>Major Activity/Event</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>First use as aerosol</td>
<td>Akzo Nobel</td>
</tr>
<tr>
<td>1992-95</td>
<td>Diesel fuel demonstration</td>
<td>AVL, BP, DTU, HTAS, Navistar</td>
</tr>
<tr>
<td>Jan 1995</td>
<td>DME multi-purpose fuel strategy</td>
<td>BP visit with NEDO, TEPCO, EPDC and others</td>
</tr>
<tr>
<td>Feb. 1995</td>
<td>BP press conference and first papers in Detroit</td>
<td>AVL, BP, DTU, HTAS, Navistar</td>
</tr>
<tr>
<td>1996-2001</td>
<td>IEA DME Annex XIV and XX (workshops and studies)</td>
<td>TNO and 16 companies</td>
</tr>
<tr>
<td>1996-now</td>
<td>Multiple commercial projects pursued</td>
<td>Japan DME Ltd, DME International, India DME, Chinese ventures, Iran Project</td>
</tr>
<tr>
<td>2000/01</td>
<td>Formation of IDA and JDF</td>
<td>160+ members</td>
</tr>
<tr>
<td>2004</td>
<td>DME 1 – First International DME Conference</td>
<td>137 delegates, 40 presentations</td>
</tr>
</tbody>
</table>
The First Papers in Detroit

International Congress & Exposition, Detroit February 1995

Low-Cost Manufacturing Process

Diesel Engine Research

Emissions Demonstration
DME literature and patent search show dramatically increasing global efforts.
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The changing methanol business

Today’s Markets
32MMtpa

New Markets
>>32MMtpa

Gas
Coal
Biomass

Methanol

Methanol Derivatives

- Formaldehyde
- Acetic Acid
- MTBE
- DME
- Olefins (MTO/MTP)
- Power, Fuel Cells
- New Products

Plastics, Polymers, Pains, Consumer products, Fuels
### Markets: Methanol or DME?

<table>
<thead>
<tr>
<th></th>
<th>Methanol</th>
<th>DME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic Acid/Formaldehyde/MTBE</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LPG</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Diesel Engines</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Fuel Cells</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gasoline Engines</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>MTO, MTP and MTG</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

(Chemically, methanol is first converted to DME)

**Important Issues:**
- Delivered Cost (per Btu or Carbon)
- Performance
- Customer Acceptance
- EHS – Performance and Perception
## Market Comparison

<table>
<thead>
<tr>
<th>Target Products</th>
<th>Annual production MMTPA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LNG</strong></td>
<td>140</td>
</tr>
<tr>
<td>Diesel</td>
<td>1100</td>
</tr>
<tr>
<td>Crude Oil</td>
<td>3800</td>
</tr>
<tr>
<td>Ammonia</td>
<td>130</td>
</tr>
<tr>
<td>Methanol, chemical</td>
<td>32</td>
</tr>
<tr>
<td>Gasoline</td>
<td>900</td>
</tr>
<tr>
<td>Methanol to Olefins</td>
<td>140</td>
</tr>
<tr>
<td>Methanol to LPG (DME)</td>
<td>215</td>
</tr>
<tr>
<td>DME (power, diesel)</td>
<td>200</td>
</tr>
</tbody>
</table>

*Potential*
Opportunities

**MULTI-SOURCE PRODUCT**
Supplier Interests

Gas monetization
Clean Coal utilization
Biomass conversion
Methanol marketing

**MULTI-PURPOSE PRODUCT**
Market Interests

Fuel diversification
LPG alternative
Ultimate diesel
Power generation
Hydrogen carrier
Chemical Feedstock
Role of DME in gas monetization

1. Moving Gas to Markets

- Pipelines
- LNG (Liquefied Natural Gas)
- GTP (Gas to Liquids)
- Gas by Wire

2. Create New Markets for Gas

- Diesel, gasoline
- Chemicals, plastics
- Cooking, power
Role of DME in coal and biomass

COAL

- Abundant, cheap
- Domestic vs imports (China)
- Clean conversion technology
- CO2 sequestration

BIOMASS

- Niche business (Sweden)
- Environmental drivers
- CO2 mitigation
Methanol Plant Costs are Decreasing

BP and Methanex announced that the industry pacesetter 5,000 TPD Atlas plant started-up on June 2, 2004.
Transition: Chemical to New Markets

Methanol (DME) Price/Cost, $/ton

Today

Conventional Fuels at $20/BBL crude oil

Future

Industry Trend

Today

Future

Methanol (DME) Price/Cost, $/ton

0 2 4 6 8

$/MMBTU

50 (70) 100 (140) 150 (210)
NPC/Iran Methanol
5,000 TPD

Memo: Not including <5,000 MTPD methanol plants

Trinidad – (2) 5,000 TPD
Atlas Methanol
Methanol Holdings

Oman Methanol - 5,000 TPD
Qatar Fuels Additives 6750 TPD

NPC/Iran Methanol
5,000 TPD

Oman Methanol
5,000 TPD

Methanol Australia
5,000 TPD

Methanol

Methanol for Power/Olefins

DME

Memo: Not including <5,000 MTPD methanol plants
NPC/Iran Methanol
5,000 TPD

Trinidad – (2) 5,000 TPD
Atlas Methanol
Methanol Holdings

Oman Methanol - 5,000 TPD
Qatar Fuels Additives 6750 TPD

Nigeria/Eurochem
7,500 TPD MTO

PetroWorld/Starchem
>12,000 TPD

Qatar/PetroWorld
>12,000 TPD

NPC/Iran Methanol
5,000 TPD

Memo: Not including <5,000 MTPD methanol plants
Large Methanol/MTO/DME plants (built, proposed)

Proposed Supply for New Methanol/DME Markets: 23 MMTPA methanol
(Equivalent to 200,000 BBL/D GTL-FT)

Memo: Not including <5,000 MTPD methanol plants
Potential DME Demand in Asia (2010)

Total = 105 Million T/yr

Source: JFE, “Feasibility Study of DME from Brown Coal in Australia, 2001
DME as an LPG Substitute – Why?

- DME’s physical properties similar to LPG
- LPG is domestic fuel and chemical feedstock
- LPG market is large (180MMTPA in 2000) and growing fast (5MMTPA through 2015; 9/13MMTPA DME/methanol equivalent)
- Regional supply/demand imbalances/shortages
- Attractive pricing/economics
- Developing countries (China, India) need portable (bottled) fuel – even faster demand growth
- Strong quality of life improvement and environmental driver
LPG/DME Interchangeability

- LPG/DME Blends:
  - Up to 20% blend of DME with LPG: no or very minor system modifications

- Pure DME Systems:
  - Storage/Pumps: 20-35% increase in fuel storage/pump capacity; more frequent delivery is required
  - Material Compatibility: seals

A commercial gas stove can be used for DME without modification.

Picture courtesy of NKK Corp.
DME for Power Generation – Why?

Because...

- CCGT are power plants of choice
- Large market: 300 GW
- Growth can be fuel constrained
- DME is an excellent fuel for CCGT
- Price Competitive
- Guaranteed Turbine performance
- 1 MW requires 5.5 tons of DME
- 5000tpd DME feed a 0.85GW plant
- Also suited for diesel generators
- Fuel for stationary fuel cells

Combined Cycle Gas Turbine (CCGT) is the power plant of choice today with up to 60% efficiency fired with natural gas.
DME as Diesel Alternative – Why?

- Completely SOOTLESS (No smoke or particulates)
- 100% SOx reduction
- 90% NOx reduction
- Meets/exceeds 2007 emission standards
- Performs in conventional diesel engines with modified fuel injection system
- Quiet combustion
- High Cetane
- Fuel Distribution: needs LPG like infrastructure

Pictures Courtesy of Volvo Truck Corp and NKK Corp.
Methanol and DME for Power Generation

- Methanol/DME are excellent gas turbine fuels
- GE, Siemens Westinghouse provide commercial offerings of Methanol /DME-fired E class and F class gas turbines
- GE, SW guarantee power output, heat rate and performance
- Methanol/DME exhibit record efficiencies and low emissions
- MHI (Japan) extensive studies

Fuel Grade Methanol for Power Generation-

PetroWorld:

- Africa West Coast: 12,000-15,000 T/D, StarChem, July 2003

Picture Courtesy of GE
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DME: An Integrated Project

Upstream Gas Field Production

• Remote gas monetization
• Coal mine
• Biomass collection or manufacture

Manufacturing

• Modified methanol plants
• 5,000 tpd+
• Gas refinery

Transportation

• Shipping

Multiple Markets

• Fuel marketing
• Chemical marketing
• Pricing formulas
• Well to wheel value chain integration

Big, multi-party projects

>$1,000,000,000

International DME Association
Dimethyl ether: A fuel for the 21st Century
Commercial challenges

- Resistance to new alternative fuels
- New infrastructure costs
- Need for new partnerships (value chain)
- Large integrated projects
- High investments costs – financability?
- Lack of leadership
- Competition with LNG and GTL
- Customer acceptance of DME
- No industry momentum
Technical challenges

- DME manufacturing (record plant sizes, new technology)
- LPG tanker modifications/optimization
- Diesel>LPG>power generation
- DME/LPG blends (handling, seals)
- DME diesel fuel injectors
- DME lubricity additives
- Long-term performance
Global challenges

- International standards
- Raising awareness of DME
- Global collaborations
- Strategic partnerships with other industries (methanol, LPG, clean transportation fuel)
- Competition with LNG, GTL-FT and hydrogen fuel cells
- Lack of first successful plant
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Over the past 3 years, global recognition of DME’s potential manifested by the formation of three associations representing about 160 companies, technical institutes, universities and individuals:

- To promote public awareness and DME application.  
  - www.aboutdme.org

- To coordinate Japanese National DME Initiative - $200 million over 2002-2005
- To develop DME manufacturing technology, shipping/distribution and marketing for multiple end-use applications

- To advance understanding and use in Korea.
OBJECTIVES

- Promote public awareness of DME
- Serve as unifying force for all regional developments
- Monitor global DME developments
- Collect and provide all relevant DME information (website)
- Deliver presentations, organize workshops and conferences
- Provide platform for international contacts
- Assist in the creation of business opportunities
- Develop strategic partnerships with related organizations
DME in China

Shandong Jiutai Chemical Industry, Linyi, Shandong
• 30,000 T/yr. December 2003 start-up.
• 60,000 T/yr. Construction started January 2004
• Plans to increase production capacity to 300,000 T/yr by end of 2005; then to 1 million T/yr by 2009.

Luthianhua Group Inc, Luzhou, Sichuan
• 10,000 T/y – Commercial DME plant for fuel use - August 2003 start-up. Toyo Engineering methanol dehydration technology.
• 110,000 T/y – with 2005 start-up

• In the next 5 - 10 years, China will construct a group of large dimethyl ether units.
• Besides the units in Shandong and Sichuan, dimethyl ether units with different capacities will also be put up in Ningxia, Shanghai, Xinjiang and Shaanxi.

So: China Chemical Reporter, May 26, 2004
DME in Iran

Zagros Petrochemicals Project
(June 16, 2004 Press Release)

• To be constructed at Bandar Assaluyeh, Iran with a capacity of 800,000 MTPY of DME.

• Based on technology and catalyst developed by Haldor Topsøe A/S for dehydration of methanol.
DME in Japan

Japan DME Forum coordinates multiple programs.....

• Utilization
  • Power generation systems
  • Household/industry fuel
  • Diesel related technologies
  • Emission tests from diesel engine
  • Marketing study
  • Road test of DME vehicles

• Production
  • Production technologies
  • Ocean transportation

• Codes & Standards
  • Studies for standardization of DME fuel

DME Commercial Projects - Studies
• Japan DME Ltd: 5,000 t/d, Western Australia
• DME International Inc, 2,500-4,000 t/d, Qatar/Indonesia/Australia
• Mitsui & Co, TEC: 7,000 t/d, Iran, Indonesia
DME in Korea

• Conducting engine research, elaster testing
• DME Pilot Plant (100 kg/d), KOGAS R&D Center
Other DME Activities Around the World *

**Sweden**
- DME from Biomass Gasification Project
- Fossil Fuel Free Växjö

**Russia**
- Moscow program: "Alternative fuels use in city’s motor transport for 2002-2004”
- VNIIGAZ (GAZPROM Research Institute) developing technology to manufacture DME

**USA**
- DME-Fueled Shuttle Bus Demonstration, Penn State University

**Italy**
- Snamprogetti Program: DME as LPG substitute, and LPG/DME interchangeability in diesel engines (with SwRI)

**Brazil**
- A network, headed by the Petrobras Research Centre, was established including one Research Institute and three University Laboratories.

**Europe/USA**
- AFFORHD. Alternative Fuel for Heavy Duty Engines
  - Volvo, AVP/PTI, DTU, BP, TNO, Växjö
  - 2002-2005, 4 million euro

**Ocean Transport**
- DME has been accepted in the IMO Gas Carrier Code, according to Norske Veritas, DNV. DNV can issue safety certificates for gas carriers to transport DME (September 2003)

* Only a partial list of the extensive global efforts
Conclusions

Dramatic progress has been made in the past 10 years in understanding and advancing the DME business

- DME is a very promising new fuel
- Many drivers and opportunities
- Significant challenges have to be overcome
- A global DME effort has evolved - led by Asia.
- International DME Association, Japan DME Forum and Korea DME Forum have been formed.
- DME community must join forces for DME acceptance and growth

The Future is Now