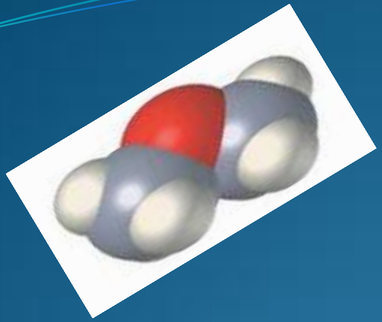

DME as an Alternative Fuel in Korea

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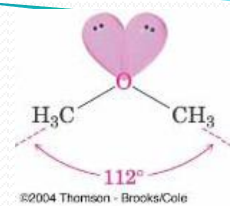
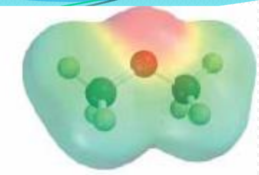
President of KDA
(www. Koreadme.com)

Contents

I. General Aspects

A. What is the DME ?

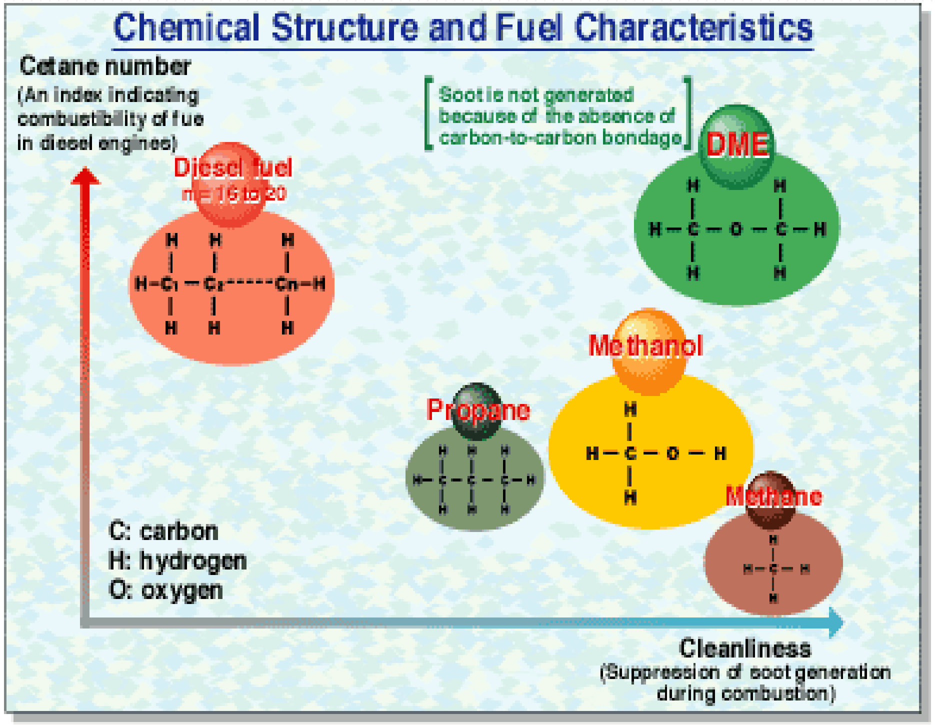




Properties	DME	Propane	Methane	Methanol	Diesel
Chem Formular	CH_3OCH_3	C_3H_8	CH_4	CH_3OH	C_{10}~C_{18}
B.Point(°C)	-25.1	-42.0	-161.5	64.5	180~170
Liq.viscosity (kg/ms@25°C)	0.12~0.15	0.2	-		2~4
Sp. gravity	1.59	1.52	0.55	-	-
Vap. Press (atm@25°C)	6.1	9.3	1@161.5°C	1 @64.7°C	0.035max@21°C
Explo Limit (%)	3.4~17	2.1~9.4	5~15		0.6 ~6.5
Jgnition Temp (°C)	350	504	632	470	-
Cetane No.	55 ~60	5	0	5	40 ~ 55
Net Calorific value(kcal/kg)	6,900	11,100	12,000	5,024	10,000
Net calorific value (kcal/Nm^3)	14,200	21,600	6,600	-	-
Energy Density* (MJ/l)	18.97	23.5	7.88	15.69	35.08

*Energy Density (*)is a value at 246kg/cm^3.

B. Merit and Demerit for DME vehicle)



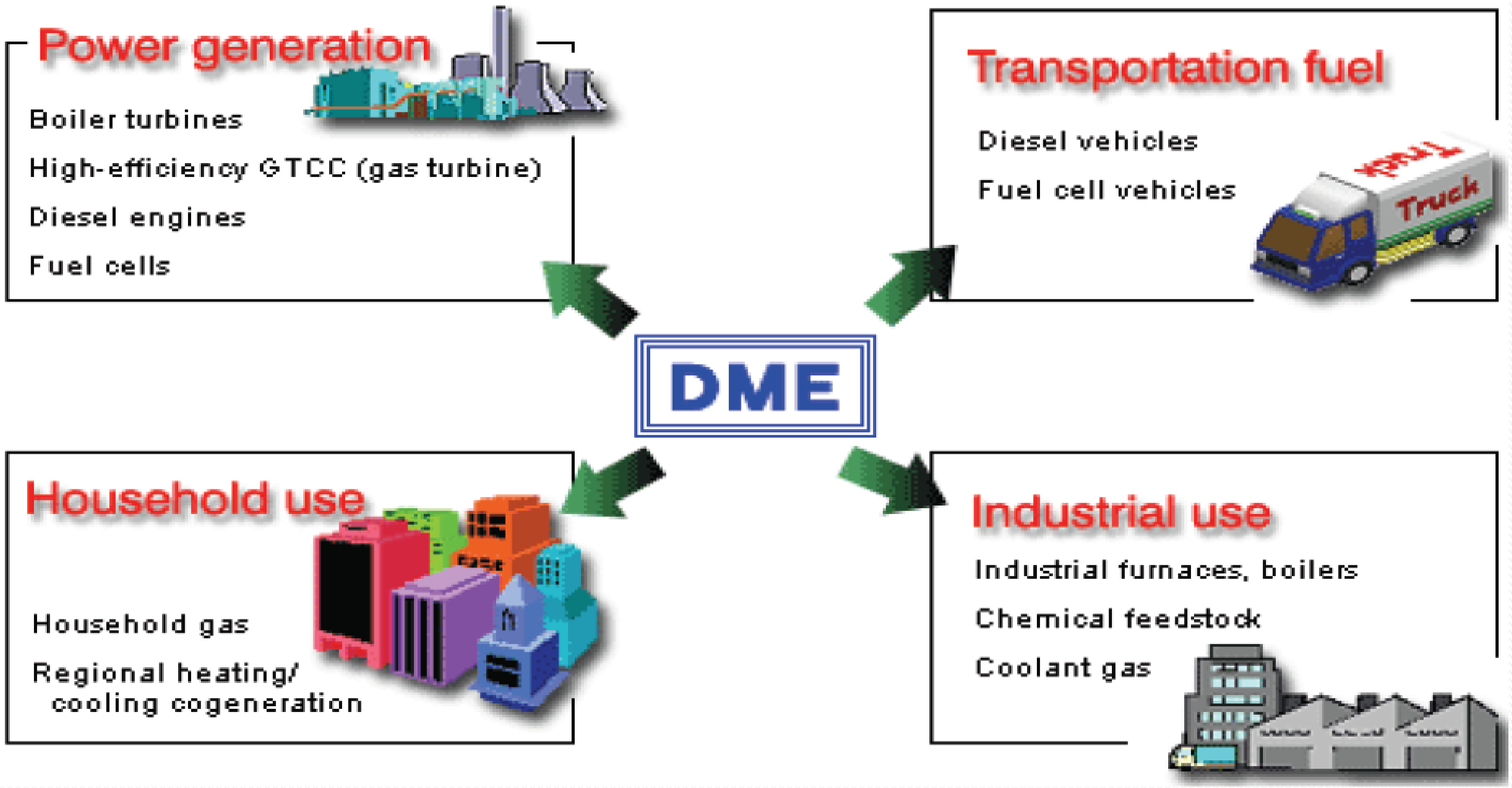
Merit

- High Thermal Efficiency
  : Equal to DI Diesel E/G
- Compression Ignition
  : about 60 of Cetane Number
- Smokeless Combustion
  : nearly Zero PM (O_2 34.8wt%)
- High EGR Tolerance
  : NOx can be Reduced
- Combustion Noise Reduced.
- No health hazard
- LPG Infra can be Used
  : Liquefied at 5-6 bar

Demerit Combustion Noise Reduced.

- Low Lubricity & Viscosity : Wear & Leakage Problem
- High Compressibility : Difficult to Injection Control
- Elastomer attack : Sealing program

C. Where to use it in Korea?



D. How to make it in Korea?

NG
Coals
Bio Sources
Steel Comp

Syngas
($CO+H_2$)

• Bifunctional DME Catalysts

DME

(Cu, Cr, Zn)

MeOH

(Co, Fe)

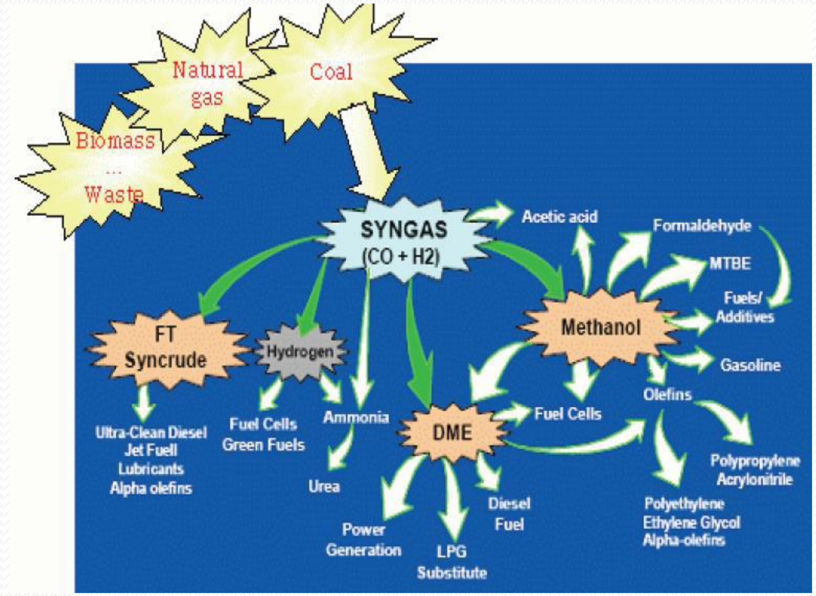
F- T Liquids

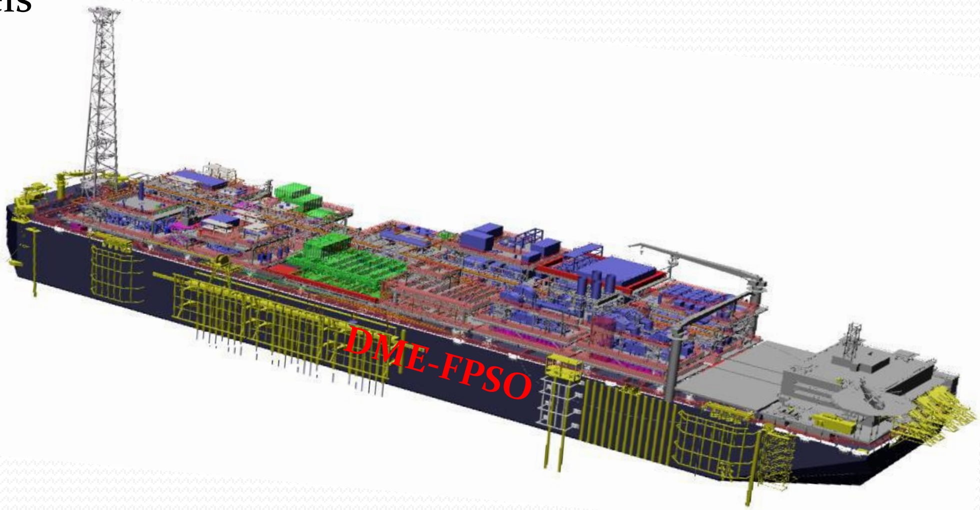
Gasoline

Naphtha

Middle Distilates

Diesel/Jet Fuels





E. Is it feasible and economical?

➢ Profitability Calculation

- 1ton DME requires 1.42tonnes of MeOH
- Fixed cost ~$45/t
- DME sales price is a function of LPG price
- Listed sale price is usually ~80% of LPG price
- DME sales price represents an about 37% premium to energy value

❖DME Production Cost =1.42MeOH Price+Fixed Costs

❖DME Selling Price = LPG Price x (Selling Factor) x Selling Factor Avg x Selling Factor Avg = 75 ~90 %

(Ben Iosefa, the 6th Asian DME Conference, Seoul, Korea 2009)

F. Dev. of KOGAS's Economic DME Process

- **Tri- Reforming** — CO_2 10% reduction, CDM leveraged
- **Process Efficiency** — 70%, 10% higher than others
- **Lower EPC** — 60 ~ 85% of competitors

G. Milestones on KOGAS DME Plant

Demo Plant 10TPD
(2004 – 2008)

Overseas DME Plants

1. Saudi Arabia:
   1MTPA(2010 – 2013)
2. Oman (MOU, 2010)
3. Indonesia(MOU,2010)
4. Iran (MOU, 2010)

Pilot Plant 50KPD
(2003 – 2006)

Lab/Bench Scale
(2001 – 2003)

DME-FPSO (2010-2015)

II. Alternative Transportation Fuel in Korea

A. R&D of DME Vehicles in Korea

1. Emission test(cvs-75mode) w/ Diesel Oxydation Catalyst (KIER)

Proto-type DME Truck (3.3 Liter)

	Diesel	DME	DME[w/DOC]
Nox[g/kWh]	3.34	2.18	2.22
CO[g/kWh]	2.20	3.54	0.39
THC[g/kWh]	0.89	0.37	0.25

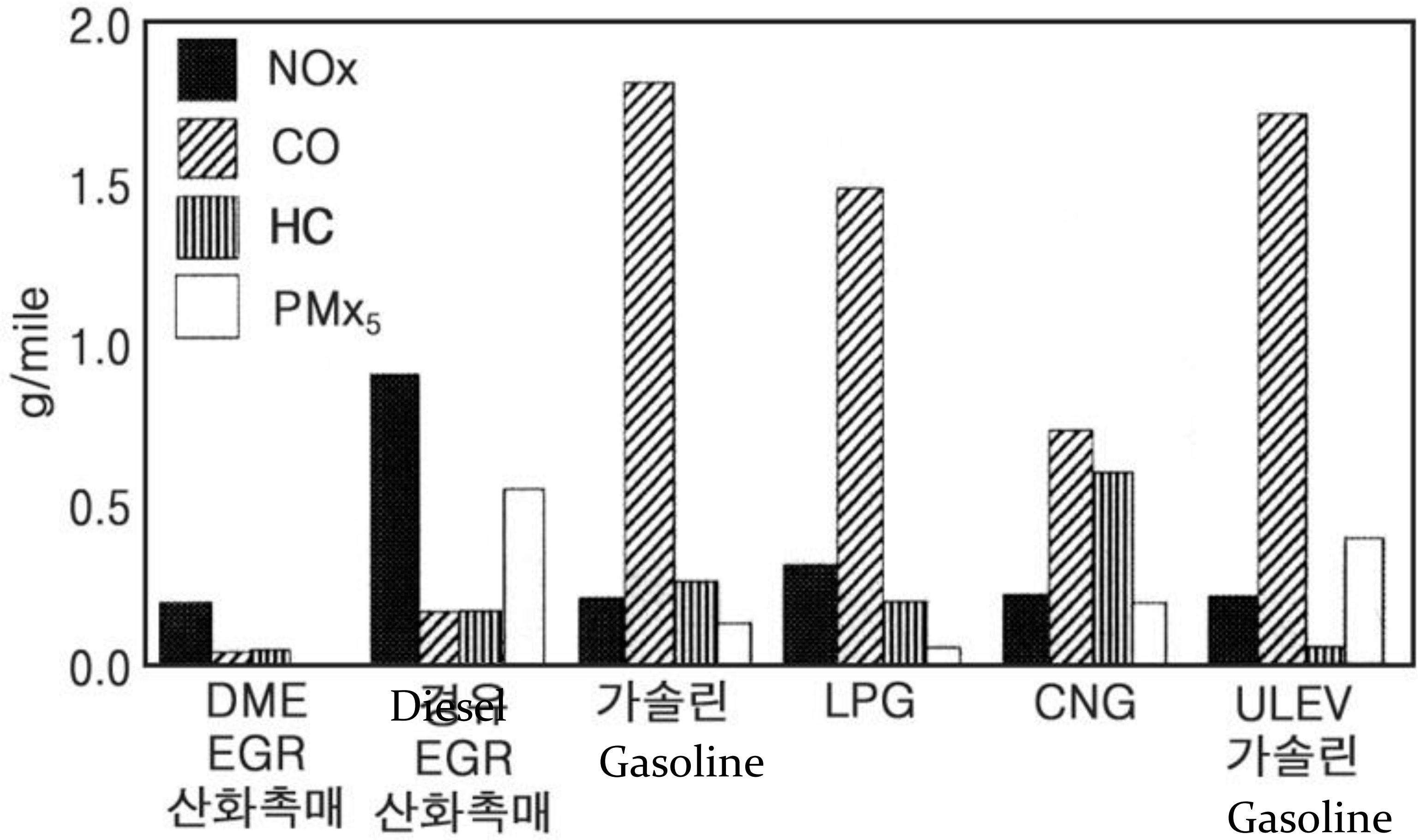
Proto-type Midium-duty DME Bus(KIER)

Model	BM090(DAEWOO)
Displacement	8,071 cc
Type	6 cylinder, TCI
Engine	DE08TiS
Power	225 PS/2,300 rpm
Torque	90 Kg.m
Speed	120 km/h

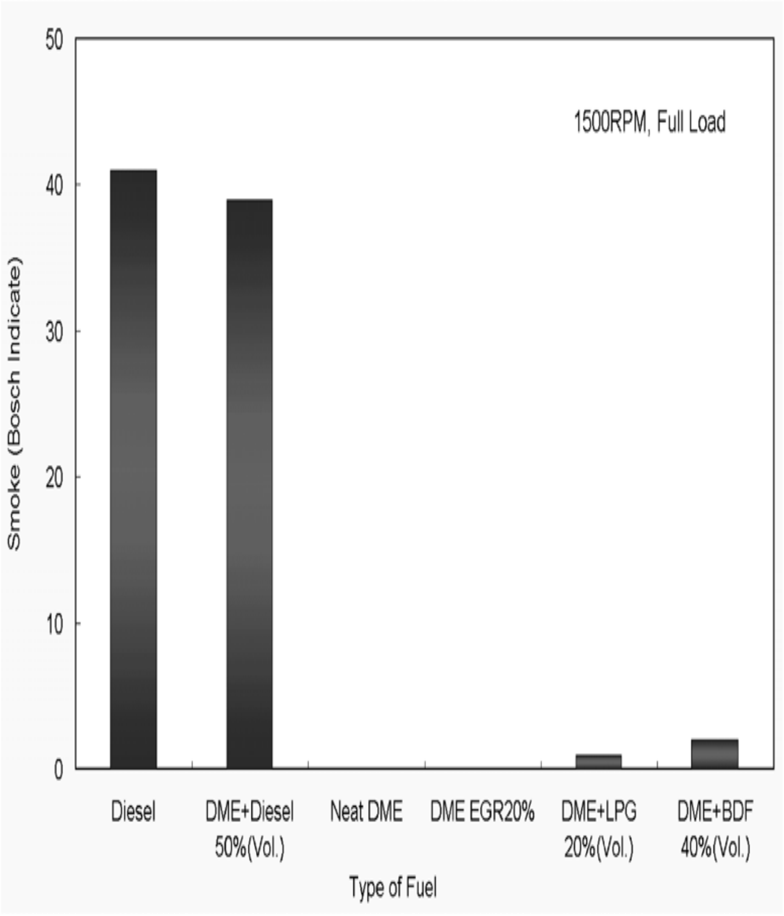
The results of vehicle tests
-EGR effects [KATECH, 6th Asian DME Conf.]

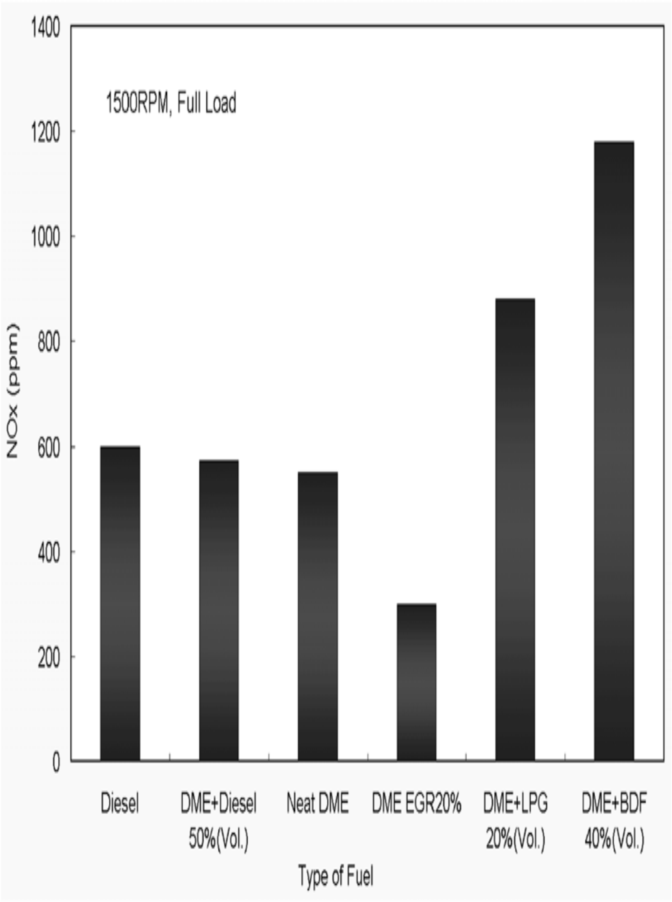
Case (1991 cc)	Condition (Hot start)		Emission (g/km)				Fuel Economy (km/L)
	Start		HC	CO	NO x	CO_2	
Base (Diesel)	Cold Start	w/EGR & boost	0.064	0.349	0.918	194.53	13.77
DME	Hot Start	w/ EGR & boost	0.180	0.641	0.350	184.42	10.52
DME	Hot Start	w/o EGR & boost	0.31	0.541	1.159	185.97	10.42

2. Exhaust Gases from various Fuels (Dae Yeop Lee, Inha Univ.)

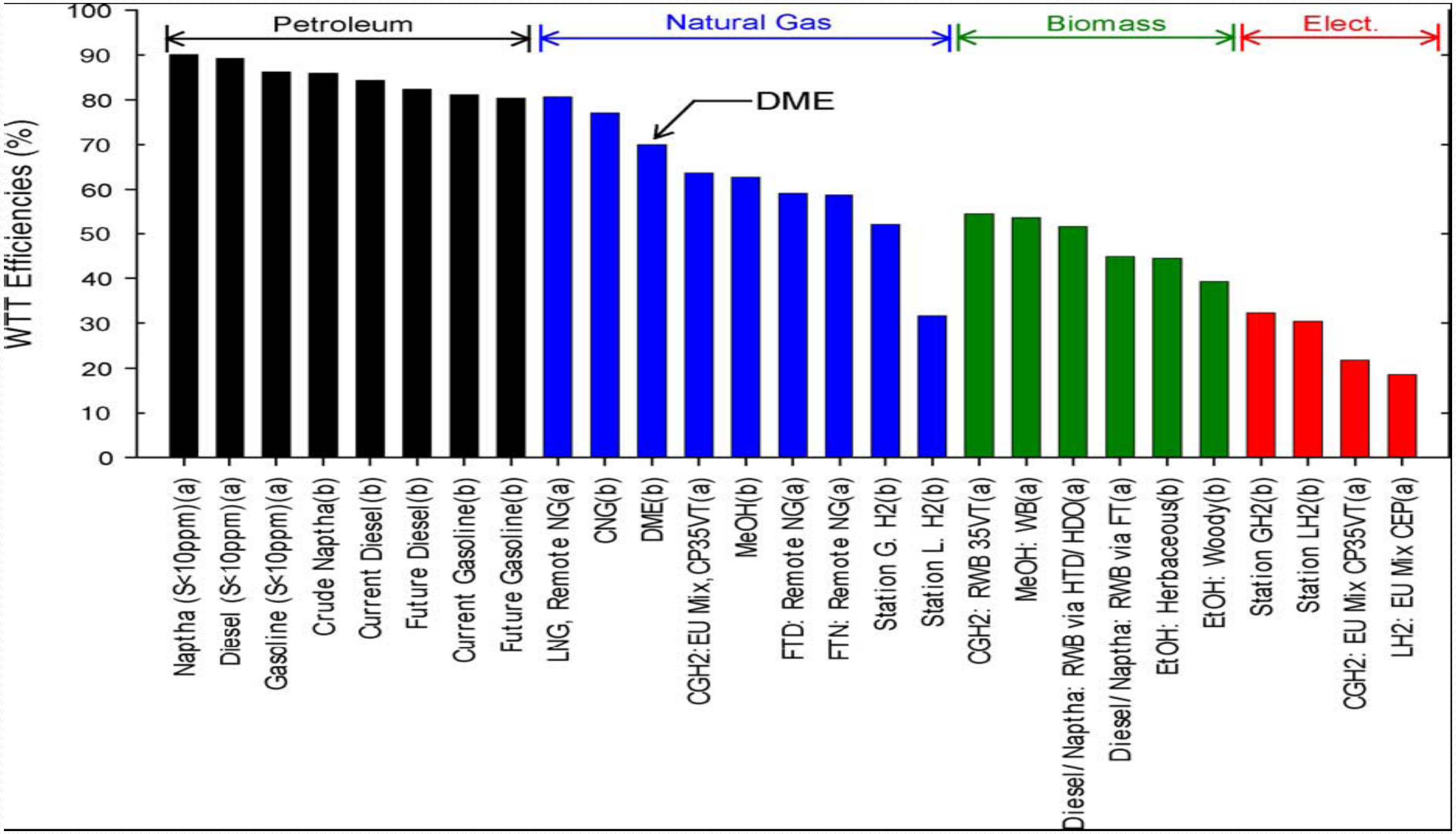


2-1. Smoke & NOx from various Fuels (Y.J.Lee,Y.D. Pyo, KIER)

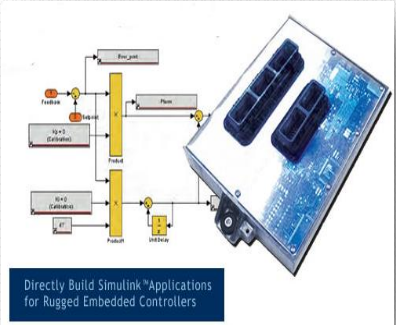




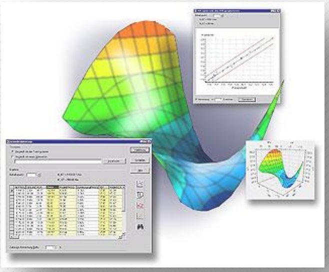
3. Energy Efficiency of DME



4. Engine Performance Test based on broad Operation Range (KATECH)

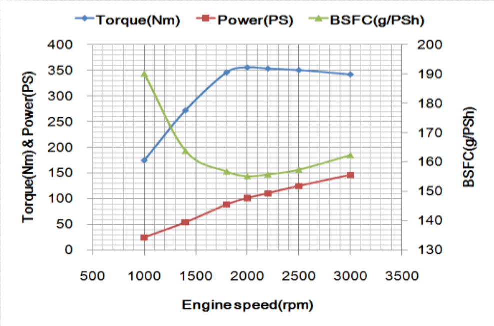


< Self-made engine controller >



< Engine map >

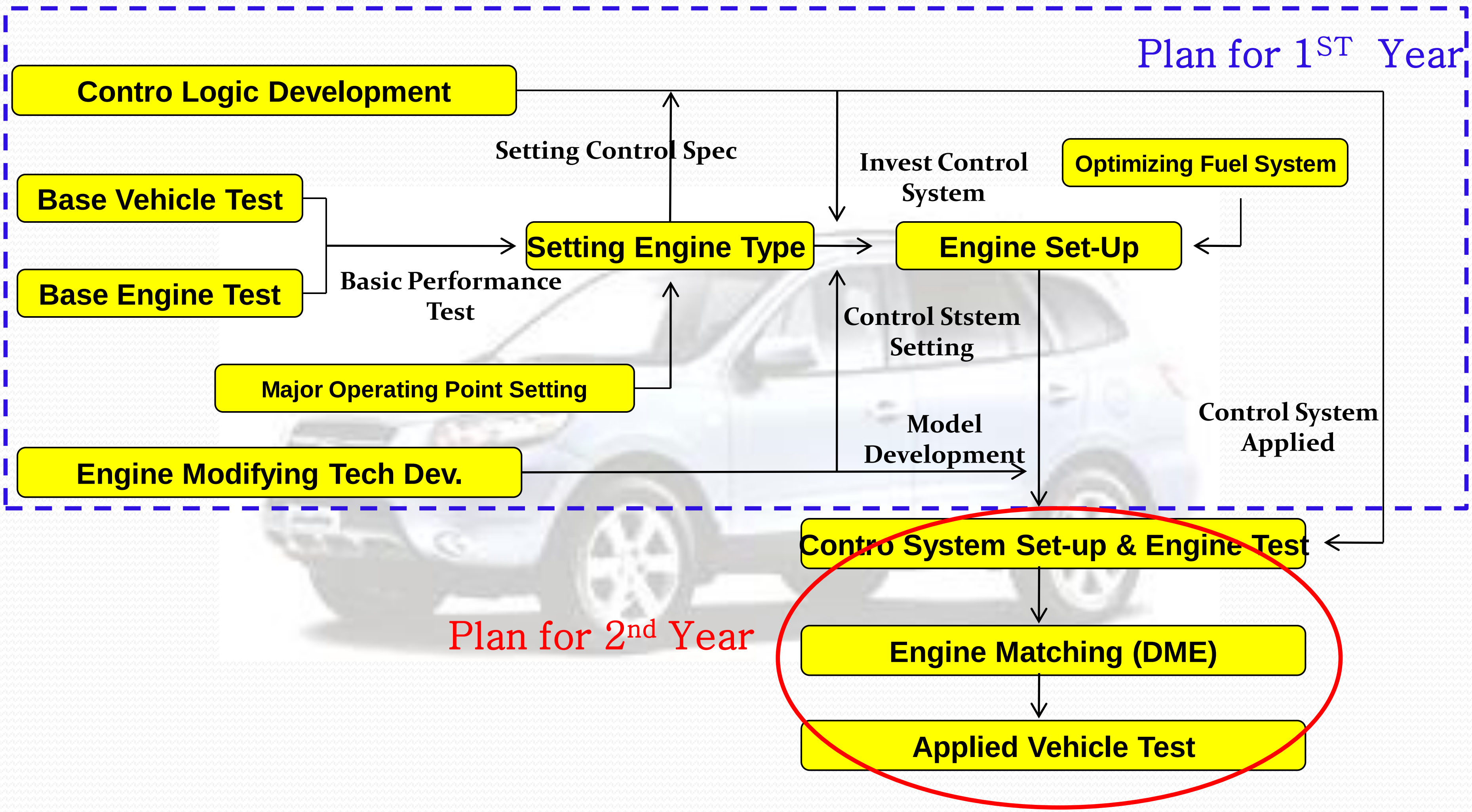
< Engine >



< Engine performance >

< Create engine map using engine model>

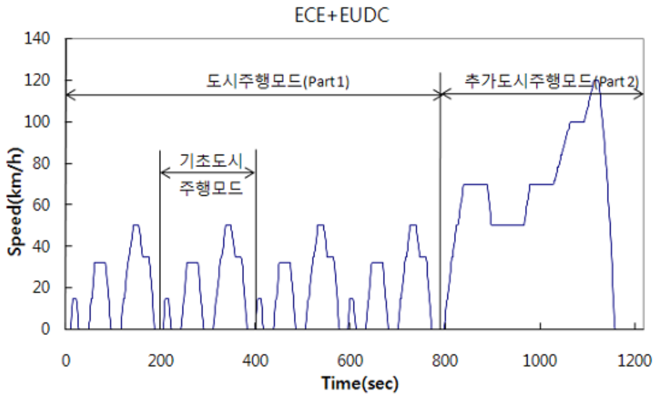
4-1. Control Logic Development for DME Vehicles(KATECH)



4-2. Santafe Performance Test (KATECH)

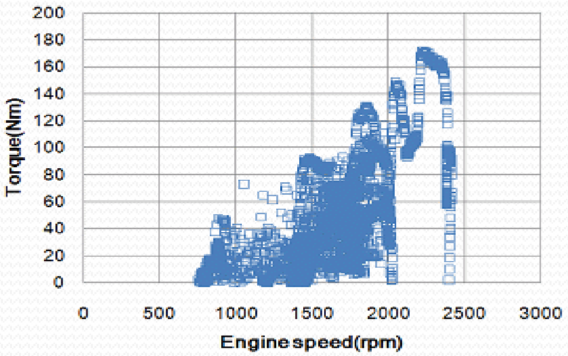
Vehicle Power Line Mode Test

Base Vehicle Driving Mode & Performance Test Result s



Test results (EURO 4 Level)	
Parameter	NEDC (Cold start)
F. E.(km/L)	12.66
HC(g/km)	0.069
CO(g/km)	0.374
NOx(g/km)	0.304
CO_2(g/km)	209.6

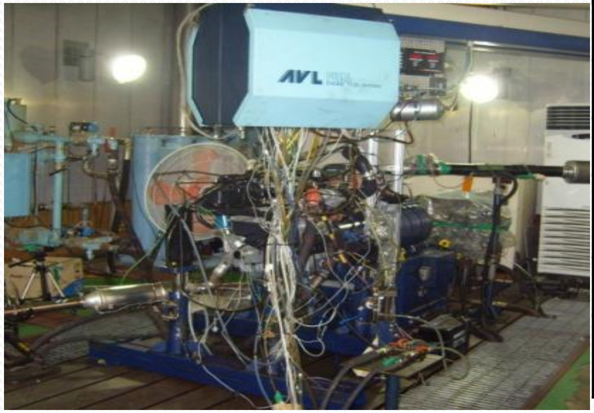
Major Range of Engine Driving Mode – Testing Major Performance Range of Engine



RPM	Max. torque(Nm)	BEMP (bar)
1000	60	3.5
1200	79.2	4.7
1400	98.4	5.8
1600	117.6	6.9
1800	136.8	8.0
2000	156	9.2
2200	175.2	10.3
2400	194.4	11.4

4_3. Engine Power Test (D-2.2 eng.)(KATECH)

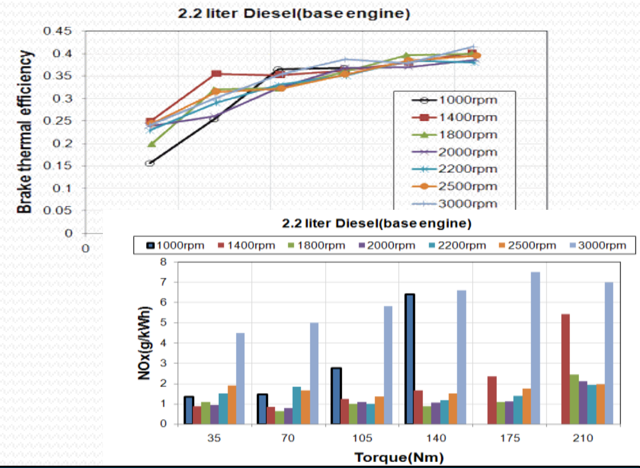
Photo for Engine



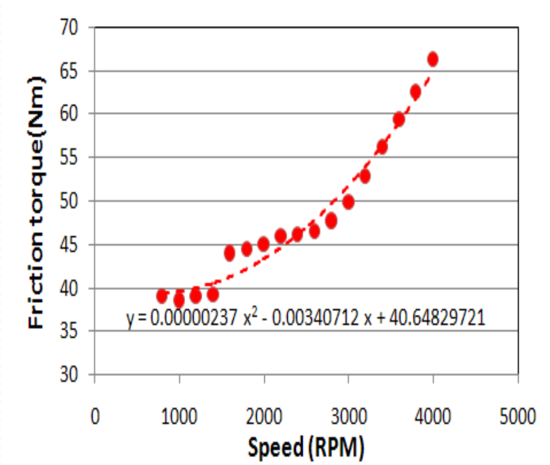
Base Engine Spec.

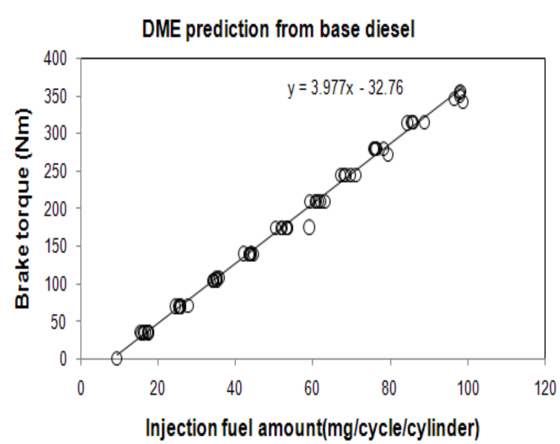
Description	Specification
Displacement	4cyl - 2200 cc
Bore × Stroke	87 × 92 (mm)
Comp. ratio	17.3
Breathening sys	VGT / HP EGR
Fuel system	Common rail type

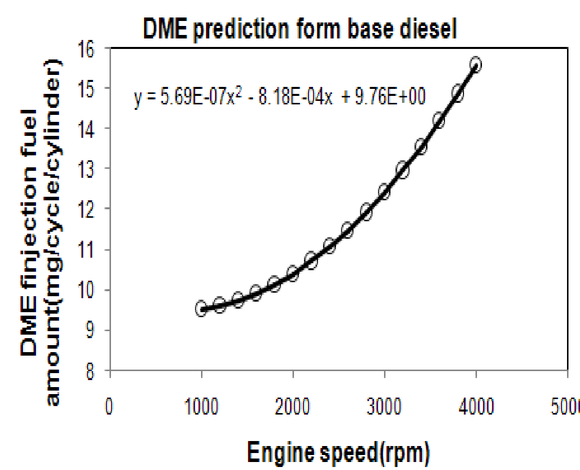
Comparison Data of base Engine



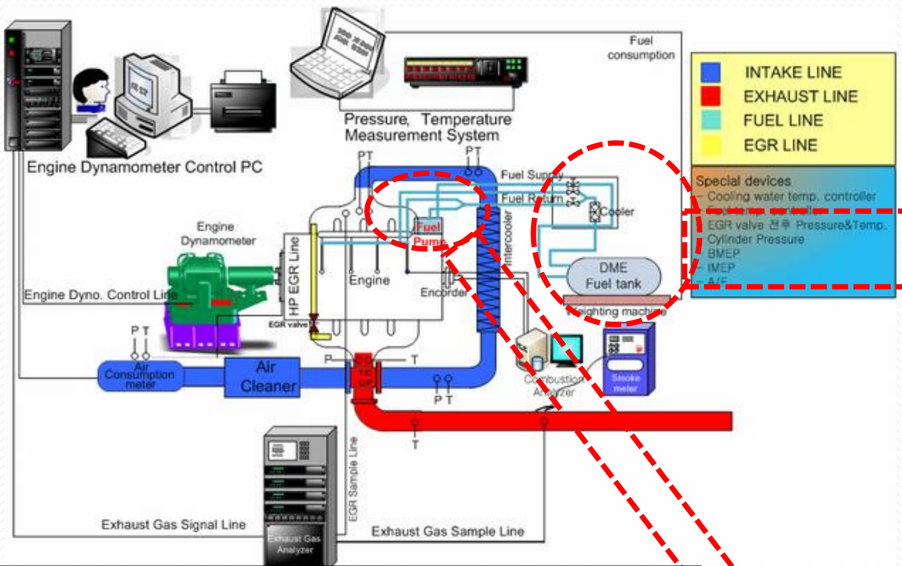
Base 엔진 데이터를 이용한 DME 엔진의 기본 보정 데이터 및 보정용 기본 모델 구성



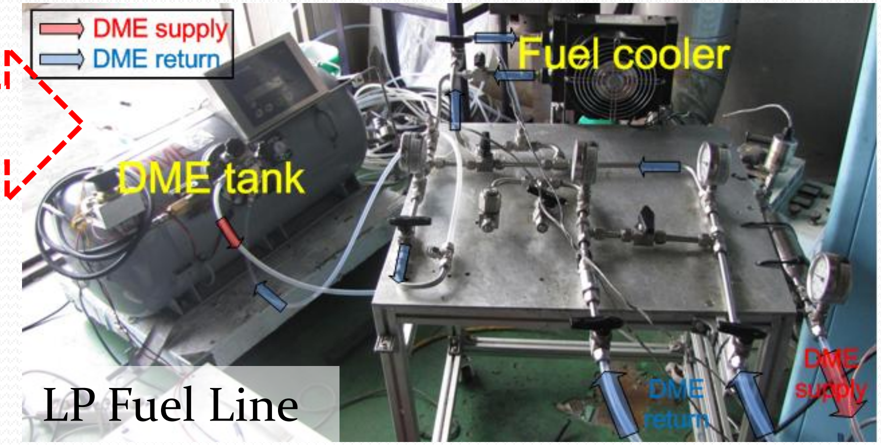


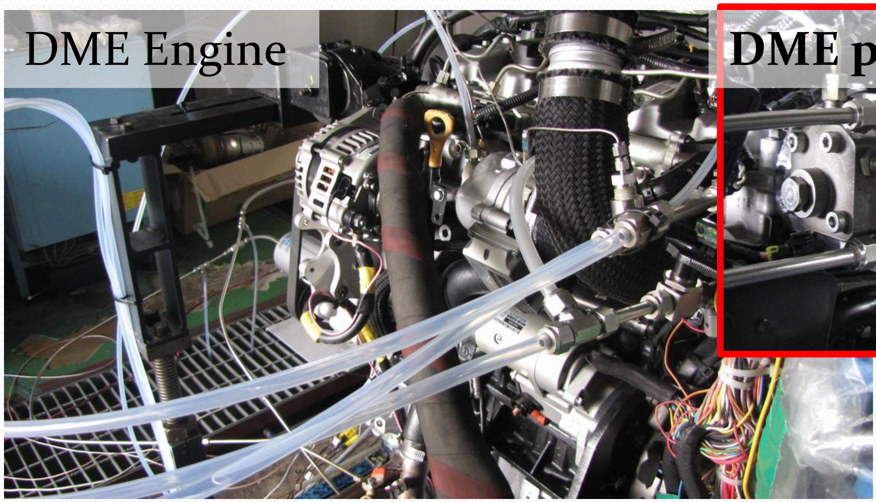


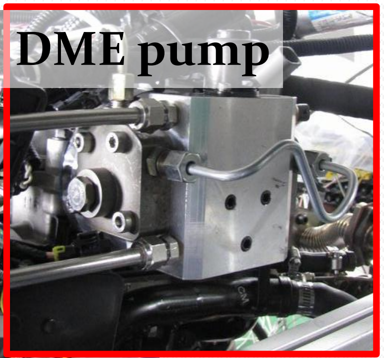
4-4. Engine Testing Equipment Set-Up for DME Fuel (KATECH)



LP & HP Fuel System for DME Engine Replacement

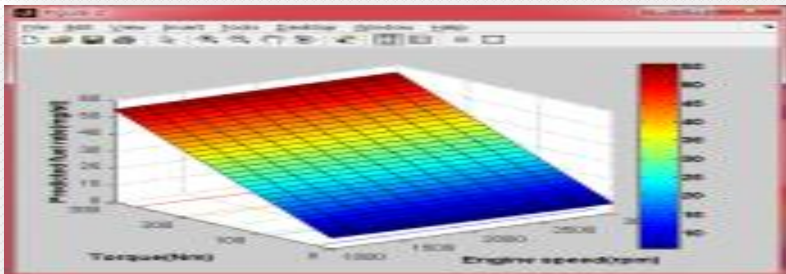






4-5. Basic Algorism for DME Fuel Injection (KATECH)

- Verifying Injection Model for DME Fuel (Injection duration, timing, pressure)



: Diesel
required fuel rate

Injection timing v.s. Fuel Ratio

4-6. Suitability Test for Required Fuel Pressure(TATECH)

- Pressure 600 bar acquired @ 2500rpm
- Good Enough for Optimum Engine Performance.

B. Overseas Buses and Trucks

Sweden DME BUS

Volvo Truck

China DME BUS

ISUZU DME BUS

C. Development of DME Vehicles in Overseas

Europe

Country/ Name	EU/AFFORHD
Period	2002 - 2003
Organizers	Volvo/AVL/DTU/TNO/ BP/Vaxjo city
Vehicle Spec	HD DME Track Engine :9.4L with I/C Turbo
Performance	Emissions (target) -PM: 0.02 g/kWh (EURO4) -NOx: 2.0 g/kWh (EURO5)
Mfg Sample Number	1 unit : 2005 - 3 units :2006 - 2008 30 units :2008 -

China

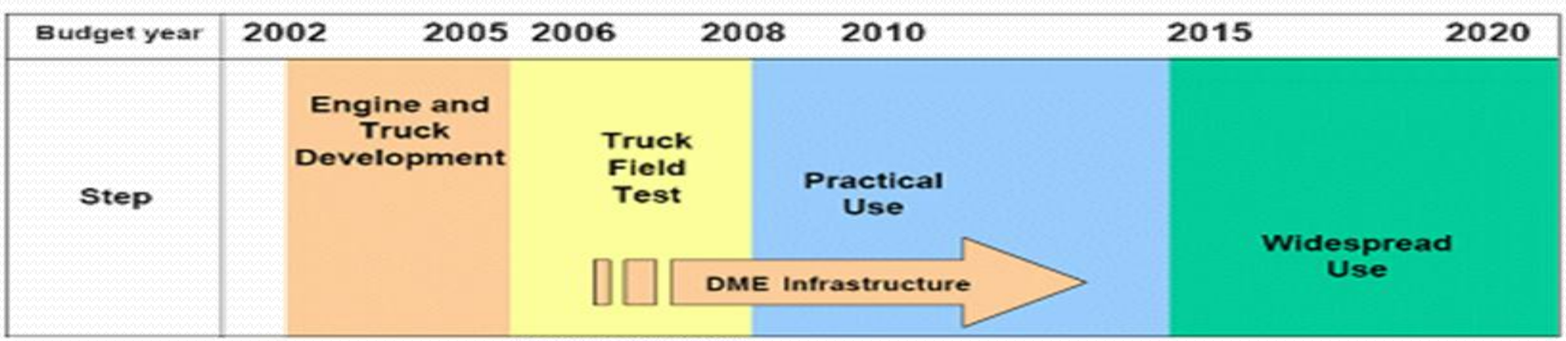
Country/ Name	China/ Shanghai City Bus
Period	Announced in May '05
Organizers	Shanghai Traffic Univ./ Shanghai Automobile/ Shanghai Diesel /others
Vehicle Spec	Shanghai city DME Bus Engine:8.3L with I/C&T/C
Performance	Emissions (target) -PM: 0.05 g/kWh(EURO3) -NOx:4.014 /kWh(EURO3)
Mfg Sample Number	10 units :- 2006/E (plan)

Russia

Country/ Name	Russia/ LDT in Moscow
Period	2002- :Renewal every year
Organizers	Moscow Traffic Bureau/ Engine Research Center/ FGUP-NAMI /Mos.S.Univ.
Vehicle Spec	LT DME Track (bi-fuel) Engine :6L with Turbo
Performance	Emissions (target) -PM, NOx : unclear
Mfg Sample Number	As of 2006: 3 teams x 10 = 30 units 50k units :2005-2010

D. DME Vehicle in Japan

Vehicle View					
Category Usage	HDV Long haul fleet	MDV Working w/crane	LDV Urban delivery	LDV Urban delivery	HDV Road cleaning
GVW ton (Payload ton)	20 (10)	7.9 (3.5)	5.8 (2)	4.9 (2)	16.5 (6.5-7.5) [plan value]
FIE	in-line jerk type	Common rail	in-line jerk type	Common rail	in-line jerk type
Fuel tank Liter x No.	171 x 2	135 x 1	134 x 2	135 x 1 [plan value]	171 x 2 [plan value]
Manufacturer	Nissan Diesel corp. NTSEL	Isuzu (advanced engineering center Ltd)	Bosch corp. (JPN) NTSEL	Isuzu (advanced engineering center Ltd)	Nissan Diesel corp. NTSEL
Remarks	·Certificated by MLIT in Aug.' 06 ·w/DeNOxCat	·Certificated by MLIT in Nov.' 05 ·w/crane	Certificated by MLIT in May' 06	To be certificated by MLIT in Mar ' 07	To be certificated by MLIT in Mar ' 07



D. DME Vehicle in Japan (Road Test)

Kanetsu Highway, HDT

Road Cleaning Work, Yokohama

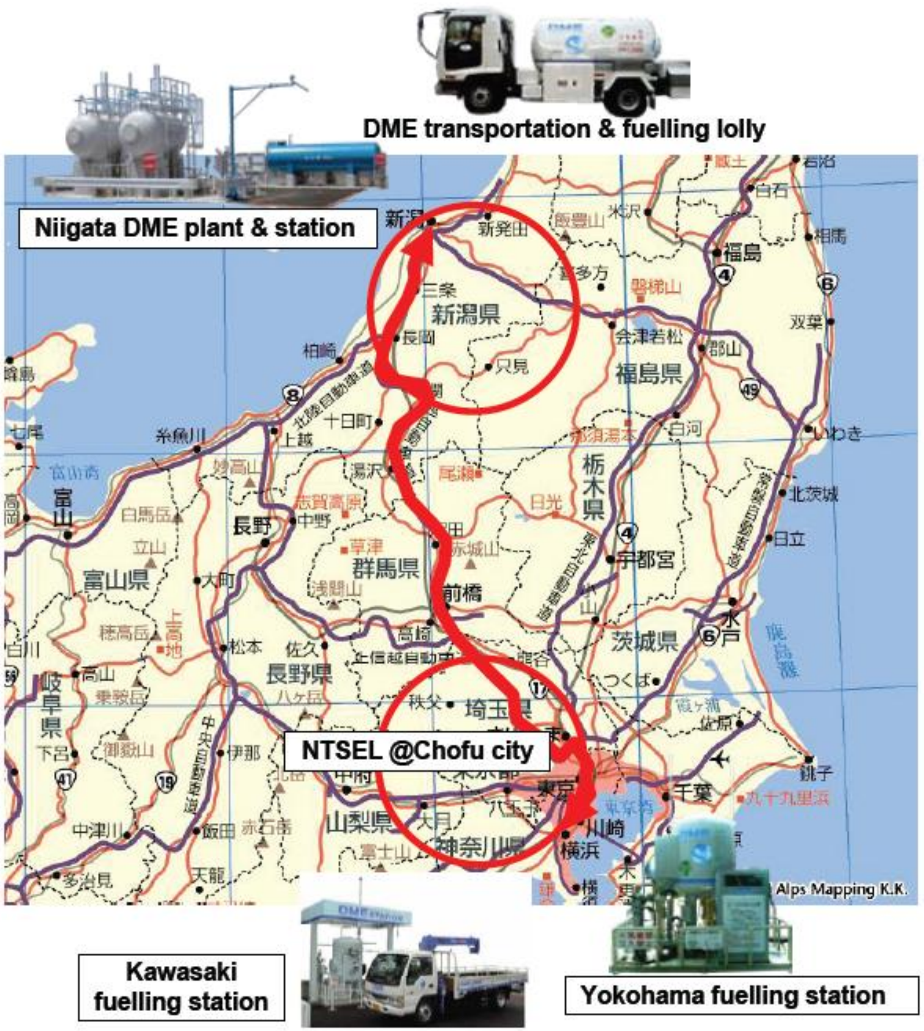
Up-Slope Test, Hakone, MDT

Niigata Filling station, HDT

High speed oval, Tsukuba, LDT

Kawasaki Filling station, MDT

E. Route of HDT Road Test for DME Vehicles



- **Route of HDT Road Test**
  - Long haul fleet between Yokohama and Niigata where DME fuelling stations are already set up.
- **Running Distance**
  - HDT :400km/day x 20days/month
  - LDT :140km/day x 20days/month
- **Payload condition**
  - To drive with zero, half and full payload by dummy weights in cases for each purpose
- **Test Items**
  - Exhaust emissions and bsfc to be tested at point of start, middle and finish for deterioration check
  - Drivability assessment by driver
  - Disassembled inspection check of FIE system after certain distance
- Further improvement to be carried out on durability, reliability and practicability if any problems to be found during road test

III. Conclusions

- **Market expects cheaper and cleaner energy of DME**
  -Korea needs 0.5~1.0 million tons a year until 2013
  -Global needs more than a quarter billion tons a year
- **Localization of DME Production Technology**
  –Localization of Source Tech and License assurance
  –Dev. of Core Technology for DME Prod. Tech.(Catalyst, Reactor Design, Sep. Process)
  –New DME-FPSO Process Development using DME Tech.
- **Development of Overseas Gas Field**
  –Plant Export of DME Production using Natural Gas, Biomass, Coal Bed Methane
- **KOGAS looks for Partners possessing Gas source to join on this promising shuttle**
- **CO_2, CDM(Clean Development Mechanism) deal is a hidden source of profit**
- **Creation of DME New Demand**
  –Power generation, Industrial uses, Households, Transportation
  –Construction of Infrastructure for Domestic Supply
  –Development of Equipment for DME/LPG Blending,
  –DME Vehicles

Thank you
for
your attention!