The Trend of Technology Development for Environmental Protection in the Petroleum Industry

2005. 09. 22.

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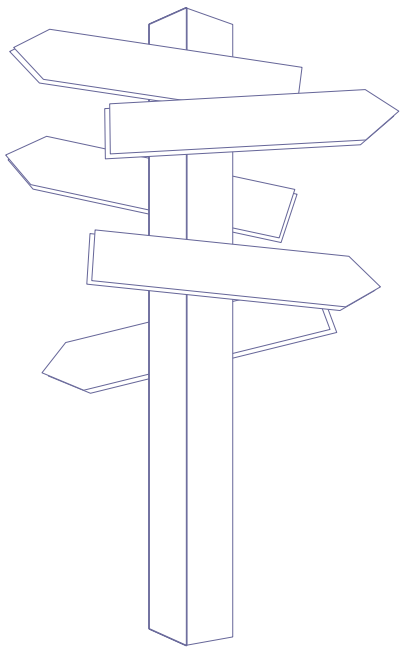
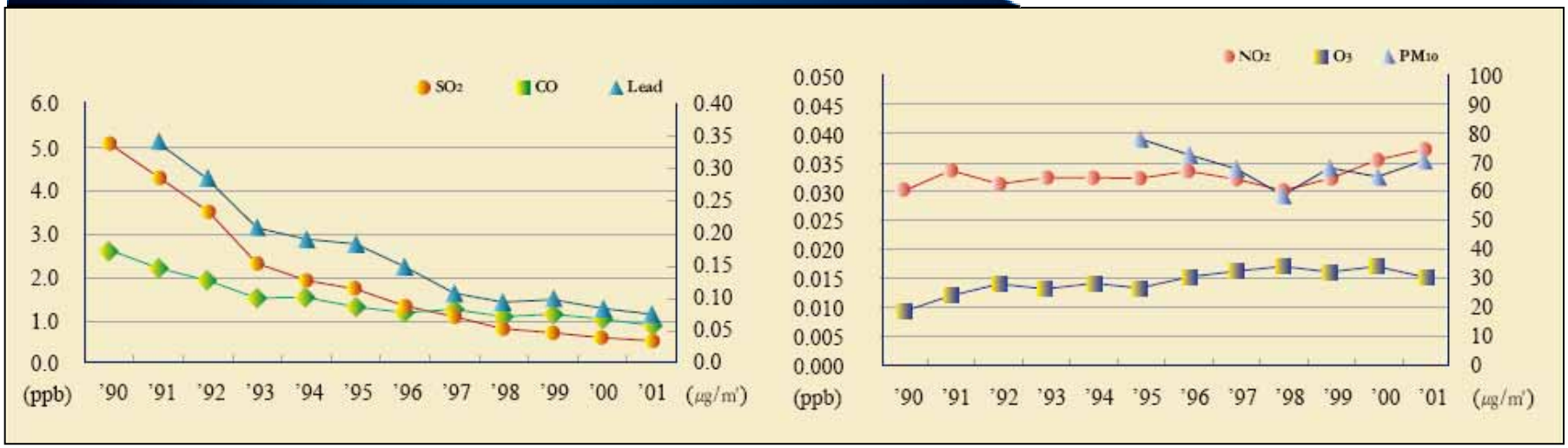


Air Quality Status in Metropolitan Area

Air Quality Condition

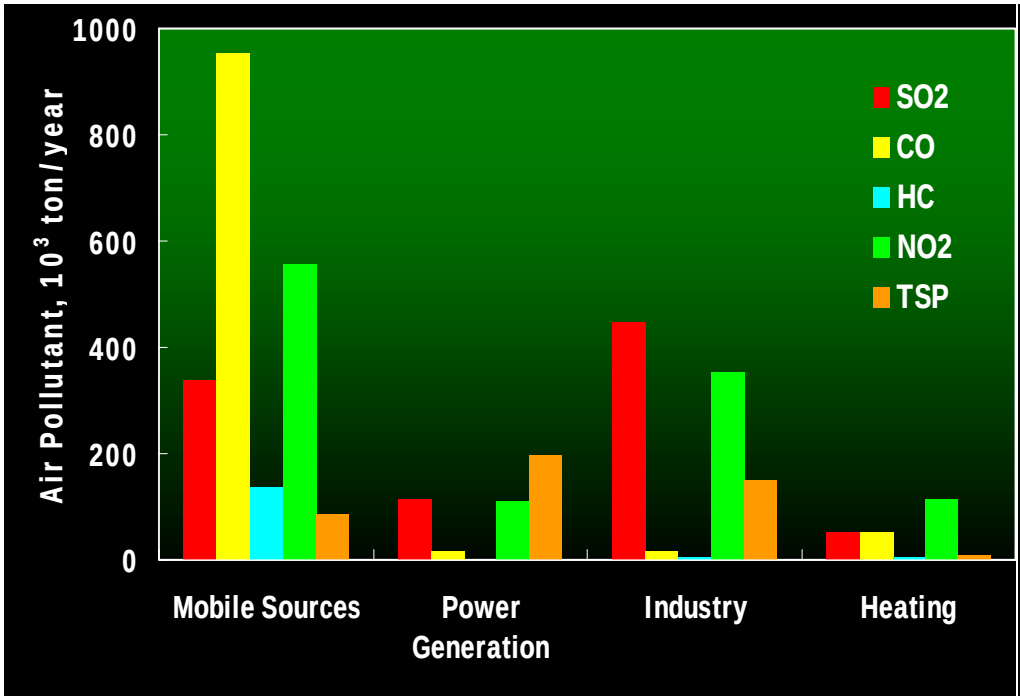
- SO_2 and CO concentrations mark below the Air Quality
- Steady increase in PM_{10} concentration due to rising vehicle emissions dust & sandstorms (DSS) transporting from China
- Steady increase in NO_2 and O_3 also caused by vehicle

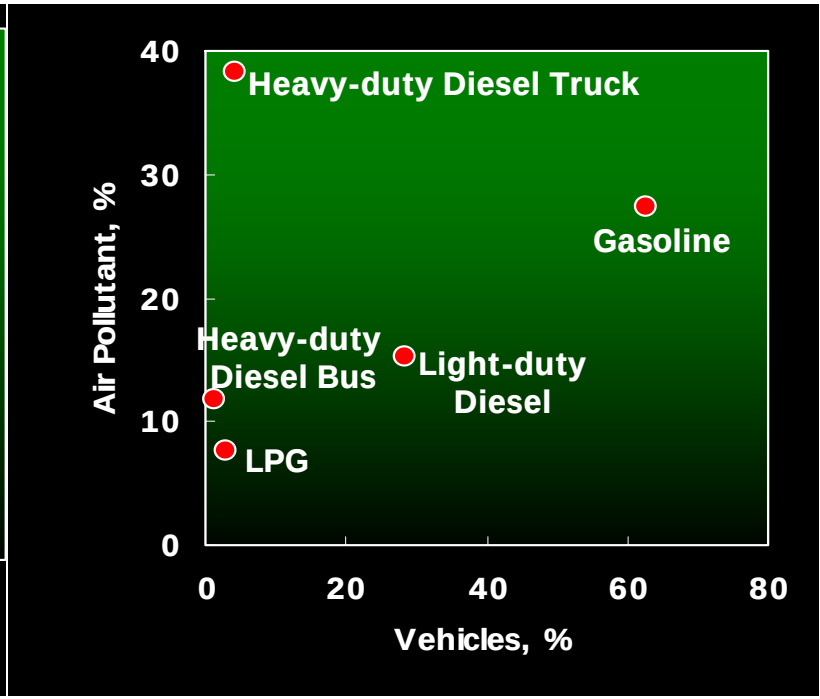
Trends in Air Pollutant Levels in Metropolitan Area



Source: Ministry of Environment, Korea 2004

Sources of Air Pollutants





- 56% of total pollutant was originated from mobile sources and about 80% of it was from automobile.
- Mobile sources occupied over 90% in CO and No_x
- Number of vehicle increased 93 times from the 1970's level
  ※ '70yr: 0.13M ⇒ '80yr: 0.53M ⇒ '90yr: 3.40M ⇒ '00yr: 12.05M

Source: Environmental Statistics Yearbook 2000, The ministry of Environment

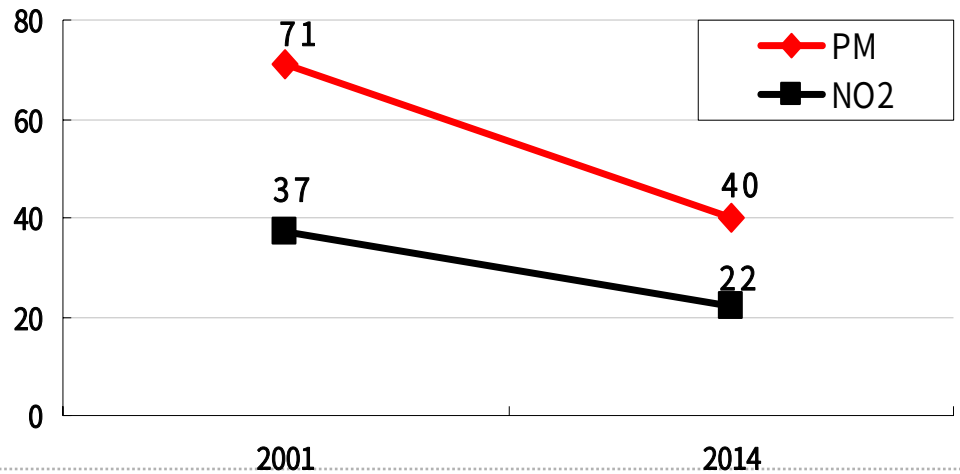
Special Act on Seoul Metropolitan Air Quality Improvement

Air Quality Status in MTA and Other Areas

Category	NO_2 (ppm)	Number of O_3 Warning	PM_{10}($\mu g/m^3$)
Metropolitan Area (Seoul)	31(37)	24(5) times	67(71)
Other Areas	22	5 times	53

A 10-year Framework Plan for Air Quality Improvement

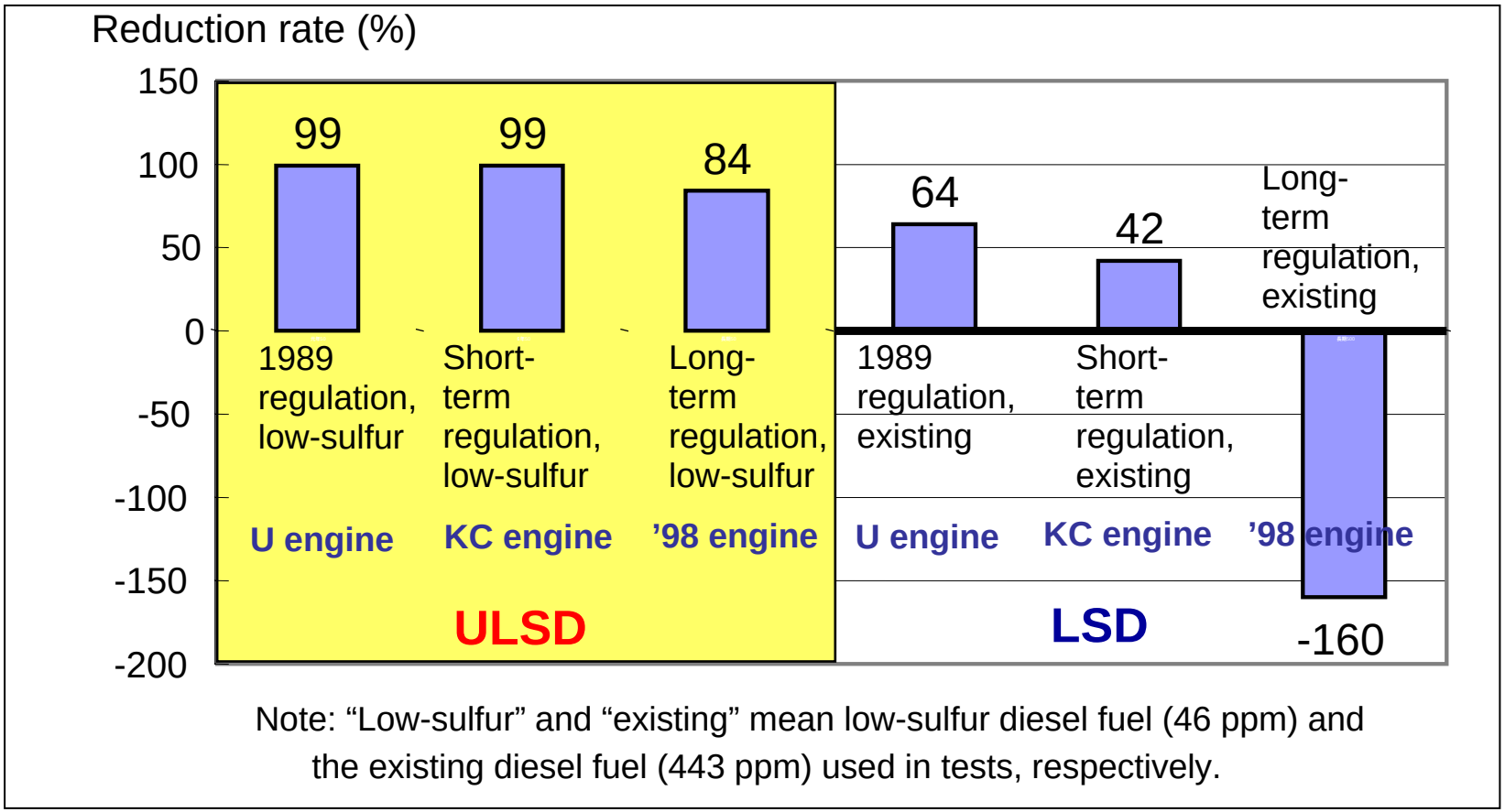
TARGET:



- **Diesel vehicles are the major of the mobile PM and**
- **Good fuel efficiency of diesel vehicle is increasing its**

Ultra Low Sulfur Fuel to Enable the Removal of PM

- **Ultra low sulfur diesel (ULSD) enables deep removal of PM by**



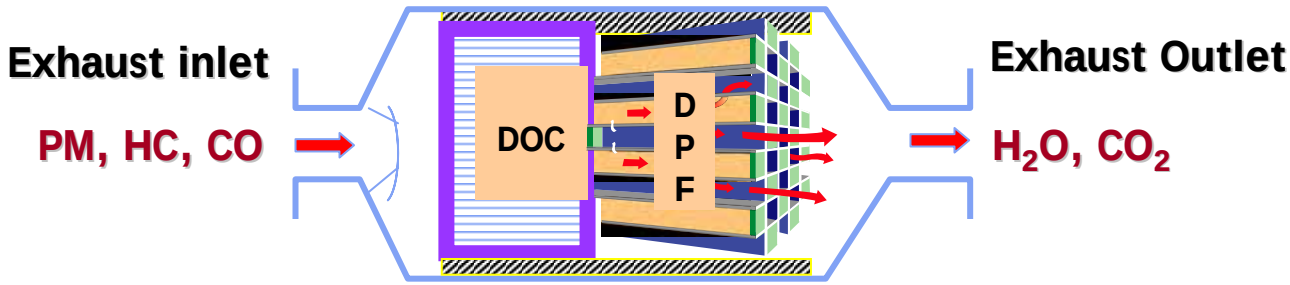
Note: "Low-sulfur" and "existing" mean low-sulfur diesel fuel (46 ppm) and the existing diesel fuel (443 ppm) used in tests, respectively.

DPF (a) (D13-mode: change in sulfur content)

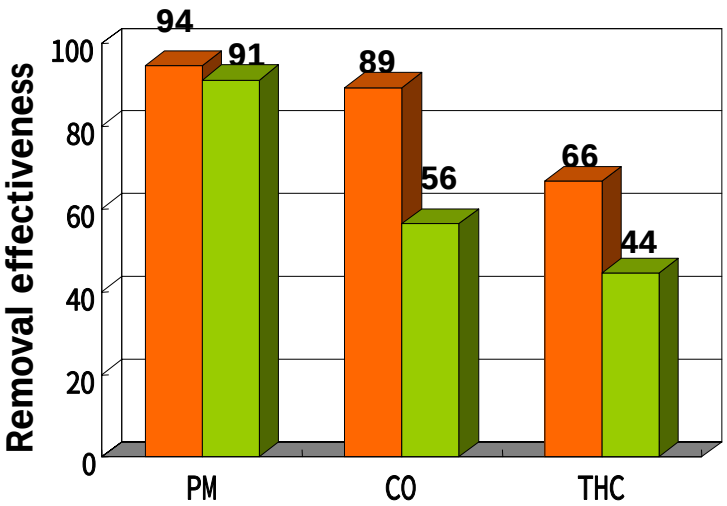
Source: JCAP Data

DPF for LSD and ULSD

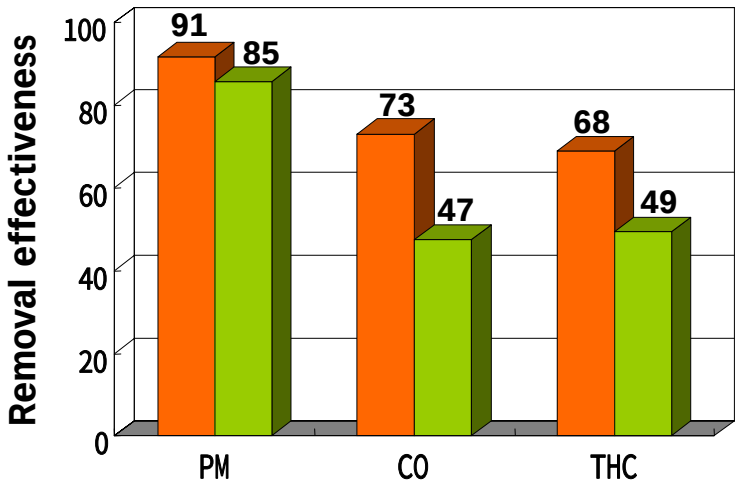
- SK catalytic DPF shows good performance for LSD(500 ppm S) also
- However ULSD provides not only higher removal but also wider operation windows for DPF application



Japanese KC-Engine ('94)



Japanese U-Engine ('89)

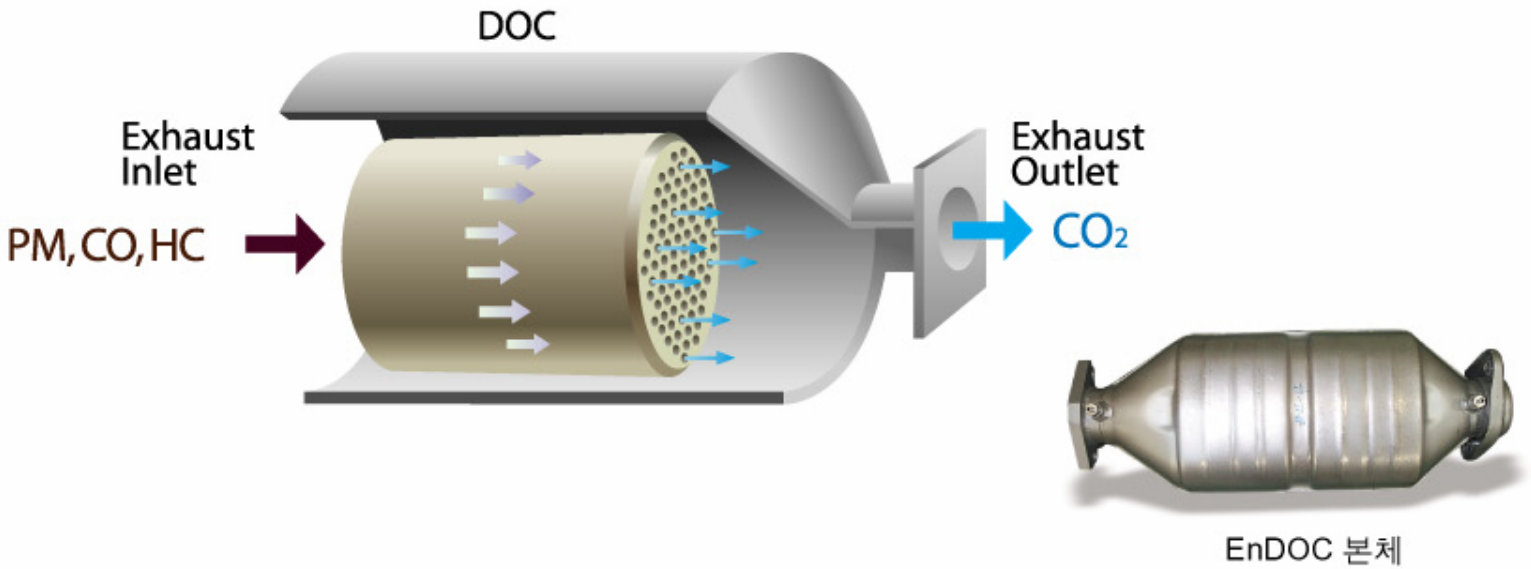


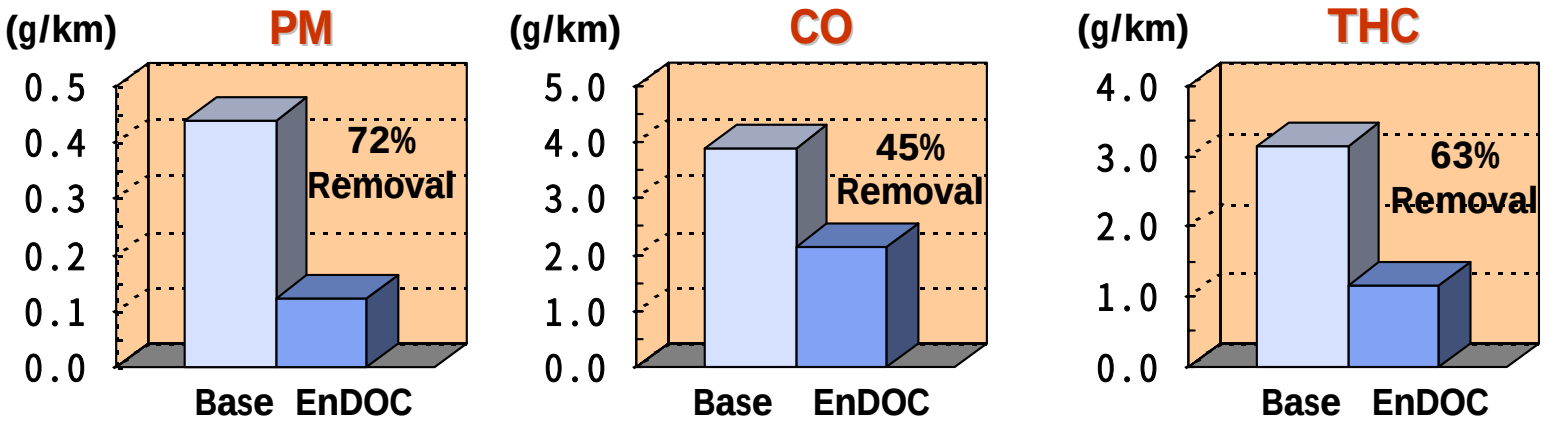
CPF#1 : ULSD Application (50ppmS) CPF#2 : LSD Application (500ppmS)

Source: Nissan Diesel Test Result for Government Approval

DOC for ULSD

- **SK's compact and low cost DOC(diesel oxydation catalyst) also quite high removal efficiency**





Tested in Japan Fuel:ULSD Test Mode: Tokyo 2

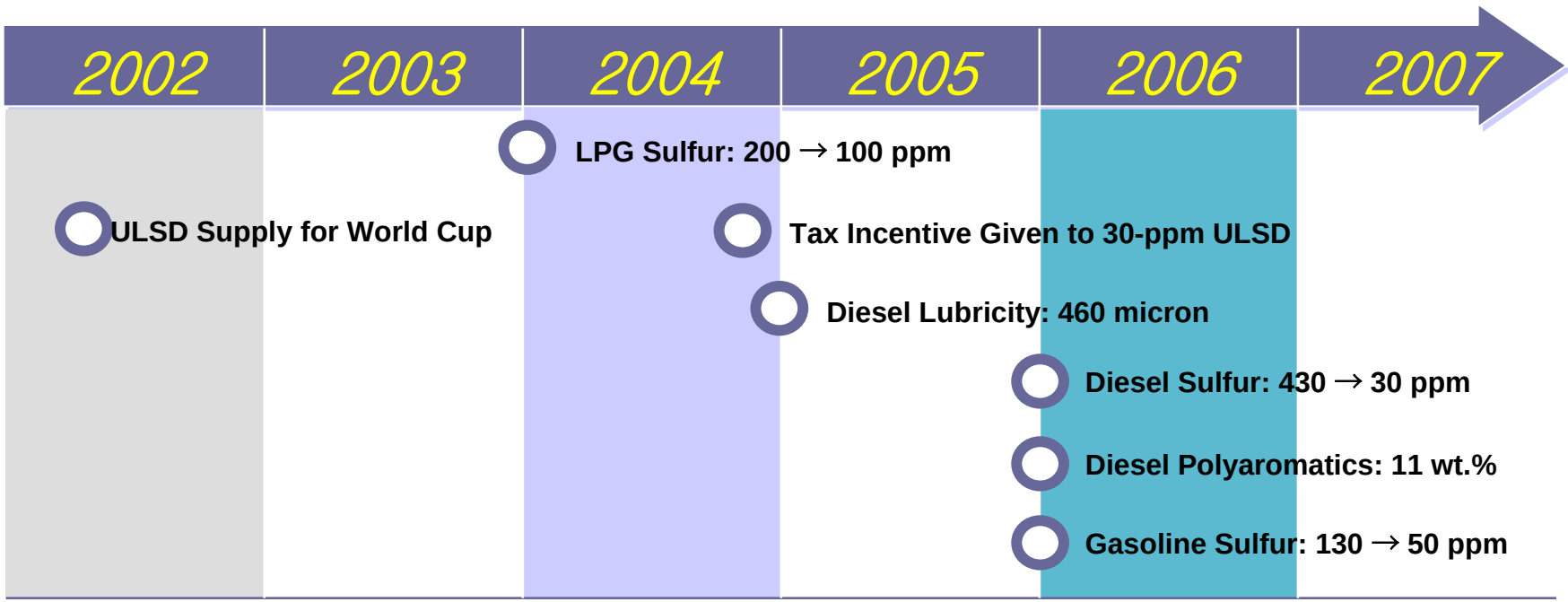
DeNOx System

- NOx reduction technology is quite
- DeNOx systems are not fully commercialized

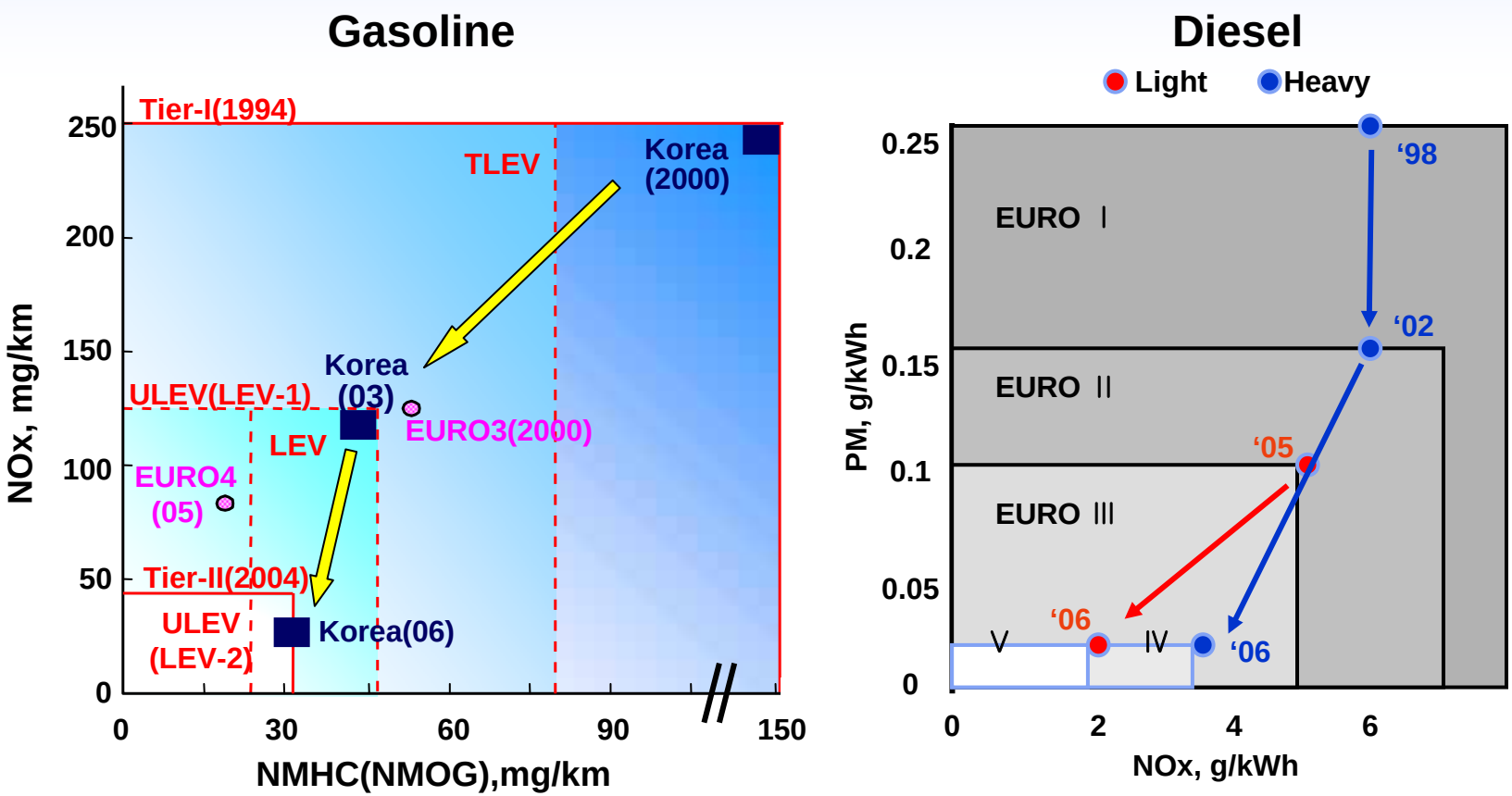
DeNOx System	DeNOx Efficiency	Fuel S Limits	Fuel Penalty	Issue
Urea SCR	85~90%	~500 ppm	2~3%	Infra, Low Temp Slip
Diesel SCR	20~60%	~50 ppm	2~6%	HC Slip
NOx Trap	80~95%	~5 ppm	1.5~4%	Fuel & Pt Cost

Supply of Ultra Low Sulfur Fuels

- Fuel sulfur specifications are getting more restricted for catalytic post-treatment of exhausts from the vehicles
- Tax incentive has been given to promote early production of which is also effective for PM reduction by itself
- Polyaromatics which is known as coke precursor will be



Emission Restriction on Manufacturing Vehicles



- The restrictions on the manufacturing vehicle emission was as like Europe for diesel vehicle and USA for gasoline vehicle are very challenging and stringent target

Emission Reduction Plan for Diesel Vehicles

- **Installation of emission reduction equipment by 2012 for 1.1 million vehicles which is operation at Seoul metropolitan area**
- **Total budget for this program is 6.3(4.3 central) trillion Won**
- **2005 Plan: 47000 vehicles, 189.4(947 central) billion Won**

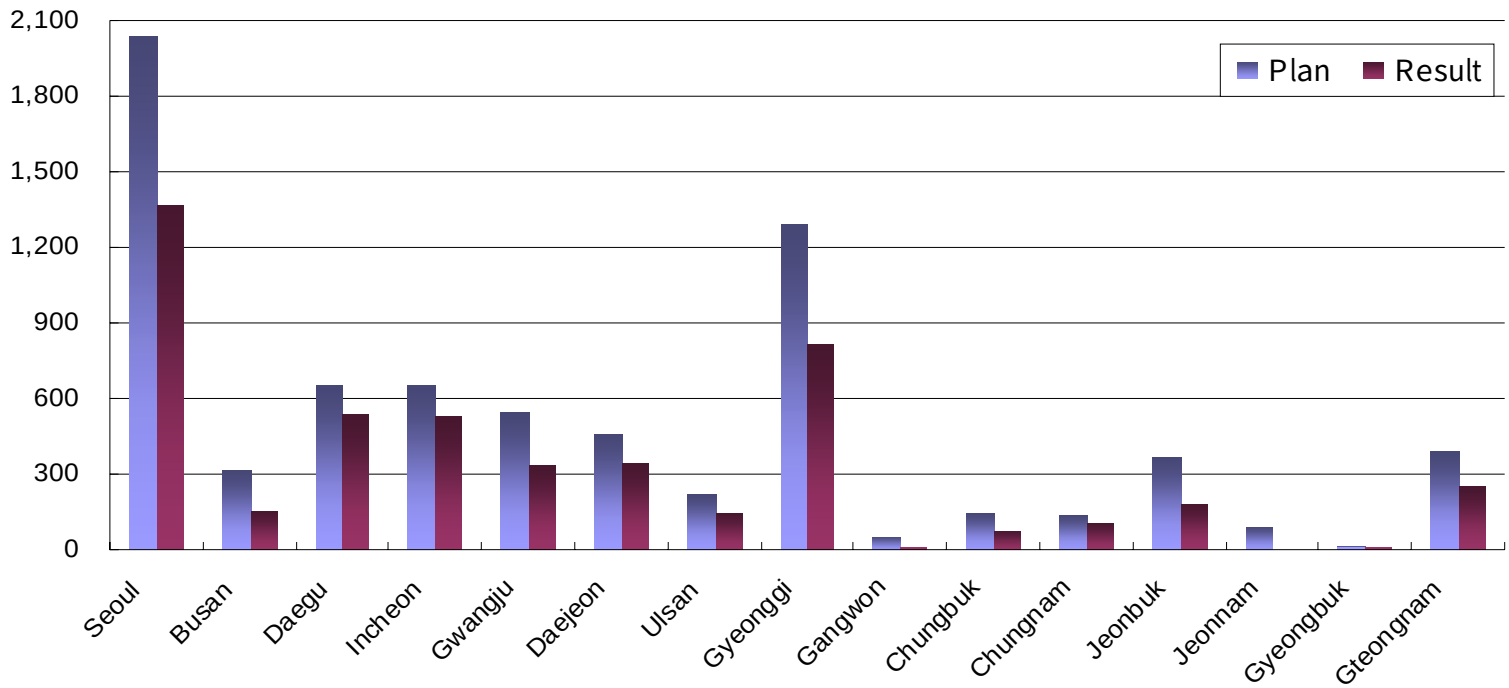
	Number of Vehicle	Budget (Million Won)
DPF	15,861	55,514
DOC	13,541	11,124
Engine Replacement	6,623	15,382
Early Retirement	11,778	12,747
Vehicle Age	12 yrs.	7 yrs.

CNG Bus Supply Program

- **Mandatory Purchasing of CNG Buses**

< The Target of CNG Bus Supply >

	Total	~ 2004	2005~2007
CNG Bus	20,000	7,400	12,600
Fuel Station	400	183	217



- **Problems: Cost effectiveness, fuel mileage (weight of tank & volume)**

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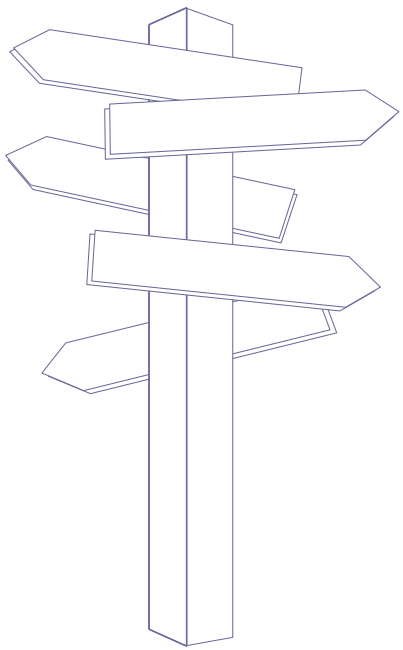
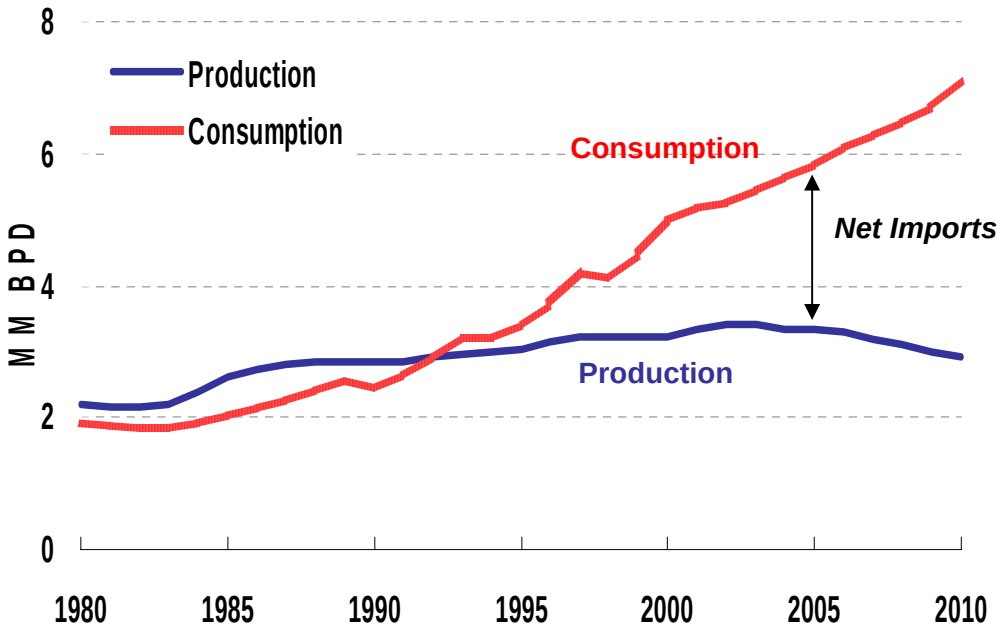
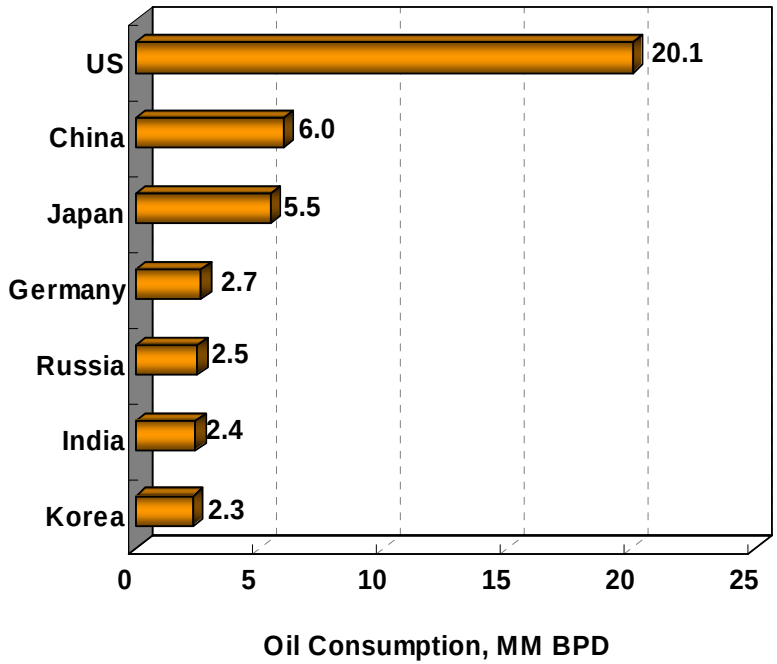


Oil Balance in China

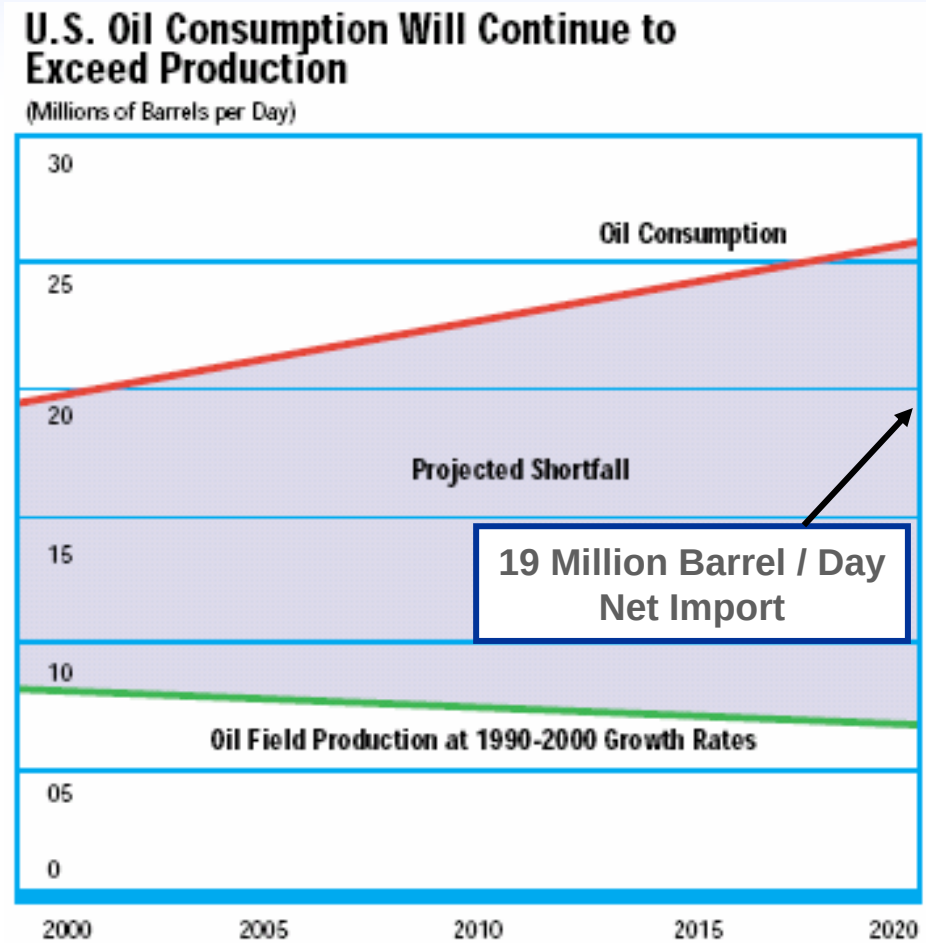
- China has been a net importer of oil products since 1993
- The amount of net import is already greater than Korea
- Imports are expected to rise from 1.7 in 2001 to 4.2 MM BPD in 2010





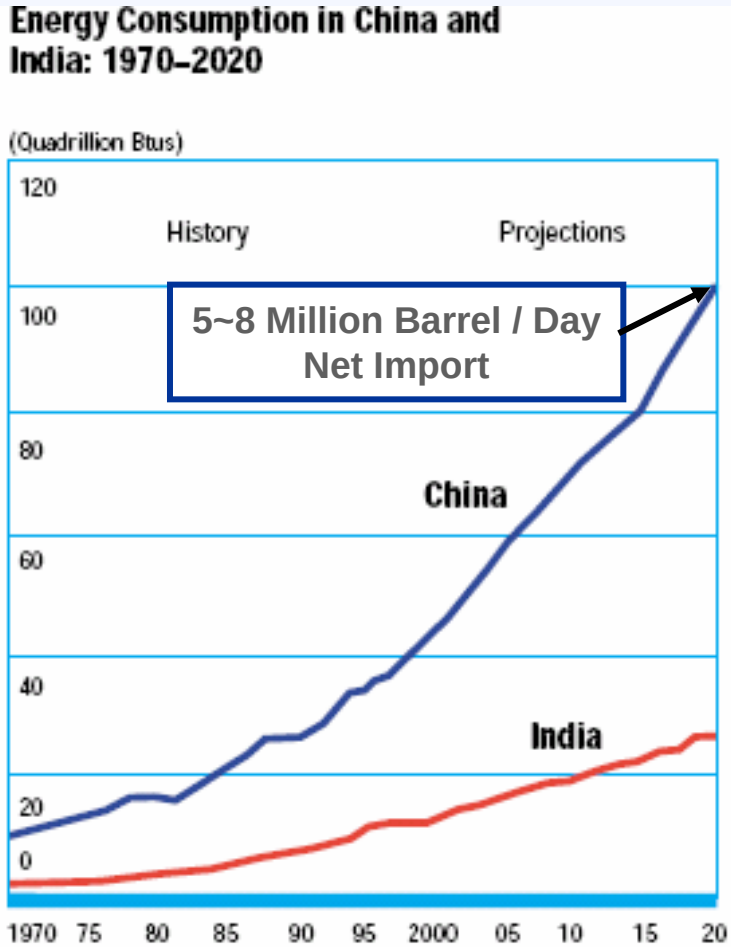
World Energy Outlook 2002, IEA(Internatinal Energy Agency)

China is not a single cause for the oil shortfall



Over the next 20 years, U.S. oil consumption will grow by over 6 million barrels per day. If U.S. oil production follows the same historical pattern of the last 10 years, it will decline by 1.5 million barrels per day. To meet U.S. oil demand, oil and product imports would have to grow by a combined 7.5 million barrels per day. In 2020, U.S. oil production would supply less than 30 percent of U.S. oil needs.

Source: U.S. DOE, Energy Information Administration

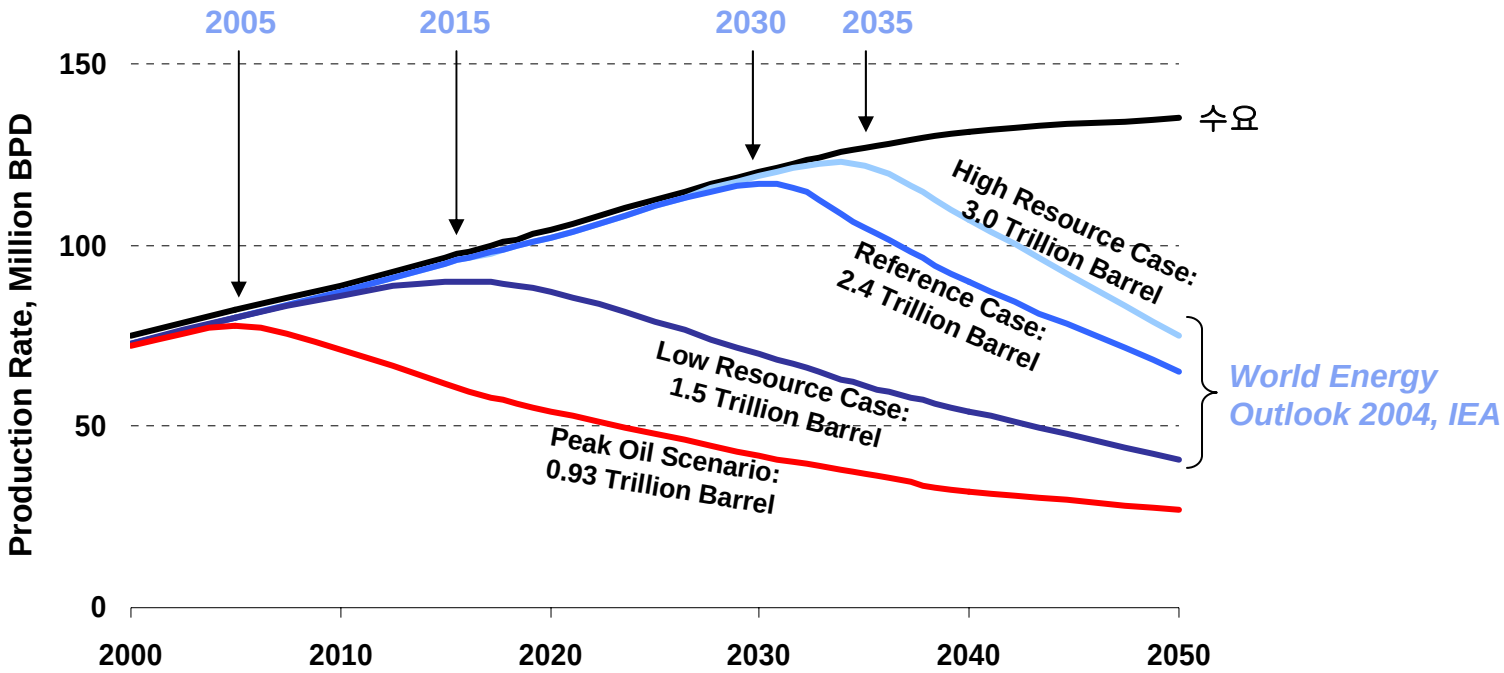


China and India account for the bulk of projected growth in oil demand in non-OECD countries.

Source: U.S. Department of Energy, Energy Information Administration.

Peak Oil Scenario

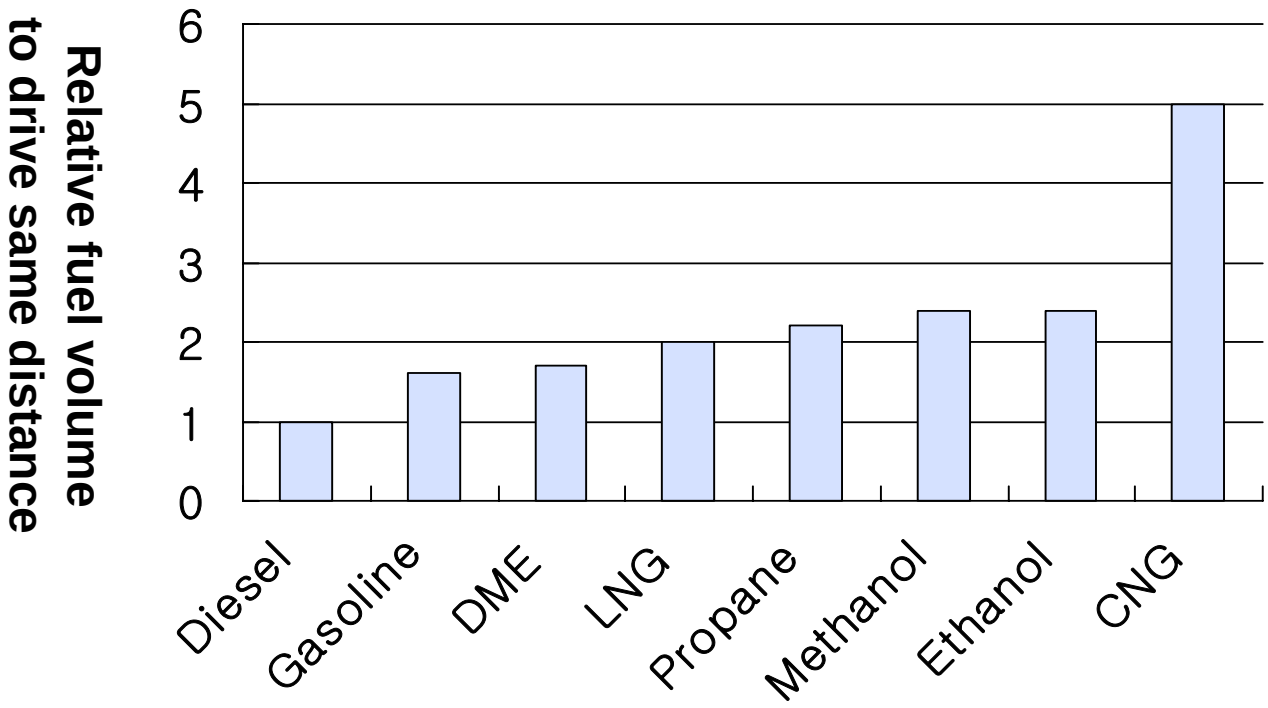
- Peak oil group claims that the production peak has already been reached
- IEA who has optimistic perspective predicts that the peak will reach from 2015 to 2035.



Kjell Aleklett, Uppsala University, Sweden
http://www.peakoil.net/uhdsg/Default.htm, OIL AND GAS LIQUIDS 2004 Scenario, C.J.Campbell

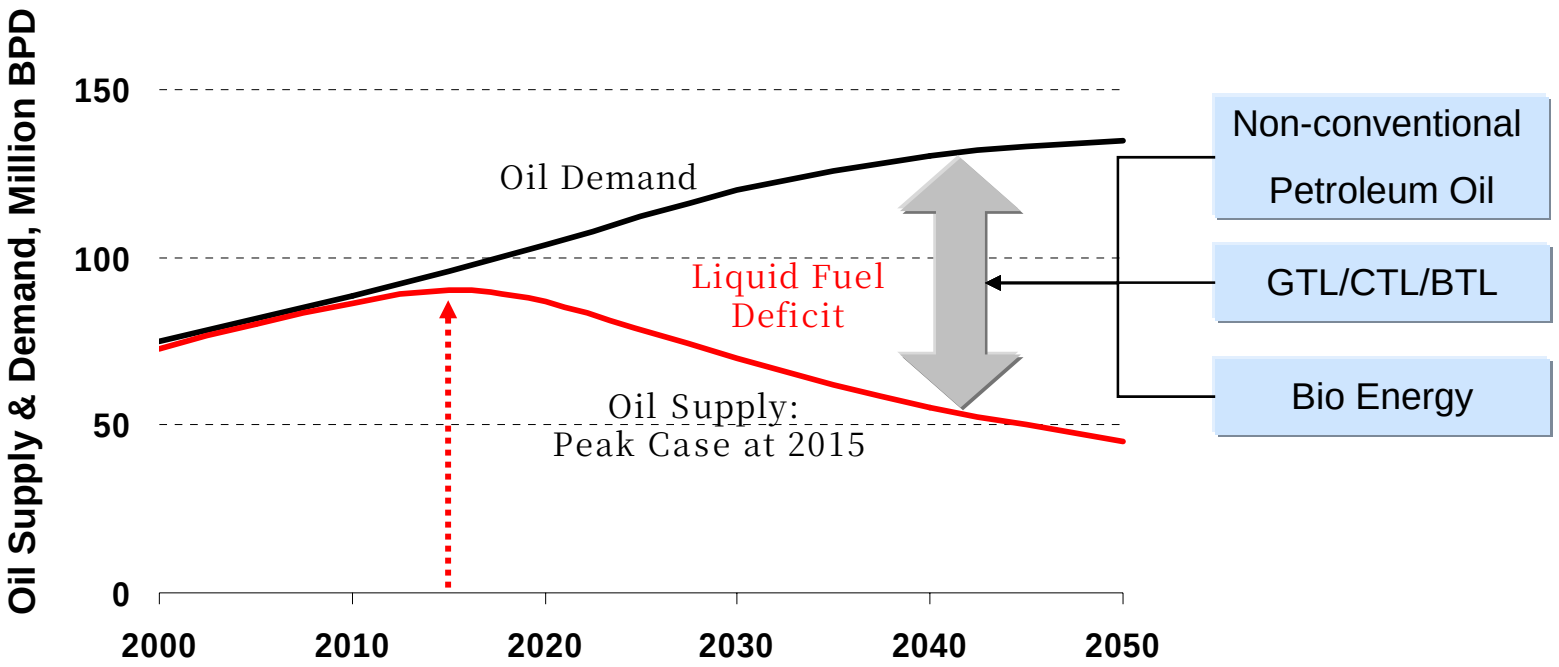
Consumer prefers liquid fuels

- The low fuel mileage of gas energy based vehicle requires more filling station and fueling efforts. However consumers do not like inconvenience of gas vehicle
- CNG and Hydrogen vehicles are also quite difficult to distribute caused by their difficulties to construct gas based fuel infrastructures
- Liquid synthetic fuels such as Fischer-Tropsch diesel and DME will be the most prominent fuels in the future



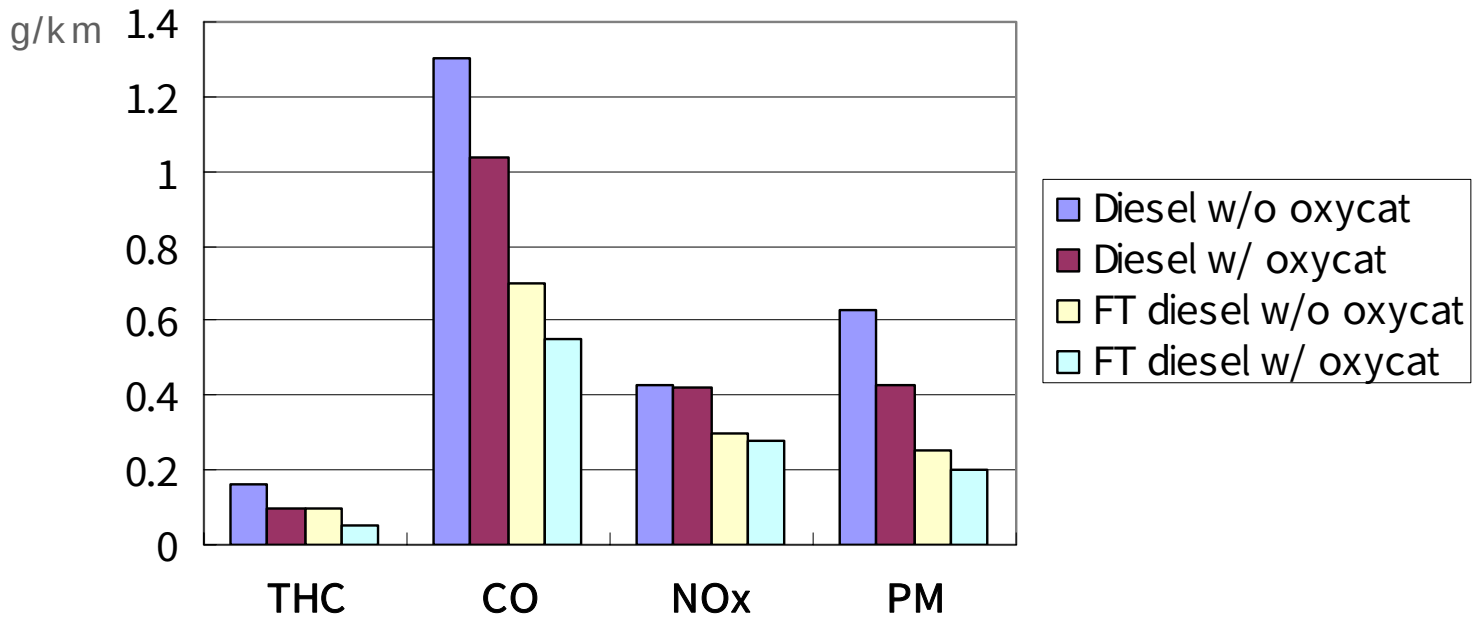
Supply of Liquid Fuels in the Future

- It is highly probable that the natural oil production rate will reach the peak around 2015, therefore the price of oil will continue to increase
- In order to fill the gap of the supply and demand, various kinds of liquid fuels will be developed
- Also the technology for energy efficiency improvement is getting more important



IEA, World Energy Outlook 2004

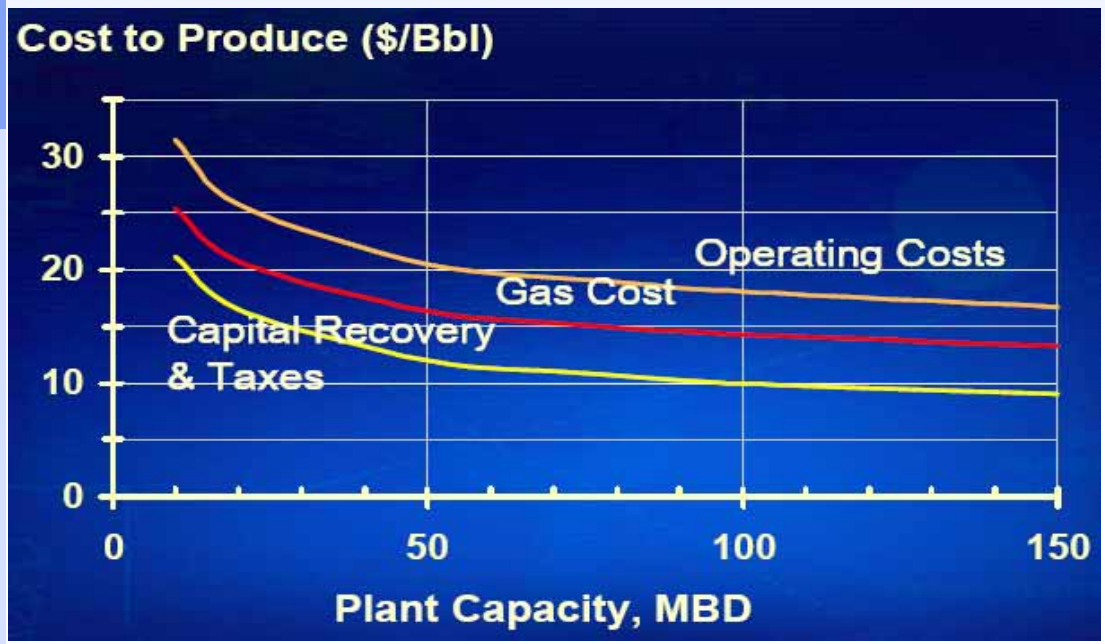
The Emission Benefit of FT Diesel



Source: Toyota Motors

- FT diesel has sulfur free, aromatic free and very high cetane characteristics
- FT diesel provide excellent emission performance
- FT diesel may provide a chance to meet advance vehicle regulations such as Euro4 & 5 but FT diesel will not be used by itself

Economics of FT Plant



Unit Cost of Production ($/Barrel)

	GTL	Refinery
Natural Gas (@ $.50/MMBtu)	$ 4.00	
Crude Oil (@ $17/Bbl)		$17.00
Operating Costs	3.00	2.50
Cash Costs	7.00	19.50
Capital Recovery, Taxes	12.00	6.50
Total Cost to Produce	$19.00	$26.00

- Production cost to produce FT diesel can be competitive when the price of crude oil is higher than $15 per barrel
- Considering the quality benefit, the rush for GTL project will be made
- The huddle for the GTL project is technology itself because it requires large capital investment and its technology is not fully proven yet

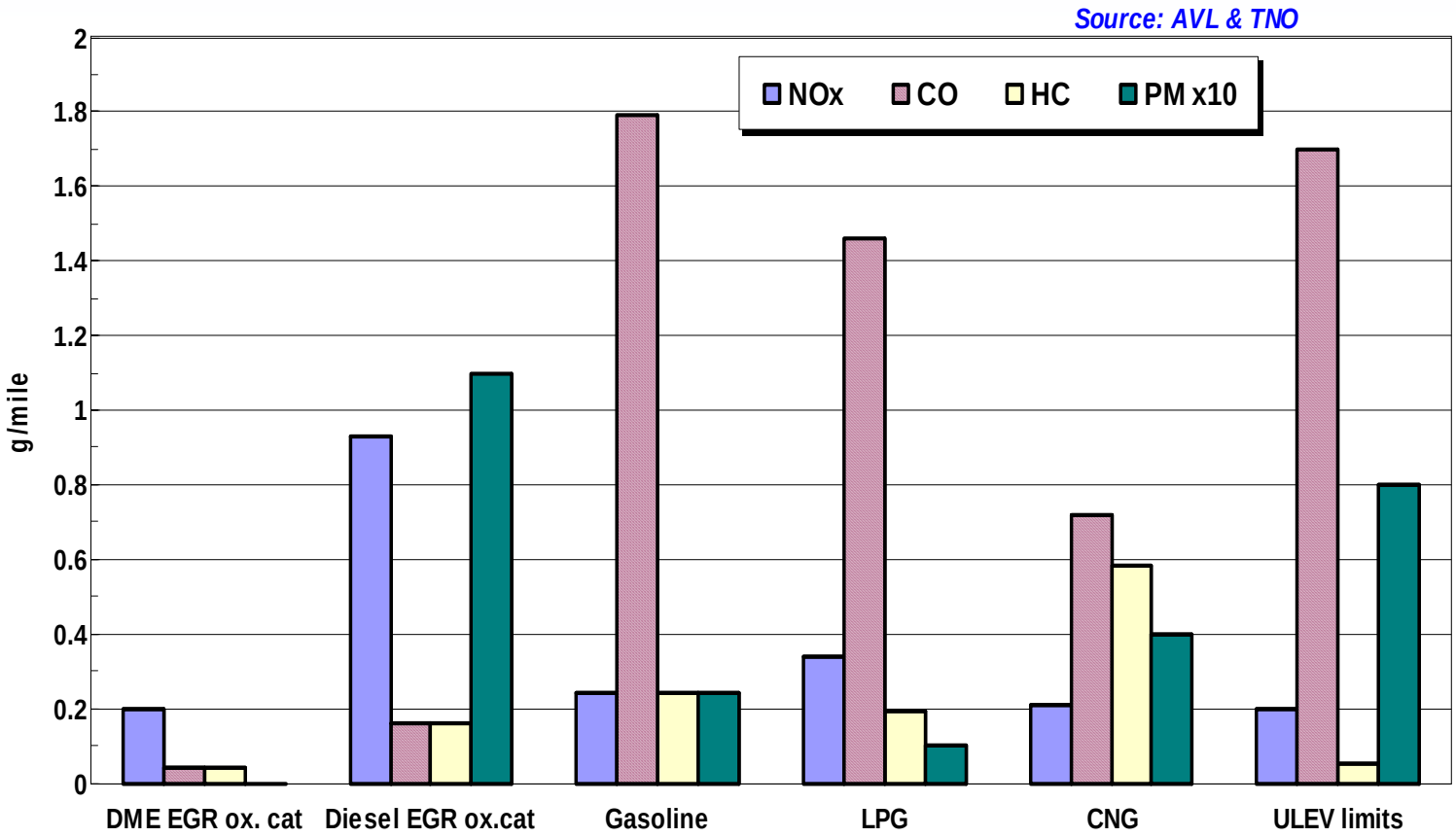
Source: Conoco, EFI Conference

Merits and Strength of DME Fuel

Clean Diesel Fuel	▪ High Cetane Number : 55-60, High Efficiency Diesel Engine ▪ Clean Fuel : Sulfur free, Zero PM, Low NOx Control Cost
Liquid Fuel	▪ LPG like ▪ Effectiveness for Transportation and Storage ▪High Mileage ▪LPG Mixture Application (Complete Combustion: Low CO)
Low Infra Cost	▪ 1/3 Infrastructure Cost compared with LNG ▪ Utilization of Existing LPG Infrasturucture
Low Production Cost	▪ High Synthesis Efficiency (DME: ~ 70%, FT: 55%~60%)
Liquid Hydrogen	▪ Easy to Produce Hydrogen for Fuel Cell Application
Sustainability	▪ Utilization of Stranded Gas and Coal ▪ Utilization of Biomass

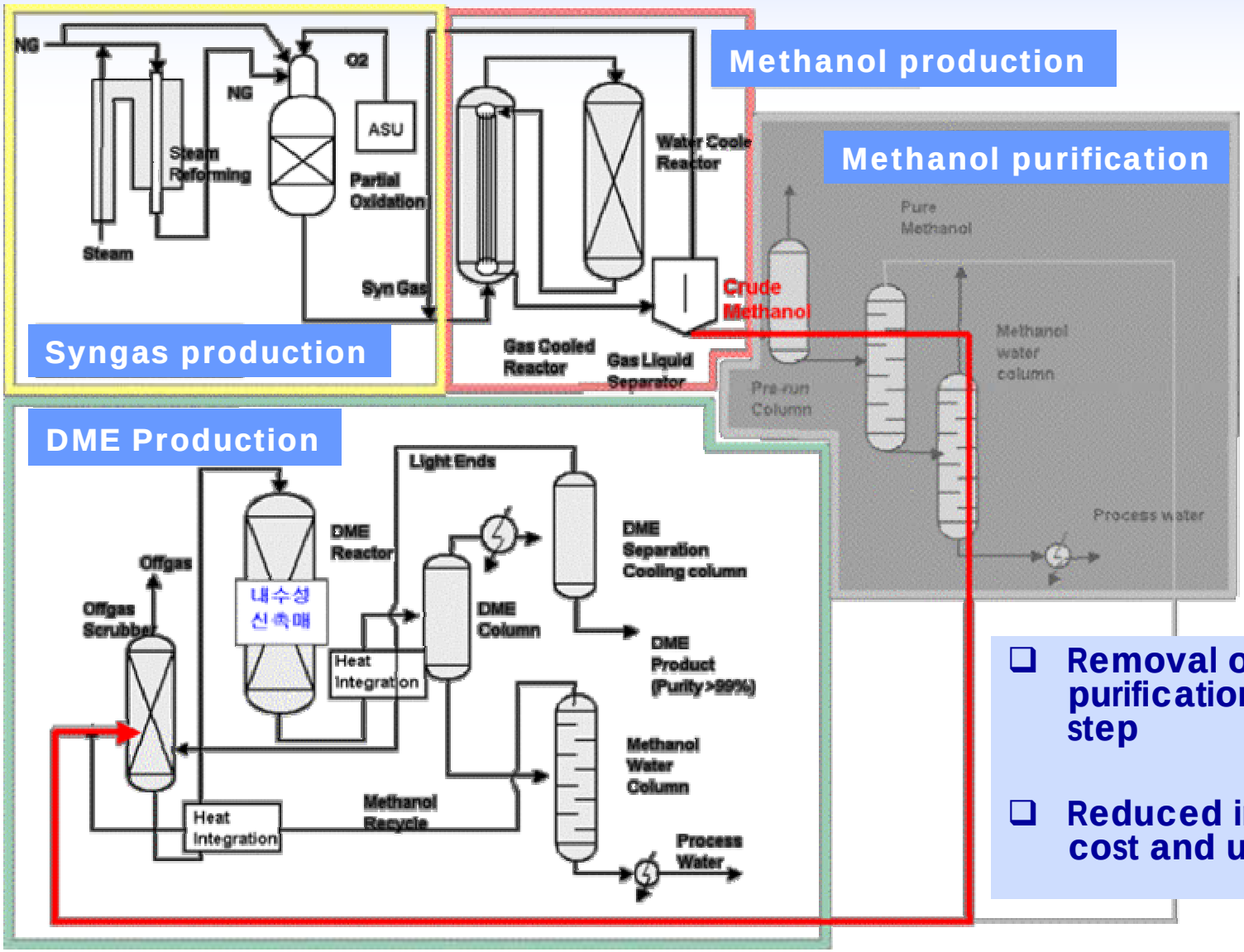
The Emission Benefit of DME

Comparison exhaust emissions light-duty engines US-FTP 75 test cycle



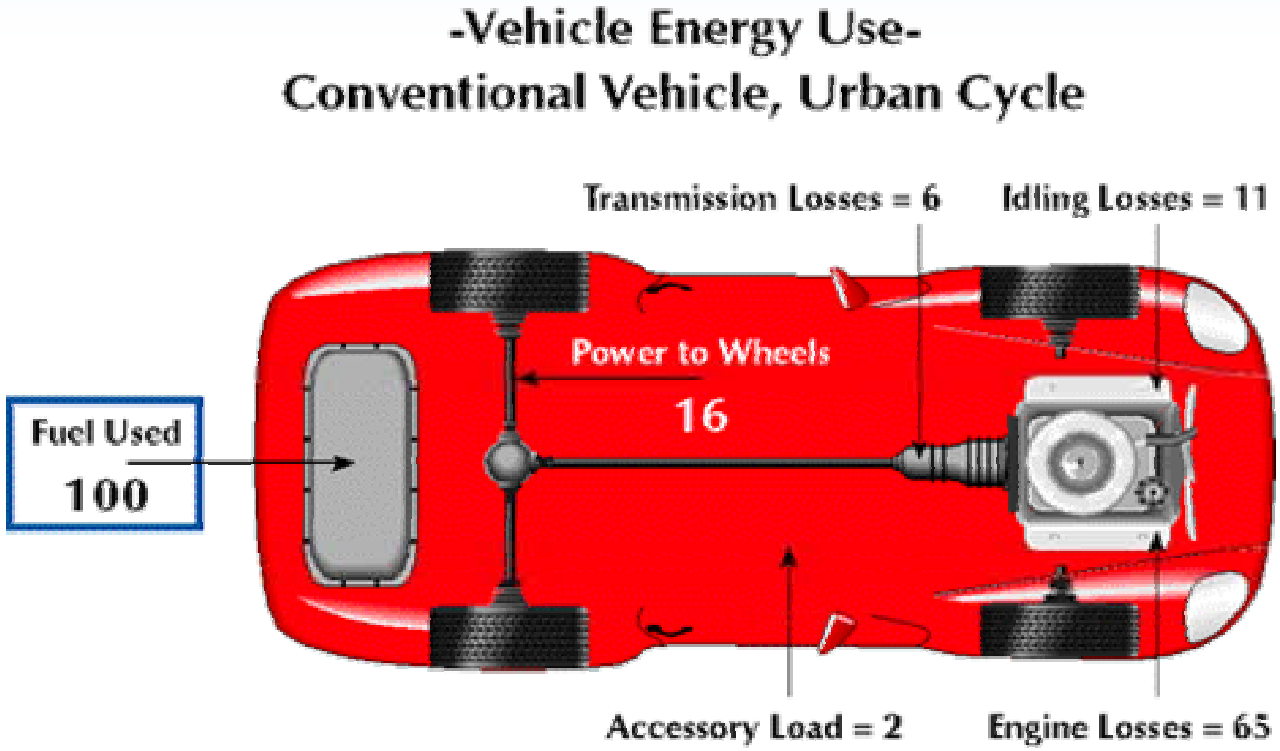
- DME has very high cetane characteristics to be able to use for high efficiency diesel engine
- DME does not generate PM which is the weakest property of diesel

SK DME Process



- Removal of methanol purification process step
- Reduced investment cost and utility cost

Energy Efficiency needs to be Improved

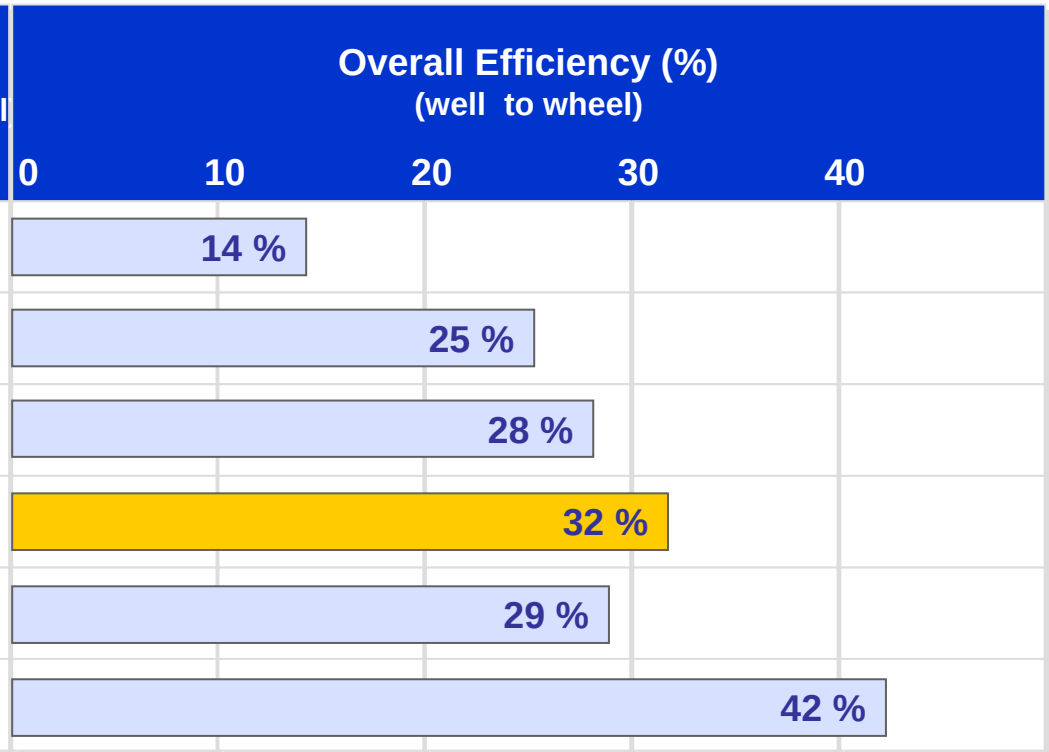


- For modern gasoline car, only 16% of energy is utilized as a driving power
- Common rail diesel vehicles, hybrid electrical vehicles and fuel cell electrical vehicles can provide much higher fuel efficiency

Improvement of Vehicle Energy Efficiency

Overall Efficiency(%) = Fuel Efficiency(%) x Vehicle Efficiency(%)

Vehicle	Energy ε (well to tank) (%)	Car ε tank to wheel (%)	Overall Efficiency (%) (well to wheel)
Recent gasoline car	88	16	14 %
Prius I	88	28	25 %
Prius II	88	32	28 %
New Prius	88	37	32 %
Toyota FCHV	58 Natural-H2	50	29 %
FCHV (target)	70	60	42 %



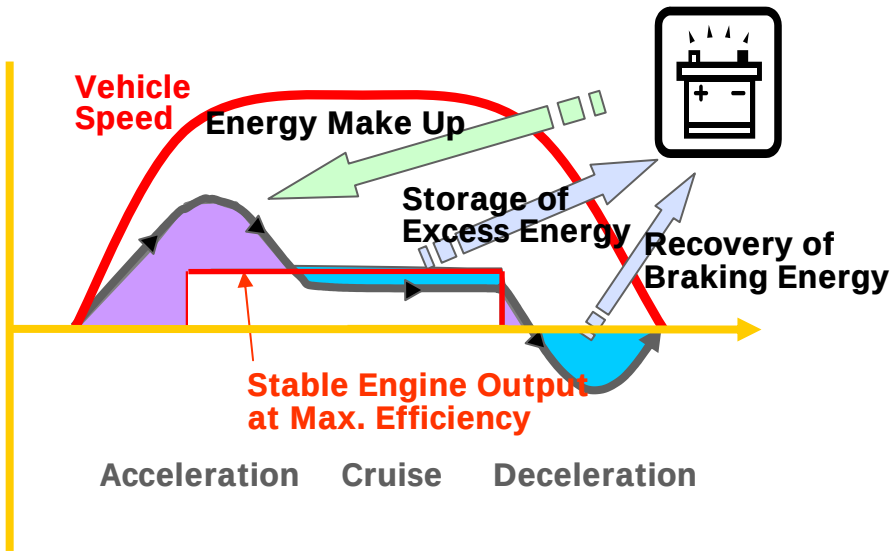
- The efficiency of HEV is improved greatly compared with conventional car
- The efficiency of Fuel Cell HEV is not superior to HEV because of the high energy loss to produce & provide the hydrogen

Source: Toyota, Transportation Research, 2002

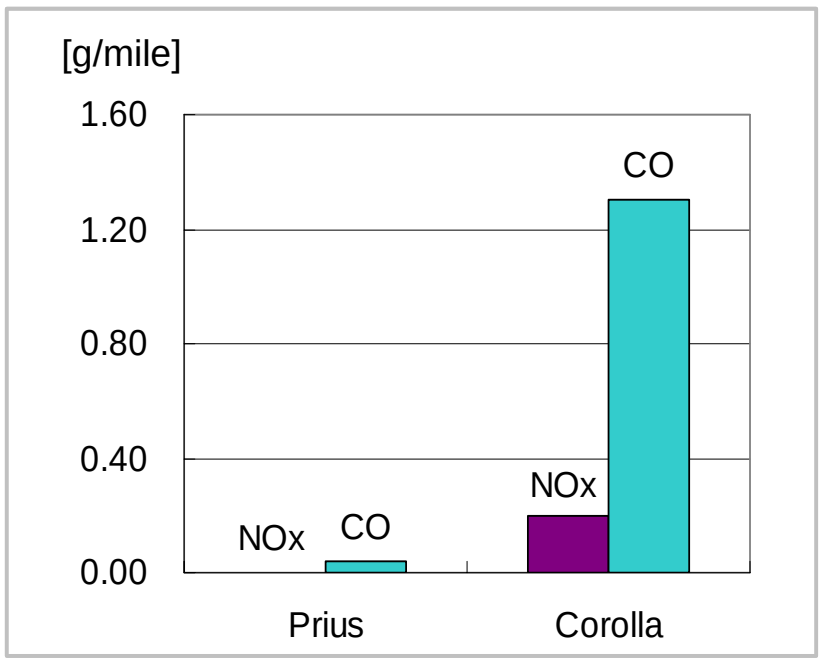
HEV- Low Emission and High Performance

- Start/Stop and stable engine operation provide excellent emission performance
- Emission of HEV is around 1/10 of conventional vehicle which is complies to Zero Emission Vehicle (ZEV) regulation
- HEV also can provide more battery power in addition to the engine power, therefore the vehicle performance is better than the same class engine vehicles

Operation Method



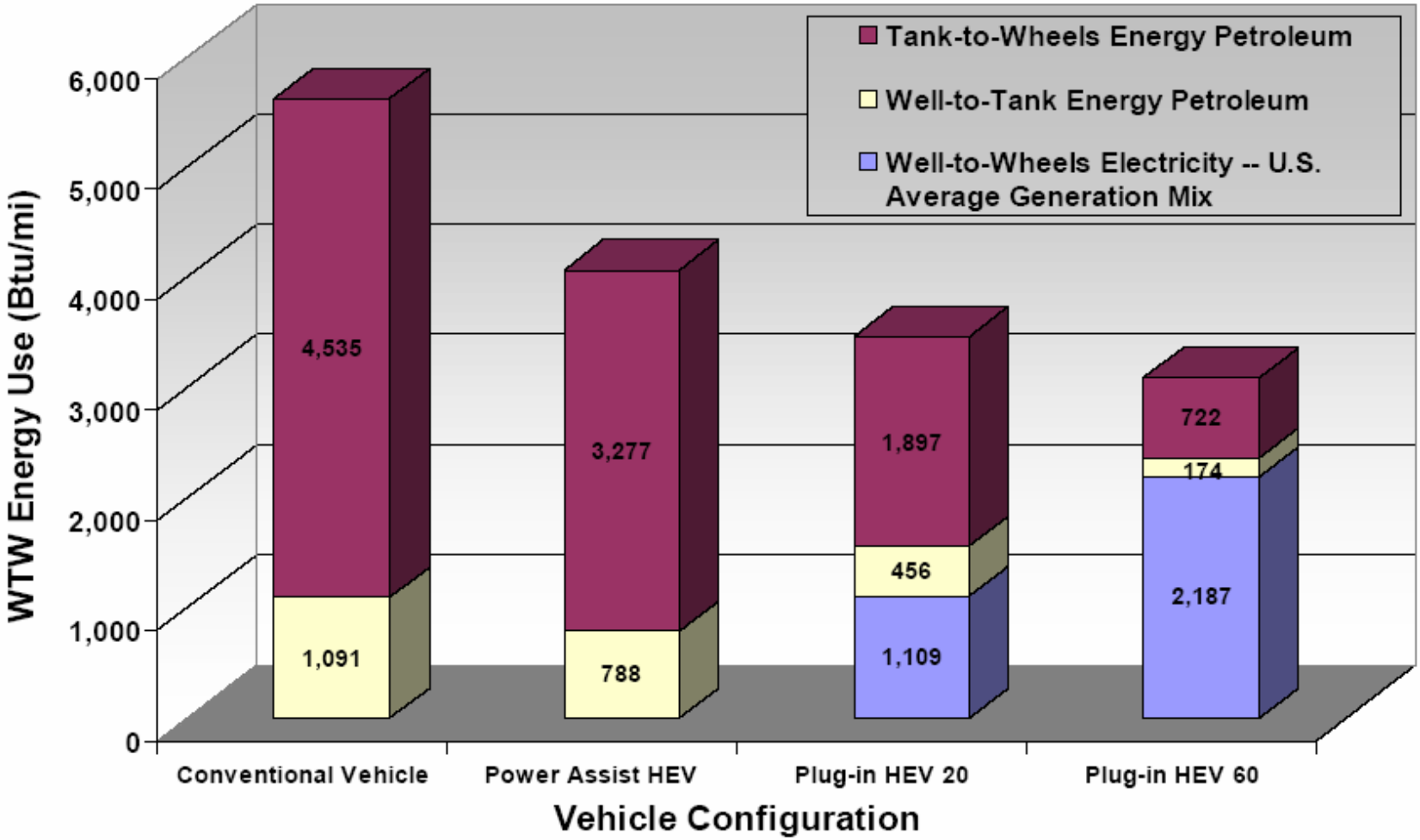
Low Emission



Source: Toyota, Transportation Research, 2002

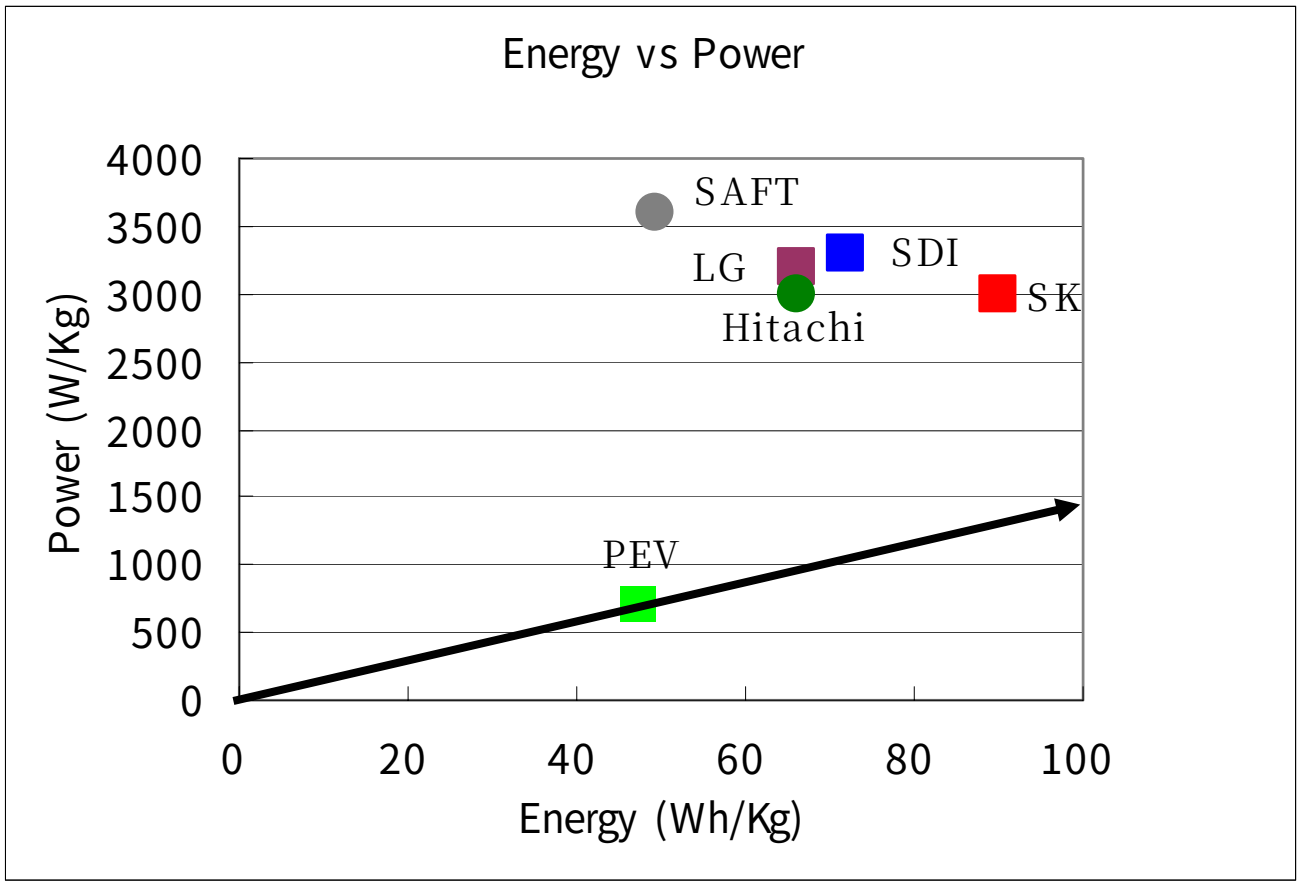
Plug-In HEV

- Plug-In HEV can reduce the oil dependence but it requires lager size battery (3 times battery for 20 mile BEV driving , 9 times for 60 mile BEV driving)
- Also it requires daily recharge efforts



High Power and High Energy Density Battery

- Most Lithium battery shows excellent power compared with NiMH battery which is already commercialized for HEV
- Compactness is very important for HEV application
- SK battery shows higher energy density together with high power performance
- SK battery is effective not only for HEV but also for Plug-In HEV application



Source:

SAFT: EVS21

SDI: AABC05

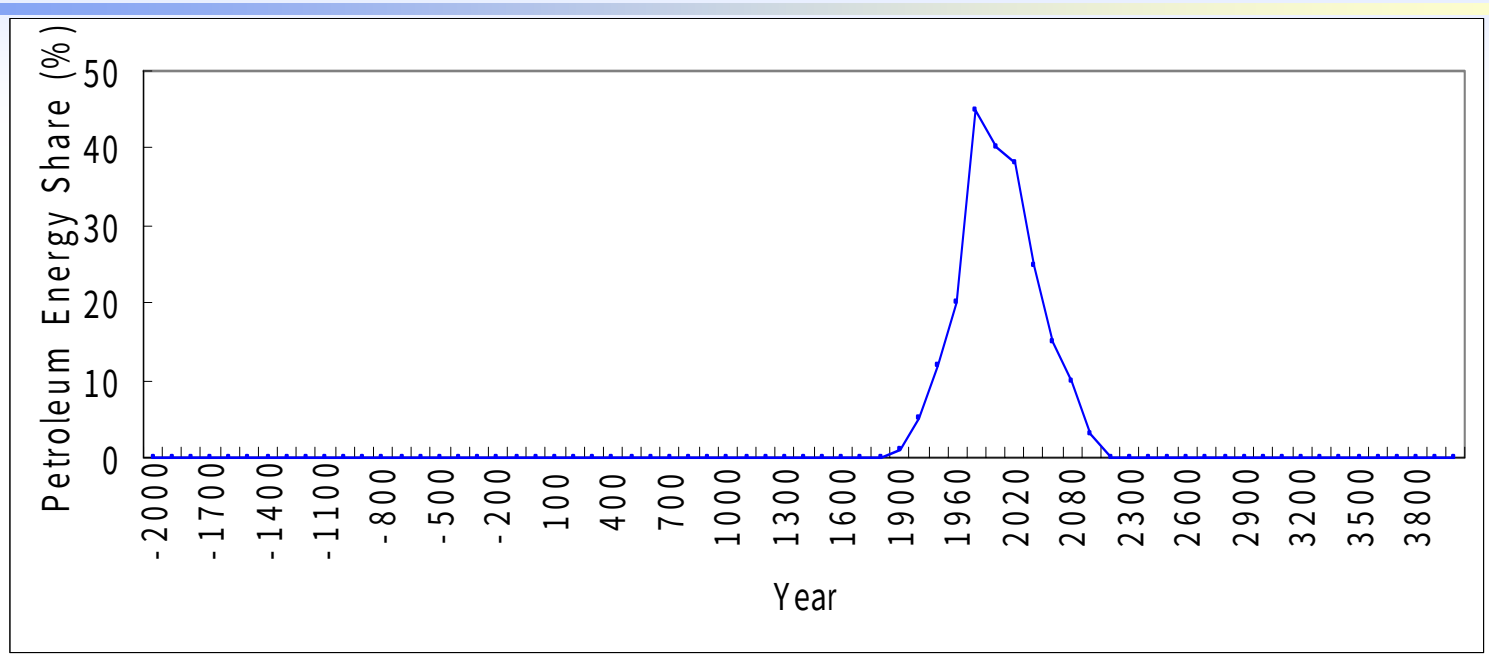
Hitachi: AABC05

LG: EV Symposium 04

SK: EV Symposium 05

PEV: Own Test

Concluding Remarks



- Diesel fuel demand will keep increase more and more but the emission from the diesel car needs to be reduced applying DPF/DOC and DeNOx technology. Ultra low sulfur diesel enables implementation of the emission reduction technologies
- It is certain that conventional petroleum oil will not last more than 100 years
- However synthetic liquid fuels from gas, coal, non-conventional oil and bio-mass , will fill the gap of supply and demand for a while
- The synthetic fuels are also environmentally cleaner than the natural petroleum
- Also energy efficiency of vehicle will be improved greatly. HEV will do a decisive role for this changes