Global Efforts To Encourage Heavy Duty Vehicle Fuel Economy Improvements

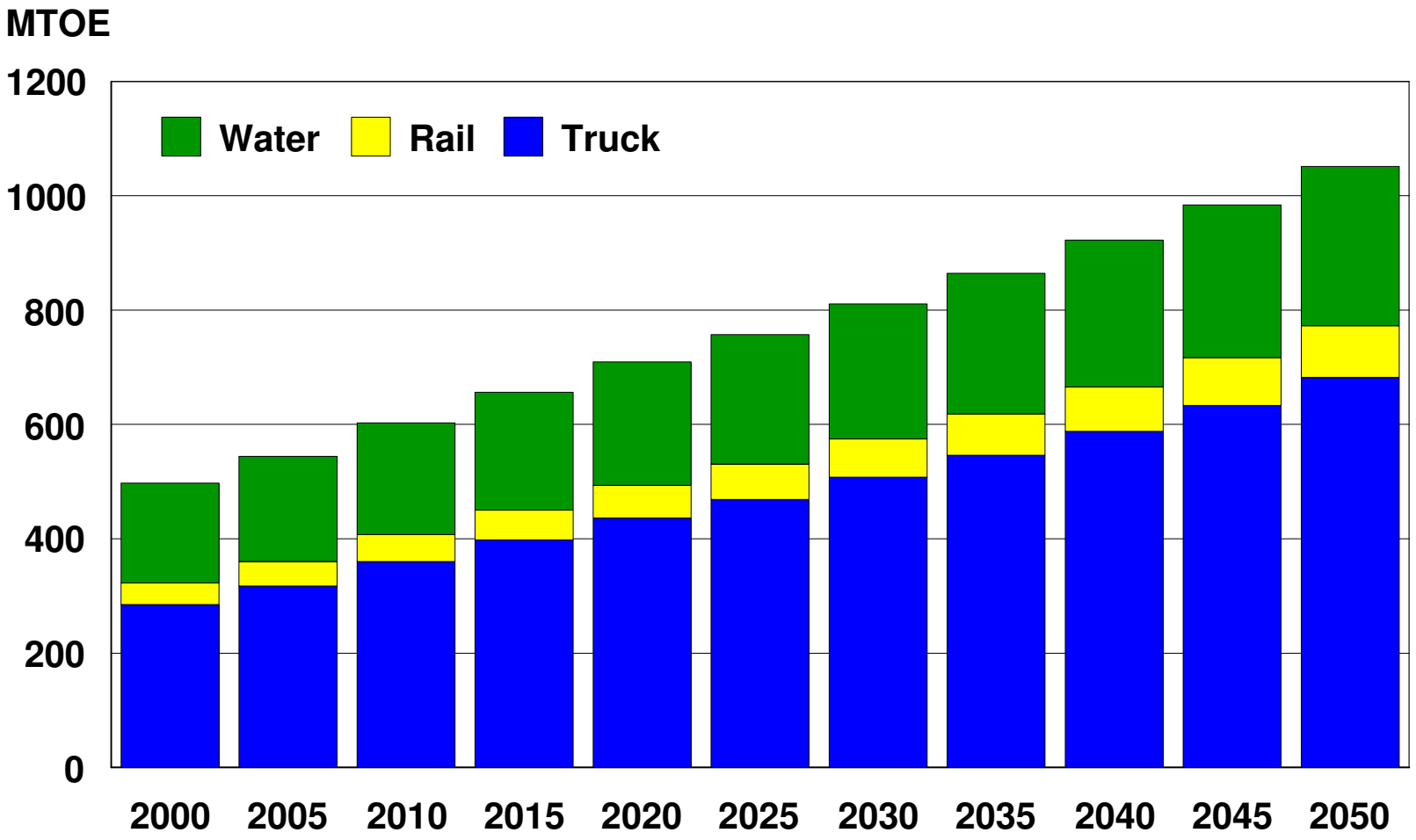
Improving The Fuel Economy of Heavy Duty Fleets

February 22, 2006

Michael P. Walsh

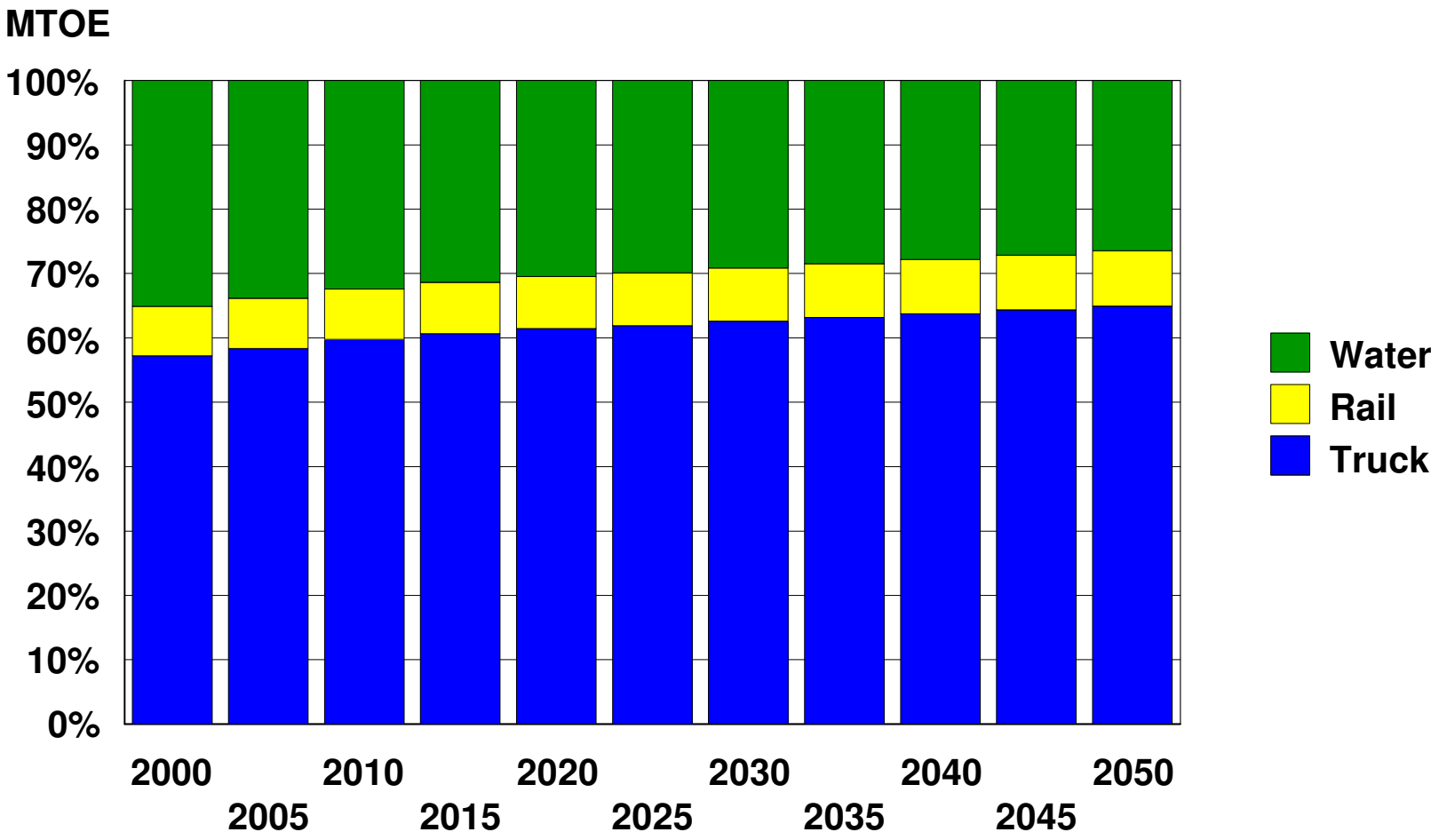
International Consultant

Global Freight Energy Use



Source: WBCSD

Global Freight Energy Use



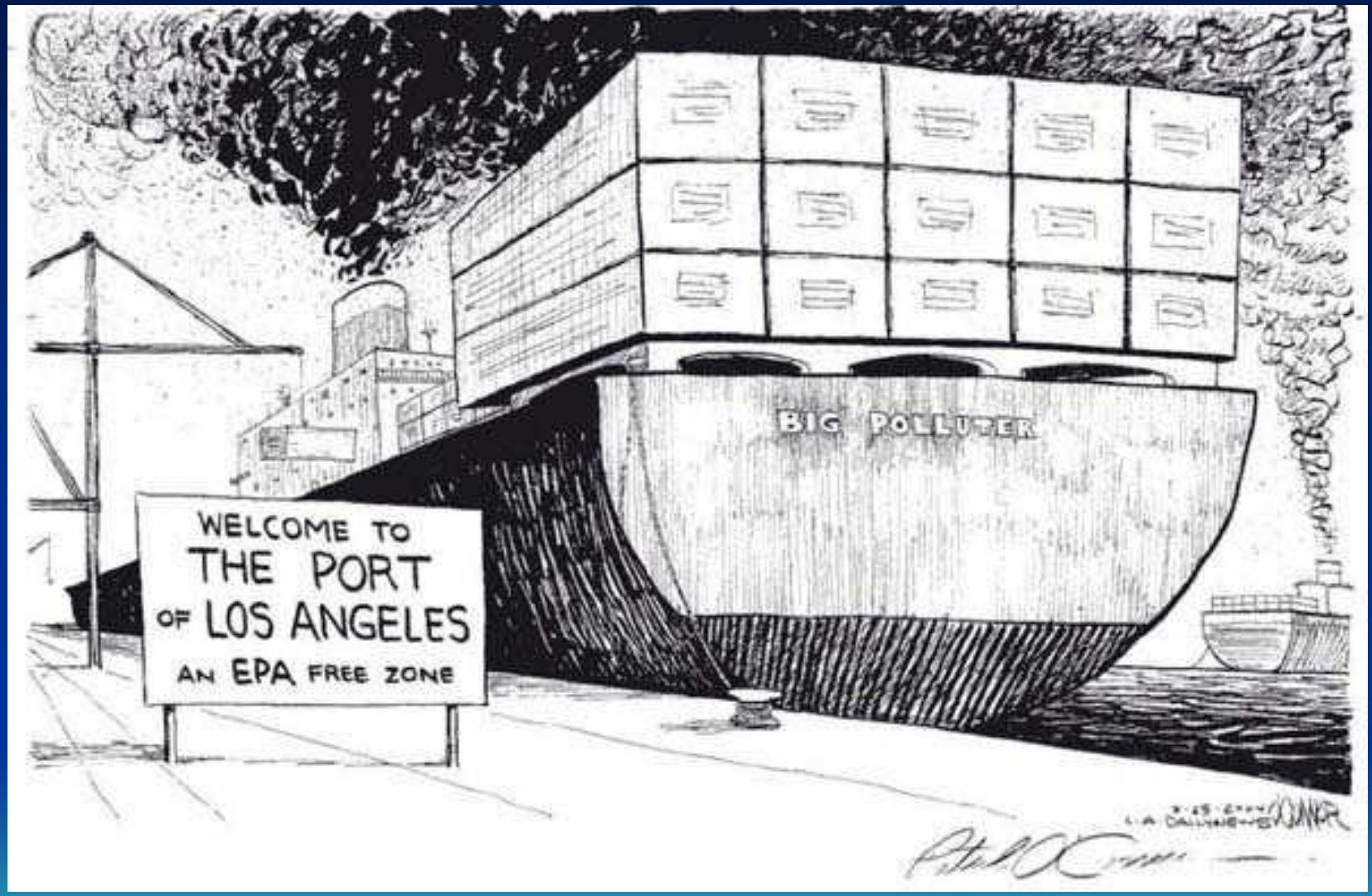
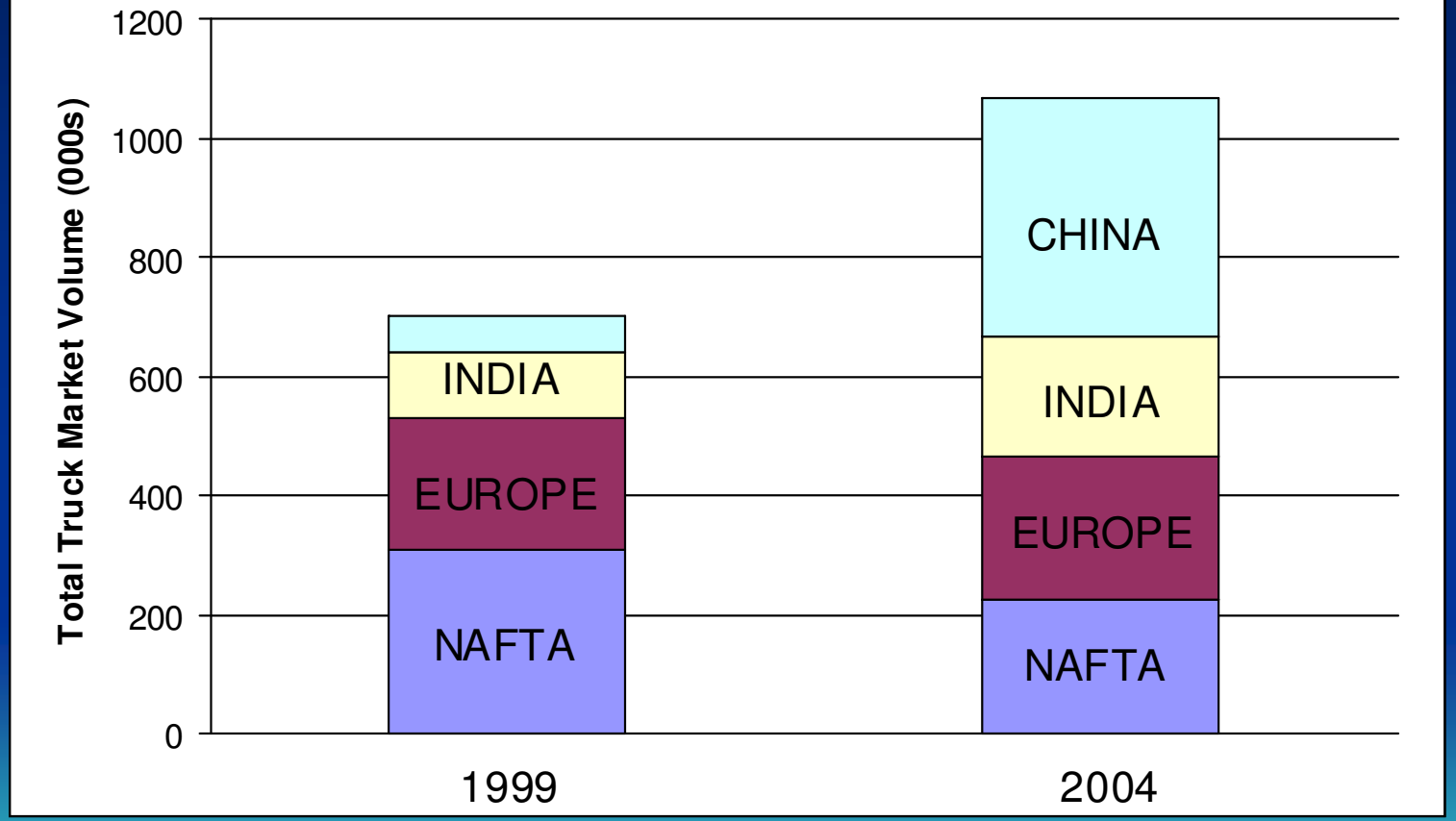
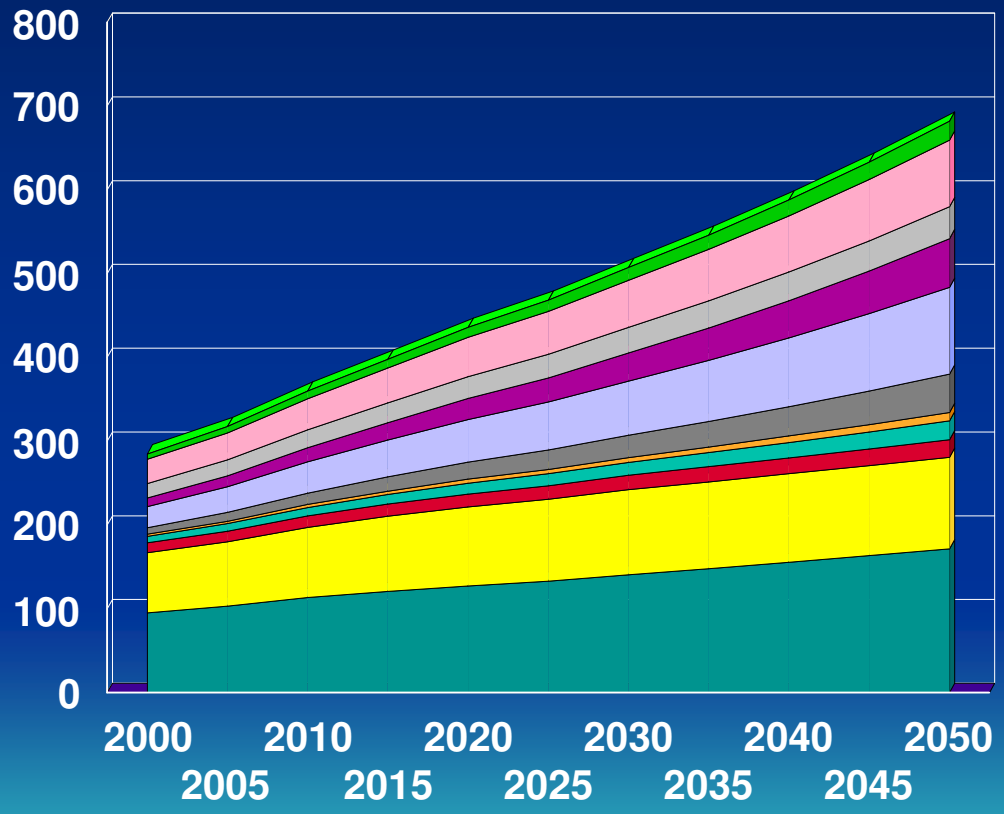

BIG POLLUTER
WELCOME TO
THE PORT
OF LOS ANGELES
AN EPA FREE ZONE

Figure 2 -- Major Commercial Truck Markets



This doesn't count as a truck!

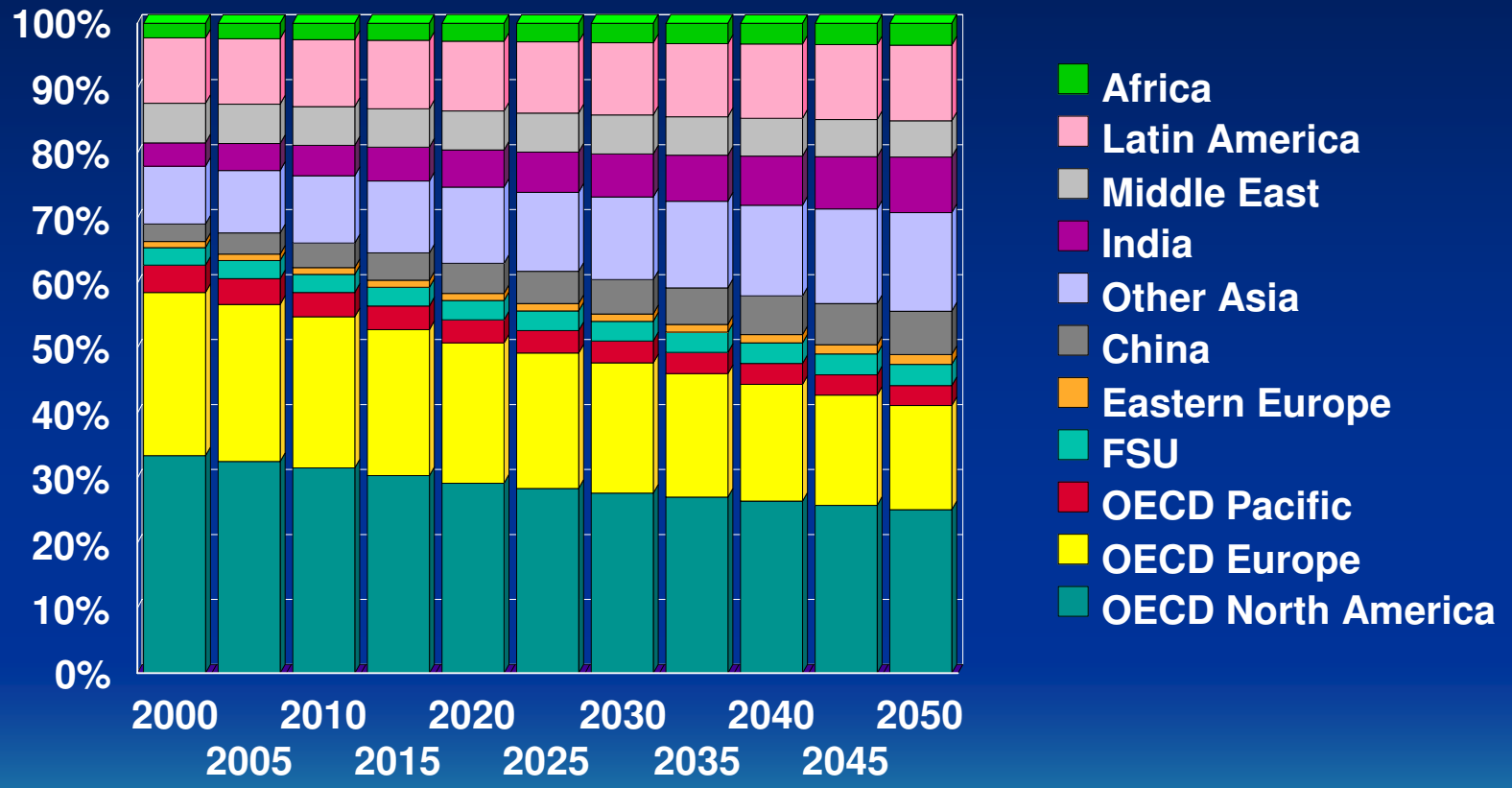
Heavy Truck Energy Use
MTOE



- Africa
- Latin America
- Middle East
- India
- Other Asia
- China
- Eastern Europe
- FSU
- OECD Pacific
- OECD Europe
- OECD North America

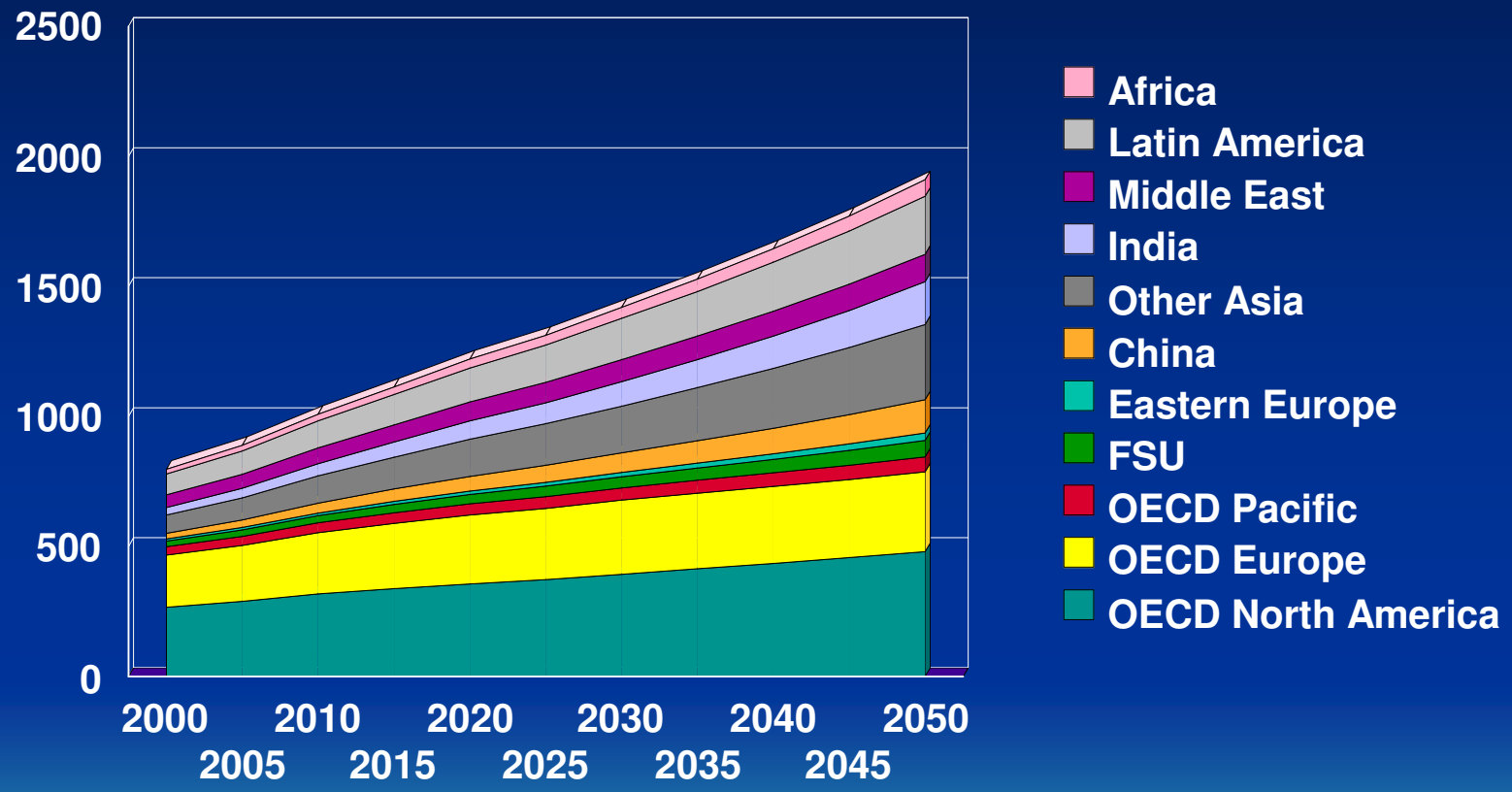
WBCSD

Heavy Truck Energy Use
MTOE



Source: WBCSD

Carbon Dioxide Emissions Directly From Trucks (Megatonnes)



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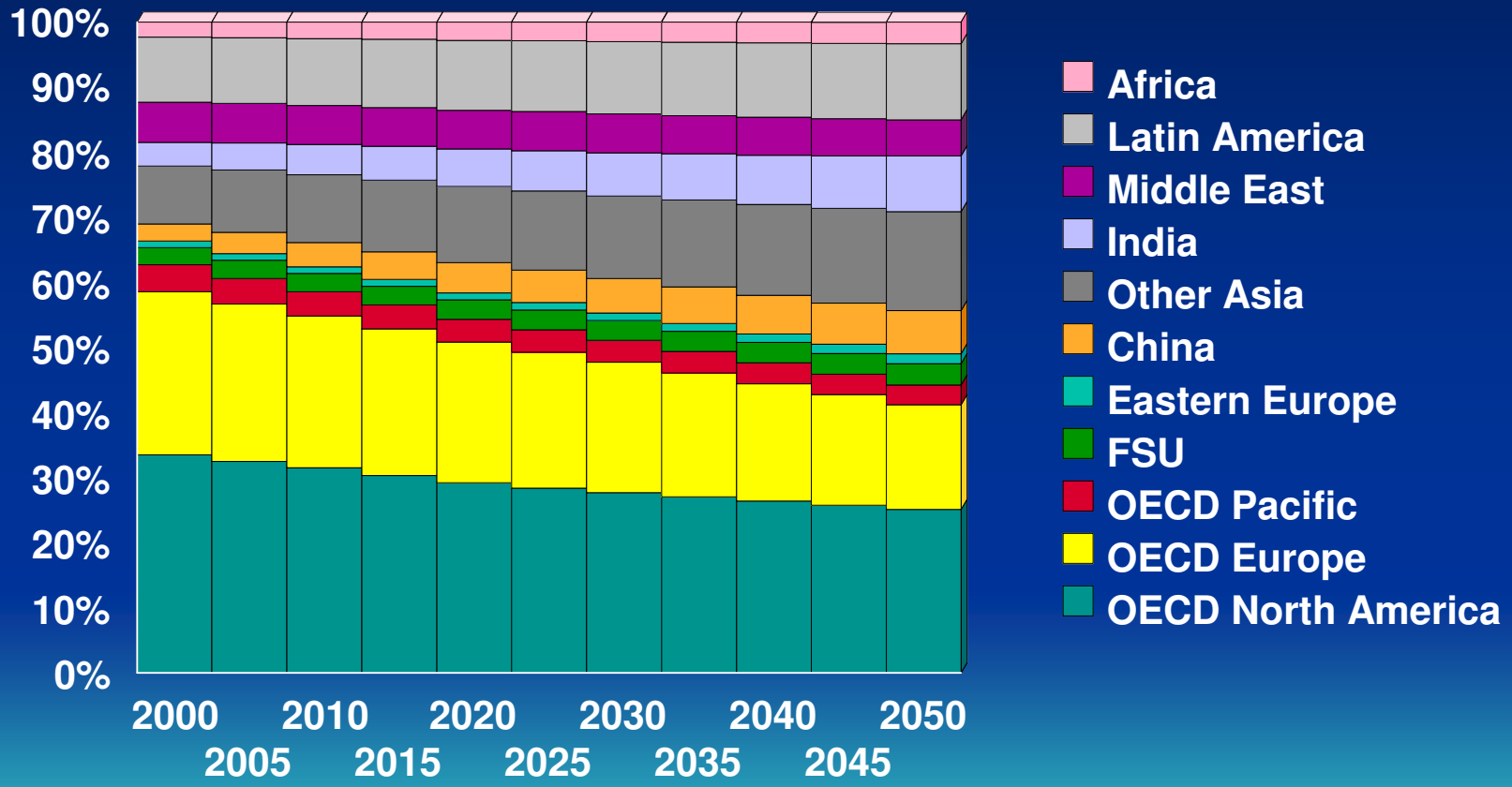
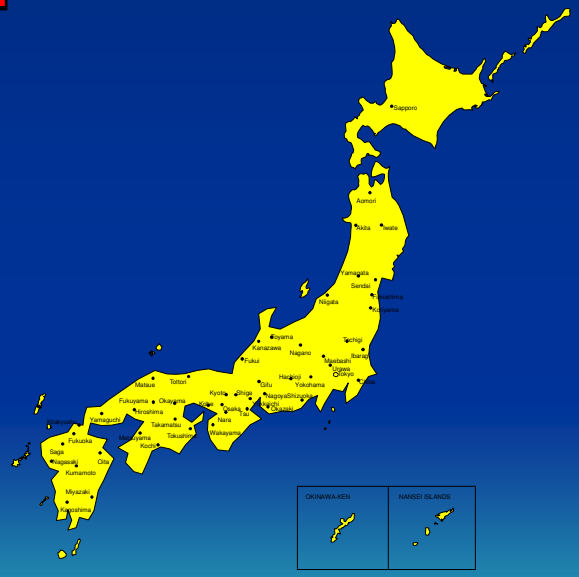


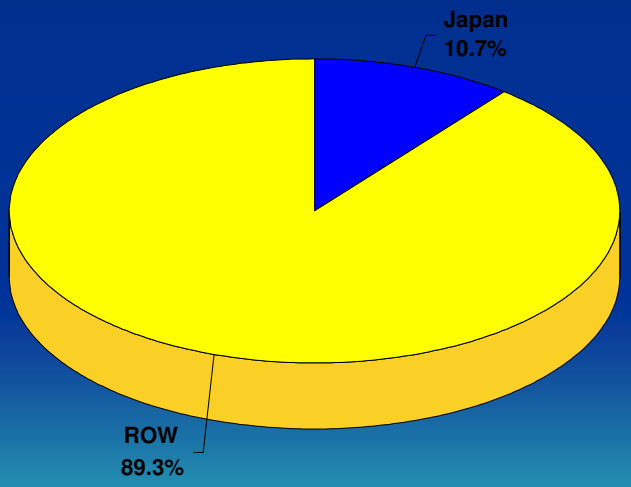
WBCSD

Japan Is Providing Global Leadership

Japan



Japan New Vehicle Sales



The Fuel Economy Standards Will Be Revised For Passenger Cars And Light- And Medium-duty Vehicles Beyond 2010 By METI And MLIT

- The 2010 fuel economy standards will be attained by all Japanese automakers no later than 2006.
- The standards should take into account real world fuel economy.
- Cold start and the use of air conditioners should be considered.
- Developing lean burn DI gasoline and diesel passenger cars are strongly recommended, complying with the future stringent emissions regulations.

Japanese Heavy-duty Vehicle Fuel Economy Targets will be in effect in 2015 (by METI and MLIT)

- The purpose is to reduce fuel consumption and CO_2 emissions from heavy-duty trucks and buses.
- Fuel economy is evaluated based on engine test data and numerical simulation models, taking into account a variety of vehicle types.
- Public comments were obtained on the proposed target of an average improvement of 12% by 2015 compared to levels in 2002.
- It is expected that advanced engine and vehicle technologies will be developed to achieve the targets.

Source: Professor Daisho

Heavy-duty Vehicle Fuel Economy Targets (GVW>3.5 t)

< Trucks >

	2002	2015	Improve-ment
Other than tractors	6.56	7.36	12.2%
Tractors	2.67	2.93	9.7%
Overall	6.32	7.09	12.2%

< Buses >

	2002	2015	Improve-ment
Transit Buses	4.51	5.01	11.1%
Ordinary Buses	6.19	6.98	12.8%
Overall	5.62	6.30	12.1%

Evaluated Fuel Economy Improvement Measures To Be Adopted By 2015 Compared To The Fuel Economy Levels In 2002

1. Engine Improvements
    1. Improvements in Thermal Efficiency
        1. 4 valves and centering injection nozzles(1.0-1.5%)
        2. Direct-injection(4.0-5.0%)
        3. Raising injection pressures (2.0%)
        4. Optimizing combustion chamber geometry (0.5%)
        5. EGR (1.0-1.5%)
        6. High turbocharging pressures (2.5-4.5%)
        7. Improving turbocharging efficiency (0.3-0.5%)
        8. Variable geometry turbocharger (0.5%)
        9. Intercooling (1.5-2.5%)
        10. Turbo compounding (0-1.5%)
        11. Optimizing overall [illegible] %)

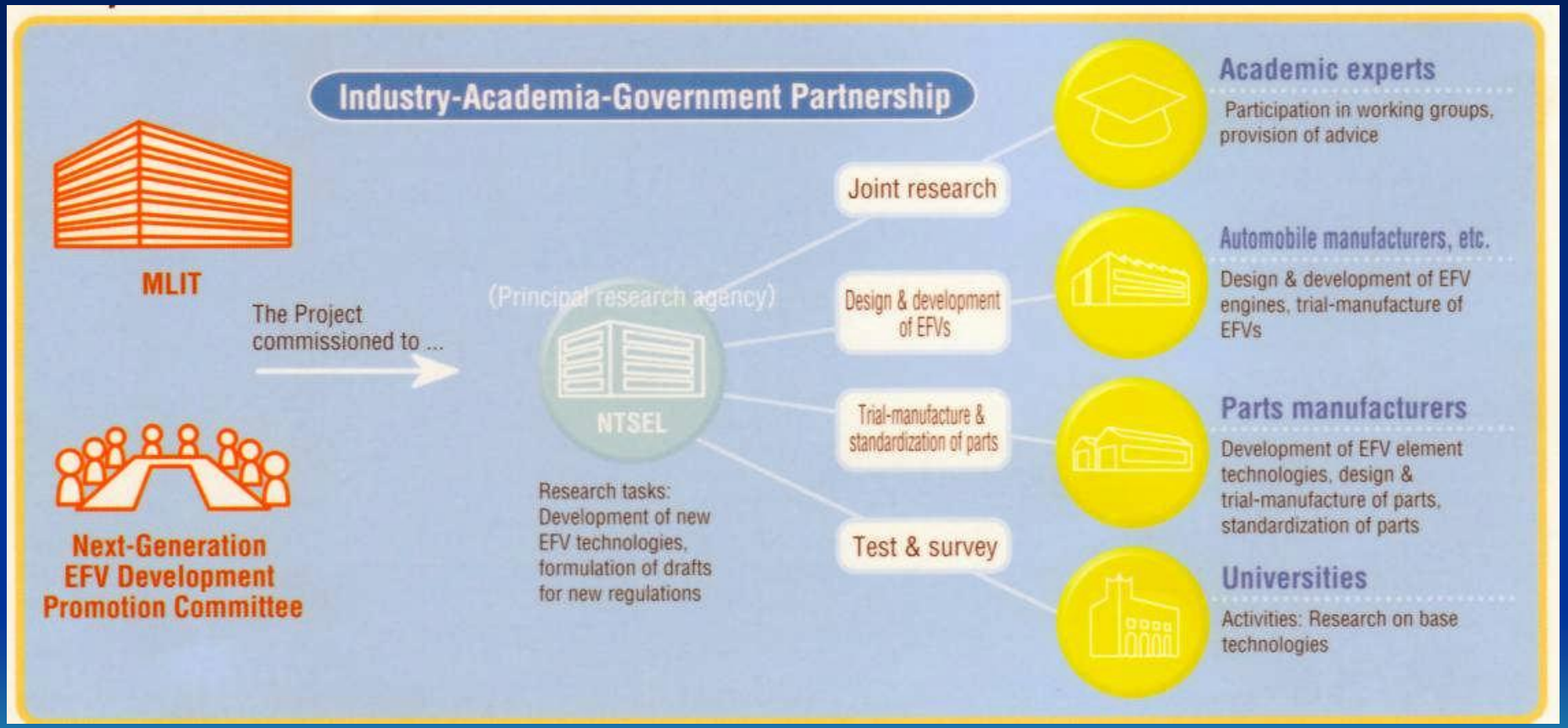
- Continued -

2. Reducing Engine losses
    1. Reducing friction (1.0-1.5%)
    2. Reducing engine speed at idle (0.5%)
    3. Reducing accessory power losses (0.5-1.0%)

2. Optimizing Engine Operation Range
    1. Multi-staged transmission (1.0-5.0%)
    2. Automatic torque converter (-9.0 to -4.0%)
    3. Lowering differential gear rations (0.5-3.0%)
    4. Direct connection at the top (0.5-3.0%)

3. Stopping the Engine at Idle (0-4.0%)

Industry-Academia-Government Partnership



Environmentally Friendly Heavy Duty Vehicles and Development Targets

Vehicles under development		Dimethyl Ether (DME) Truck	Compressed Natural Gas (CNG) Truck	Series-hybrid Bus	Parallel-hybrid Truck	Super-Clean Diesel Engine
Current target of performance levels	Exhaust emission performance: Oxides of nitrogen (NOx)	One-quarter or less of the new long-term regulation limit	One-quarter or less of the new long-term regulation limit	One-quarter or less of the new long-term regulation limit	One-tenth or less of the new long-term regulation limit (achieved if combined with IPT)	One-tenth or less of the new long-term regulation limit (0.2 g/kWh, with D13 mode)
	Exhaust emission performance: Particulate matter (PM)	≈ 0.0 g/kWh (No black smoke)	≈ 0.0 g/kWh (No black smoke)	One-quarter or less of the new long-term regulation limit	One-tenth or less of the new long-term regulation limit (achieved if combined with IPT)	Half or less of the new long-term regulation limit (0.013 g/kWh, with D13 mode)
	Fuel efficiency	Equivalent to the base diesel engine	Carbon dioxide (CO_2) emission during transient operation: Equal to or less than the base diesel engine	Two-fold or more improvement	Two-fold or more improvement	10% improvement from the current level (10% CO_2 reduction)

(EFV - ①)

Dimethyl Ether (DME) Truck

Exhaust emission NOx achievement value 0.11 g/kWh <0.5 g/kWh Target
PM achievement value 0.001 g/kWh ≒0.0 g/kWh Target
Fuel consumption Equivalent to the base diesel engine

Technical Features

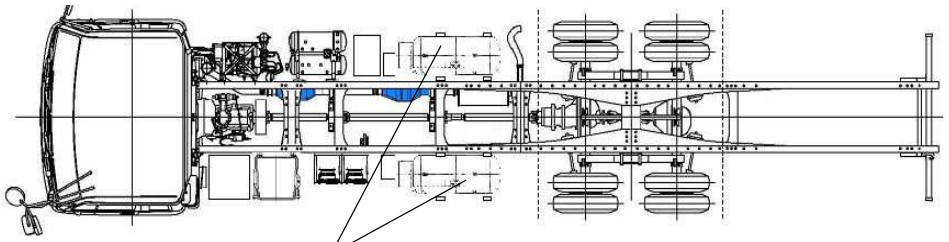
- No black smoke, Drastic reduction of NOx
- High-efficiency equivalent to diesel engines, Long range cruise

Main new development elemental Technology

- High pressure fuel injection system
- EGR, NOx strage reduction catalyst

Developed DME HD Truck

GVW 20t
HD Truck



(EFV - ②)

Natural Gas HD Truck

Exhaust emission NOx achievement value 0.161 g/kWh <0.5 g/kWh Target
PM achievement value 0.002 g/kWh ≒0.0 g/kWh Target

Fuel consumption Less than base diesel engine in CO2 emission rate (639 g/kWh)

Technical Features

- Low emission with three-way catalyst technology
- Improvement of loading by high-output engine

Main new development elemental Technology

- Gas fuel supply system for HD engine
- Three-way catalyst and EGR system for CNG
- Inter-cooler Turbo charge system

GVW
25t

Developed CNG HD Truck

(EFV - ③)

Series Hybrid Bus

Exhaust emission NOx achievement value 0.33 g/kWh <0.5 g/kWh Target
PM achievement value 0.0011 g/kWh ≒0.0 g/kWh Target

Fuel consumption 48 % improvement from the base diesel vehicle

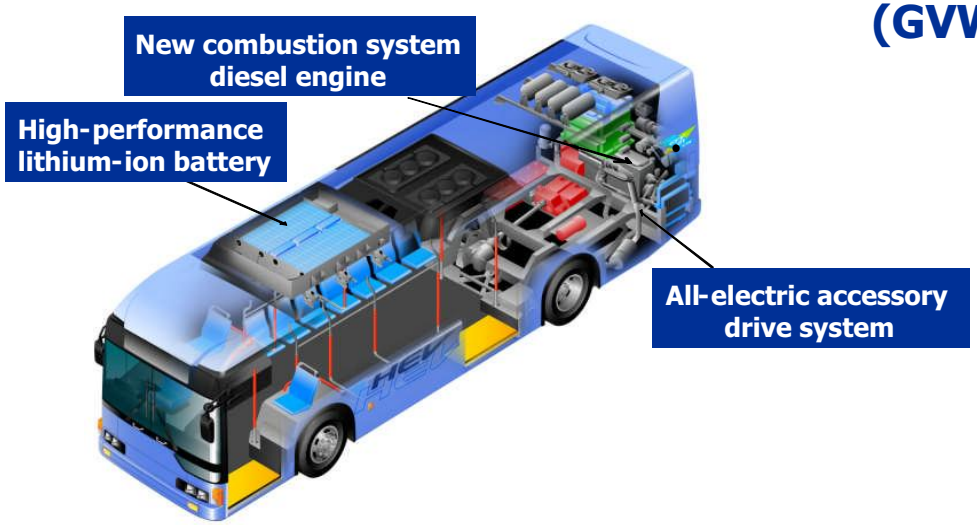
Technical Features

- Exhaust emissions reduced by new combustion diesel engine
- Fuel efficiency improved by all-electric accessory drive system
- Energy efficiency enhanced by high-performance lithium-ion battery

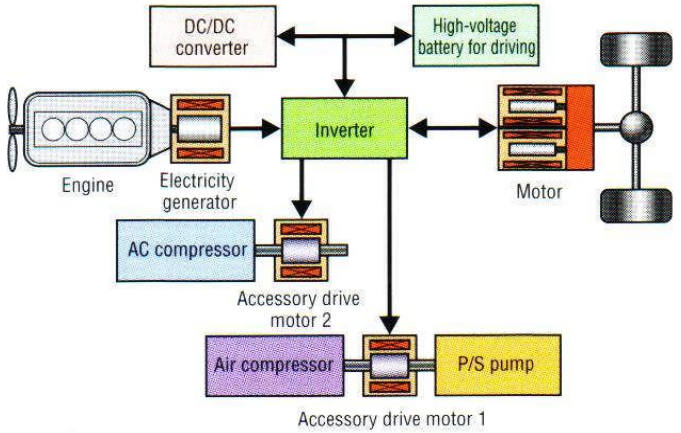
Main new development elemental Technology

- New combustion like PCCI (Premixed Charge Compression Ignition)
- High-performance lithium-ion battery, EBS (Electrical brake system)
- All-electric accessory drive system

Developed Series Hybrid Bus



City Bus for 72 passengers capacity (GVW 14 t)



(EFV - ④)

Parallel Hybrid Truck

Exhaust emission NOx achievement value 0.0 g/kWh <0.5 g/kWh Target
PM achievement value 0.0022 g/kWh ≒0.0 g/kWh Target

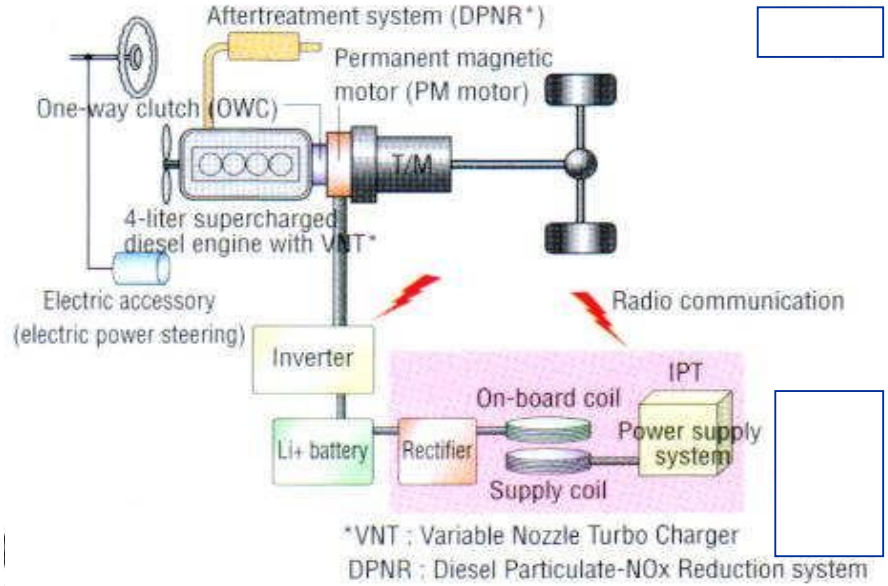
Fuel consumption 50 % improvement in CO2 emission rate from the base diesel vehicle

Technical Features

- Hybrid system with increased energy recovery
- IPT system enabling electric driving
- High-performance lithium-ion battery
- Low-emission diesel engine

Main new development elemental Technology

- High-performance permanent magnetic motor
- Electrical control transmission
- Inductive Power Transfer (IPT) system



Developed parallel hybrid truck

GVW 13t HD Truck

(EFV - ⑤)

Engine for GVW 25t HD Diesel Truck

Super Clean Diesel (SCD) Engine

Exhaust emission Low sulfur fuel (< 10ppmS), D13 mode

NOx achievement value 1.0 g/kWh (Before Cat.), 0.2 g/kWh (After Cat.)*

PM achievement value 0.05 g/kWh (Before Cat.), 0.013 g/kWh (After Cat.)*

Fuel consumption The same level as the base diesel engine

※ : NOx, and PM 80 % reduction by After-treatment system

Technical Features

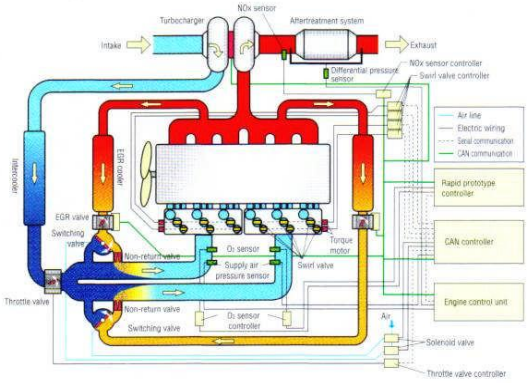
- Lean combustion by ultra-high turbo-charger
- Wide range high EGR system
- High Pmax engine structure

Main new development elemental Technology

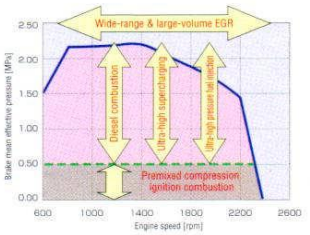
- Electrically controlled ultra-high pressure fuel injection system
- The world's first electronically controlled ultra-high turbocharger
- Ultra-high efficiency EGR cooler, electrically controlled EGR valve
- New piston, conrod etc. for high Pmax
- NOx, PM simultaneously reduction after-treatment system

Developed Super Clean Diesel Engine

Ultra-High Supercharging Turbocharger



Combustion Concept



1. The basic combustion will be a diesel combustion based on high supercharging and high EGR.
2. Premixed compression ignition combustion will be used partially (where the load is light).

Combustion targets

① High supercharging will provide the combustion with highly dense air.
② Air/fuel mixing will be enhanced by injecting fuel with high-pressure into the highly dense air.
③ Higher BMEP will reduce the relative friction and heat loss.
④ Wide-range and large-volume EGR will drastically reduce NOx.

The Challenges for On-Highway Trucks

Ultra Low Sulfur Diesel Fuel

Particulate Reduction with the use of Particulate Filters

Manufacturer Run In-Use Emission Testing

Closed Crankcase

NOx Reduction with Advanced Technologies

On-Board Diagnostics

Additional Maintenance Requirements

New Lubricating Oils Compatible with Aftertreatment

Anti – Idling Requirements

Reduced Energy Consumption