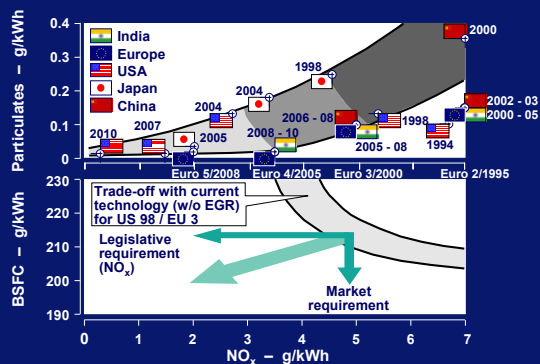


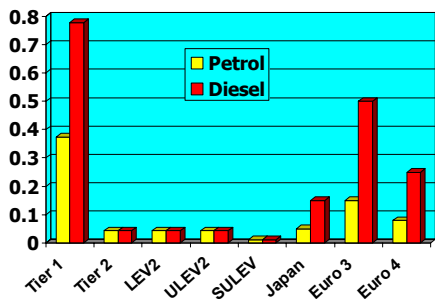
# Comments To The Health Effects Institute Special Committee On Emerging Technologies

Michael P. Walsh  
May 2005

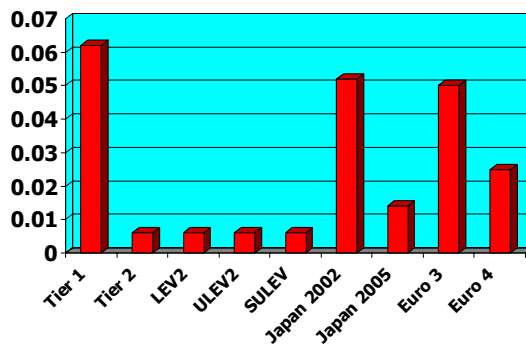
## Emission Legislation Limits and fuel economy



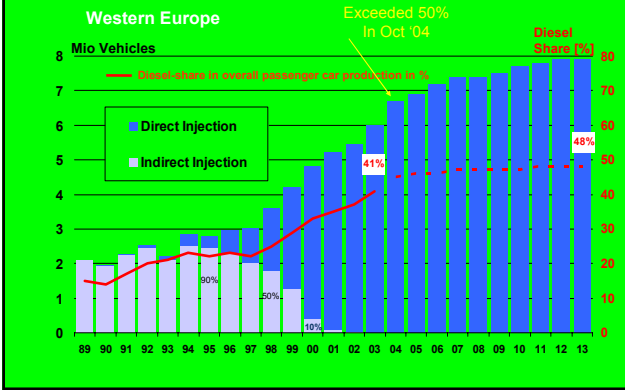
## Light Duty Vehicle NO<sub>x</sub> Standards (g/km)



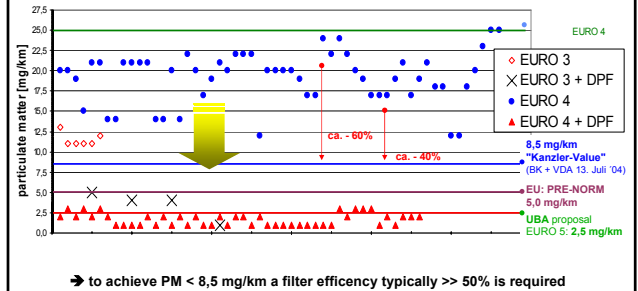
## Light Duty Vehicle PM Standards (g/km)



## Production of Diesel Passenger Cars



## Distribution of certified PM-values of current Diesel Cars



## Cooled EGR and Particulate Reduction Hardware Requirements with DPF for Euro 4

**Euro 3**

- Base engine:**
- Mechanically sound engine
  - Lube oil consumption < 0,1g/kWh
  - Peak firing pressure potential 200 bar

**Displacement**  
0.9 - 1.4 liter / cyl.

**Rated speed**  
2200 - 2600 rpm

- +
- High performance EGR-system
  - Improved vehicle cooling system
  - Fully flexible FIE with > 1600 bar
  - 2-stage turbocharging for > 32 kW/l

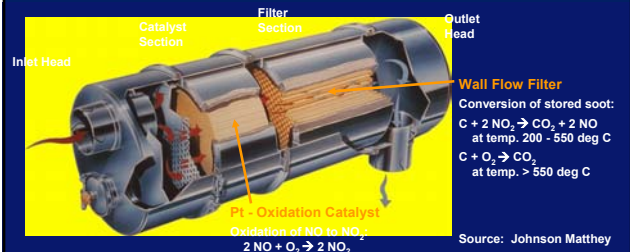
- +
- Combustion system**
- high EGR tolerance
  - combustion bowl for low soot in oil
  - alternative combustion at part load for temperature management

+

Diesel particulate filter >70% eff.

**Euro 4**

## Emission Reduction Technology EGR + Particulate Reduction with DPF



<b>Advantages</b>	• High PM conversion rates
<b>Challenges</b>	• Regeneration: min. 250°C exhaust gas temperature • Low sulfur fuel required to avoid too frequent maintenance due to ash accumulation

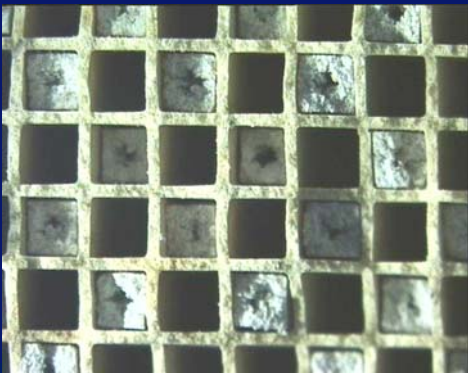
Spectacular Filter Damage  
Ring-off-Cracks and Melting of the  
Cordierite Material source Johnson Matthey



and this is how it starts



Ash Plugging of Filter Cells



### Cooled EGR and Particulate Reduction Hardware Requirements with POC for Euro 4

**Euro 3**

- Base engine:
- Mechanically sound engine
- Lube oil consumption < 0,1g/KWh
- Peak firing pressure potential 200 bar

Displacement  
0.9 - 1.4 liter / cyl.

Rated speed  
2200 - 2600 rpm

+

- High performance EGR-system
- Improved vehicle cooling system
- Fully flexible FIE with > 1800 bar
- 2-stage turbocharging for > 32 kW/l

+

- Combustion system
- high EGR tolerance
- combustion bowl for low soot in oil
- alternative combustion at part load for temperature management

+

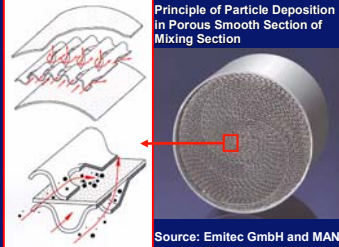
Particulate oxidation catalyst > 50%

**Euro 4**

## Emission Reduction Technology EGR + Particulate Reduction with POC

### Mechanism and Effectiveness:

- Carbon-PM oxidized by NO<sub>x</sub> being formed in Oxicat
- HC, Sol-PM and CO oxidized in Oxicat
- Conversion Rates (ESC & ETC):
  - Particulates:  $\eta_{PM} \approx 50\%$   
Target:  $\eta_{PM} \approx 70\%$  by further development
  - Hydrocarbon:  $\eta_{HC} \approx 85\%$
  - Carbon monoxide:  $\eta_{CO} \approx 90\%$



### Advantages

- No risk of filter blocking, no active regeneration
- Small packaging volume

### Challenges

- Lower conversion rates compared to DPF
- Requires higher fuel injection pressure
- Low sulfur fuel required

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## Engine Concept Requirements Hardware Requirements with SCR for Euro 4

### Euro 3

#### Base engine:

- Mechanically sound engine
- Lube oil consumption < 0,1g/KWh
- Peak firing pressure potential 135 bar

Displacement  
0.9 - 1.4 litre / cyl.

Rated speed  
2200 - 2600 rpm

Specific power  
26.4 kW / litre

+

- No EGR-system
- Fully flexible FIE with > 1600 bar
- Peak firing pressure potential 145 bar
- 4 Valve cylinder head

+

#### Combustion system

- Combustion bowl for low soot in oil
- Alternative combustion at part load for temperature management

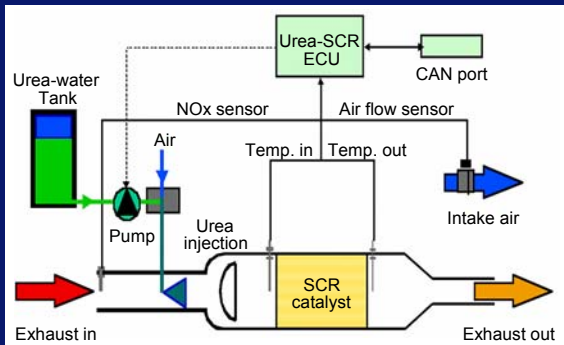
+

SCR system > 60%NO<sub>x</sub>, 50%PM eff.

Euro 4

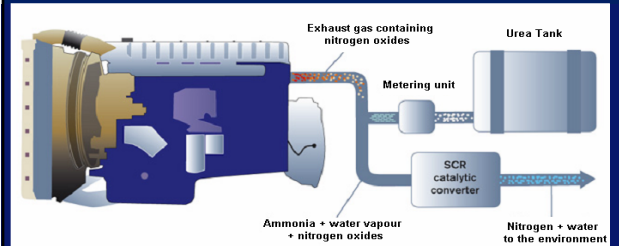
14

## SCR - Selective Catalytic Reduction



15

## Emission Reduction Technology Selective Catalytic Reduction - SCR



### Advantages

- Better fuel economy compared to EGR + part. reduction

### Challenges

- Urea infrastructure required
- Regeneration: min. 200°C exhaust gas temperature
- Low sulfur fuel required

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**Proposed Limit Values of Diesel-powered Vehicles in Japan (2009~)(Draft)**

	PM	NOx	NMHC	CO	Achievement Timing	
Passenger car	0.005 ±62%	0.08 (±43%)	0.024 0%	0.63 0%	2009	
Trucks	Light-weight (GVW1.7t or less)	0.005 ±62%	0.08 (±43%)	0.024 0%	0.63 0%	2009
	Middle-weight (GVW over 1.7t ~ 3.5t or less)	0.007 ±53%	0.15 (±40%)	0.024 0%	0.63 0%	1.7 ~ 2.5t 2010 2.5 ~ 3.5t 2009
	Heavy-weight (GVW over 3.5t)	0.01 ±63%	(next target) 0.7 (±41%) (challenge target) about 1/3 of 0.7 (±88%)	0.17 0%	2.22 0%	3.5 ~ 12t 2010 over 12t 2009

- ※ 1 . Unit : Heavy-weight :g/kWh  
Except Heavy-weight :g/km
- ※ 2 . Lower column means ratio of reduction from the new long-term standards (enforce by 2005).
- ※ 3 . GVW : Gross weight Vehicle, NMHC : Non-methane hydrocarbons

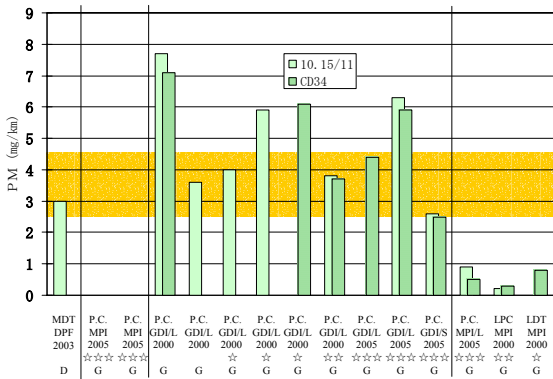
**Proposed Limit Value of Gasoline-powered Vehicles (2009) (Draft)**

	PM	NOx, NMHC, CO	Achievement periods
Passenger car	0.005	N.C.	2009
Light-weight (GVW1.7t or less)	0.005		
Middle-weight (GVW over 1.7t ~ 3.5t or less)	0.007		
Heavy-weight (GVW over 3.5t)	0.01		

- ※1 Unit : Heavy-weight :g/kWh Except Heavy-weight :g/km
- ※2 GVW : Gross weight Vehicle, NMHC : Non-methane hydrocarbons

note) Target values of particulate matter are applied only to lean-burn, direct-injection vehicles mounted with storing-type NOx reduction catalyst.

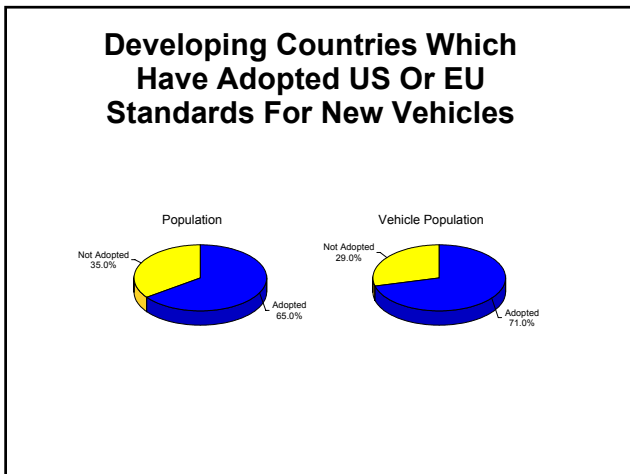
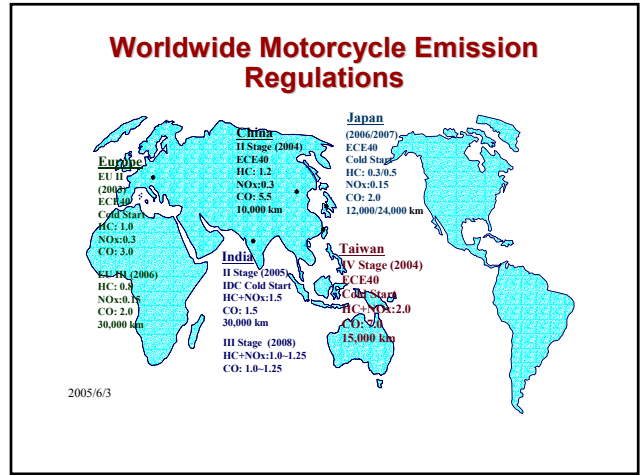
**Comparison of PM exhaust emission (JAMA DATA)**



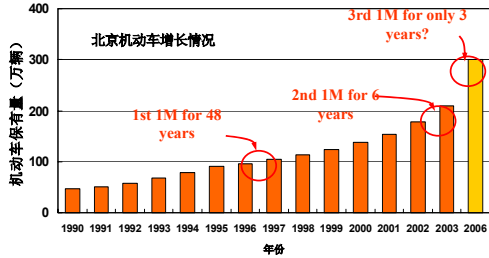
**Emission Reduction Technology (Diesel Vehicles)**

	2003-04	2005	2009-10
Improvement of combustion chamber and air-intake system	○	○	○
Improvement of fuel injection system	○	○	○
Cooled EGR	△	○	○
Turbo Charger	△	○	○
HCCI(Homogeneous Charge Compression Ignition)	×	×	△?
NOx sensor	×	×	○
Urea sensor	×	×	△or○?
Exhaust After-treatment Device			
Oxidation Catalyst	△	○	○
Passive type Diesel Particulate Filter(DPF)	△	○	○
Selective Catalytic Reduction (SCR)	×	△	○
NOx Adsorber	×	×	○

Note) ○ : Prevalled △ : Limited use × : Not Possible



### Vehicle Growth in Beijing is Exploding



Source: He Kebin

### Pollution Shifting From Coal Based To Vehicle Based

Shanghai November 2004

Beijing November 2004



### Control Measures on Motor Vehicle Pollution

Emission Standards For New Vehicles

Time Category	Before 2000	2000	2001	2002	2003	2004	2005
PC	ECE 1503	EURO I	←	←	←	EURO II	←
LDV&LDT	ECE 1503	←	EURO I	←	←	←	EURO II
HDDV	None	←	EURO I	←	←	EURO II	←
Motocycle	ECER 40	←	EURO I	←	←	←	EURO II

Beijing, Shanghai already Introduced Euro 2 in 2003

### New Vehicle Emissions Standards (light duty vehicles)

Country	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10
European Union	Euro 1	Euro 2					Euro 3				Euro 4					Euro 5
Bangladesh																Euro 2 (under discussion)
Hong Kong, China		Euro 1	Euro 2				Euro 3				Euro 4					
India <sup>a</sup>						E1	Euro 2			Euro 1		Euro 2				E3
Indonesia												Euro 2				
Malaysia			Euro 1			Euro 2										
Nepal							Euro 1									
Philippines										Euro 1						
PRC <sup>b</sup>								Euro 1		Euro 2						Euro 3
PRC <sup>c</sup>								Euro 1	Euro 2	Euro 2	Euro 3					
Singapore <sup>d</sup>	Euro 1						Euro 2									
Singapore <sup>e</sup>	Euro 1						Euro 2				Euro 4					
Sri Lanka											Euro 1					
Taipei, China							US Tier 1							US Tier 2 for diesel <sup>f</sup>		
Thailand	Euro 1						Euro 2			Euro 3						Euro 4
Viet Nam <sup>g</sup>							Euro 1									Euro 1

<sup>a</sup> Singapore  
<sup>b</sup> Delhi and other cities; Euro 2 introduced in Mumbai, Kolkata and Chennai in 2001, Euro 3 in Bangalore, Hyderabad, Hyderabad and Ahmedabad in 2003, Euro 4 to be introduced in Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad and Ahmedabad in 2005.  
<sup>c</sup> Hanoi and Ho Chi Minh  
<sup>d</sup> Gasoline vehicles under consideration.  
<sup>e</sup> For gasoline vehicles.  
<sup>f</sup> For diesel vehicles.  
<sup>g</sup> For all types of diesel vehicles.

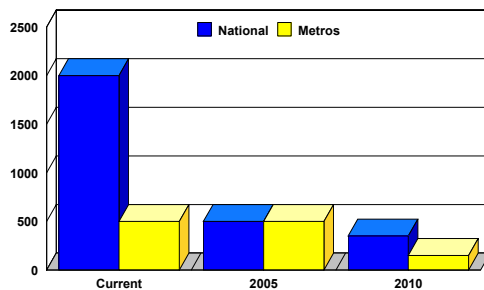




## New Vehicle Standards in India

- **Entire Country**
  - Euro 2 – April 2005
  - Euro 3 – April 2010
- **Major Cities**
  - Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad & Ahmedabad, Pune Surat, Kanpur & Agra Already Euro 2
  - Tighter emission norms for all private vehicles, city public service vehicles and city commercial vehicles
    - Euro 3 From April 2005
    - Euro 4 From April 2010

## India Diesel Fuels Road Map



Some parts of Country will not meet 2005 schedule;  
Largest Reliance Refinery Now Making 10 PPM

## Exhaust Emission Standards in Korea

- ❖ **Gasoline Passenger Car**
  - LEV of LEV-1 standard was applied in Jan. 2003.
  - ULEV of LEV-2 standard (of CARB) will be applied from 2006.1 with a phase-in of 25/50/75/100%.
- ❖ **Diesel HDV**
  - EURO-3 standard was applied in 2002.7/2003.7.
  - EURO-4 standard will be applied from 2006.10/2008.1.
  - ESC/ETC test mode will be adopted.
- ❖ **Diesel Passenger Car**
  - EURO-3 will be applied from 2005.1, but half of the cars will have to install DPF.
  - EURO-4 will start from 2006.
- ❖ **Diesel LDT**
  - EURO-3 was applied in 2002.7/2003.7.
  - EURO-4 will be applied from 2006.1/2007.1.

## Taiwan New Vehicle Emissions Standards

Vehicles	Standards	Effective date
Gasoline cars	STAGE <sub>III</sub>	1/1/1999
	STAGE <sub>IV</sub>	1/1/2008
Diesel cars	STAGE <sub>III</sub>	1/7/1999
	STAGE <sub>IV</sub>	1/1/2007
Motorcycles	STAGE <sub>IV</sub>	1/1/2004
	STAGE <sub>V</sub>	1/7/2007

Tier 2, bin 5

Possible E5  
In 2010

Euro 3

1. The emission standards of gasoline cars and diesel cars: present-USA standard, STAGE<sub>IV</sub>- EURO IV.
2. After enter the WTO, the emission standard of motorcycle will take the EURO standard or USA standard.

## Fuel in Taiwan

### The composition and performance standards in fuel

(1) The composition and performance standards in gasoline and diesel for vehicles took into forces in 2000.

(2) Gradually lower the sulfur content in diesel from 5,000 ppmw in 1989 to 50 ppmw in 2005.

Fuel	Items	2002	2005	2007
gasoline	Benzene (vol%), max	1.0		1.0
	Sulfur (ppmw), max	180		50
	RVP (psi), max	8.9		8.7
	Oxygen (wt%), max	2.0		2.7
	VOCs+NOx(mg/km), max	1700		-
	TOXICs(mg/km), max	48		-
	Aromatics (vol%), max	-		36
	Alkene (vol%), max	-		18
	Sulfur (ppmw), max	350	50	
	Cetane Index, min	48	-	
diesel	Cetane Index, min	48	-	
	Aromatics (vol%), max	-	35	

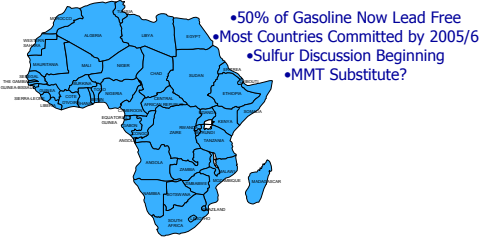
## Brazil

- **Passenger Cars & Light Commercial Vehicles**
  - US EPA 1983 Standards Since 1997
  - Tier 1 Phased in 2005-2007 (40/70/100%)
  - FedLev in 2009
  - No Diesel Cars Allowed
- **Heavy Duty Trucks & Buses**
  - Euro 3 Phased in 2004-2006
  - Euro 4 in 2009
- **Fuels**
  - Diesel Fuel S in City from 2000 to 500 in 2005 & to 50 in 2009; on rural areas from 3500 to 2000 in 2005 & to 500 in 2009
  - Gasoline S from 1000 to 400 in 2004 & to 80 in 2008
- **State of Sao Paulo Gearing Up To Push Sulfur Issue**

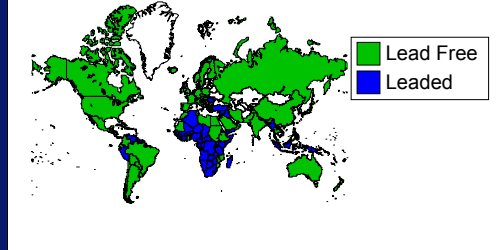
## Mobile Sources Program In Mexico

- **Tighten emission limits for new gasoline and diesel vehicles.**
  - Gasoline:
    - Tier I first introduced in 1999 (US-EPA-94).
    - Tier II to be introduced in 2006, under discussion.
  - Diesel:
    - EPA-98 currently in place.
    - Standards for new diesel vehicles under discussion.
- Key Issue Is Fuel Quality – Sulfur
- EPA Retrofit Initiative

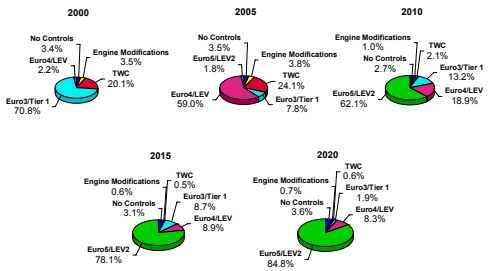
## Africa



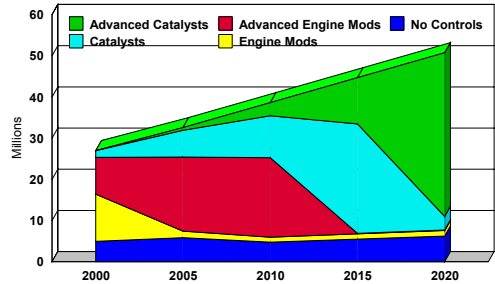
## Lead Free Gasoline Worldwide 2004



## Global Distribution of Emissions Controls New Gasoline Cars (000)



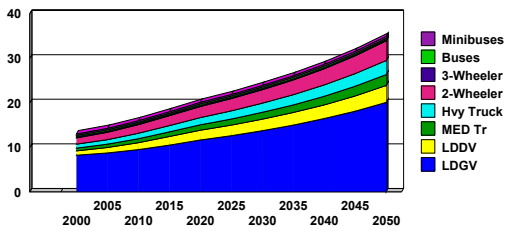
## Global Distribution of Emissions Controls Motorcycles





## Global Trends in Vehicle Kilometers Traveled

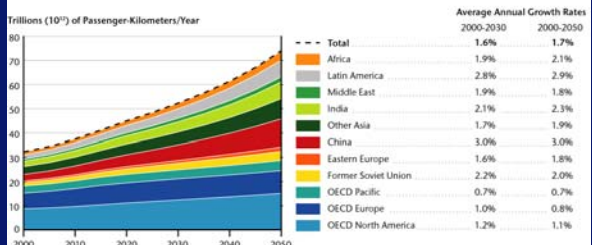
Global Road Vehicle Kilometers Traveled (10<sup>12</sup>)



Source: WBCSD

## Problem Could Get Worse Due To High Growth Especially In Asia

Personal transport activity by region

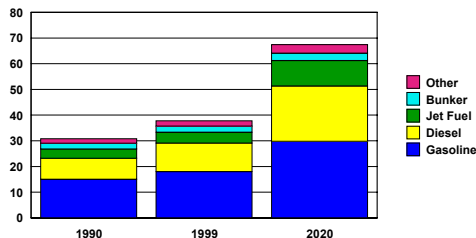


Source: Sustainable Mobility Project calculations.

...and even more significant freight transport growth: 2.4 % /year

## Recent and Projected World Transportation Fuel Demand

Million Barrels/Day Oil Equivalent

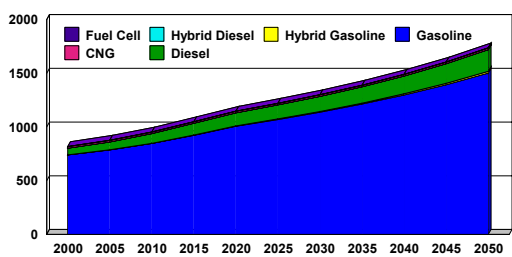


Source: EIA/DOE (2001)

Transportation is the Fastest Growing CO<sub>2</sub> Emissions Source

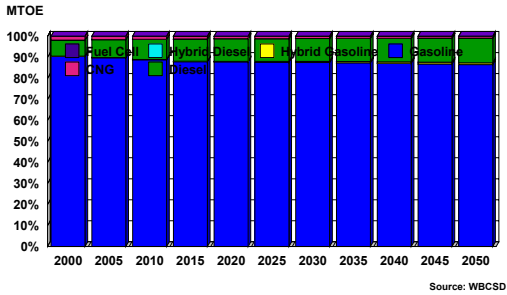
## Worldwide Fuel Consumption by Light Duty Vehicle

MTOE

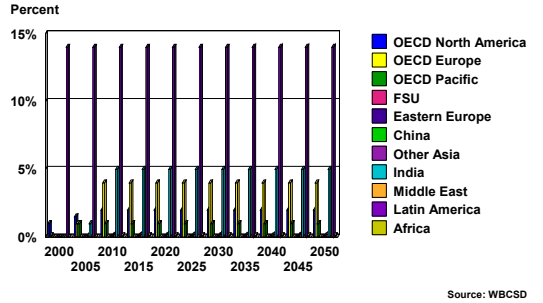


Source: WBCSD

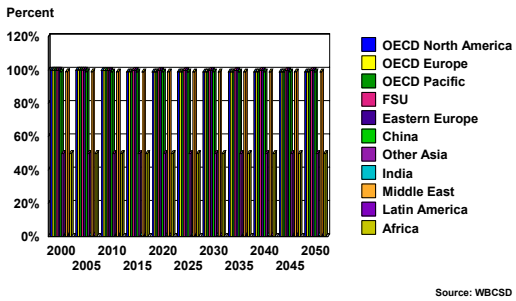
## Worldwide Fuel Consumption by Light Duty Vehicle



## Ethanol Blend Share into Gasoline



## Ethanol Blend Share Derived From Grains



## Ethanol Blend Share Derived From Sugar Cane

