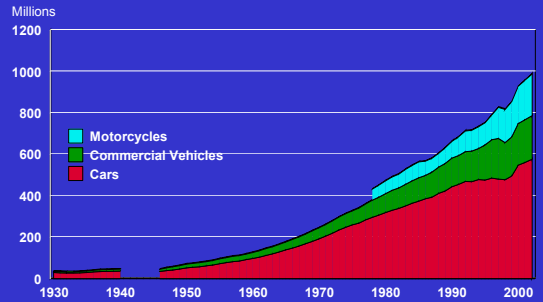


## Motor Vehicles: Overview, Alternatives, Issues

### Air Pollution as Climate Forcing: Alternative Scenarios – Their Benefits and Costs

M.P. Walsh  
 With Advice & Assistance from B. Croes, A. Ayala, R. Corey and M. DeLucchi  
 May 2005

## World Motor Vehicle Population

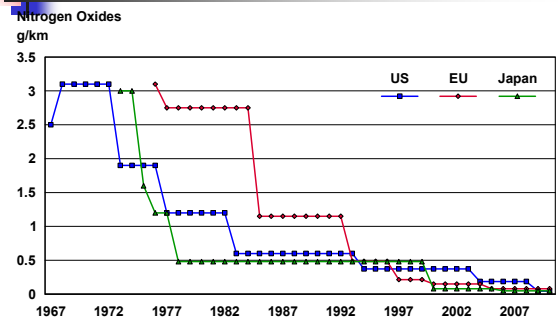


## One Result: Serious Health Concerns

- WHO Concludes ~ 800,000 Premature Deaths Each Year From Urban PM; Most in Asia
- Numerous Studies in Europe & US Consistently Link PM With Premature Deaths, Hospital Admissions, Asthma Attacks, Etc.
- No Evidence of a Threshold
- PAPA Project Indicates Similar Effects in Asia
- Ozone, NO<sub>x</sub>, Various Toxics Also Serious Health Concerns



## Emissions Standards Trends For Gasoline Cars

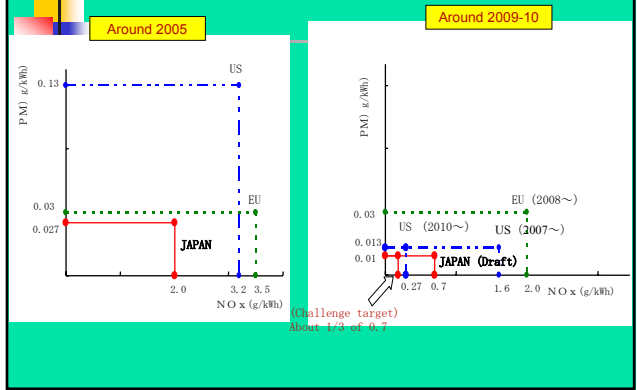


### Tax Incentives for Low Emission Vehicles and High Fuel Economy Vehicles (2004-2005)

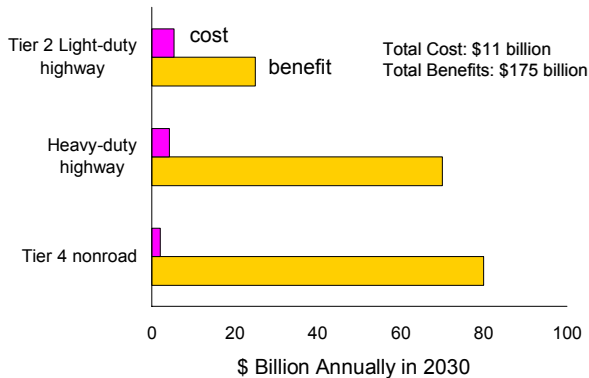
Emissions+ Fuel economy	☆☆☆: 50% lower emission vehicles	☆☆☆☆: 75% lower emission vehicles
Vehicles: achieving fuel economy standard in 2010	No incentives	*25% annual tax reduction *200,000 yen purchase tax deduction
Vehicles: 5% higher fuel economy than the standard in 2010	*25% annual tax reduction *200,000 yen purchase tax deduction	*50% annual tax reduction *300,000 yen purchase tax deduction

+: compared to the new long-term standard in 2005

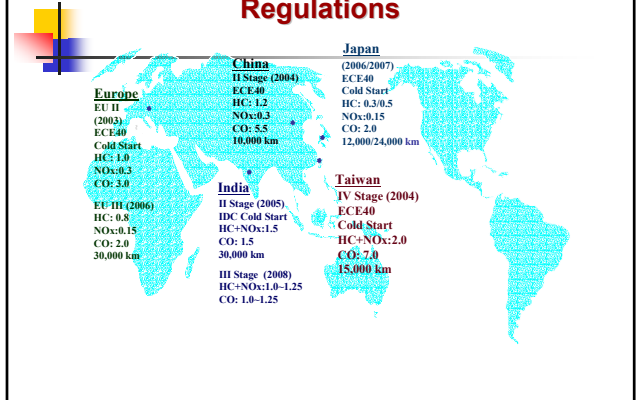
### Comparison of Future Emission Standards on HD vehicles

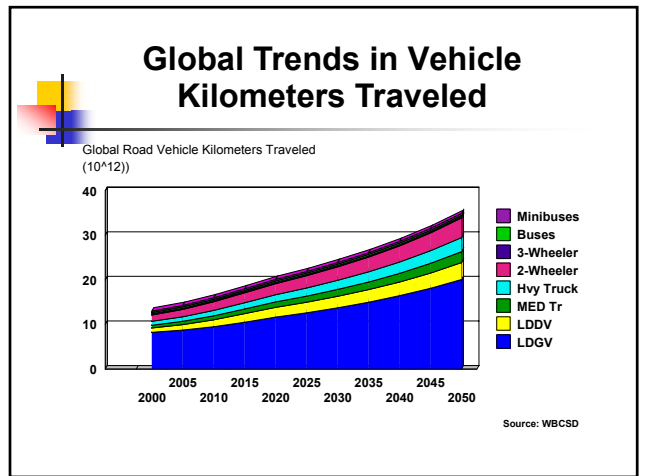
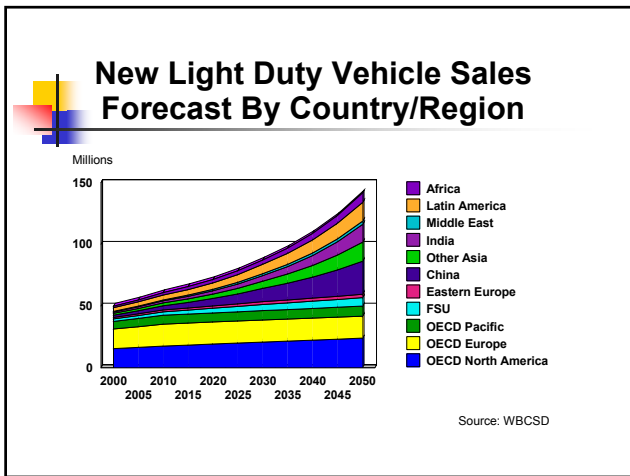
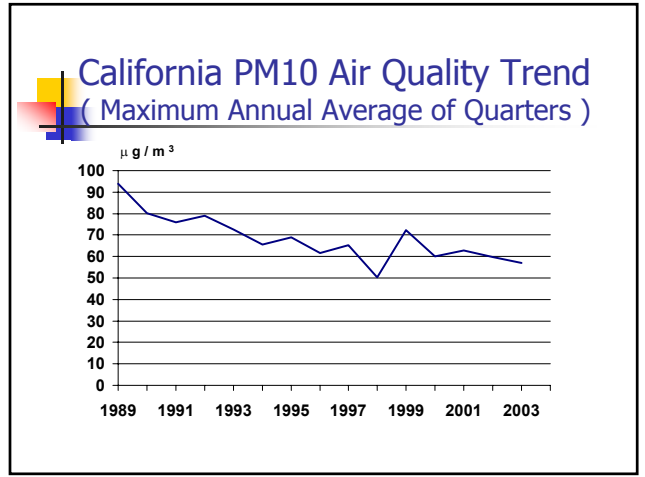
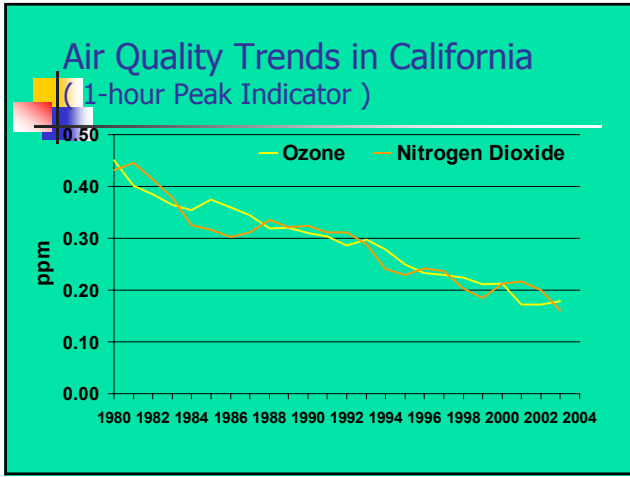


### Costs & Benefits of Clean Fuels and Vehicles



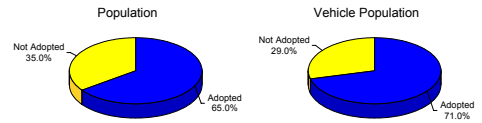
### Worldwide Motorcycle Emission Regulations







## Developing Countries Which Have Adopted US Or EU Standards For New Vehicles



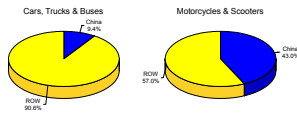
### The Challenges:

- Eliminate The Yellow Colored Areas
- Narrow the Technology/Fuel Quality Gap in Blue Areas

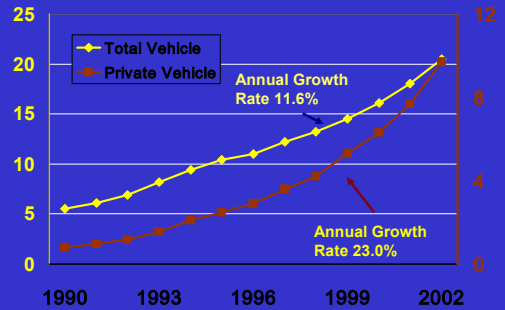
## China



### China New Vehicle Sales

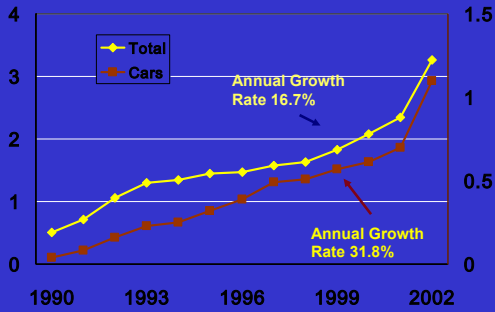


## Chinese Vehicle Population Has Been Exploding (million)



Plus Approximately 50 Million Motorcycles And Over 20 Million Agricultural Vehicles

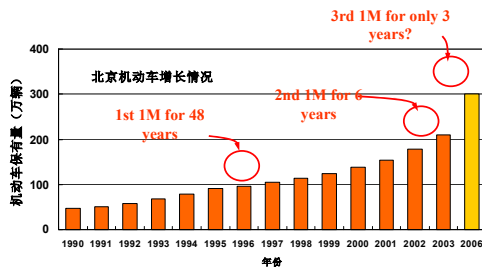
## Growth in Annual Vehicle Production Has Been Even Faster (million)



By The End of 2003, China Has Become The 4<sup>th</sup> Largest Producer In The World



## Vehicle Growth in Beijing is Exploding



Source: He Kebin

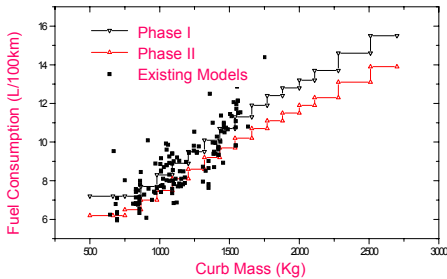
## Control Measures on Motor Vehicle Pollution

### 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	←
Motorcycle	ECER40	←	EURO I	←	←	←	EURO II

Beijing, Shanghai already Introduced Euro 2 in 2003

## China Fuel Consumption Standards – MT Cars

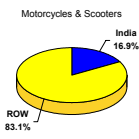
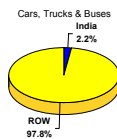


## What's In Play in China

- Nationally-SEPA
  - Mobile Sources
    - Developing 11<sup>th</sup> Five Year Plan Document
    - Putting Strong Environmental Case Together For Euro 4 Stds & Fuels
  - Euro 3 in 2007, Euro 4 in 2010 likely – April?
  - Trying to Get Sulfur Issue to State Council Soon
  - Fuels Workshop in July with US EPA
- Beijing EPB
  - Likely Euro 3 Gasoline, Euro 4 Diesel in 2005/6
  - Cleaner Fuels Adopted For July 1, 2005
  - Interested in Accelerating Euro 4 before Olympics
  - Retrofit Demonstration with US EPA
- Shanghai, Guangzhou EPB
  - Also Interested in Leapfrogging

## India

### India New Vehicle Sales

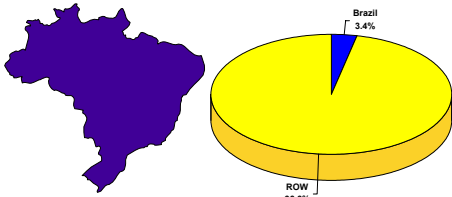


## New Vehicle Standards in India

- 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
- Entire country at 500 PPM Sulfur this year
  - Largest Reliance refinery at 10 PPM

## Brazil New Vehicle Sales

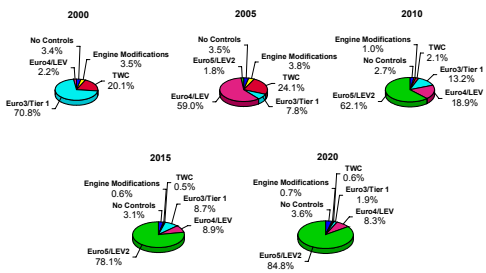
### Brazil New Vehicle Sales



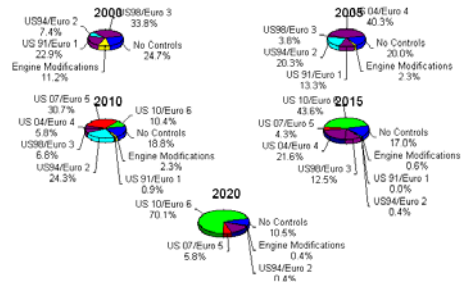
## Brazil

- 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

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



## Global Distribution of Emissions Controls Heavy Duty Diesel Trucks (000)



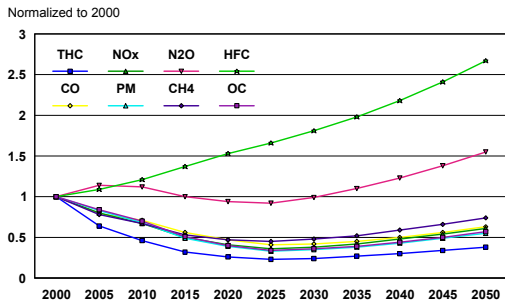
## Forecasting Emissions

- WBCSD Vehicle Growth Forecasts
- Aggregate Countries into Three Categories
  - Industrialized (OECD)
  - Rapidly Developing (Most of Asia)
  - Developing (The Remainder)
- US EPA Emissions Factors by Technology Category
- GWP's from CARB and Mark DeLucchi

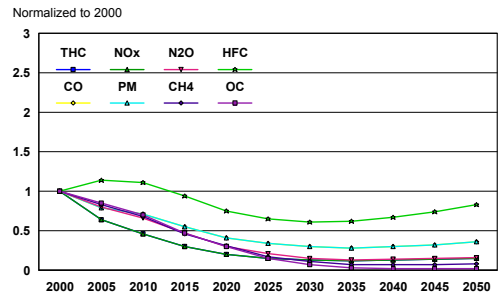
## Two Scenarios

- Business As Usual
  - Currently Adopted or Soon To Be adopted Emissions Standards
  - Industrialized Countries HFC Control (see Richard Corey presentation)
    - 50% by 2015
    - 90% by 2020
- More Aggressive Standards
  - RICs on par with industrialized by 2015
  - Developing on par by 2020
- VMT Held Constant in Both (WBCSD) No TCMS

## Vehicle Emissions Trends (Business As Usual Scenario)

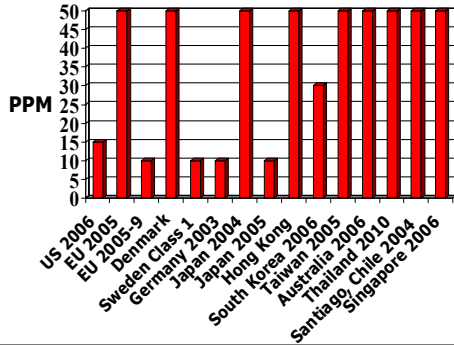


## Vehicle Emissions Trends (Aggressive Scenario)

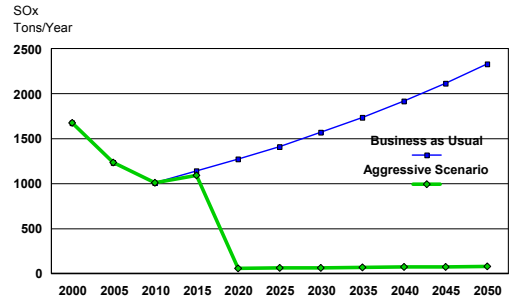




## Ultra Low Sulfur Diesel Fuel Is Spreading



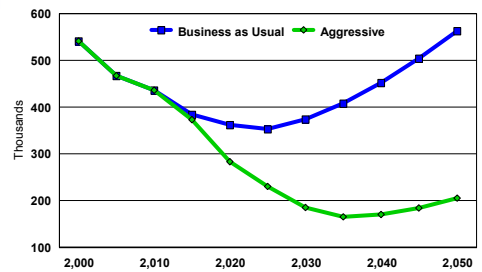
## SO<sub>x</sub> Emissions From Road Vehicles (000)



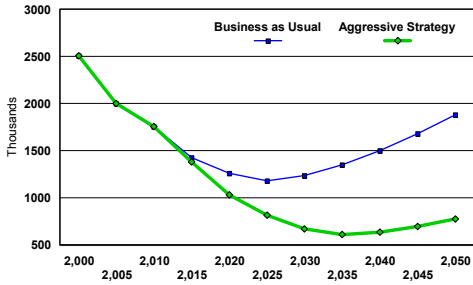
## Approaches To Global Warming Potential

	CARB	CEF
CO <sub>2</sub>	1	1
CO	1.2	9.1
NO <sub>x</sub>	0	4.4
N <sub>2</sub> O	296	280
CH <sub>4</sub>	23	15
HFC	1,300/120	1250/115
BC	0	2420
NMHC	3	3.3
OC	0	-230
SO <sub>x</sub>	0	-45

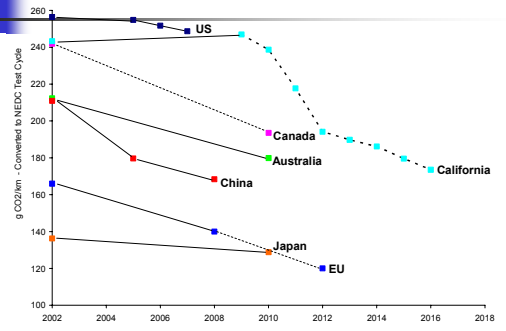
## CO<sub>2</sub> Equivalent Non-CO<sub>2</sub> Greenhouse Gases From Road Vehicles



## GWP Using the CEF Non-CO<sub>2</sub> Approach



## Comparison of fleet average GHG emission standards standardized by gCO<sub>2</sub>/km for new light-duty vehicles

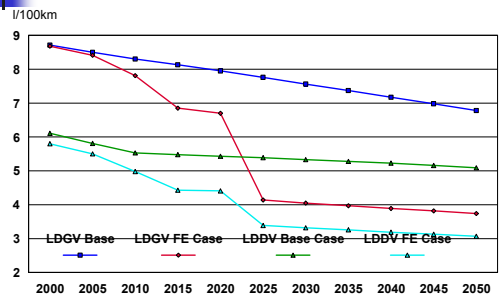


Source: Feng An, Sauer

## Carbon Dioxide Scenarios

- WBCSD Base Case
- Aggressive Case
  - ROW On A Par with Europe by 2025
  - Europe Continues Steady Progress to 2050
  - No Prescription for Diesels, Hybrids, Fuel Cells, Alt Fuels Etc

## Light Duty Vehicle Fuel Consumption



## Engine Technologies with Potential to Reduce GHGs

- 5,4 or 3 valves per cylinder
- variable valve timing
- idle stop/start
- cylinder deactivation
- variable compression ratio
- variable displacement
- advanced IC engines (diesel, DI gas)



## Other Technologies which Could Reduce Vehicle GHGs

- Transmissions
  - lockup 6/5/4 speed
  - automatically shifted manuals
  - CVTs
- Advanced Powertrains
  - integrated starter alternatives
  - hybrids
  - fuel cells

## Technologies That Reduce Methane or Nitrous Oxide

- Relatively high global warming potential compared to carbon dioxide
- Catalyst modifications have been demonstrated that reduce methane emissions
- Nitrous oxide emissions may also be reduced through catalyst modifications



## Technologies That Reduce HFC Emissions

- Better materials and fittings can reduce leakage
  - (50% Reduction Possible)
- Alternative refrigerants with lower global warming potential
  - R152a, CO<sub>2</sub>
  - (90 % Reduction Possible)
- Variable displacement compressors reduce system energy requirements, leading to lower CO<sub>2</sub> emissions





## Contrasting Approaches To Reducing Emissions

- Conventional Pollutants
  - 1970 CAA – mandatory technology forcing standards for Light Duty Vehicles
  - Now Underway for Trucks
  - Vehicles improved more than order of magnitude in one generation
- Greenhouse Gases or Fuel Economy
  - Standards only based on what is on the shelf until recently
  - Many technology advances Used for Power or Performance
  - Only Now Are We starting To Push the Technology Envelope



## Issues/Conclusions Action Agenda

- Aircraft & Marine Need To Be Addressed
- Technical Solutions to Conventional Pollution & Non CO2 Greenhouse Gases Are Available and Just Need To Be Applied & Accelerated in Developing World
- Carbon Dioxide Remains Difficult Issue But Not Because Technical or Policy Options Are Not Available
- GHG Standards Should Be Mandated For All Vehicle Categories
  - Pushing The Technology Envelope
  - Providing Sufficient Lead Time
- Fuels Technologies May Have Important Role
- Transportation Controls, BRT systems, etc Also Need To Be Part of the Solution