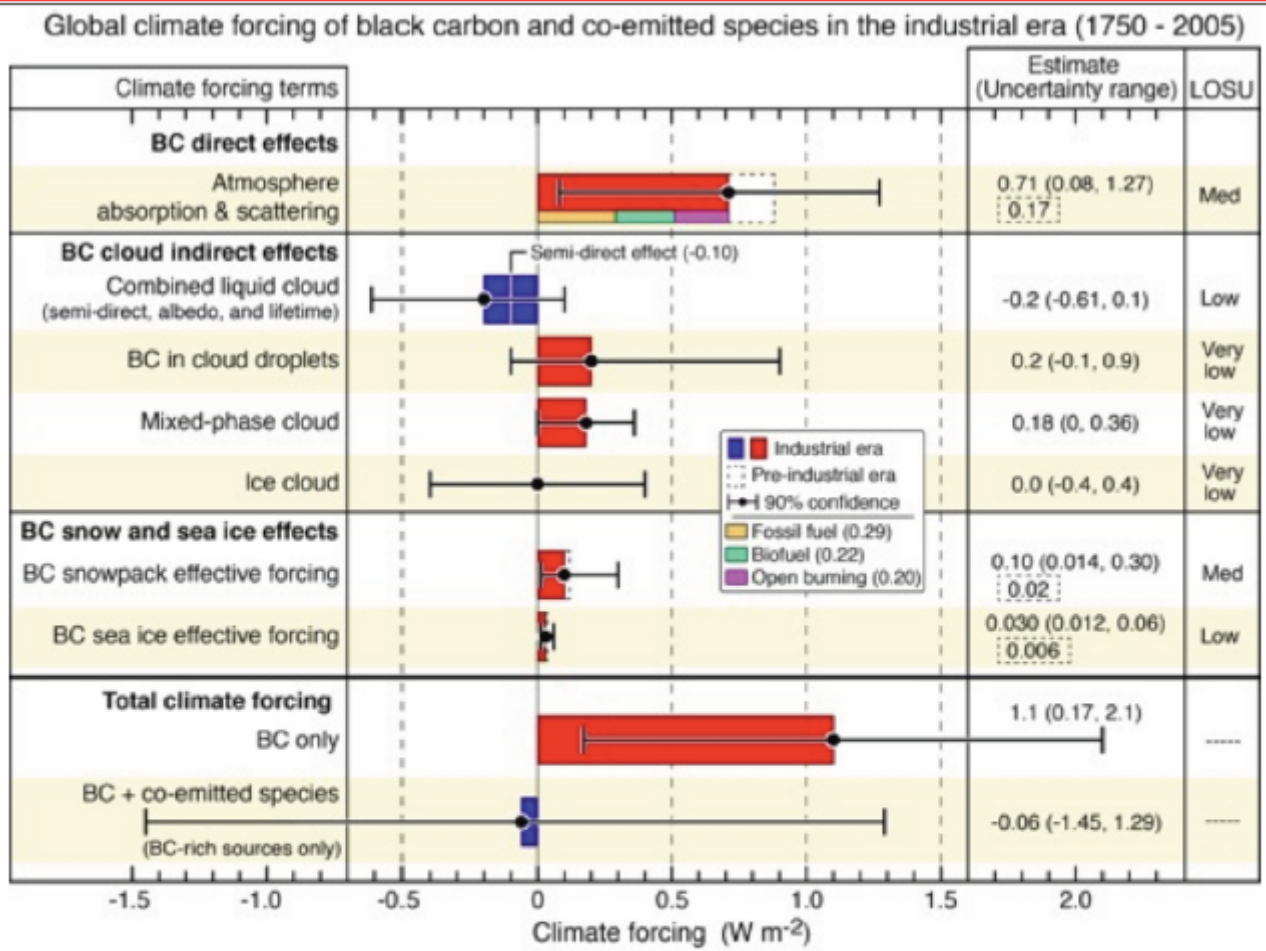
Black Carbon Emissions From Transportation Where We Stand

July 21, 2015

Michael P. Walsh
International Consultant

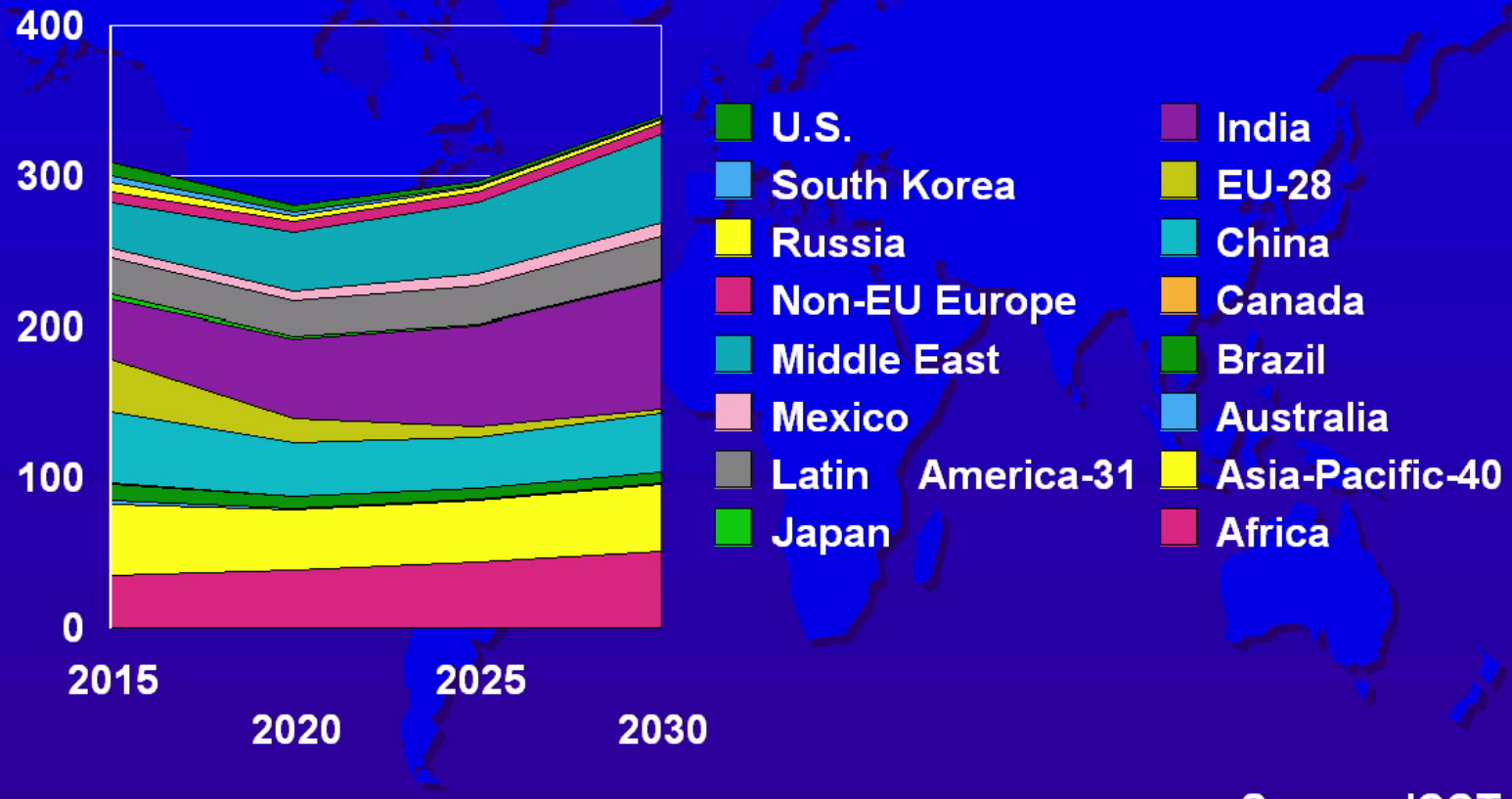
Founding Chairman
Board of Directors,
International Council on Clean Transportation

Most Recent Study Says Black Carbon is Second Only To CO2



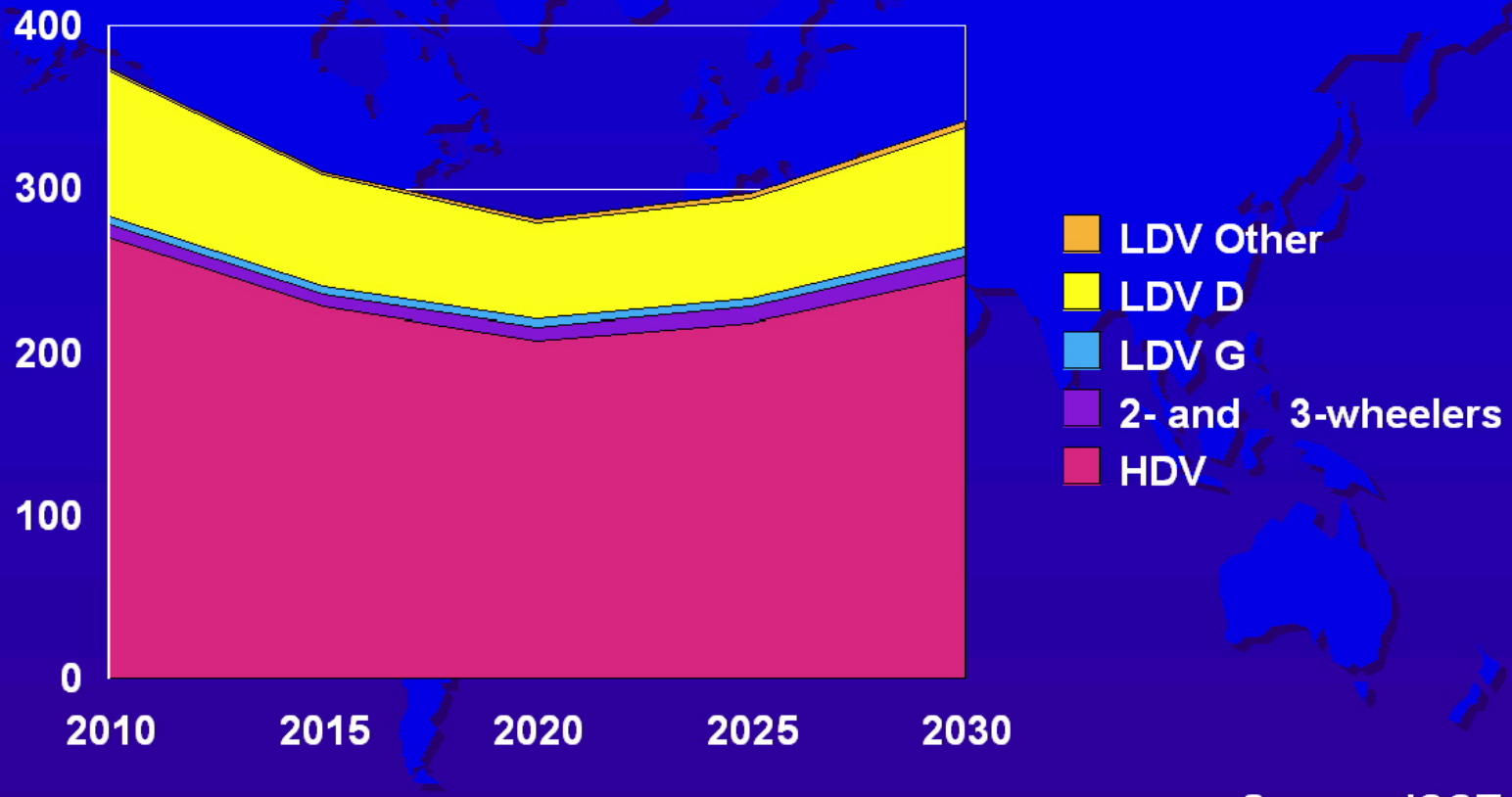
Quantitative estimates of black carbon influence, expressed as "climate forcing," or perturbation to Earth's energy balance. The upper red bar can be compared to the direct forcing of +0.34 W m^{-2} from the IPCC Fourth Assessment report. The addition of forcing components to give net forcing (lowest red bar) was one contribution of this work. For comparison, carbon dioxide forcing in the year 2005 was +1.66 W m^{-2}.

Black Carbon Emissions From Road Vehicles by Region



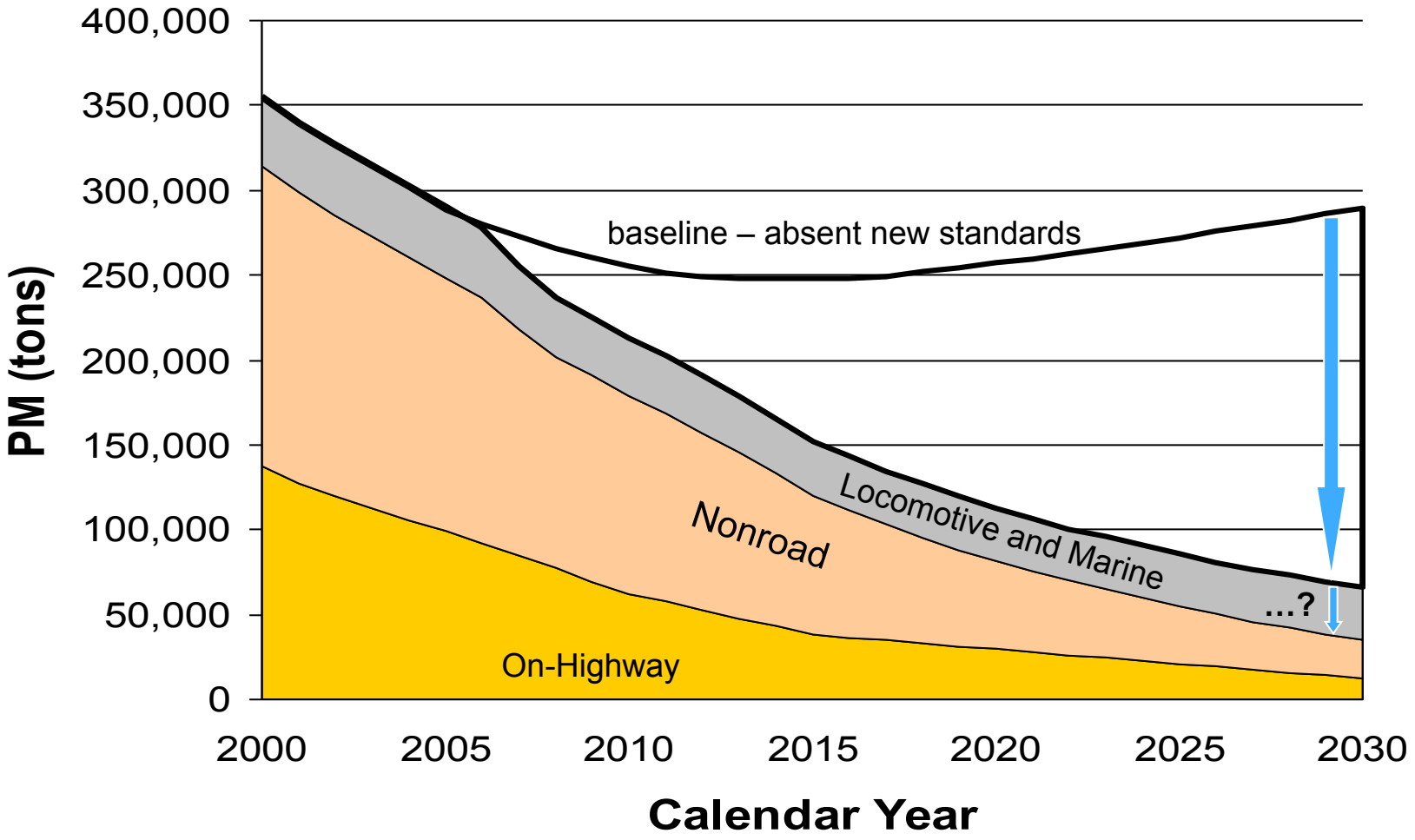
Source: ICCT
July 8, 2015

Black Carbon Emissions From Road Vehicles by Mode

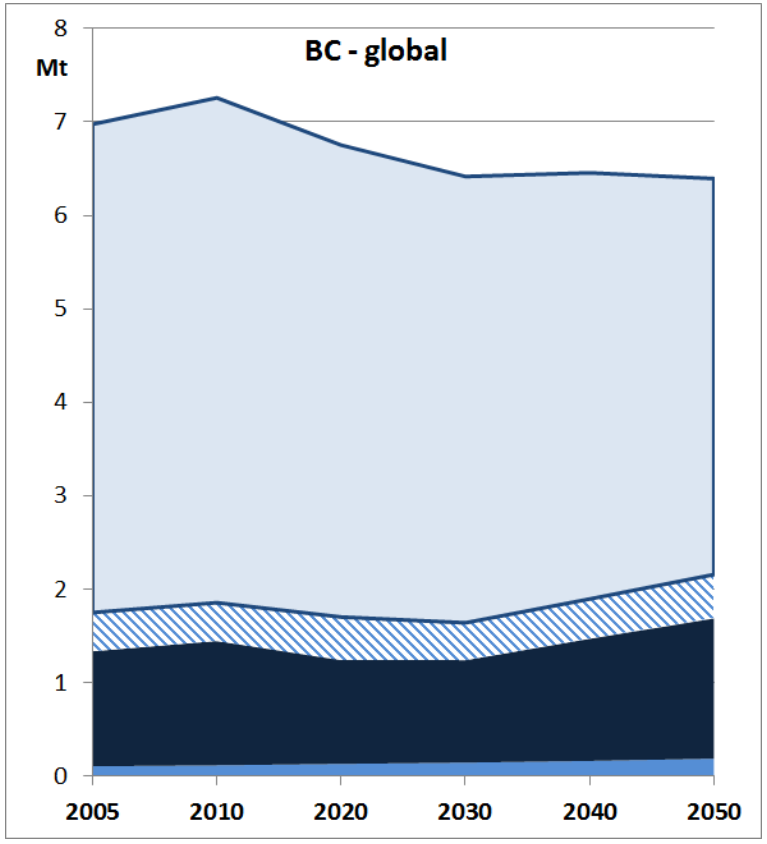


Source: ICCT
July 8, 2015

Clean Fuel and Vehicle Programs
Diesel PM Reductions



IASSA ESTIMATES (Jens Borken)



Other

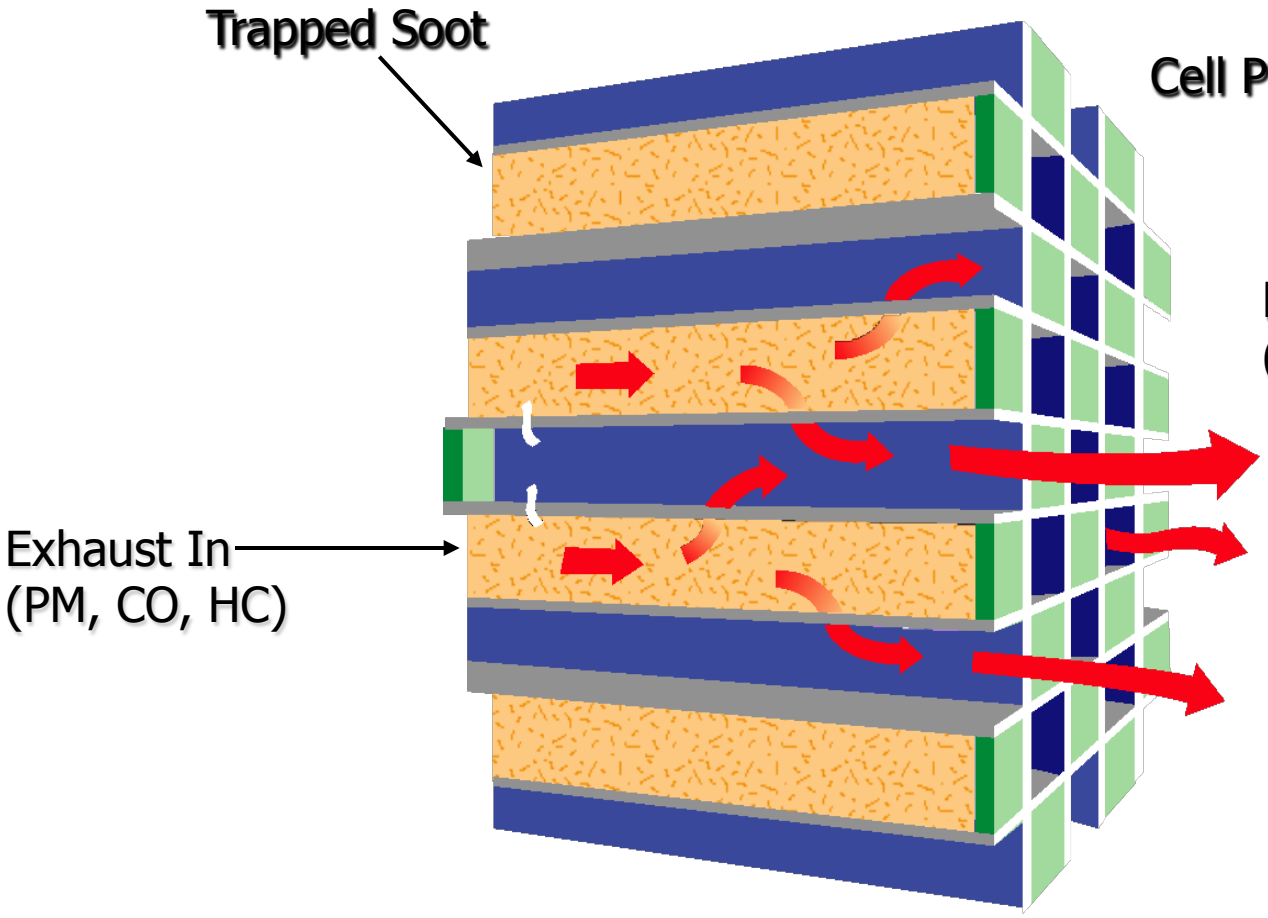
Non Road

Road Vehicles

Major Issues For Estimating Emissions

- Applicability of vehicle emissions standards for brand new and imported used vehicles
- Low Sulfur Fuels
- Compliance with certified emission levels
- Real Driving Emissions
- Age distribution (stock vintage and survival curves)
- Mileage distribution (VKT degradation)
- Gross emitters (share of the fleet and relative emission factors)
- Actual mileage (annual VKT by vehicle type and fuel type)
- Non Road Vehicles and Engines

A Critical Technology: Diesel Particulate Filters (DPFs)

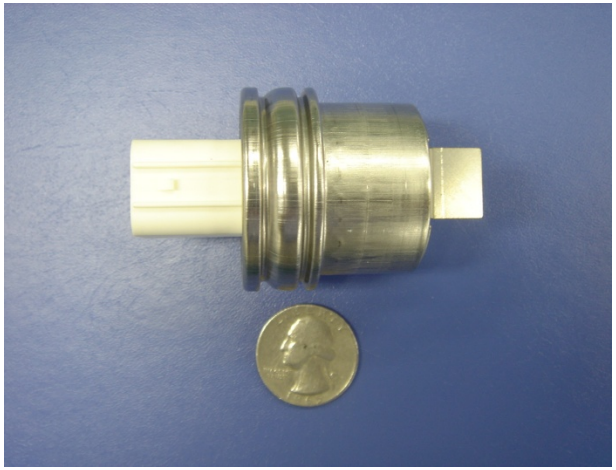


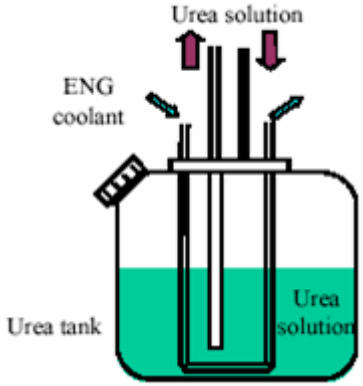
*Removes 90+% BC, PM; also HC and CO

*Requires Ultralow Sulfur Diesel (ULSD)

8

Clean Vehicles Include Sophisticated Sensors and Diagnostics Perhaps the Most Important Technology





U.S. 2007 HD Emission Performance Provides Significant Reductions in PM, CO, Air Toxic HCs

	2007 EPA Standard (g/hp-hr)	Average ACES Engine Emissions (g/hp-hr)	ACES Emissions % Reduction Relative to the 2007 Certification Standard
CO	15.5	0.33	98
NMHC	0.14	0.0064	95
PM	0.01	0.0011	89
NO_X	1.2 [a]	1.075	10

[a] Average value between 2007 and 2009, with full enforcement in 2010 at 0.20 g/hp-hr

Compounds	% Lower Than 2004 Engine Technology	
	16-Hour Cycle	CARBx-ICT
Single Ring Aromatics	82%	69%
PAH	79%	26%
Nitro-PAH	81%	49%
Alkanes	85%	84%
Polar	81%	12%
Hopanes/Steranes	99%	99%
Carbonyls	98%	78%
Inorganic Ions	38%	100%
Metals and Elements	98%	90%
Organic Carbon	96%	78%
Elemental Carbon	99%	100%
Dioxins/Furans[a]	99%	N/A

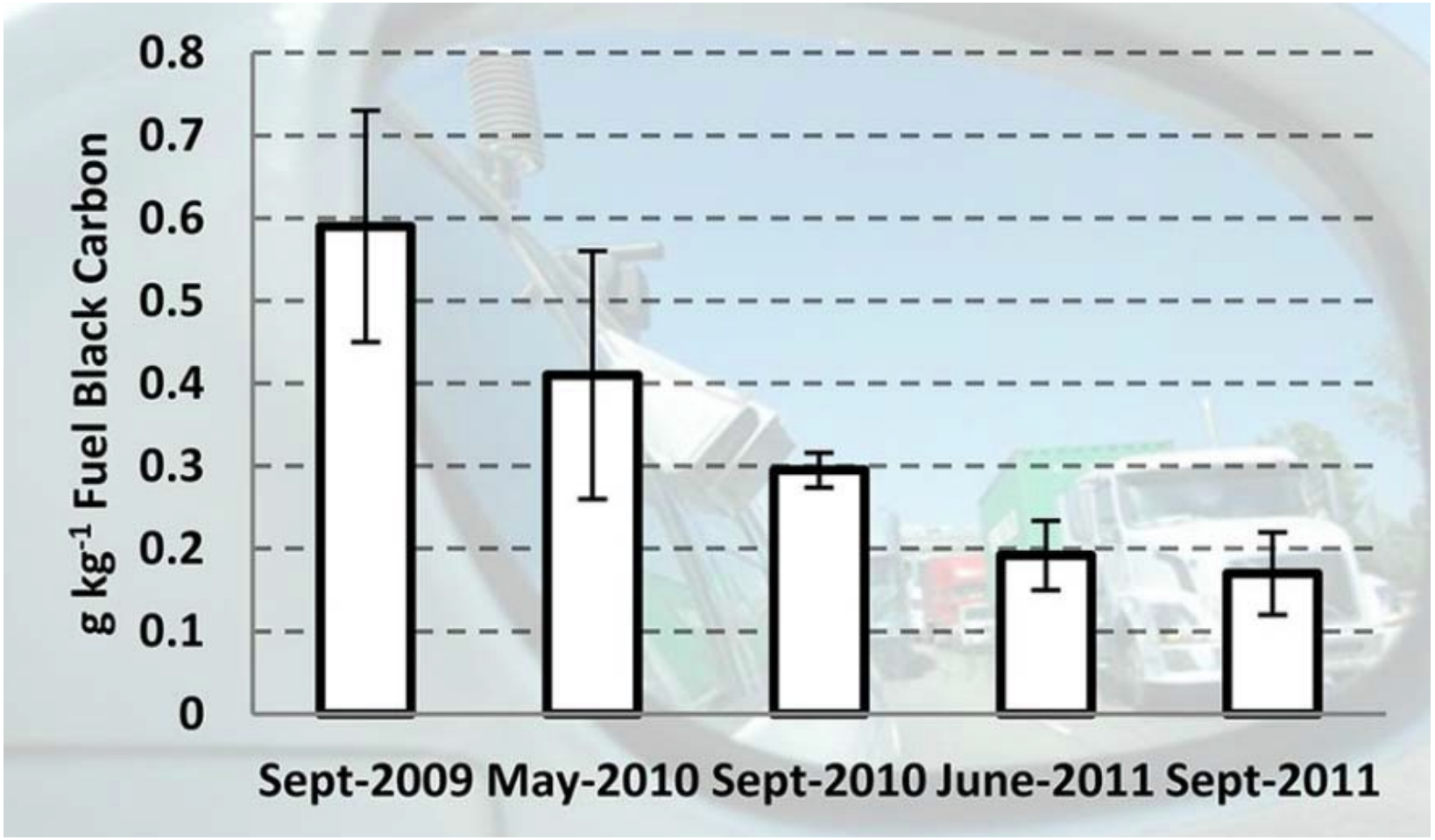
[a] Relative to 1998 Engine Technology

Source: CRC Phase 1 ACES Report;

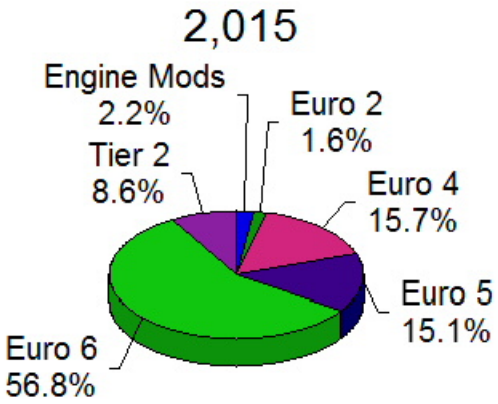
2010+ Engines Delivering Even Lower

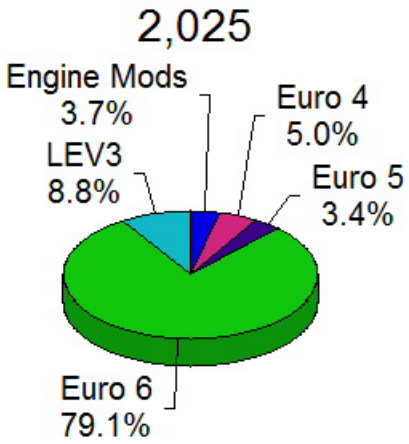
Toxic HC Emissions than 2007 Engines

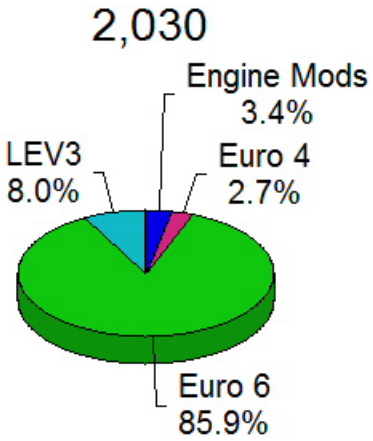
BC emissions measured on the I-710 freeway in Los Angeles during biannual campaigns between 2009 and 2011



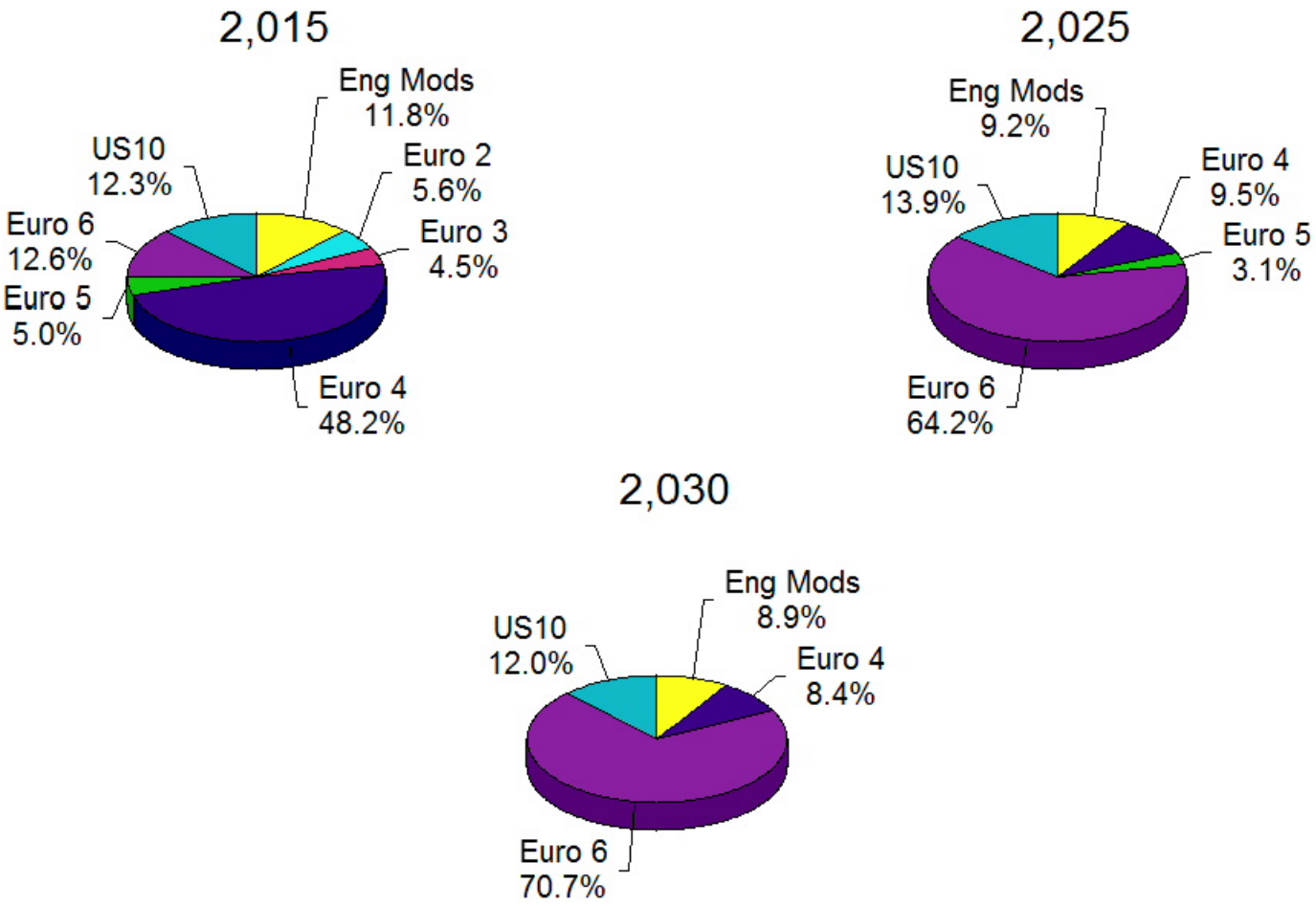
Distribution of Controls Light Duty Diesel Vehicles







Distribution of Controls Heavy Duty Diesel Vehicles



Europe is Wrestling with Upgrading Compliance Developments for Euro 1 – Euro 5

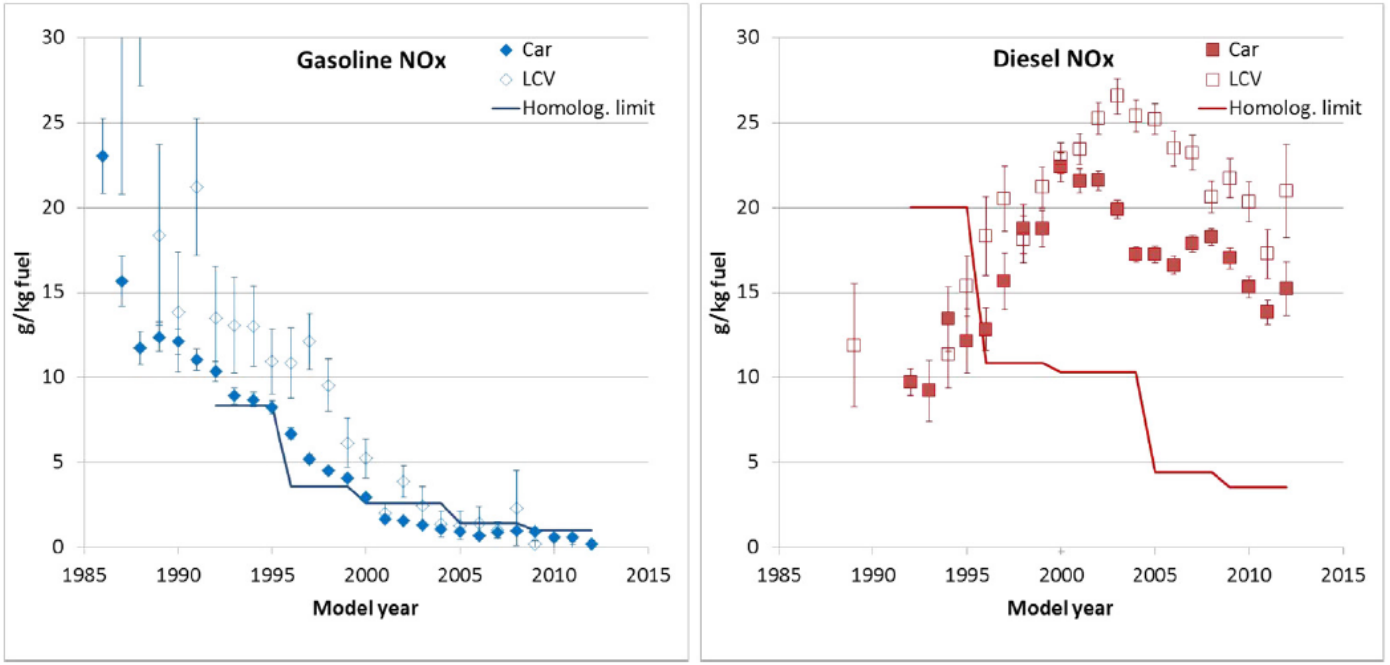
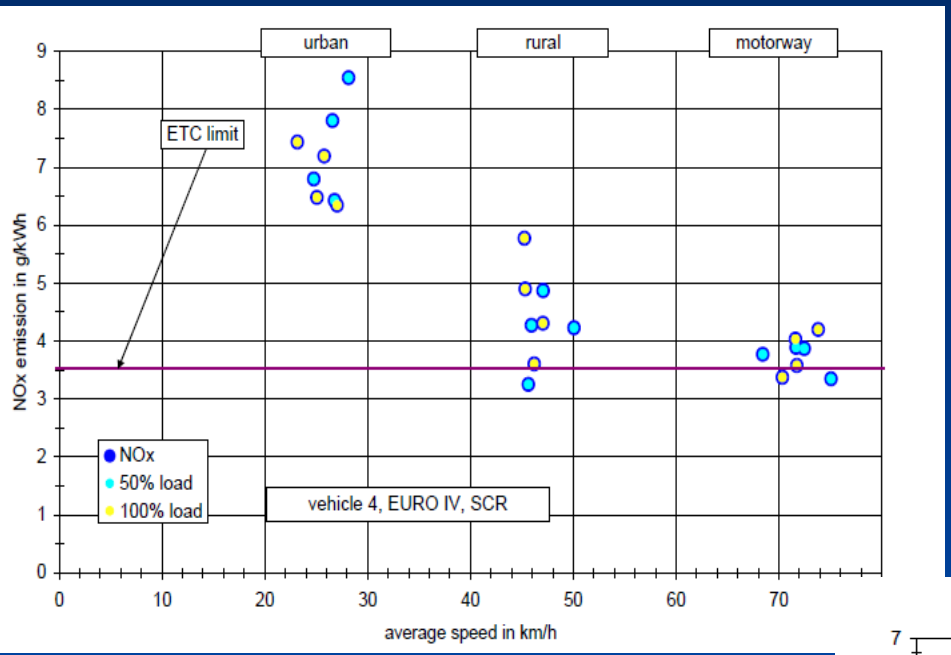


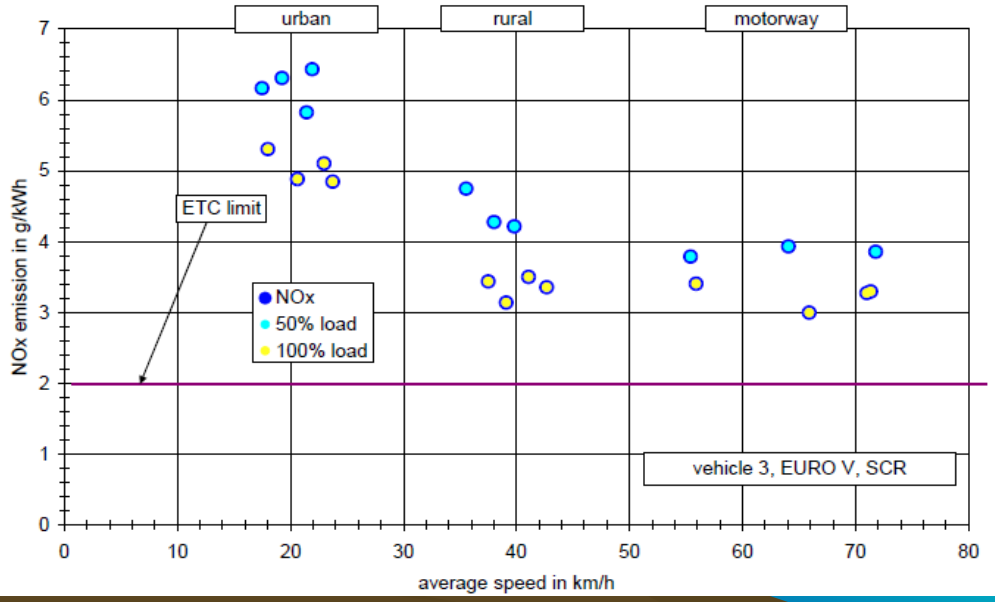
Fig. 4. Mean hot NO_x emission factors of gasoline (left) and diesel (right) passenger cars and light commercial vehicles as a function of model year. Whiskers represent the 95% confidence interval over the mean. Added are the type approval limit values for Euro 1 to Euro 5 passenger cars over the homologation test cycle in force in the respective year. For conversion from limit values in g per km see SI (using measured fuel consumption rates from Hausberger (2010)). For color plot consult online version.

Chen, Y., Borken-Kleefeld, J. (2014). Amospheric Environment 88 (2014) 157-164

Similar Issues With Heavy Duty Vehicles
The problem: High off-cycle NOx emissions in urban applications



In-use PEMS testing of Euro IV and Euro V trucks in The Netherlands found emission well above standard in urban driving!



Source: Kleinebrahm 2008

Historical Problems with EU Compliance In Use

- Poor Type Approval Test Procedure
- No Focus on Off Cycle Emissions (Cycle Beating)
- Short Durability Requirement
- Limited Warranty and Defect Reporting
- Weak OBD
- No Clear Responsibility and Authority for In Use Testing and Compliance

Advantages of Euro 6/VI Over Previous

- Tighter Standards
- New and Improved Test Procedures Provide More Comprehensive Coverage of Range of Real World Driving Conditions
- Actual In Use Focus (RDE)
- Improved Onboard Diagnostics
- Likely Gasoline Particle Filter

DPF Removal / Delete

As one of the first companies in the UK to offer DPF Removal we now have years of unmatched knowledge and experience.

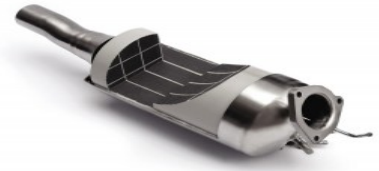
DPF (Diesel Particulate Filter) Removal

The Removal Procedure

First of all we remove the filter from the exhaust system, unlike other companies we do not fit a simple bypass pipe, this would likely lead to an MOT failure when new MOT regulations are announced. Instead, we modify the original DPF unit, discreetly cutting a small window in the top of the chamber, removing the internal filter before rewelding the window And refitting to the vehicle. This way the vehicle still appears to have a DPF fitted and appears unmodified in anyway.
Once the physical filter removal has been completed the ECU (Electronic Control Unit) is reprogrammed (remapped) and any DPF related structures removed from the vehicles software, this will prevent the vehicle from sensing the missing Filter and will prevent future DPF regeneration and warning lights. This is the most important aspect of the removal process and it is vital that the ECU is reprogrammed correctly or DPF issues will continue.
When carrying out this process we can also remap the ECU for better performance and fuel efficiency, this is normally free of charge with our DPF removal service.
Will removing the DPF result in an MOT failure? No, removing the DPF will have no affect on your MOT.
Removing the DPF from your vehicle is not only a cost effective solution but it also boasts the following advantages:

- **Increased performance**
- **Increased efficiency (MPG)**
- **Less turbo lag**
- **Reduced maintenance costs**

Call now on 01454 800 117

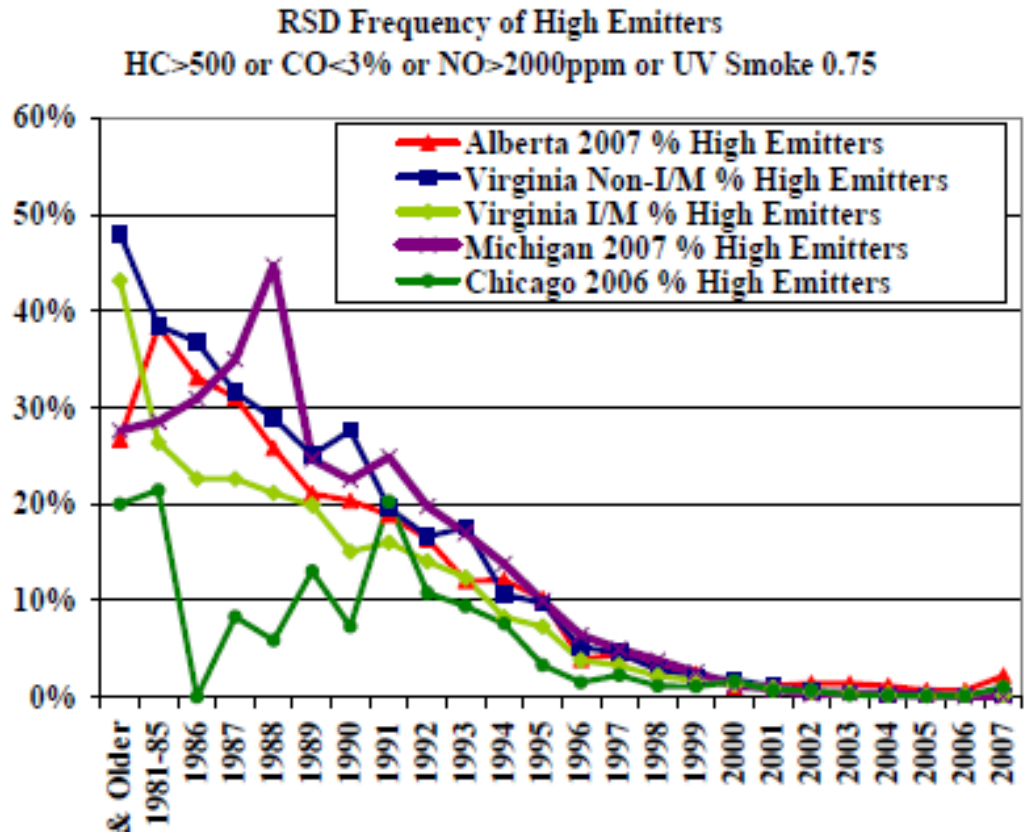


Performance Tuning

Other Compliance Issues

- China
  - Even though MEP Has Adopted Euro IV Equivalent Standards, Many Trucks Being Produced Today At Euro I, or Euro II
  - Legal Authority Issue
- India
  - In 2013 GM Found That Employees Were Using “Special Vehicles” For Official Tests That Did Not Represent Production Vehicles
- ROW

High-emitters incidence

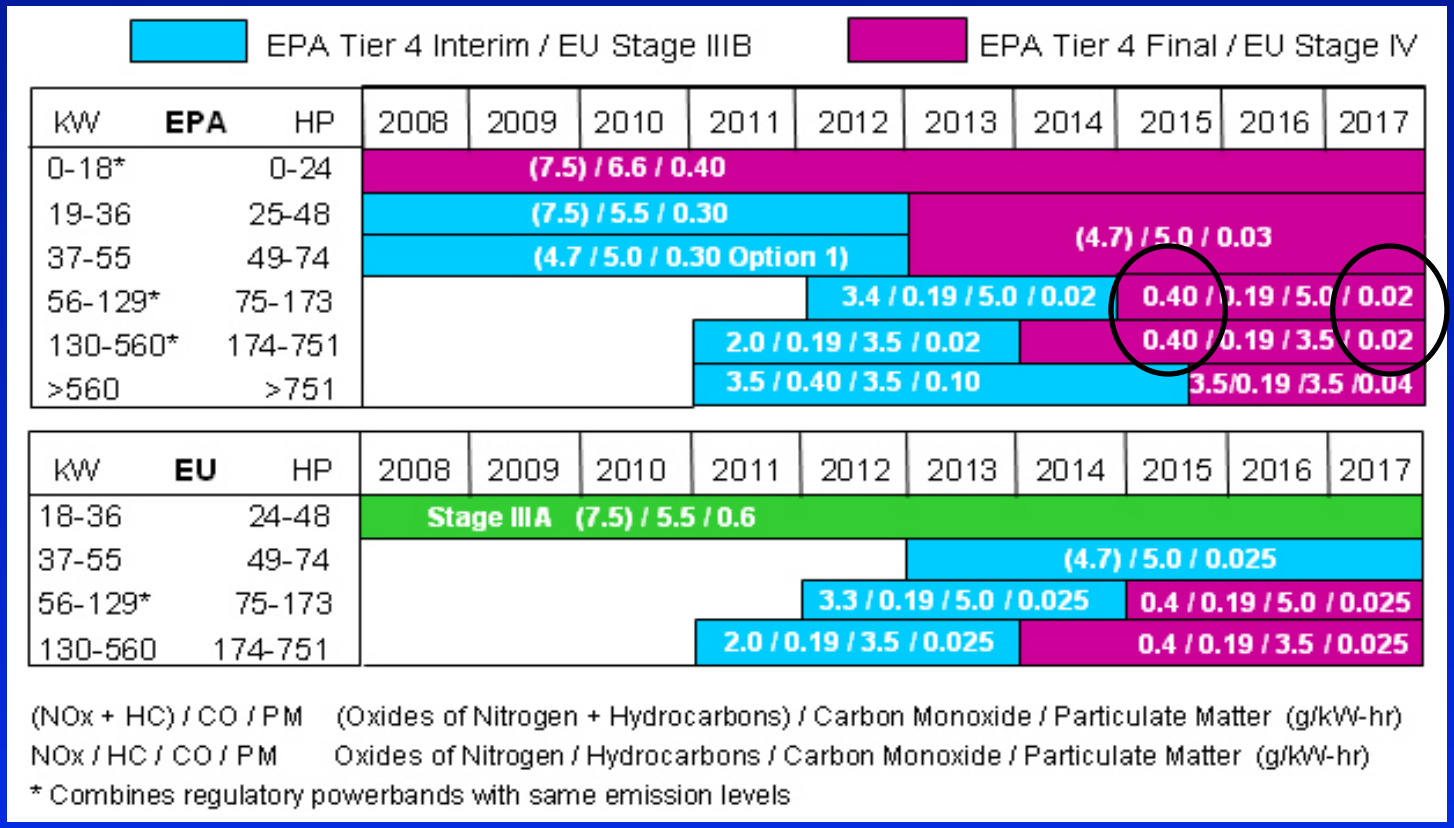


- US cars since MY 1996 (OBD II) have very low failure rate!
- Very low shares of high emitters in Europe as well

⇔ Higher shares (only) for the older (and deteriorated cars)

Borken-Kleefeld, ICCT 2013,
reproducing McClintock 2007

Tier 4 U.S./Stage IV EU Off-road Diesels Offering a Wide Range of Emission Controls



50% higher off-road limits:

PM (g/kWh)
0.020 off-road
vs.
0.013 on-road

NOx (g/kWh)
0.40 off-road
vs.
0.26 on-road

Tier 4 Final includes a variety of emission control solutions including: EGR+DOC, EGR+DPF, DPF+SCR, DOC+SCR

EU considering a Stage V standard that includes a PN limit to force DPFs on 18-560 kW engines;
EU Stage IIIB/IV and U.S. Tier 4 Standards utilize the non-road Transient Cycle (NRTC)

Fuel sulfur requirements for Non Road

US

- Fuel sulfur limits tightened to
  - 500 ppm: effective in June 2007 for non-road, locomotive, marine diesel fuels
  - 15 ppm: effective in June 2010 for non-road fuels, and in June 2012 for all locomotive and marine fuels
- Enables the use of PM and NOx aftertreatment technologies for meeting Tier 4 standards

EU

- Sulfur content of non-road diesel must not exceed 10 ppm starting from January 1, 2011
- Enables the use of DPFs for meeting Stage IIIB PM limits and NOx and PM aftertreatment devices for meeting Stage IV limits

Japan

- Sulfur in diesel sold for non-road applications limited to 10 pm starting from April 2008

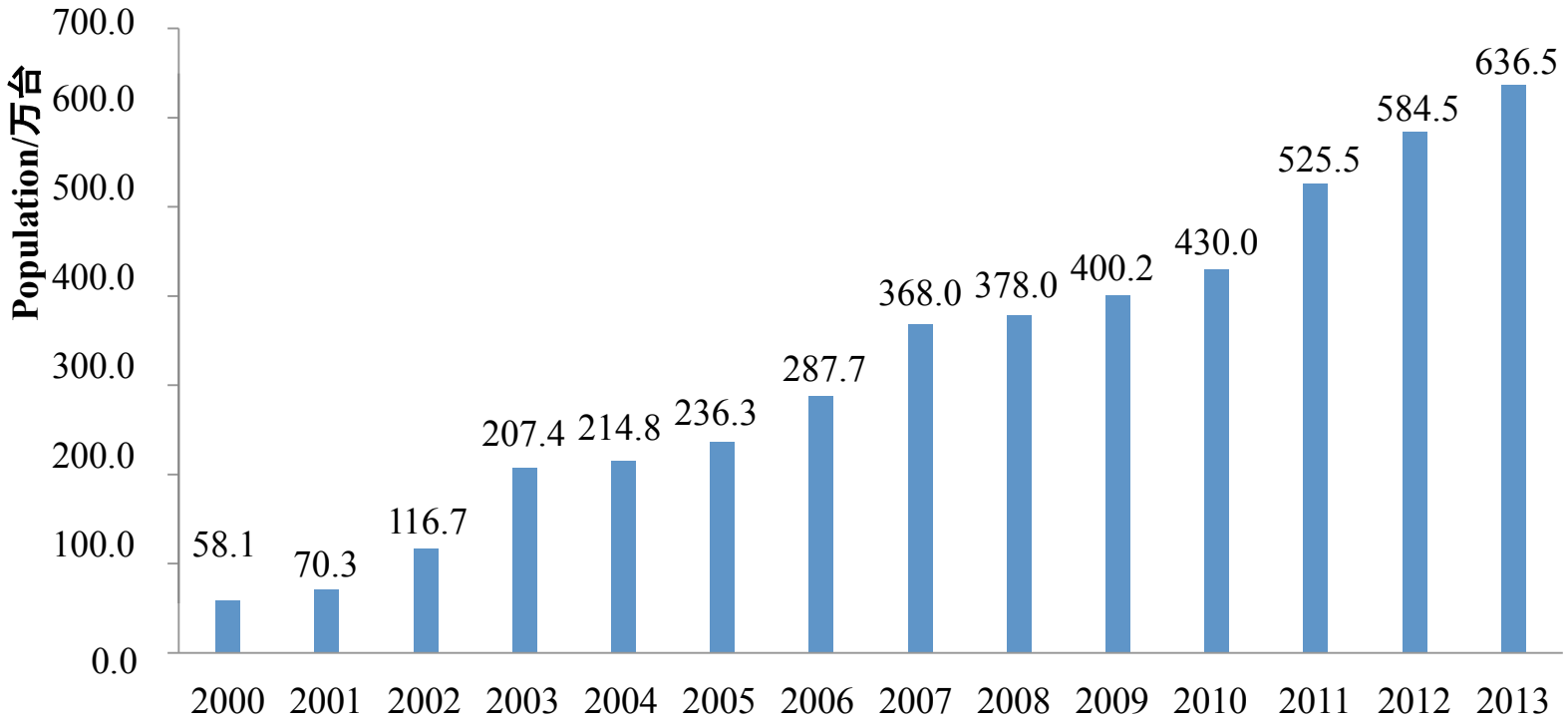
Population of Construction Machinery Growing Rapidly in China

截止到2013年年底，中国工程机械主要产品保有量约为611万～662万台。

The population of construction machinery is 6.11~6.62 million until 2013.

2000-2013年工程机械保有量 (见下图)

Population trends of construction machinery in 2000~2013



Wide Diversity of Machines!

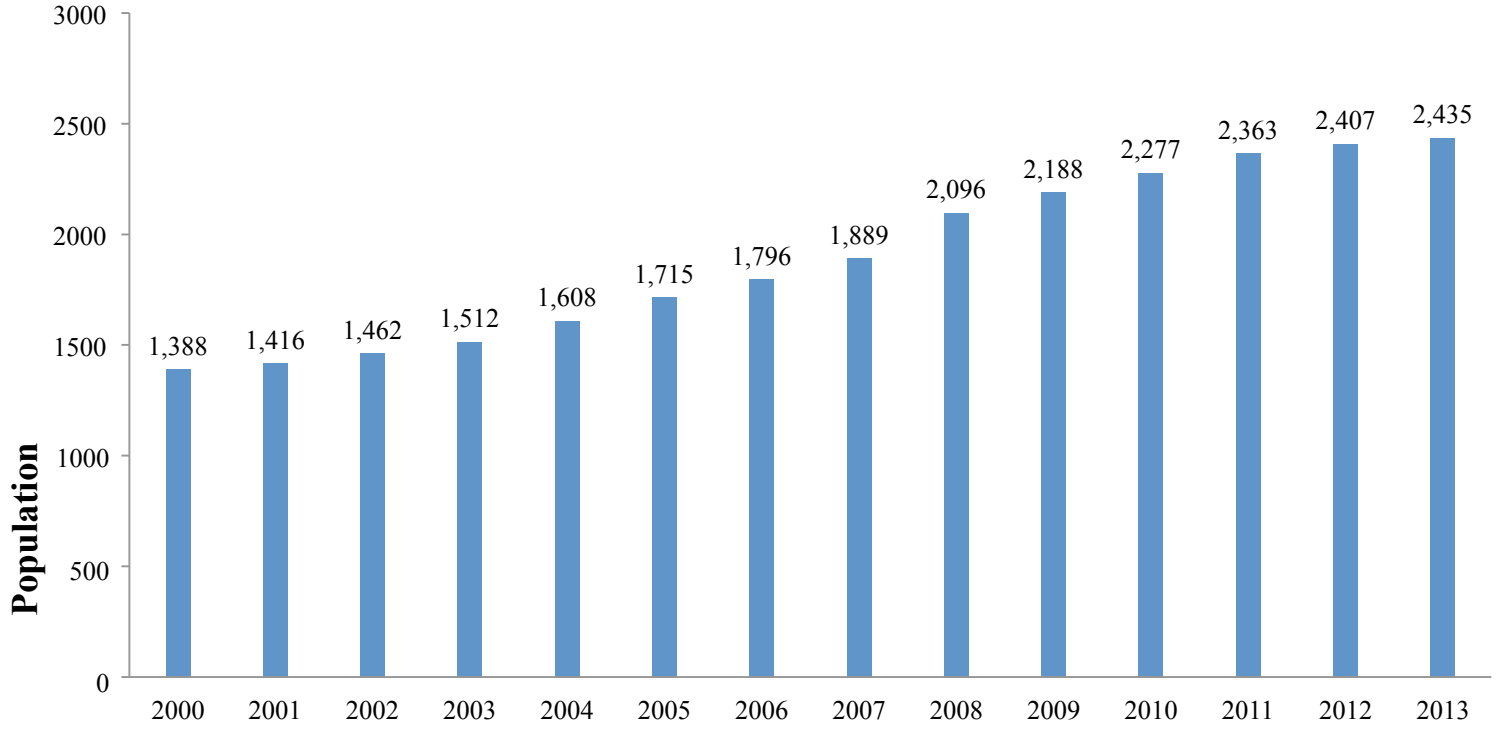
Population of Agricultural Machinery Also Growing Steadily

截止到2013年年底，中国农业机械主要产品保有量约为2435万台。

The population of agricultural machinery is 24.35 million until 2013.

2000-2013年农业机械保有量 (见下图)

Populations of agricultural machinery in 2000~2013



Types of Agricultural Machinery

Transportation Problems Not Limited To Land Based Vehicles and Engines

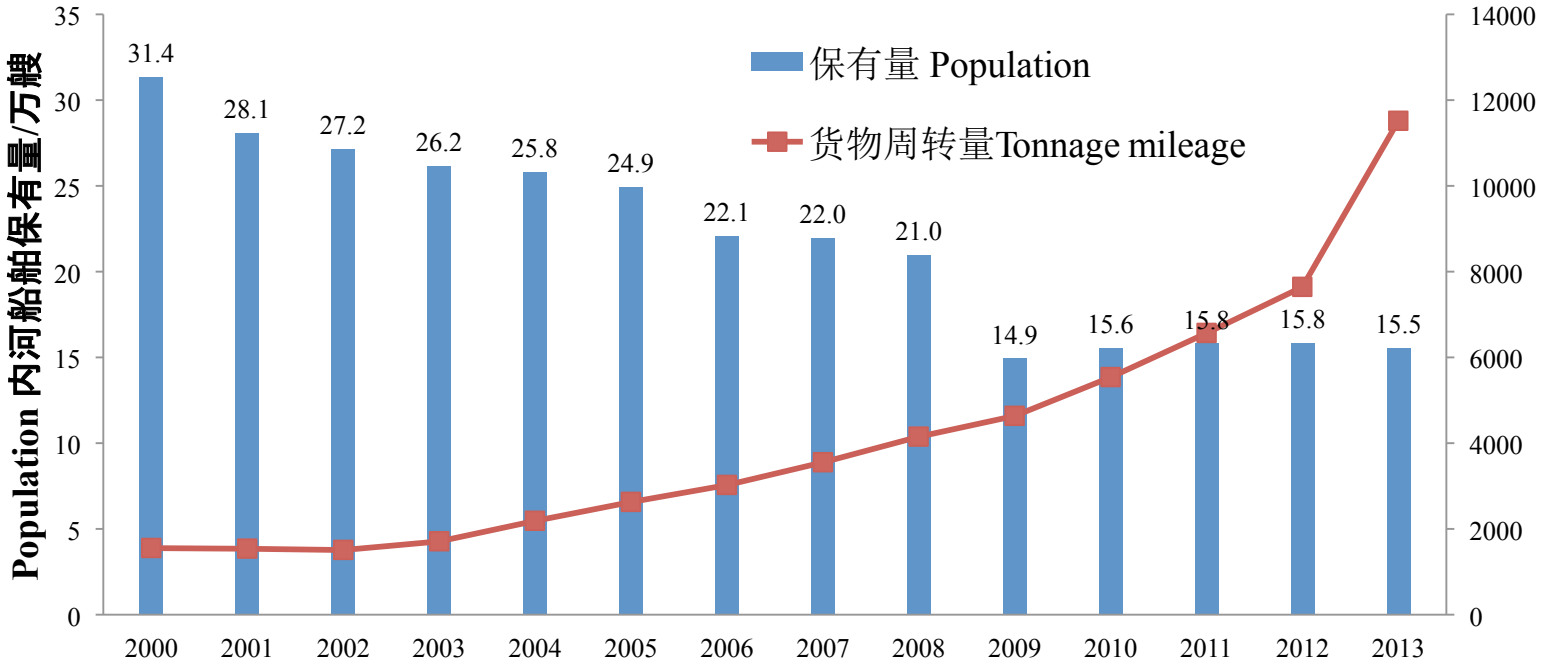
Population of Inland Marine Vessels

截止到2013年年底，中国内河船舶保有量约为15.5万艘。

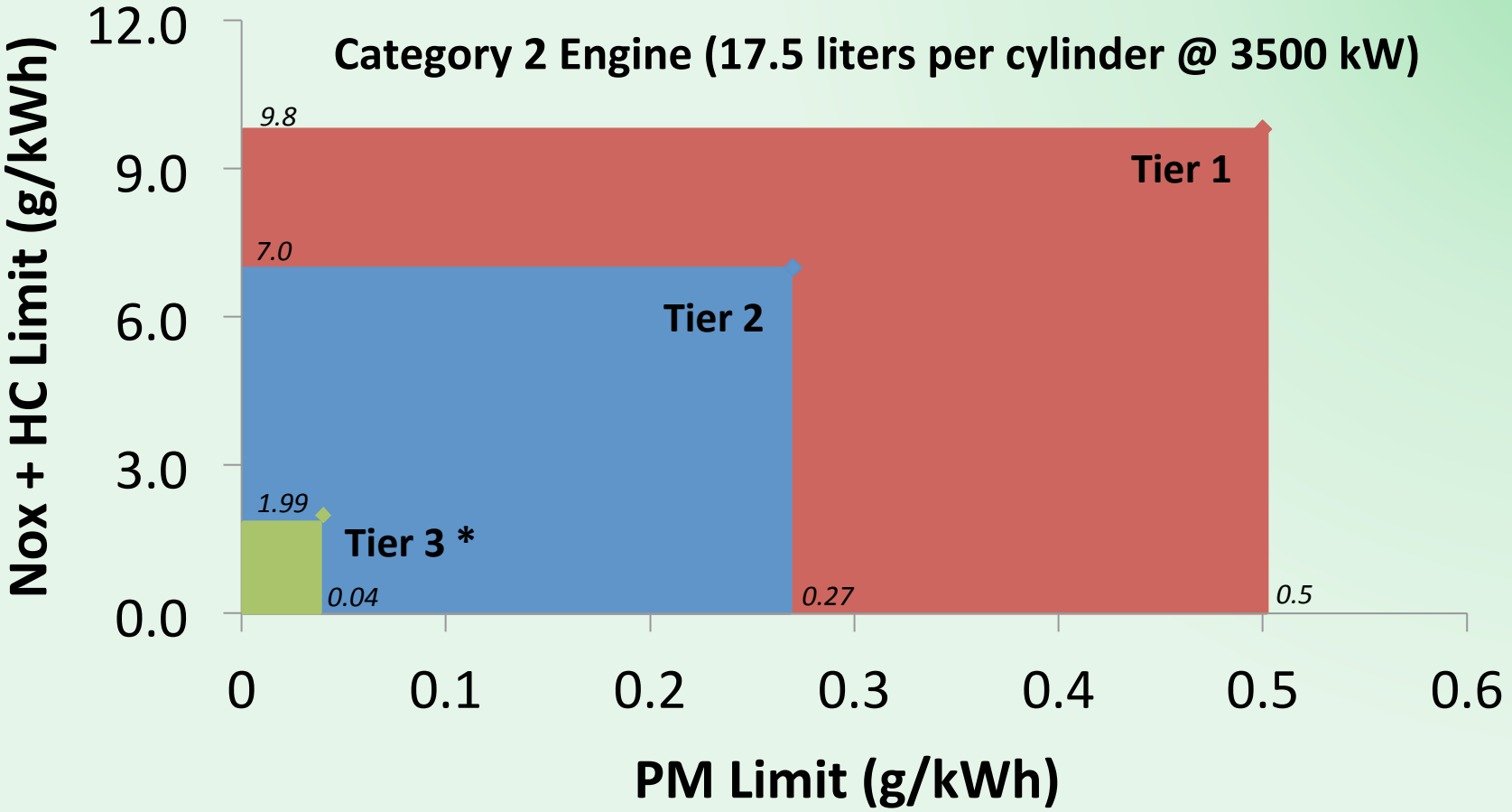
The population of inland ship is 0.155 million until 2013.

2000-2013年内河船舶保有量 及货物周转量(见下图)

Populations and tonnage mileage of inland ship in 2000~2013



Evolution of US EPA Marine Engine Emissions



* Option for Cat. 2: Tier 3 PM/NOx+HC at 0.14/7.8 g/kWh in 2012, and Tier 4 in 2015. Also, The Tier 3 PM standards continue to apply for these engines in model years 2014 and 2015 only.

Major Issues
Where Do We Stand

- Applicability of vehicle emissions standards for brand new and imported used vehicles - Good
- Low Sulfur Fuels - Good
- Compliance with certified emission levels – China Law expected soon, India ?
- Real Driving Emissions - Underway but..
- Age distribution (stock vintage and survival curves)
- Mileage distribution (VKT degradation)
- Gross emitters (share of the fleet and relative emission factors) – seems to be declining
- Non Road Vehicles and Engines – many issues