

Global Trends in Reducing Vehicular Emissions

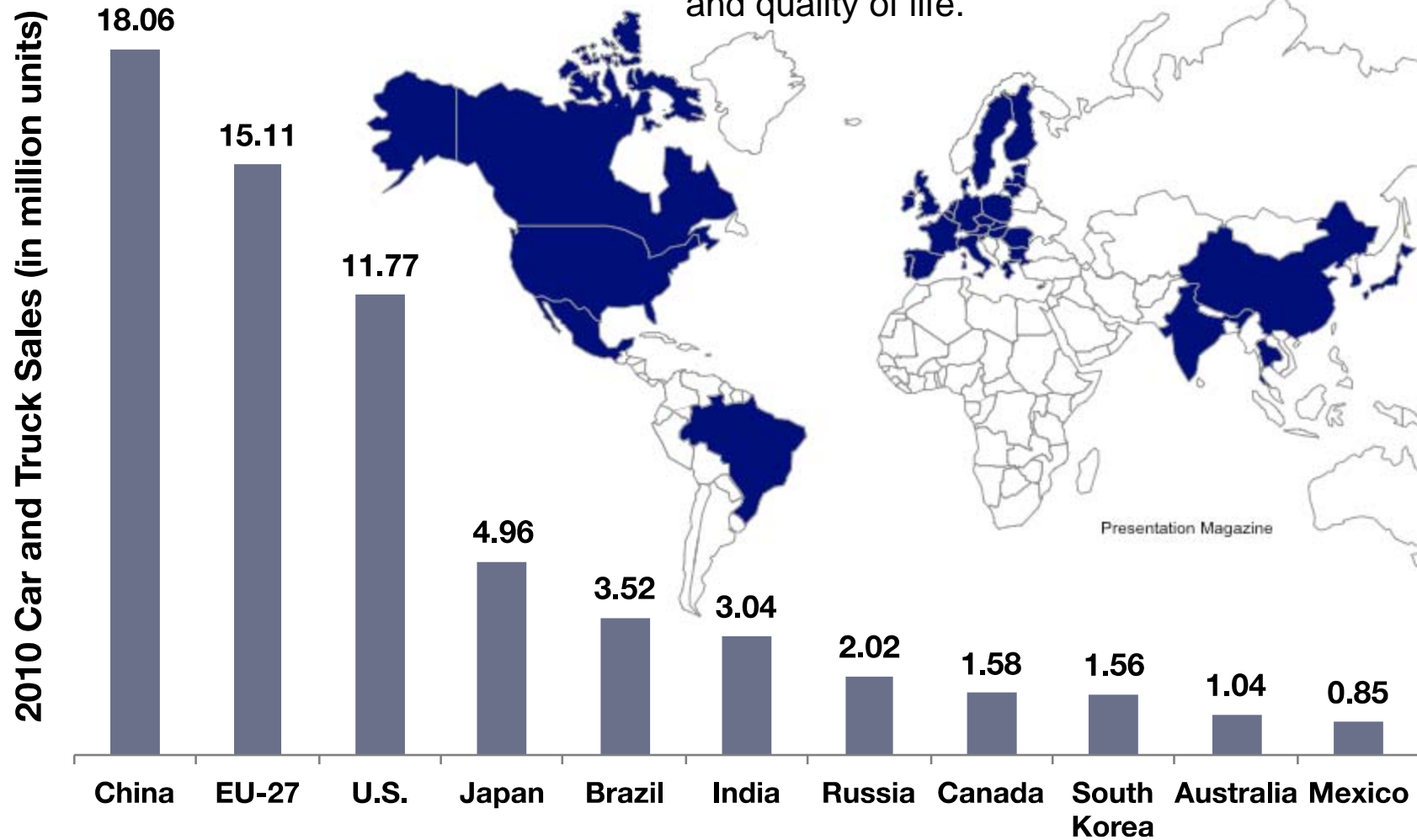
Anup Bandivadekar

September 29th, 2011



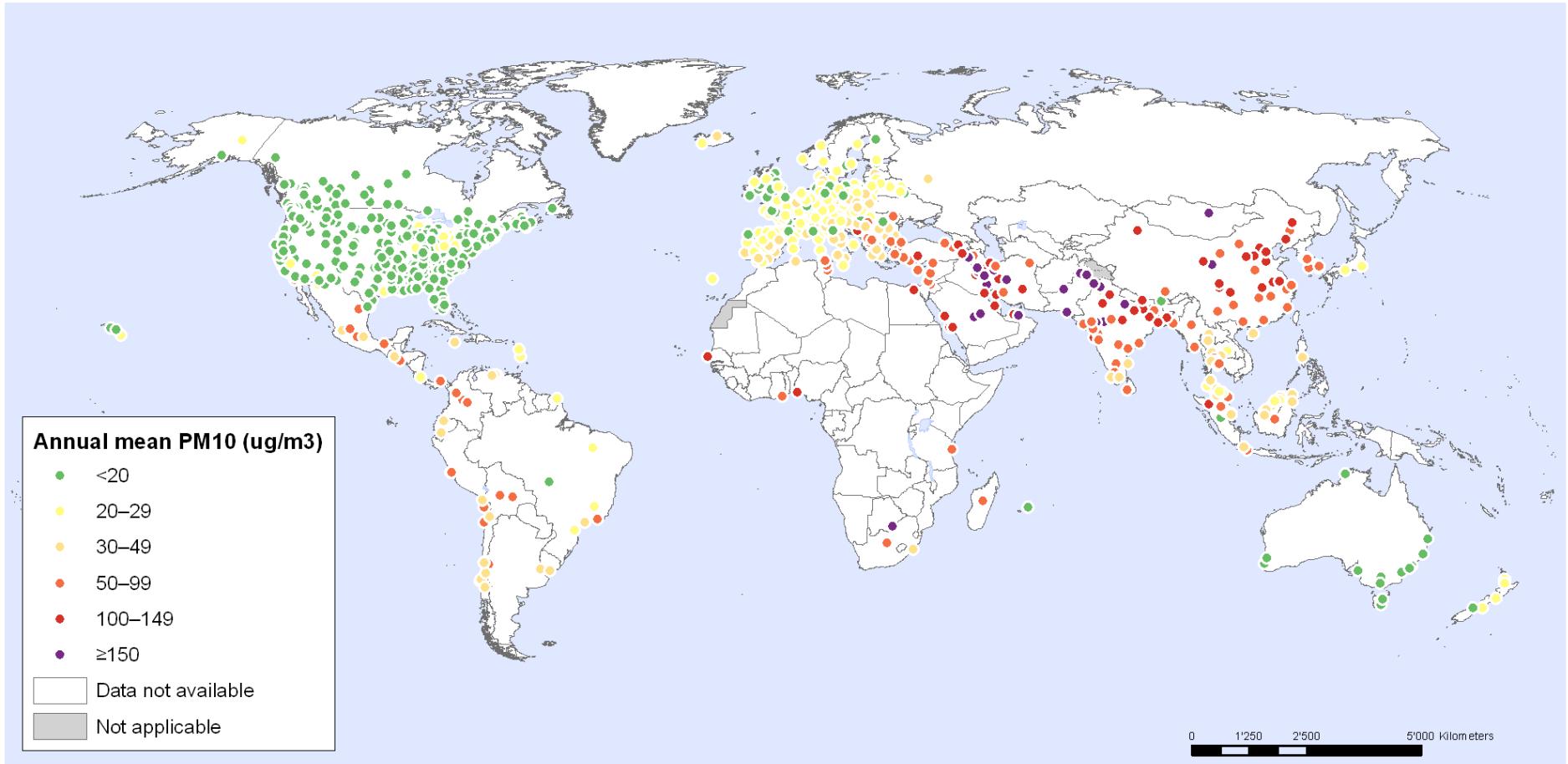
The mission of the ICCT is to dramatically improve the environmental performance and efficiency of cars, trucks, buses, and transportation systems in order to protect and improve public health, the environment, and quality of life.

Top Eleven Vehicle Markets, 2010



WHO estimated 1.34 million premature deaths from outdoor air pollution in 2008.

Exposure to particulate matter with an aerodynamic diameter of 10 μm or less (PM10) in 1081 cities, 2003–2010



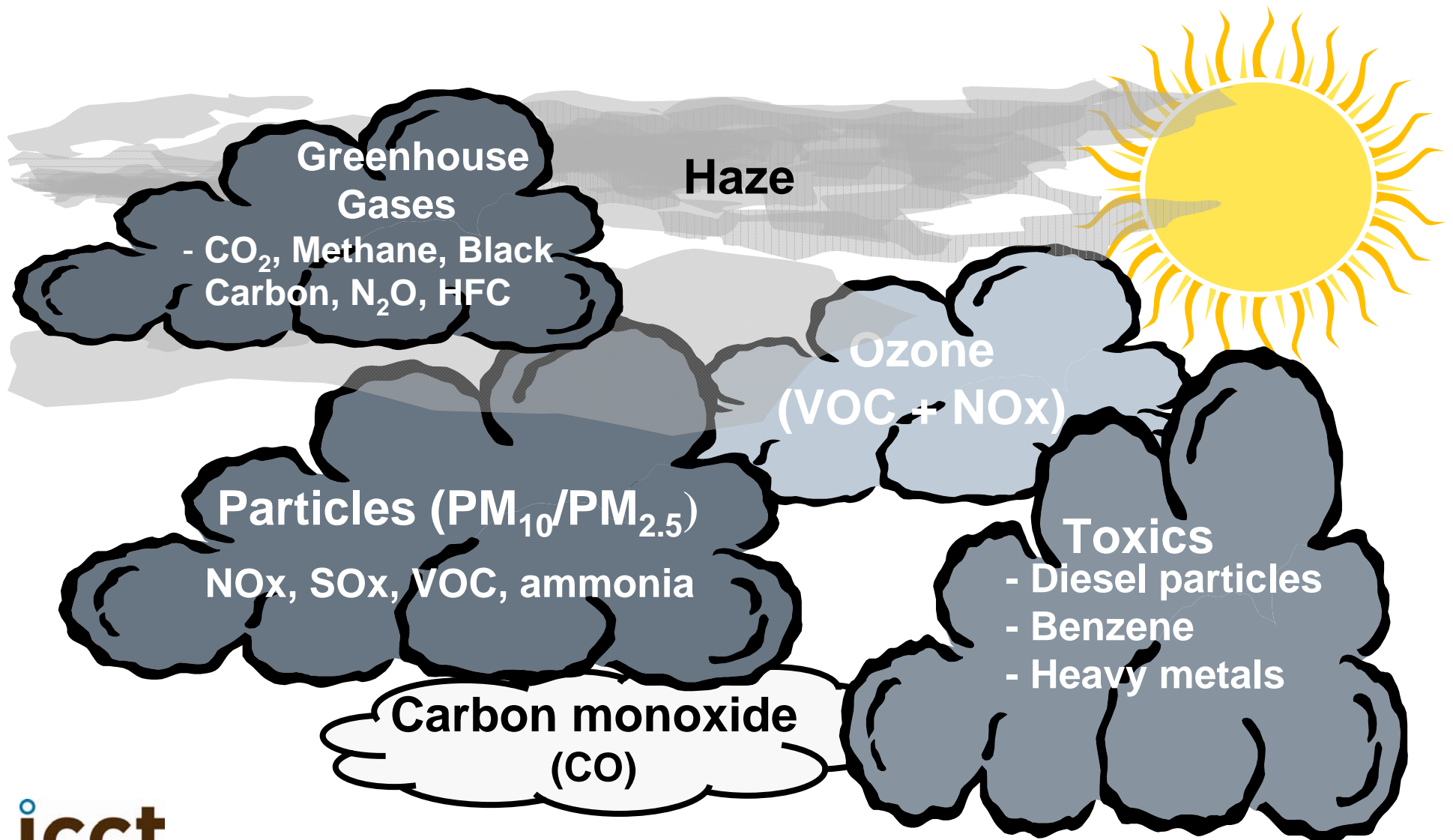
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Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization



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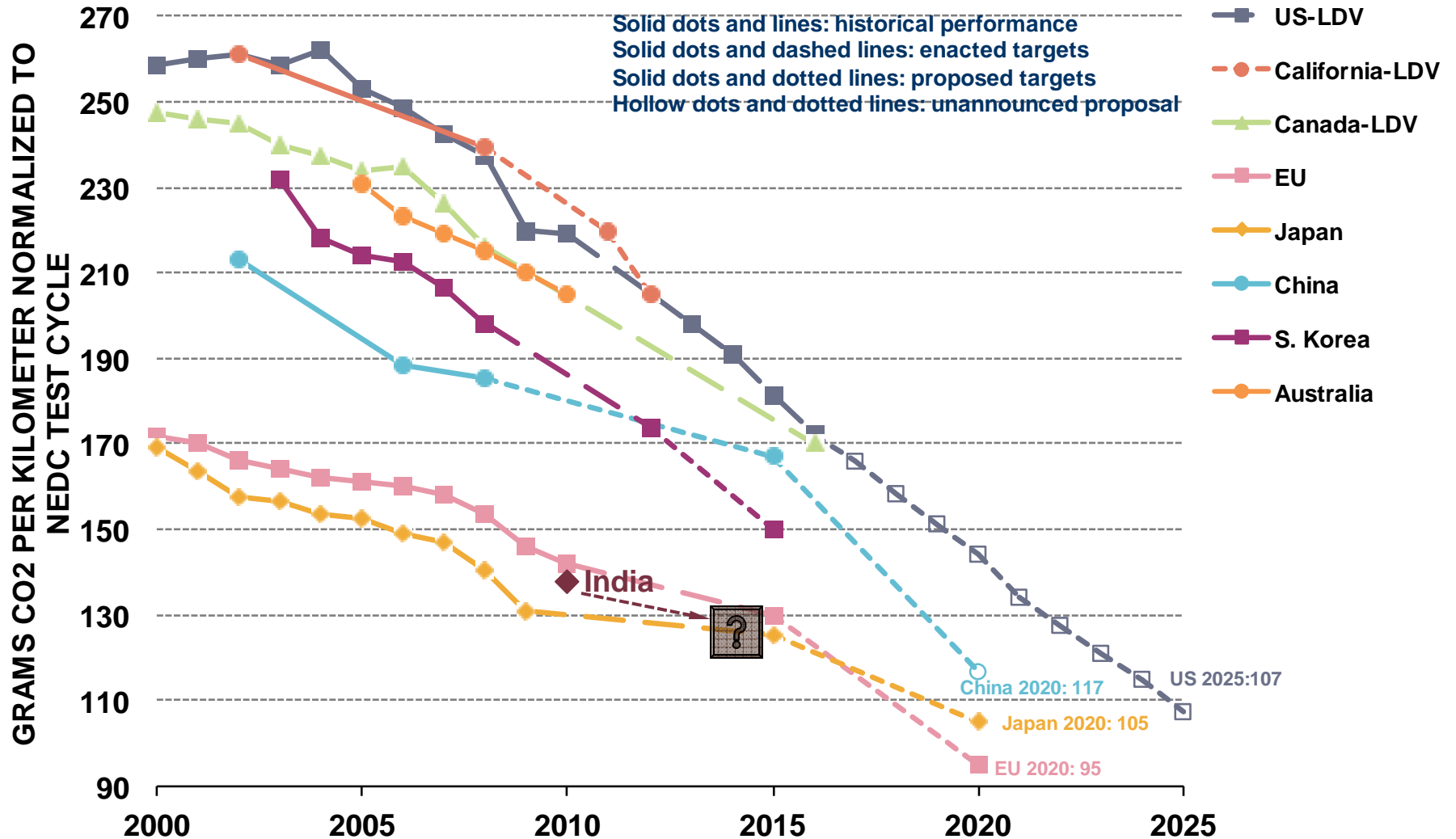
What pollutants are of concern?



Comprehensive approach should treat vehicles and fuels as a system

- Reducing fuel consumption
 - Policy instruments include fuel economy standards, fee and rebate schemes etc.
- Reducing criteria air pollutants
 - Policy instruments include new vehicle emission standards (Euro V/VI and/or US Tier II/III), and in-use emission control strategies
- Improving fuel quality
 - Reducing carbon content of fuels
 - Reducing sulfur content of fuels to near zero levels (<10 ppm)

Comparison of passenger vehicle fuel economy standards



[1] China's target reflects gasoline fleet scenario. If including other fuel types, the target will be lower.
 [2] US and Canada light-duty vehicles included light-commercial vehicles.

Regulatory landscape of heavy duty vehicle fuel economy standards

| Country/Region | Regulation Type | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|-----------------------|--------------------------------|---|----------------------------|-------------------|--|---|---|---|------|------|
| Japan | Fuel economy | | | | | | Regulation implemented starting MY 2015 | | | |
| United States | GHG/Fuel efficiency | Standard proposal | Final rule | | | Regulation implemented starting MY 2014 (mandatory DOT program starts MY 2016) | | | | |
| Canada | GHG/Fuel efficiency | | Standard proposal | Final rule | | Regulation implemented starting MY 2014 | | | | |
| China | Fuel consumption | Test procedure finalized | Industry standard proposal | Standard proposal | Final rule | | Regulation implemented starting MY 2015 | | | |
| European Union | GHG | Technical studies | | | Test procedure finalized | Mandatory efficiency reporting and regulatory development | | | | |
| California | End-user purchase requirements | Requirements for tractors and trailers (MY 2011+) | | | Additional reqs. for existing tractors and trailers (<MY 2010) | | | Additional reqs. for existing trailers and reefers (<MY 2010) | | |

New vehicle emission standards are getting tougher

- Exhaust emissions standards
 - Tighter standards
 - Euro 6/VI: PM and NOx aftertreatment on all diesels (DPF+SCR)
 - By 2020, EU motorcycle emissions down to Euro 5 level
 - California LEV III/ US Tier III: SULEV average by 2022
 - Improved test cycle, cold start measurement, particle number limit, increased durability
- Evaporative emissions
 - Whole vehicle diurnal plus hot soak standards – near zero emission expected from all vehicles including E10 vehicles
 - On-board Refueling Vapor Recovery (ORVR)

Much cleaner diesel vehicles are possible, through stricter standards and/or retrofits.



No retrofit system
Uncontrolled Diesel Exhaust
(Level 1)

Old technology
Little black carbon removal
Little ultrafine PM removal
Does not remove lube oil ash



Retrofitted with
Diesel Oxidation Catalyst (DOC)
(Level 1)

Old technology
Little black carbon removal
Little ultrafine PM removal
Does not remove lube oil ash



Retrofitted with
Partial Filter
(Level 2)

Little black carbon removal
Little ultrafine PM removal
Does not remove lube oil ash



Retrofitted with
Diesel Particulate Filter (DPF)
(Level 3)

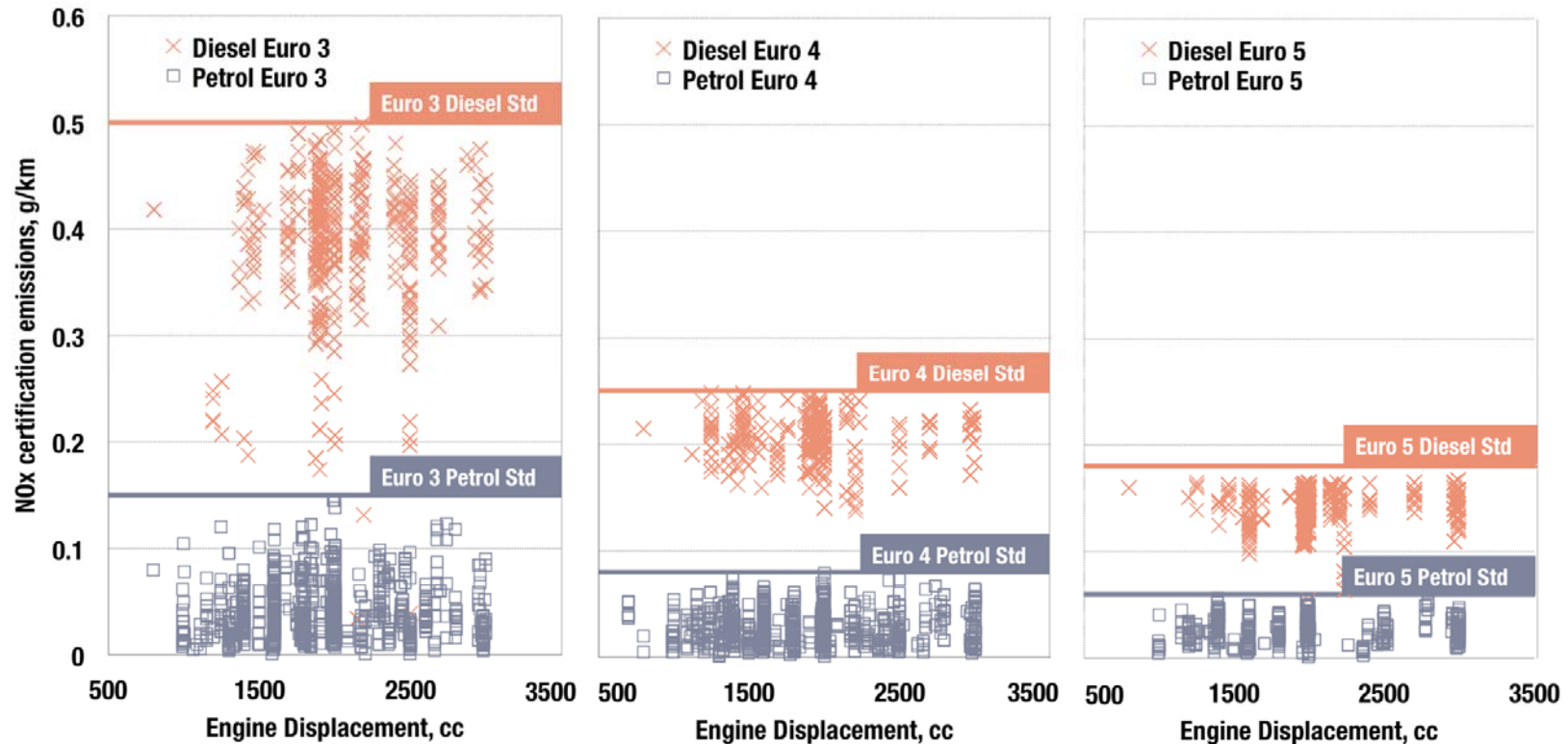
New Technology
Used on all new trucks since 2007
>85% black carbon removal
>85% ultrafine removal
>85% lube oil ash removal

DPFs are typically installed on new diesel passenger vehicles with Euro V standards and on heavy duty vehicles with Euro VI standards, but can be retrofitted to older diesels provided <50 ppm sulfur fuel is available.

Manufacturers responsible for in use emissions over full range of real world driving conditions.

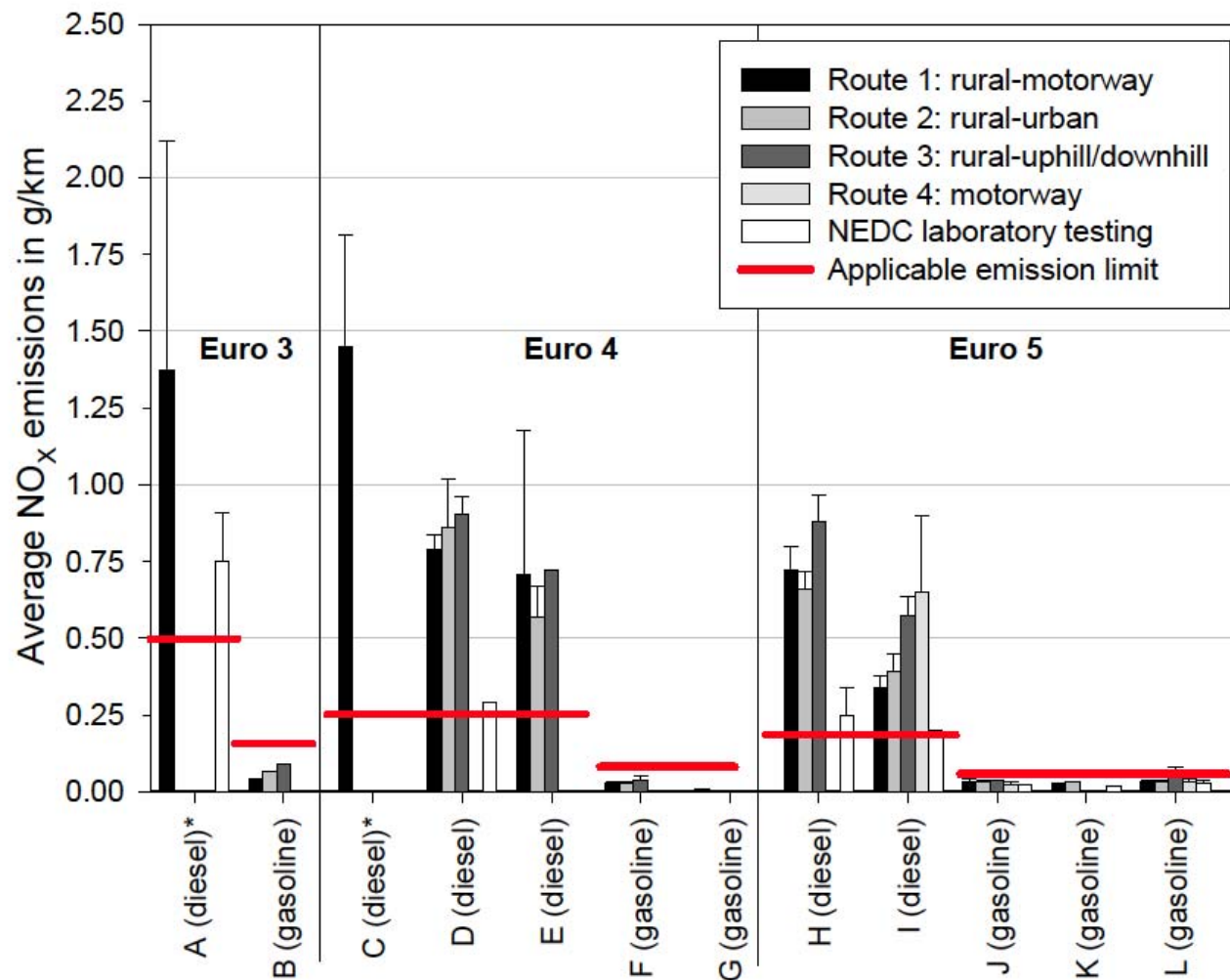
- In-use compliance tests
 - Detection of type specific design related defects or inadequate maintenance instructions
- Strengthening of on-board diagnostics
 - Frequency of monitoring: In use performance ratio (IUPR) monitoring
- Periodic exhaust inspection
 - High opacity as measured on snap acceleration test may indicate engine malfunction and increased emissions of air pollutants, primarily unburned fuel hydrocarbons or soot particles.

Petrol and Diesel Certification Levels



Emissions certification values for +600 model passenger cars in Germany, model years 2003 (Euro 3), 2007 (Euro 4) and 2010 (Euro 5). Source: Kraftfahrt-Bundesamt (KBA), Germany, 2011

Emission reductions must be achieved in real world driving: e.g. Poor SCR performance at low exhaust temperatures



Not-To-Exceed Limit provides a way to limit off-cycle emissions

China moving ahead with Euro V equivalent standards

- Light-duty vehicles (LDV):
 - China V standards proposed in March 2011; to be implemented from January 1, 2016 with consideration of implementation from July 2015
 - Beijing plans advanced implementation of China V in 2012
 - Proposed test cycle and emission limits same as Euro 5b; particulate number (PN) requirements likely
 - Draft OBD requirements same as Euro 5+, and will likely include the requirements for in-use performance ratio
 - Onboard Refueling Vapor Recovery (ORVR) under consideration
- Heavy-duty diesel vehicles (HDDV):
 - Same test cycle and emissions limit as Euro V; less stringent durability requirements
 - Implementation likely to be delayed from the previously planned January 1, 2012
- Fuel quality also a challenge for China

Roadmap for the next decade is missing in India

- Auto Fuel Policy of 2003 recommended revision every five years
 - Need to continue to treat vehicle and fuel as a system, fuel quality improvements critical for next phase of standards
- Long term roadmap needed quickly to give industry adequate lead-time
 - Technology already in the market, but on limited models in India
- One Country, One Fuel, One Regulation!
 - Availability of <50 ppm sulfur fuel countrywide opens up the possibility of leapfrogging to Euro VI standards
 - 10 ppm sulfur fuels needed countrywide eventually for optimal performance of after-treatment devices

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Proposed LEV III Standards in California

- SULEV on path to be AVERAGE by 2022
 - 73% reduction from 2008 average!
- A more stringent combined NMOG+NOx standard for both light and medium duty vehicles for MY 2014-2022
- Increase the durability requirements for emission control systems from 120,000 to 150,000 miles
- PM emissions from 10 mg/mi to proposed 3-1 mg/mi
 - A particle number standard is also under consideration
- Near zero evaporative emission expected even on E10 vehicles

Air Quality related goals in China's 12th Five Year Plan

■ Vehicles

- Establish a passenger vehicle fuel economy standard of 7 liters per 100 kilometers (33.6 miles per gallon)
- Improve heavy-duty vehicle fuel economy 11 percent
- Improve light-duty commercial vehicle fuel economy 15 percent
- Establish vehicle pollution supervision centers in 31 provinces

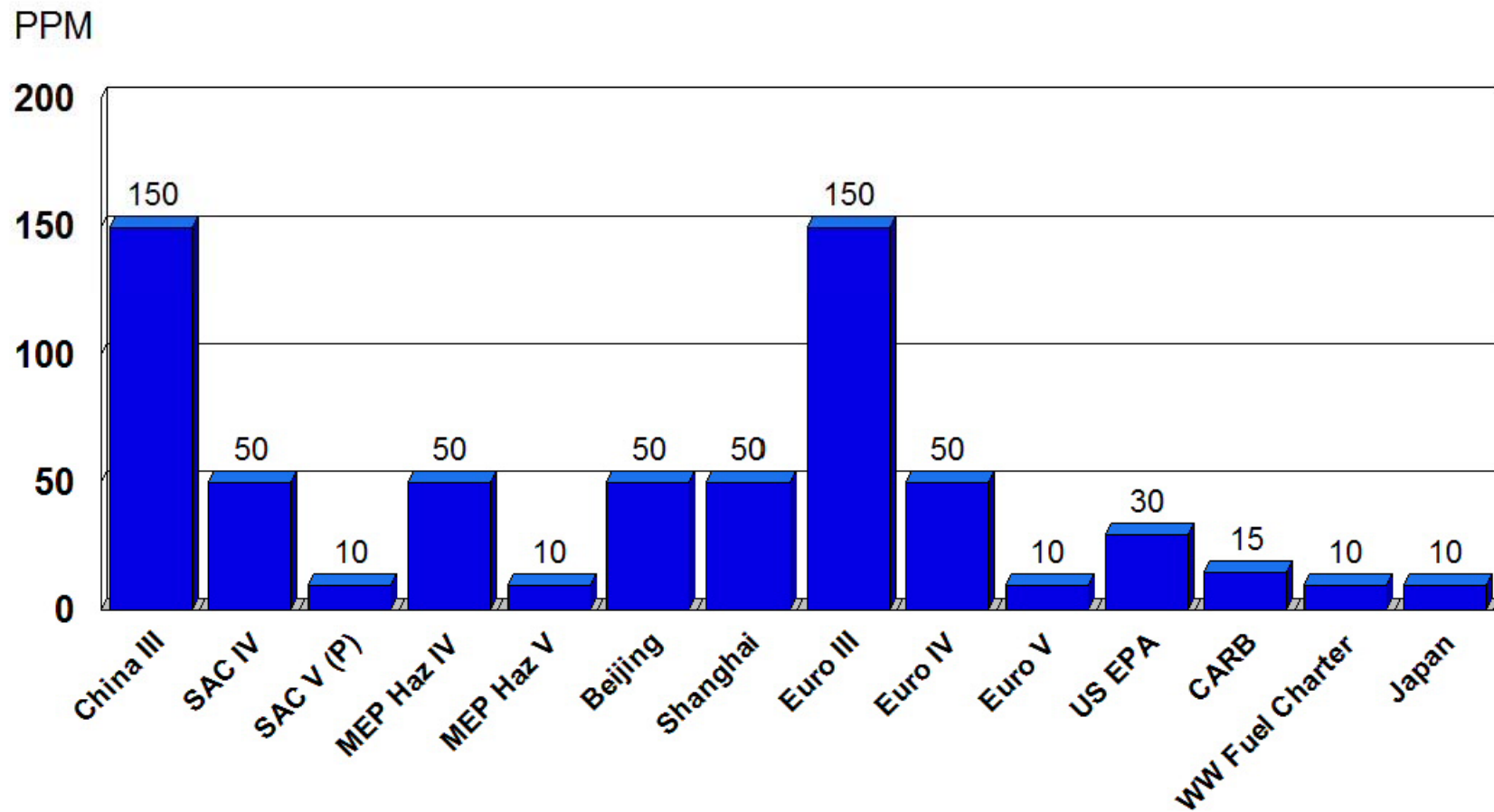
■ Air Quality

- Reduce total emissions of sulfur dioxide by 8 percent and nitrogen oxides by 10 percent
- Fully develop and implement the regional air quality management mechanism issued in 2010 FF5
- Ensure that at least 230 cities meet the World Health Organization's Grade II air quality standards FF4
- Strengthen environmental enforcement

Slide 17

- FF3** Would be good to put the carbon intensity goal too (17% below 2010 levels by 2015)
Freda Fung, 27/09/2011
- FF4** I believe it's 113 cities, not 230 cities
Freda Fung, 27/09/2011
- FF5** The regional air quality mechanism applies to 8 key regions (not nationally), including areas around Beijing, Shanghai and Guangzhou, plus six city clusters in central, eastern and northeast part of China.
Freda Fung, 27/09/2011

Sulfur Content in Gasoline Worldwide Comparison



Petrol and Diesel PV Standards

