Emission Factors for Indian In Use Vehicles

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Presentation by

Amita Baikerikar

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Progress through Research

ARAI Overview

Establishment	**: 1966**
Location	**: Pune, INDIA (150 km from Mumbai)**
Manpower	**: 500+**
Facilities	**: 11 Laboratories – Powertrain, Emissions, Safety & Homologation,**
	Passive Safety, Vehicle Evaluation, Automotive Electronics,
	NVH, CAE, Structural Dynamics, Materials, Calibration
	Post Graduate Academy
Accreditations	**: ISO 9001, 14001, OHSAS 18001 & NABL**

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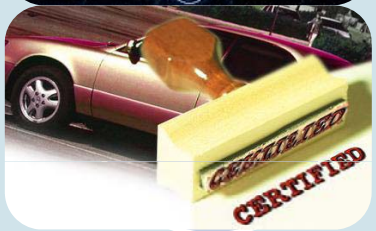
ARAI's Activities

R&D: Automotive Industry Projects,
National Interest Projects and Internal R&D Projects



Certification Testing / Homologation

Assisting GoI in Formulation of Regulatory Standards
and Harmonization of Regulations

Education and Training

Consulting Services

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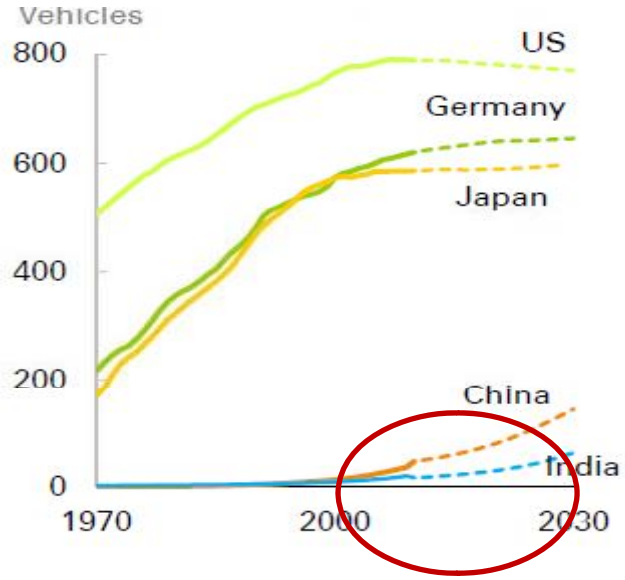
Presentation Layout

- Mobility- Indian Scenario
- Air Quality and Transportation
- Project –Source Apportionment
- Emission Factor development for Indian Vehicles
- Way Forward

Indian Scenario – Mobility

Source: SIAM and ACMA Presentations

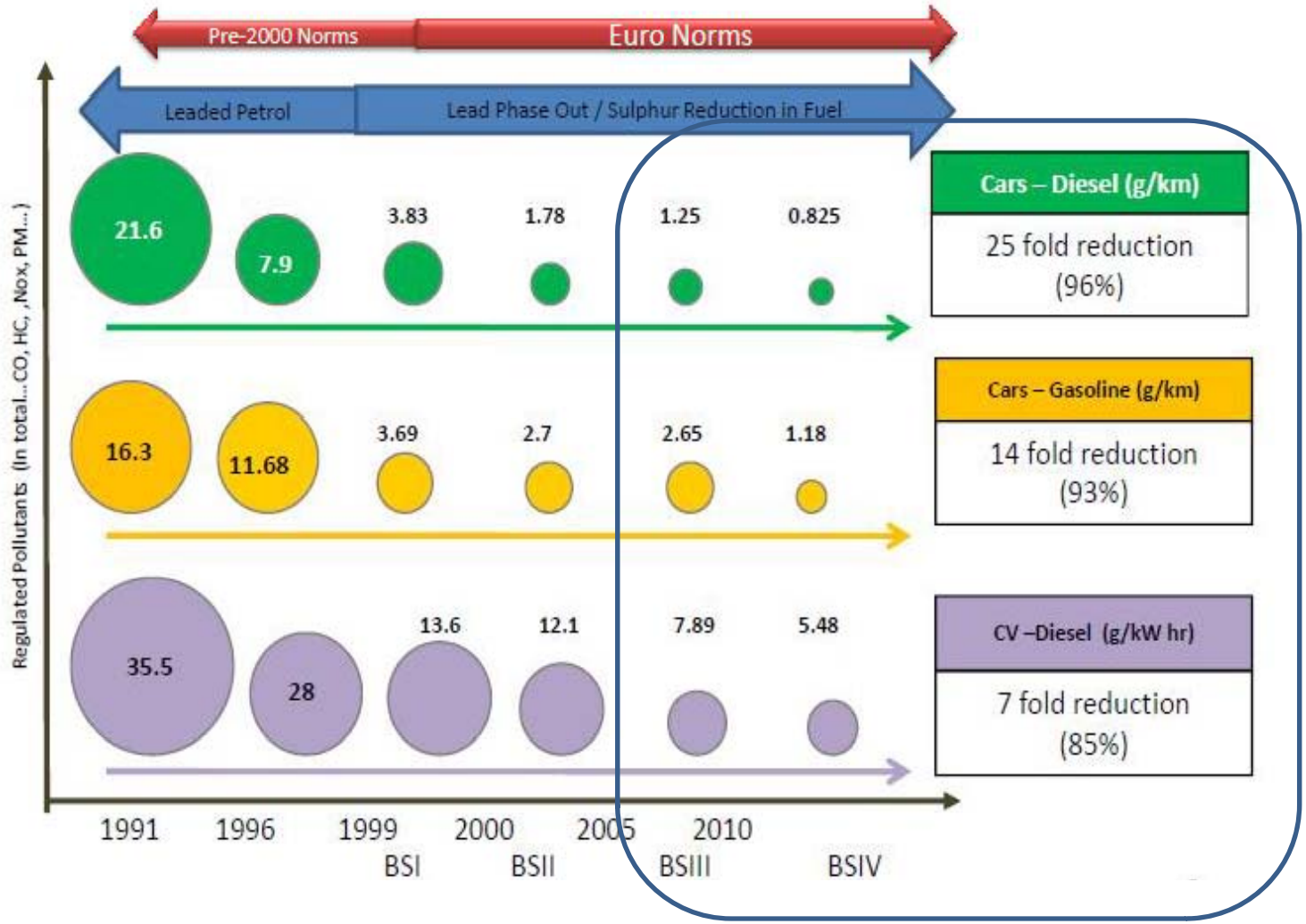
- 125 million registered vehicles in India
- Automobile production to double by 2020-21



Source: BP Energy Outlook 2030, Jan 2012

- Vehicle density per 1000 population in India expected to grow to 65 by 2030

Indian Scenario – Mobility



Adapted from SIAM Presentation 2012 on Emissions & Fuel Efficiency

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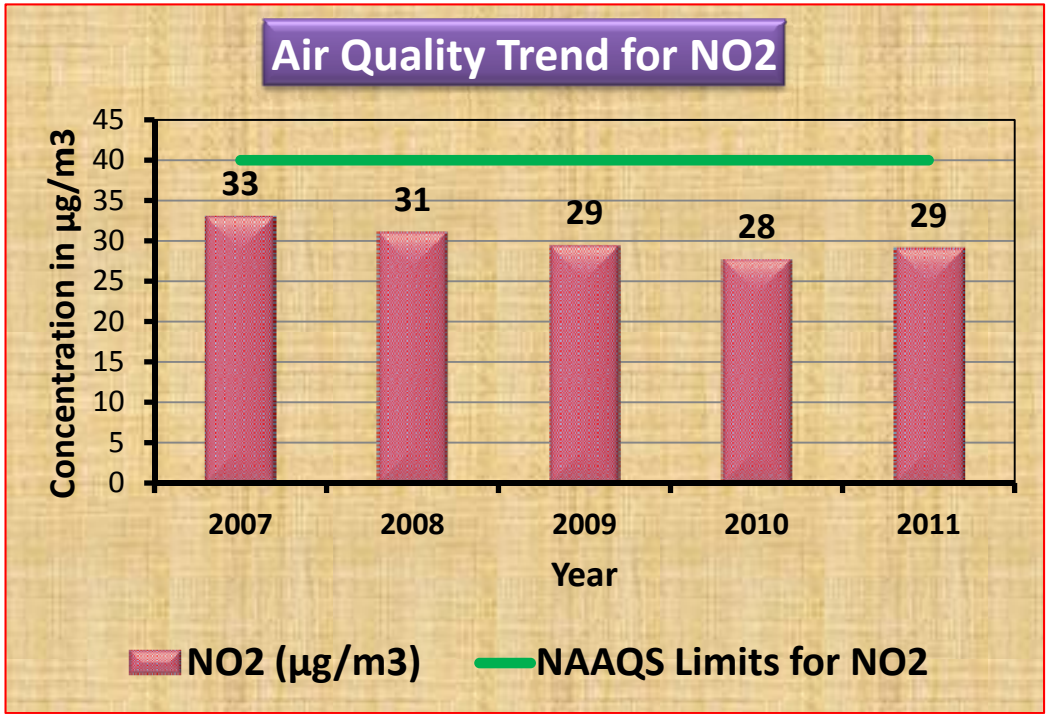
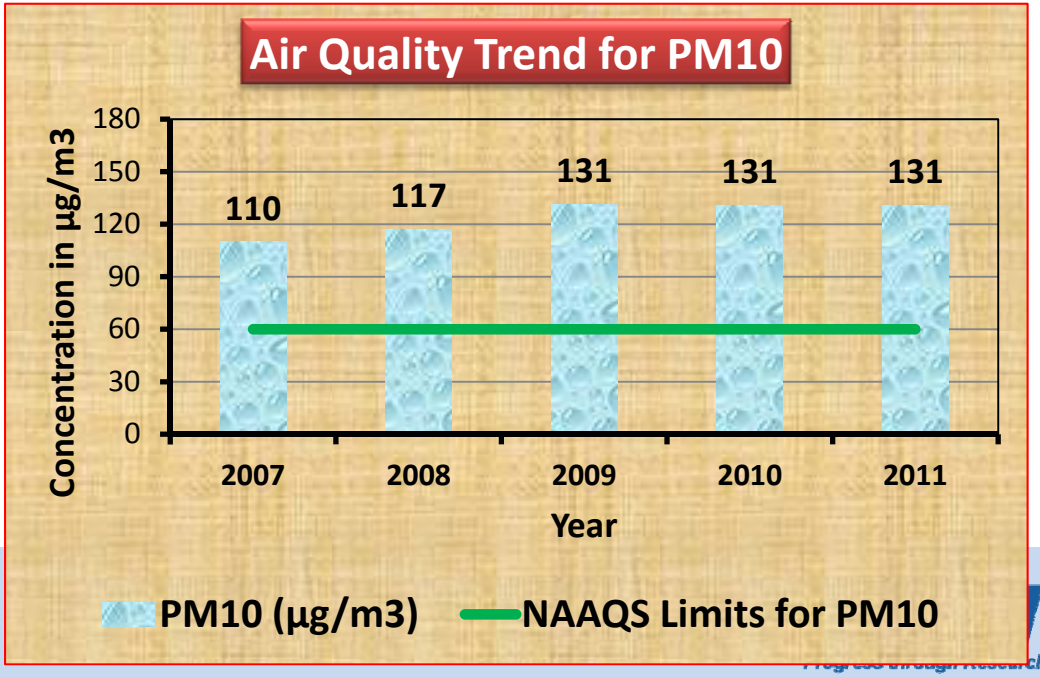
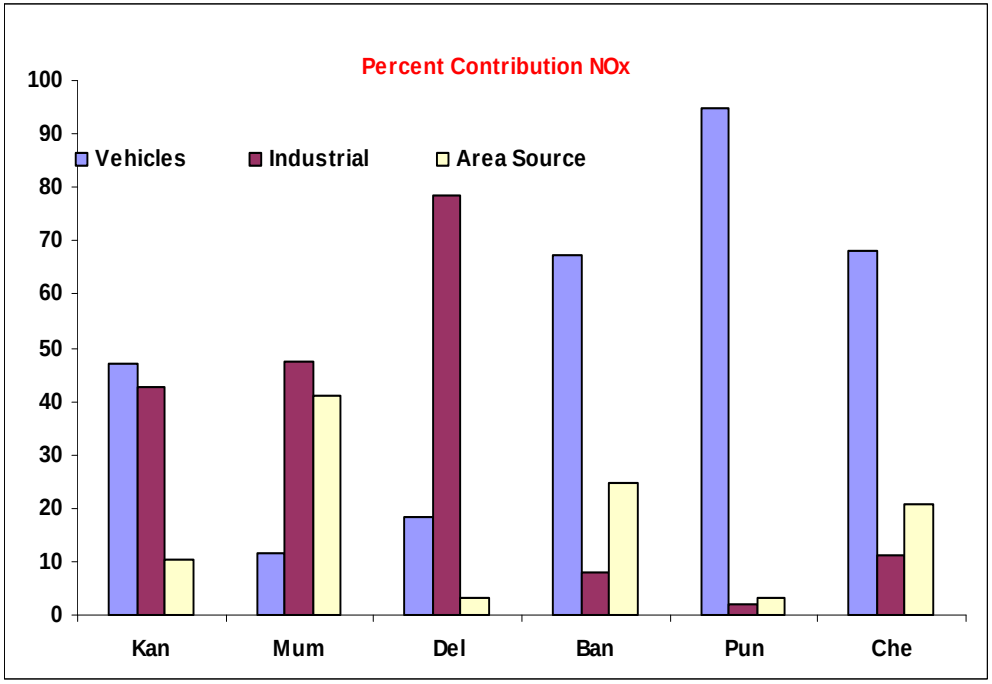


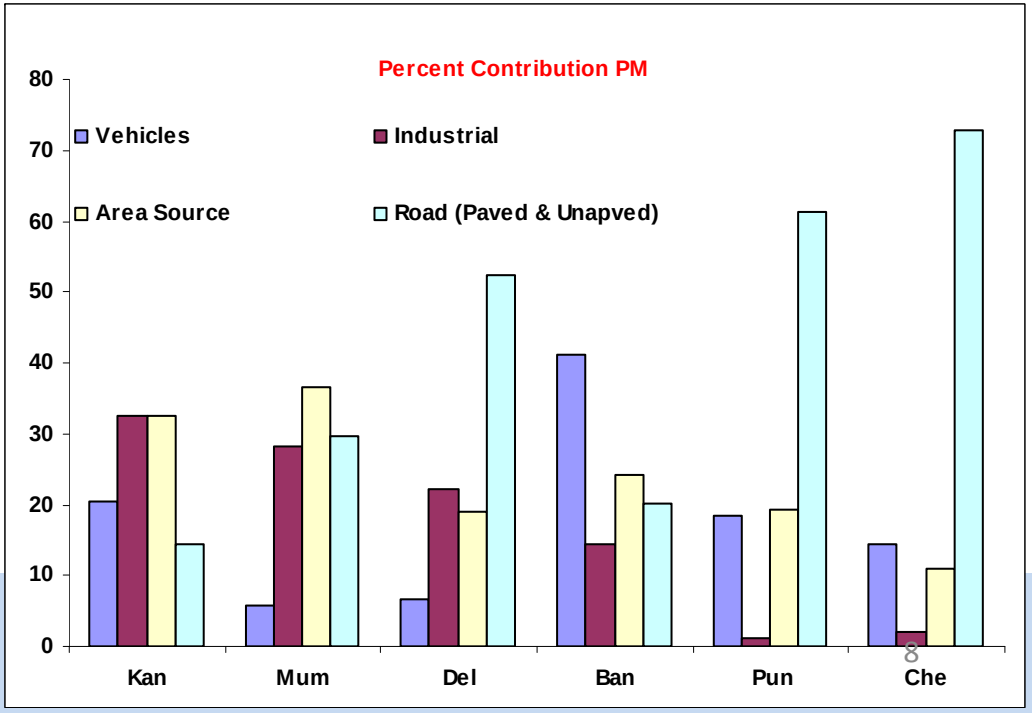
Status of Ambient Air Quality in Metropolitan Cities of India



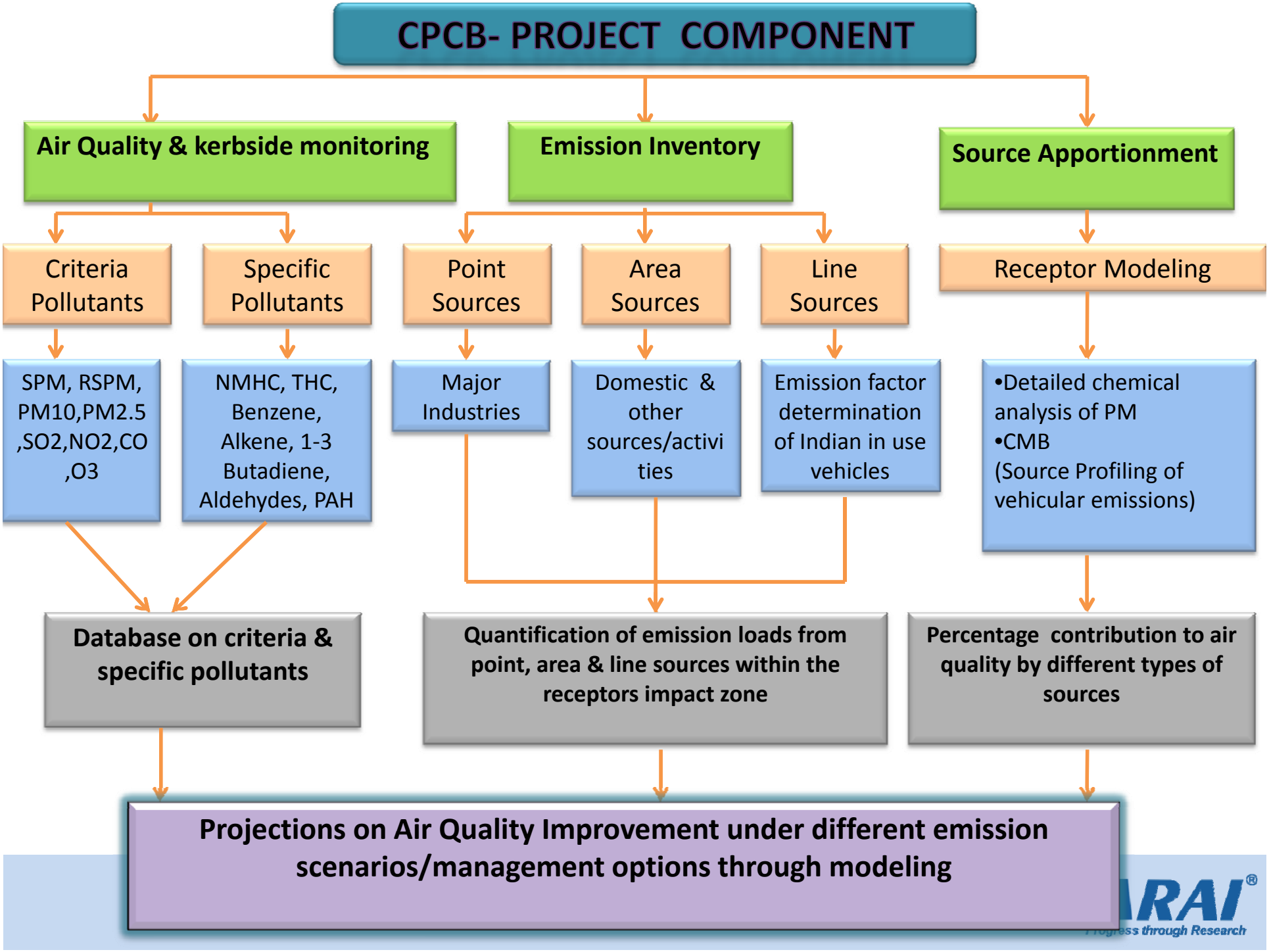
Source: CPCB ENVIS Air Data



Contribution of different sources to NOx & PM_{10}



Source :CPCB


CPCB- PROJECT COMPONENT
Air Quality & kerbside monitoring
Emission Inventory
Source Apportionment
Criteria Pollutants
Specific Pollutants
Point Sources
Area Sources
Line Sources
Receptor Modeling
SPM, RSPM, PM10,PM2.5 ,SO2,NO2,CO ,O3
NMHC, THC, Benzene, Alkene, 1-3 Butadiene, Aldehydes, PAH
Major Industries
Domestic & other sources/activi ties
Emission factor determination of Indian in use vehicles
•Detailed chemical analysis of PM
•CMB
(Source Profiling of vehicular emissions)
Database on criteria & specific pollutants
Quantification of emission loads from point, area & line sources within the receptors impact zone
Percentage contribution to air quality by different types of sources
Projections on Air Quality Improvement under different emission scenarios/management options through modeling
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Objectives of the project:

"To develop "**Emission Factors**" for different category of vehicles to reflect the variance in fuel quality, vehicle technology & age, maintenance practices, tailpipe treatment, etc. by conducting exhaust mass emission tests".

Scope of the project

1. Determination of EF for each representative vehicle model considering vehicle technology, age- 89 Vehicles/450 tests
   - In-use vehicles of different vintages (viz, 1991-96, 1996-2000, Post 2000 and Post 2005 [Tech Matrix]
   - 2 Wheelers, 3 Wheelers, Passenger Cars, LCVs and HCVs

2. Exhaust gas chemical speciation for non regulated pollutants :
   - Benzene, 1-3, Butadiene, PAH and Aldehydes

3. Tests with commercial fuel- Before and after maintenance & Tests with different fuel specifications

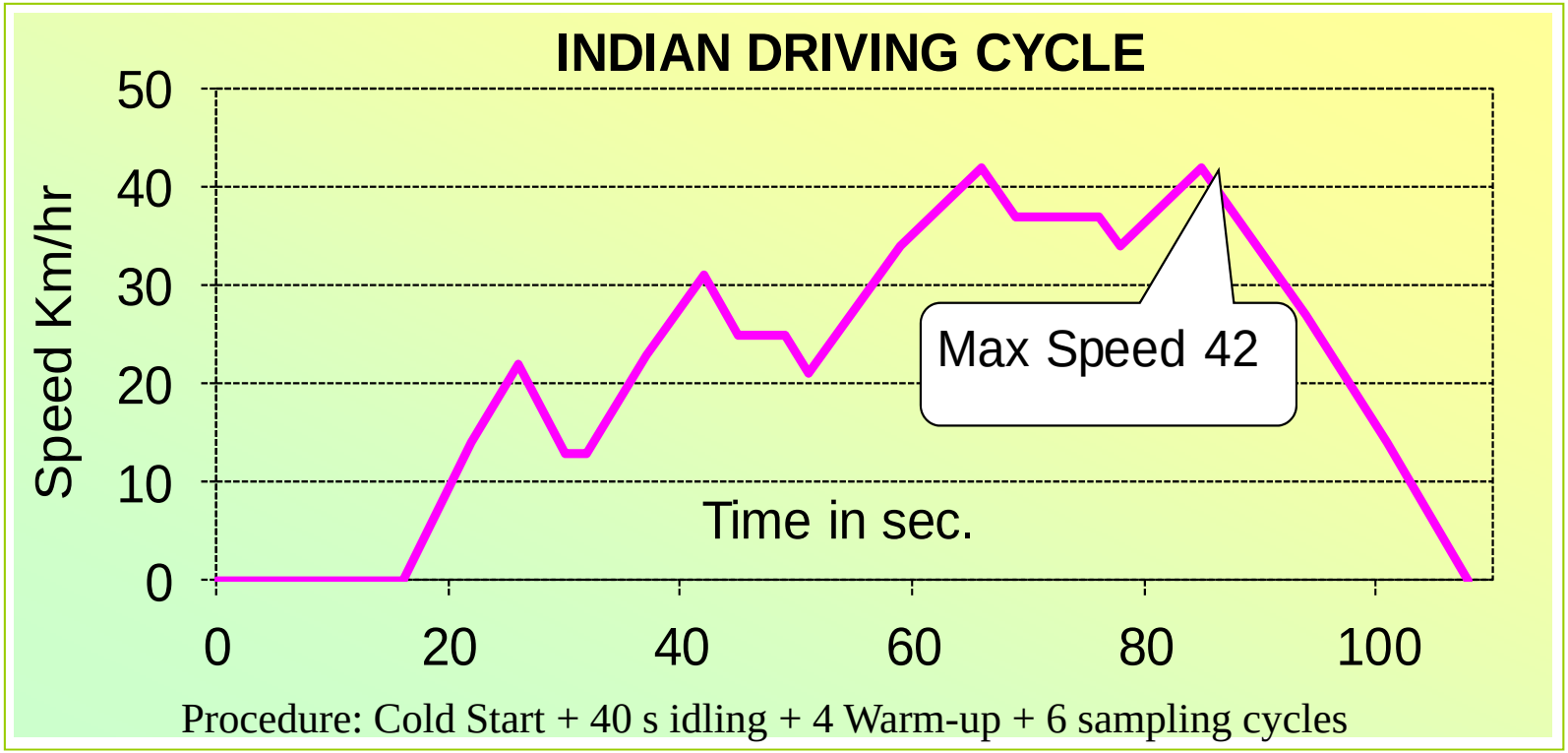
Project Execution Methodology

- Vehicle sourcing
  - Individuals, Organizers, transport operators ARAI employees, public acquaintances & Rickshaw unions
  - TA/CoP test vehicles

- Vehicle Testing
  - Prevalent Certification test procedures
  - Prevalent test cycles
  - Inertia setting

- 62 no. EF based on
  - vehicle categorization
  - Engine capacity
  - Fuel

Indian Driving Cycle for 2 and 3 wheelers



Procedure: Cold Start + 40 s idling + 4 Warm-up + 6 sampling cycles

Cycle	Time in s	Dist in m	Avg. Speed in km/h	Max. Acceleration m/s2	Maximum Deccelerat ion m/s2
		Normal	Normal	Normal	Normal
IDC (6 cycles)	648	3948	21.93	0.65	-0.63

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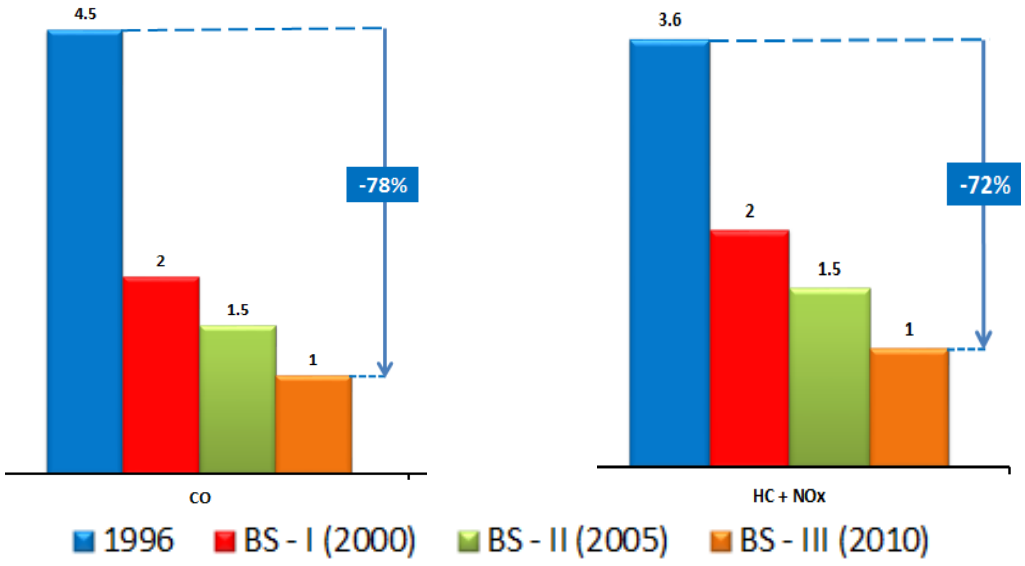
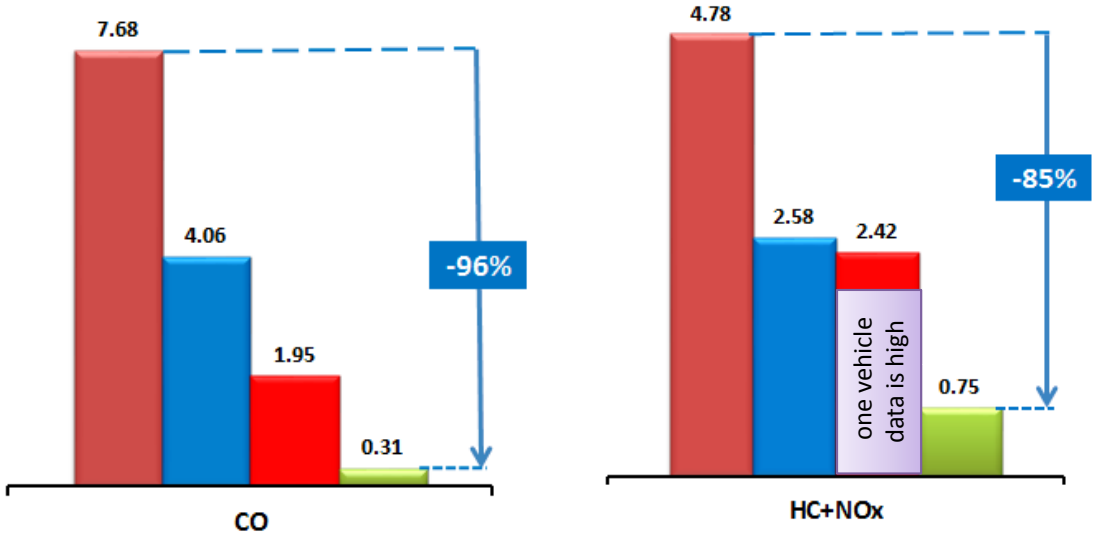
2W Emission Control Regulation History in India



(All figures in g/km)

	CO (g/km)	HC (g/km)
1991 Norms	12 to 30	8 to 12
Reduction	**92 %**	**88 %**



2W Emission Factors
2 - Stroke

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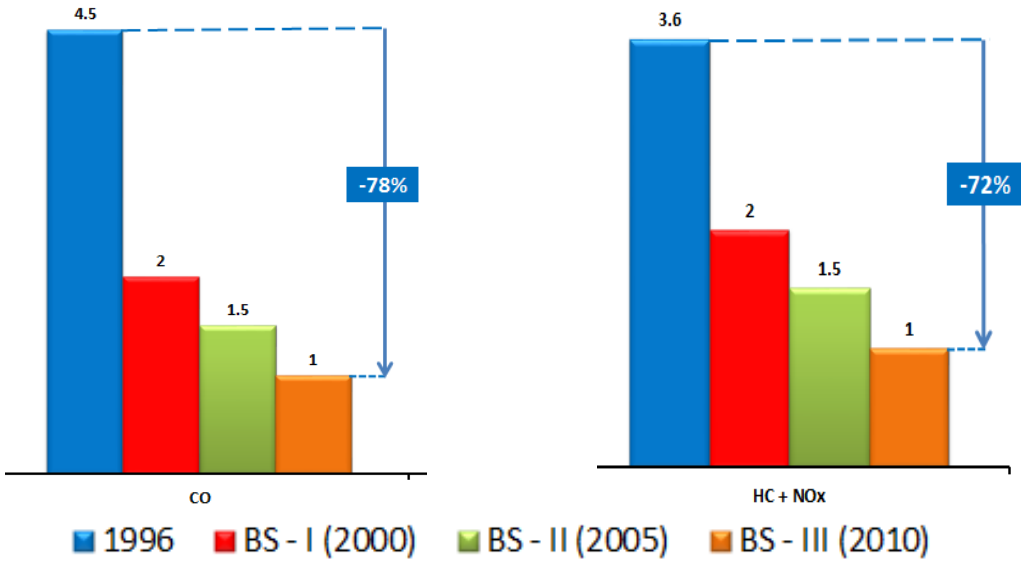
2W Emission Control Regulation History in India



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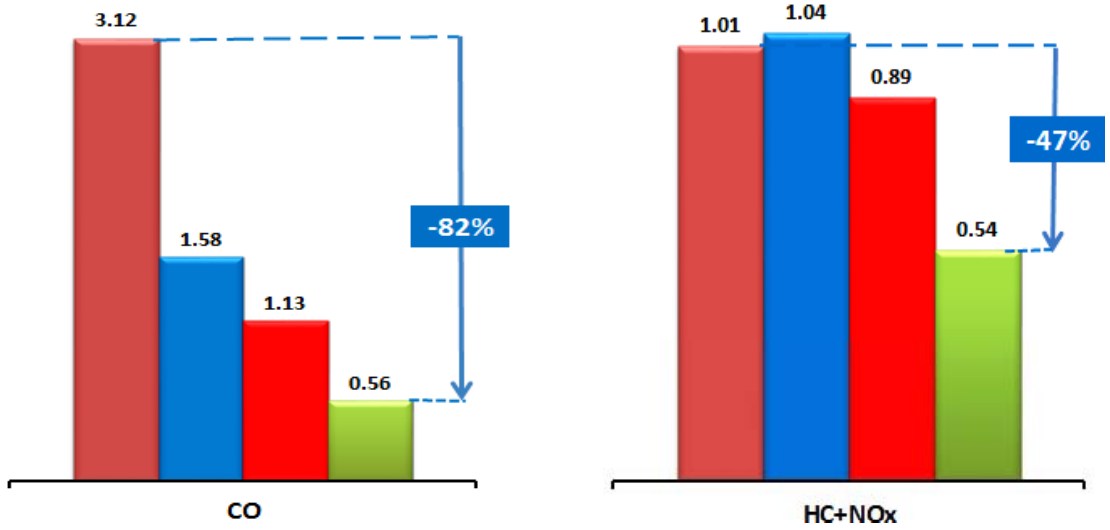

2W Emission Factors
4 - Stroke

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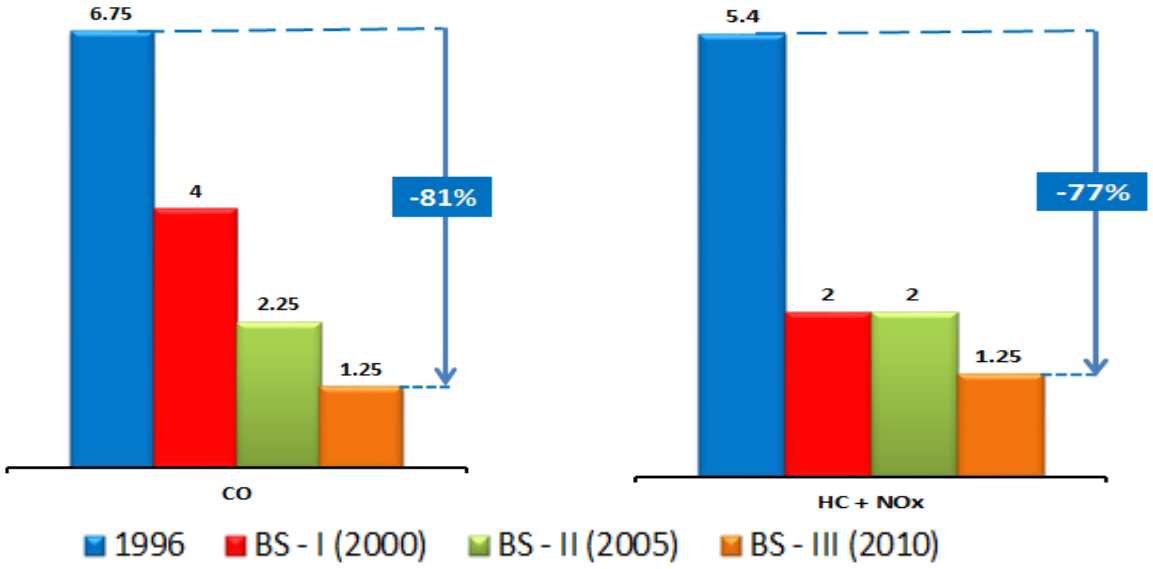
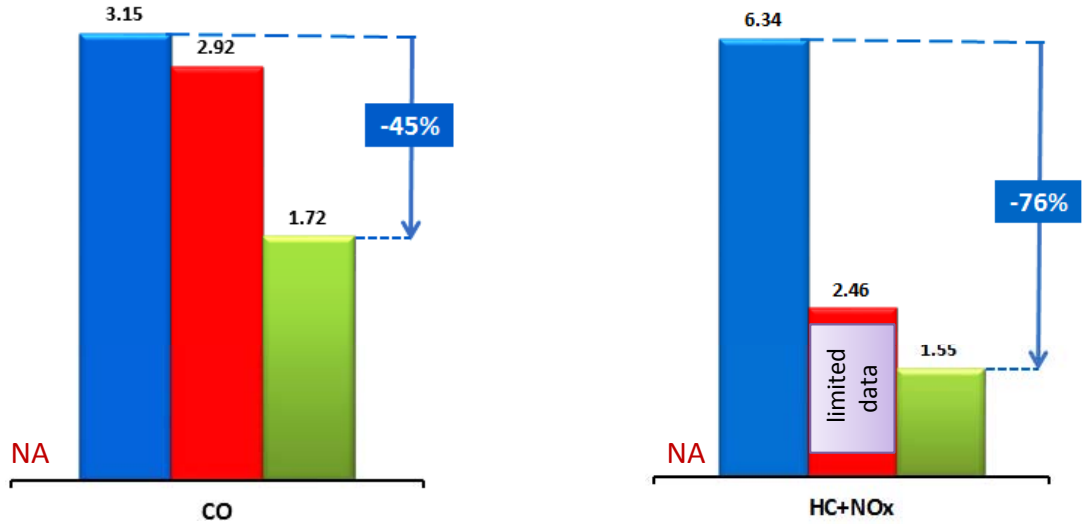
3W – Gasoline Emission Control Regulation History in India



(All figures in g/km)

	CO (g/km)	HC (g/km)
1991 Norms	12 to 30	8 to 12
Reduction	90 %	84 %



3W – Gasoline Emission Factors

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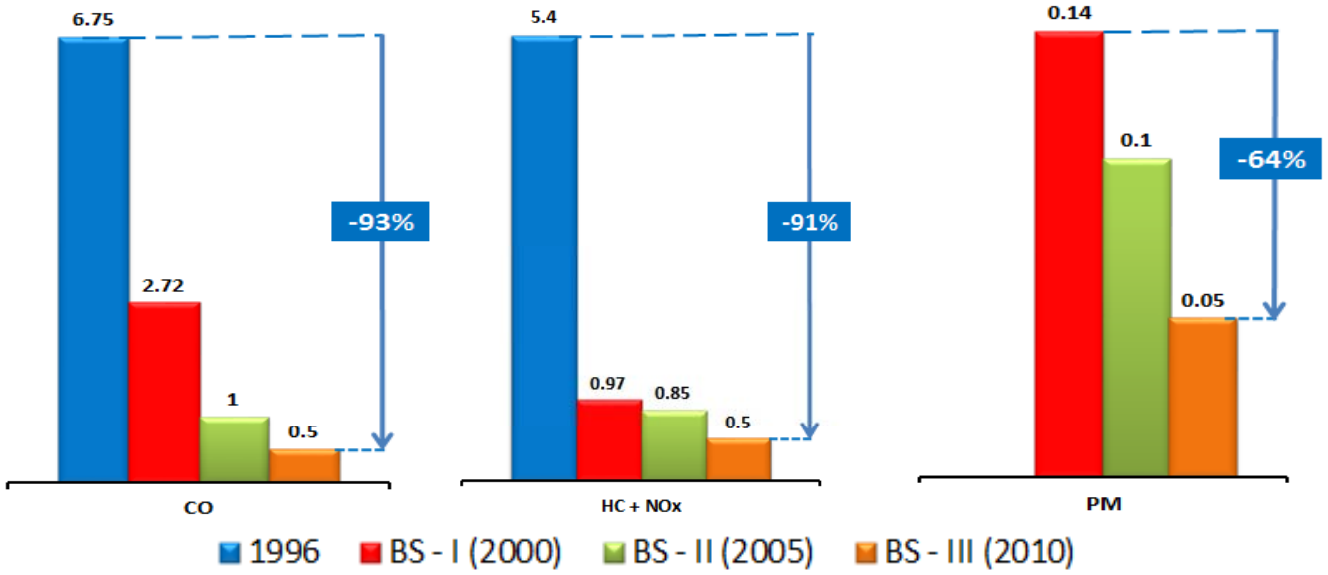
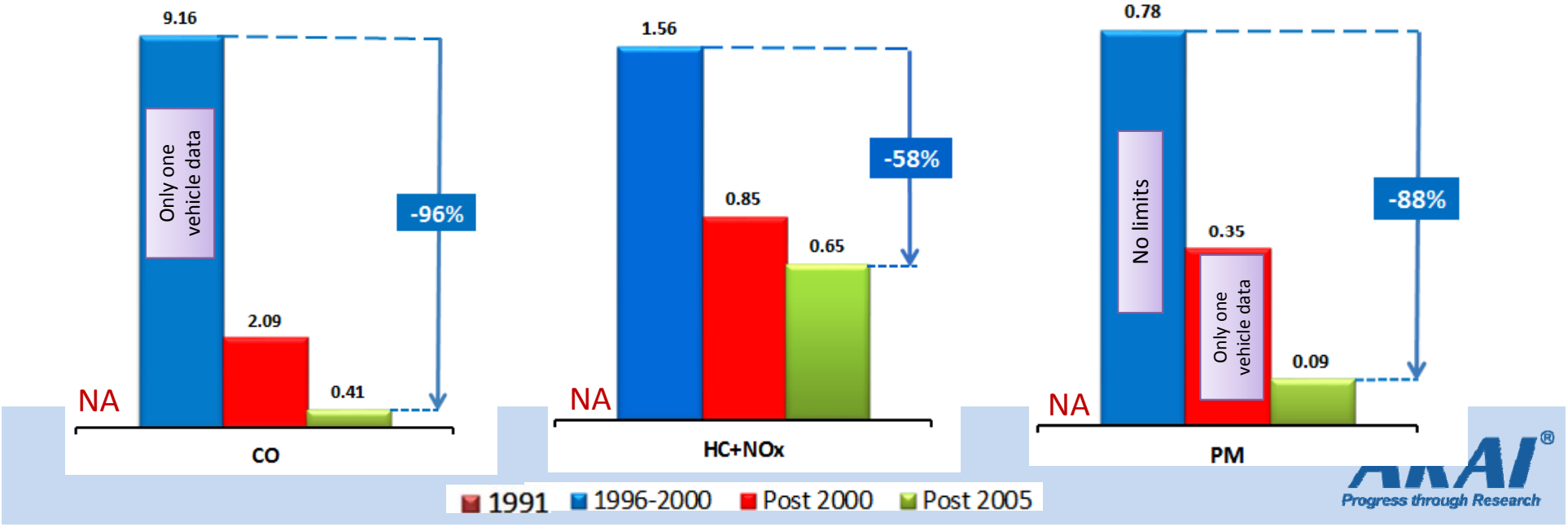
3W – Diesel Emission Control Regulation History in India

(All figures in g/km)



	CO (g/km)	HC (g/km)
1992 Norms	12 to 30	8 to 12
Reduction	90 %	84 %

3W – Diesel Emission Factors



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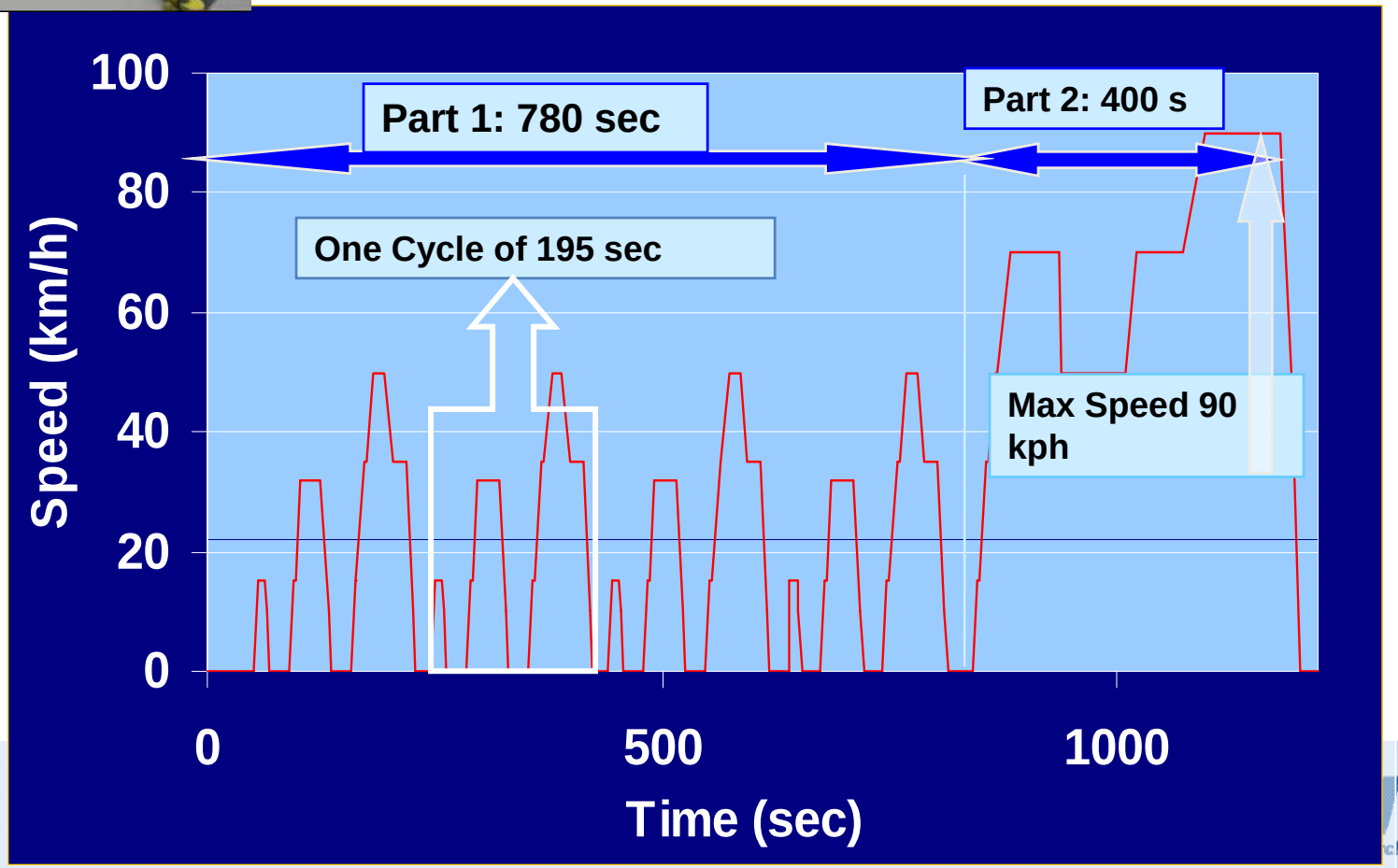
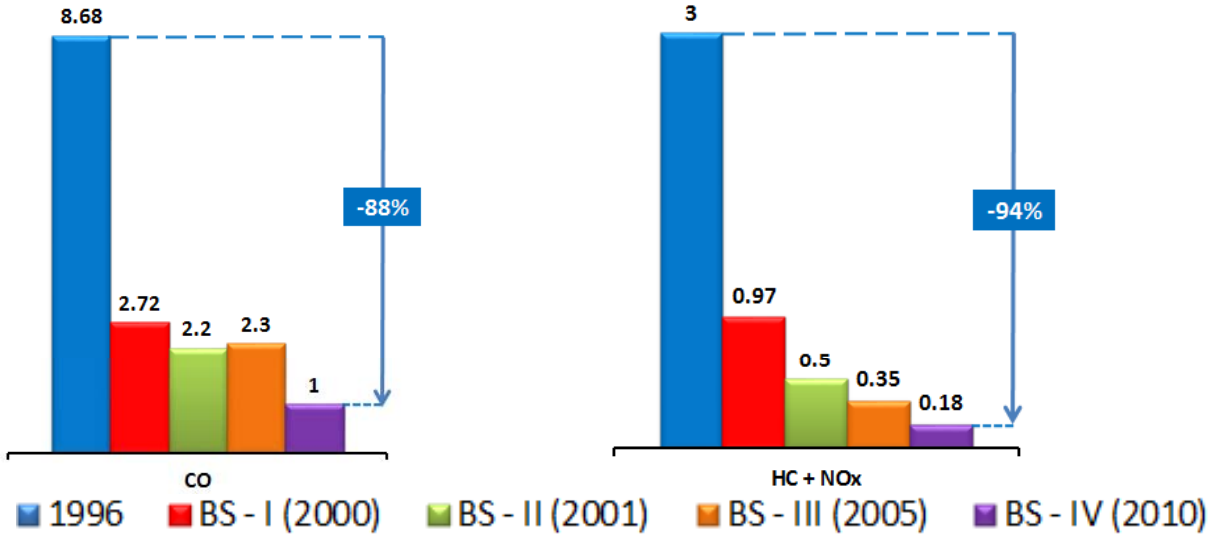
Indian Driving Cycle for 4 Wheelers



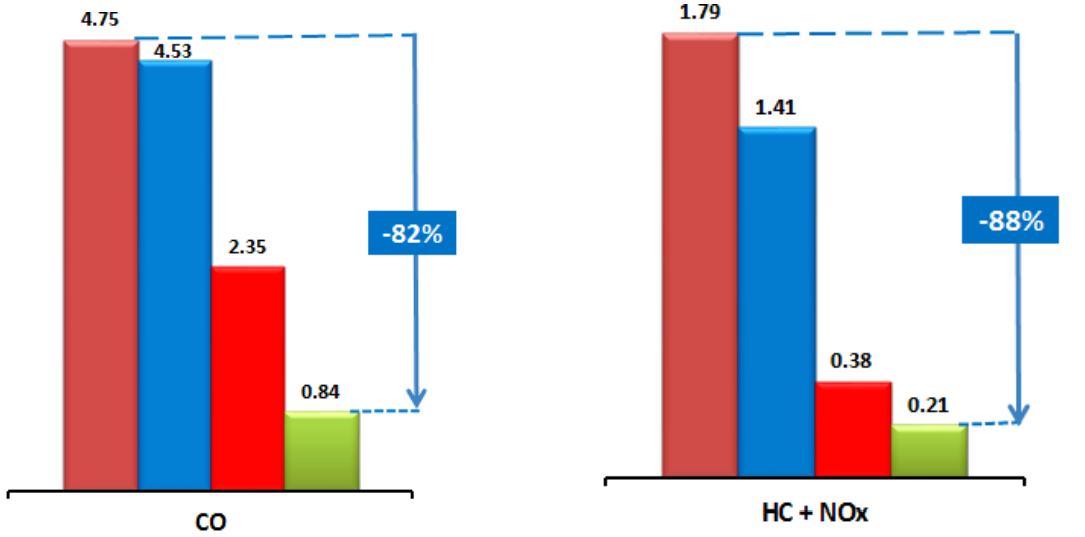
Passenger Cars & Light Commercial Vehicles - Gasoline Emission Control Regulation History in India



(All figures in g/km)

	CO (g/km)	HC (g/km)
1991 Norms	14.3 to 27.1	2.0 to 2.9
Reduction	**93 %**	**91 %**

Norms	CO (g/km)	HC (g/km)	NOx (g/km)
BS – III	2.30	0.20	0.15
BS - IV	1.00	0.10	0.08



Passenger Cars - Gasoline Emission Factors

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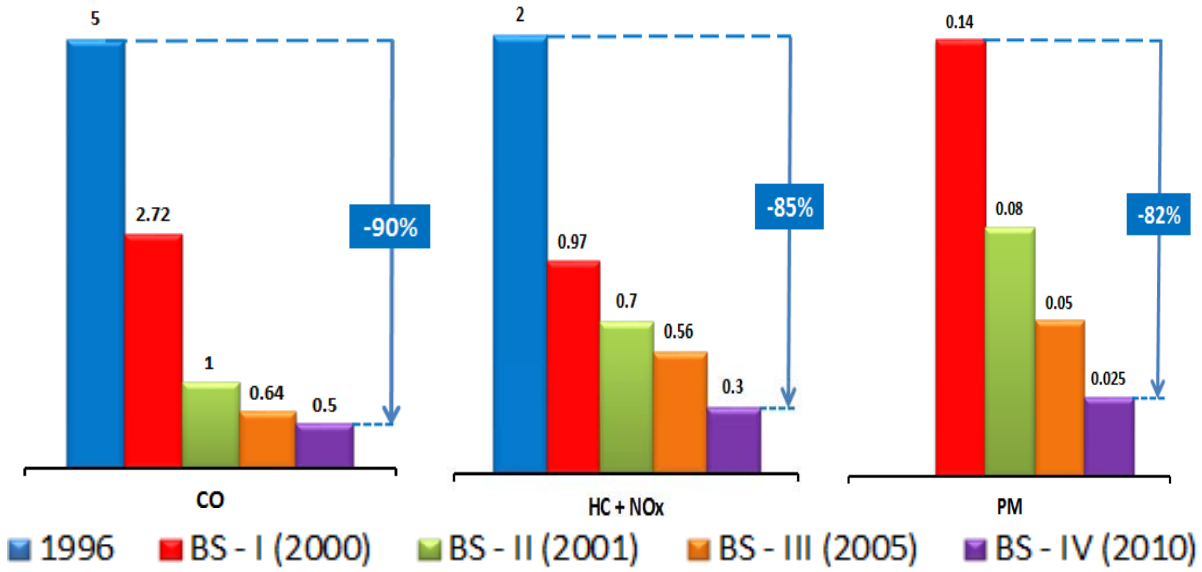
Passenger Cars & Light Commercial Vehicles - Diesel Emission Control Regulation History in India

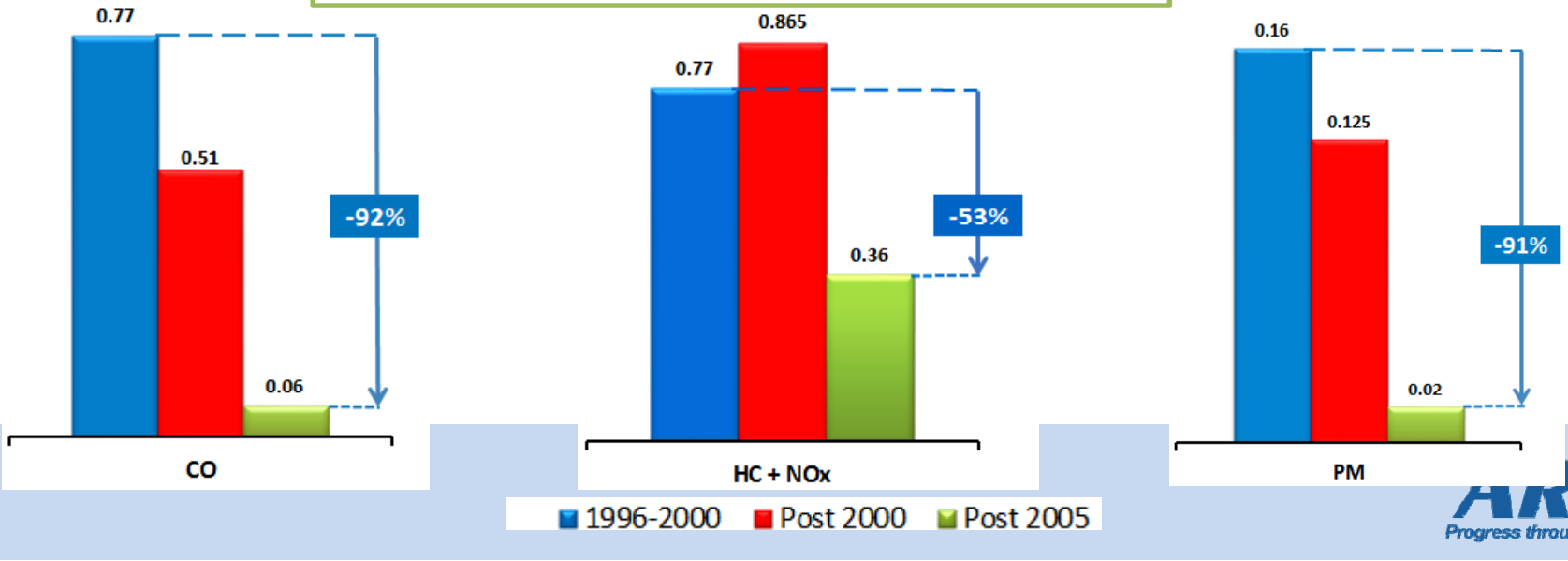


(All figures in g/km)

	CO (g/km)	HC + NOx (g/km)
1992 Norms	14.3 to 27.1	4.7 to 6.9
Reduction	96 %	94 %

Norms	CO (g/km)	NOx (g/km)	HC + NOx (g/km)	PM (g/km)
BS – III	0.64	0.50	0.56	0.05
BS - IV	0.50	0.25	0.30	0.025

Passenger Cars –Diesel Emission Factors



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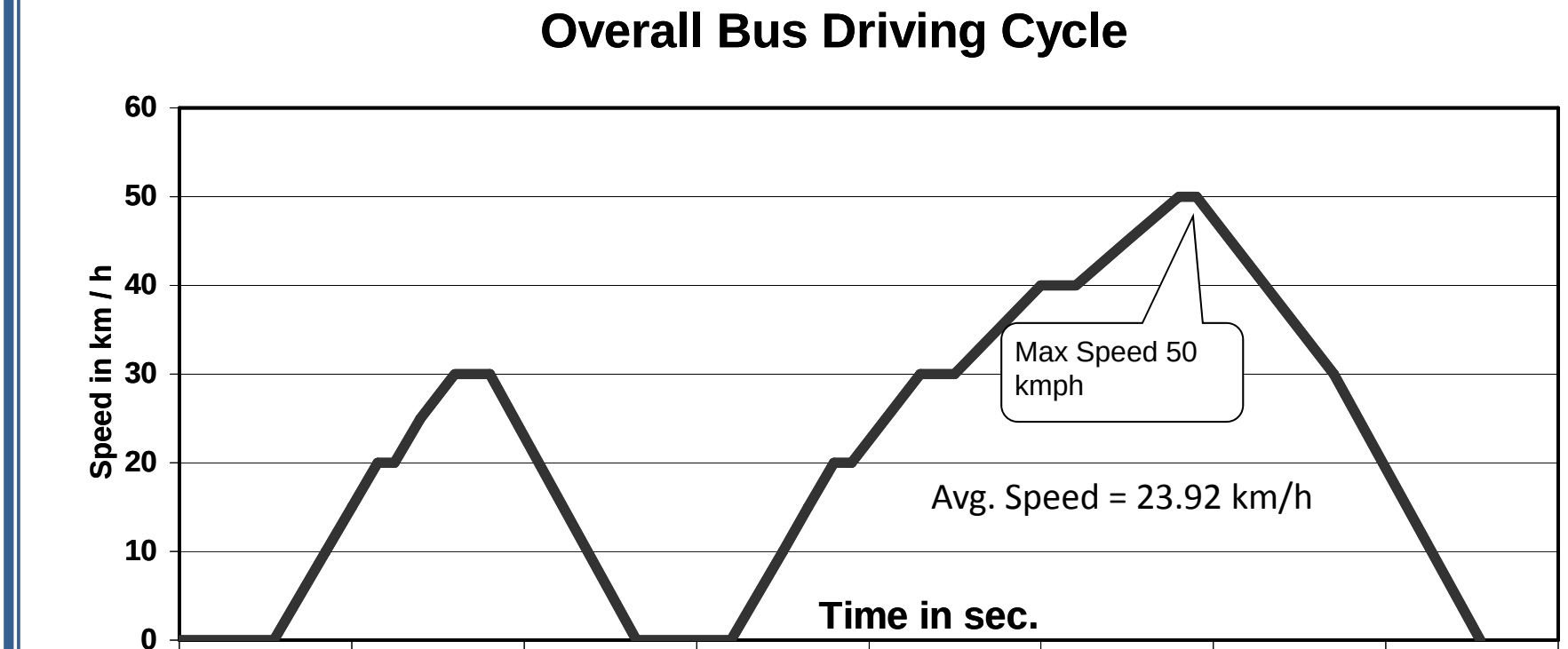
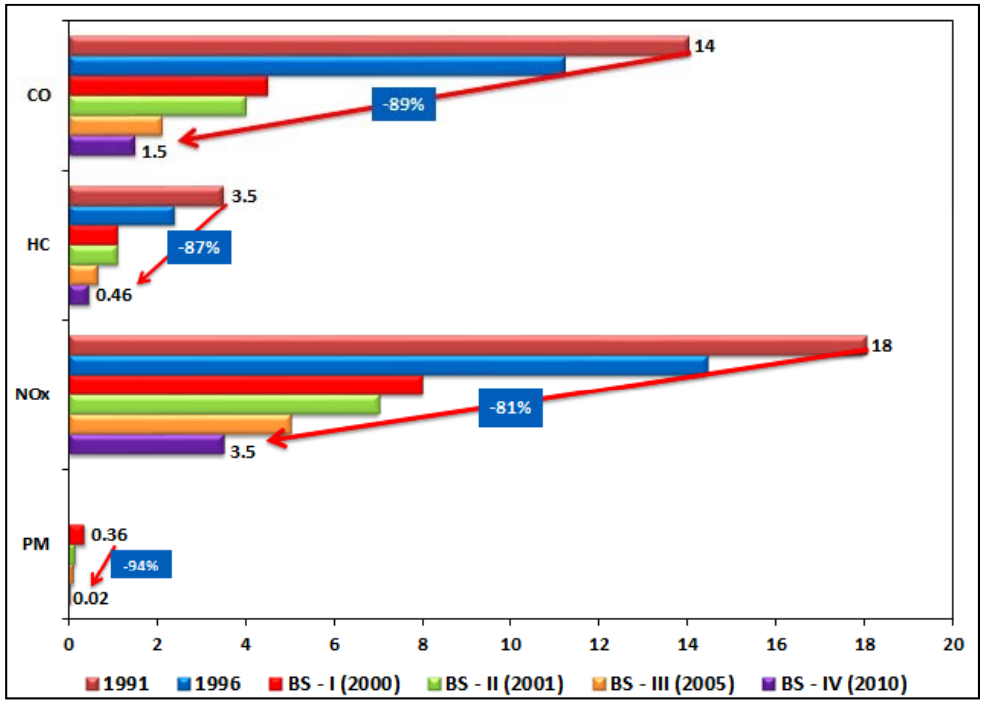
Overall Bus Driving Cycle for LCV and HCV



Procedure: Cold Start + 4 Warm-up + 6 sampling cycles (5.1 km)

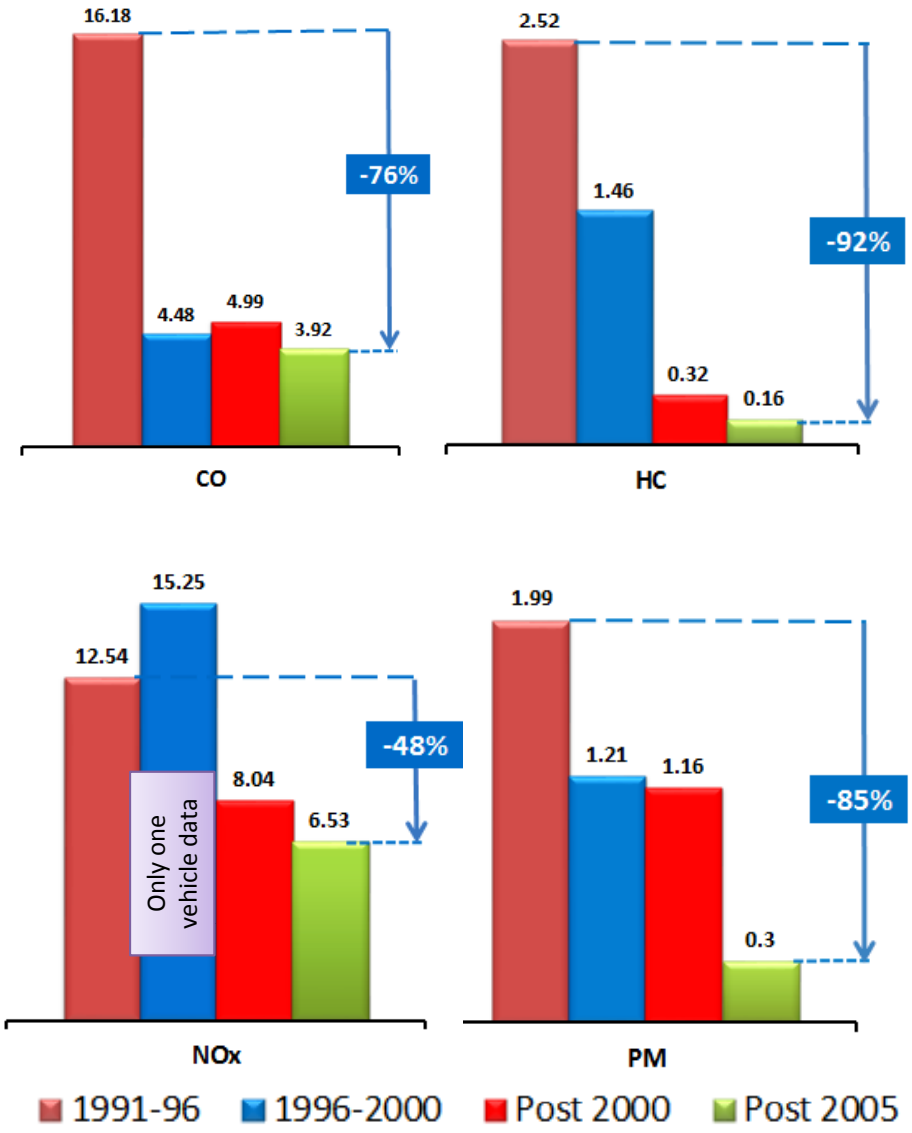
HCV Emission Control Regulation History in India

(All figures in g/kWh)



HCV Emission Factors

(All figures in g/km)



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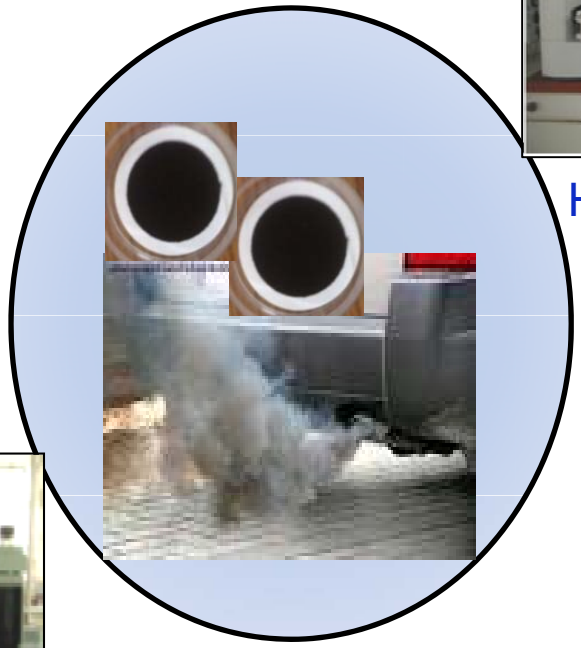
Emission Factors for Non Regulated Pollutants

Benzene and 1,3 butadiene



High Resolution Gas Chromatograph (HRGC)

Polycyclic Aromatic Hydrocarbons + Aldehydes and Ketones

High Performance Liquid Chromatograph (HPLC)

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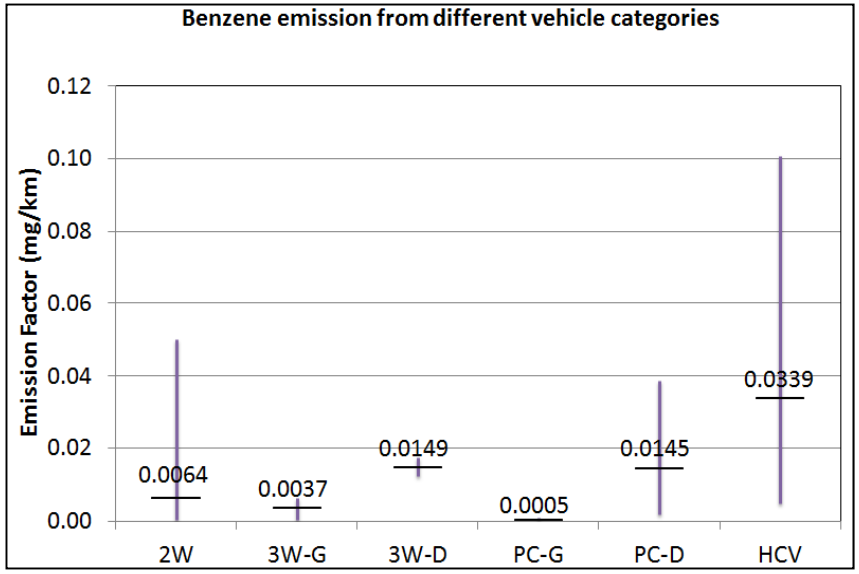
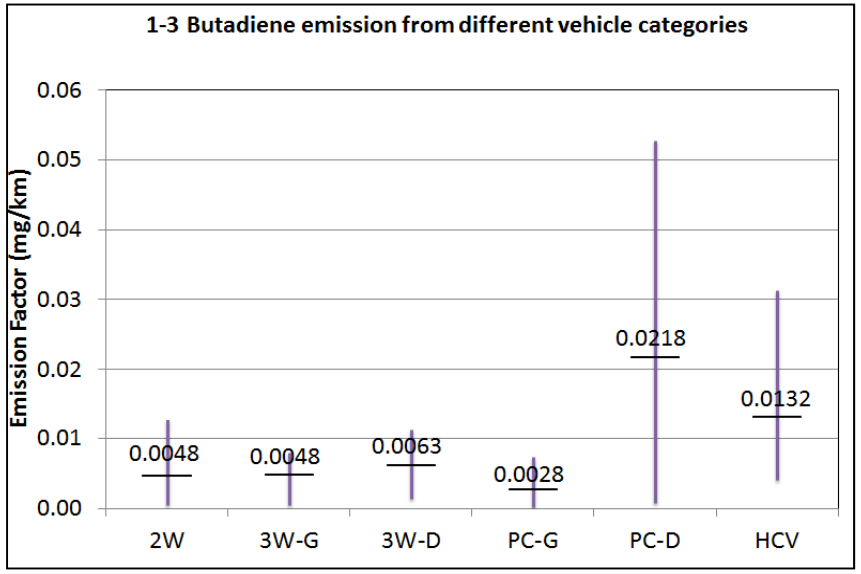
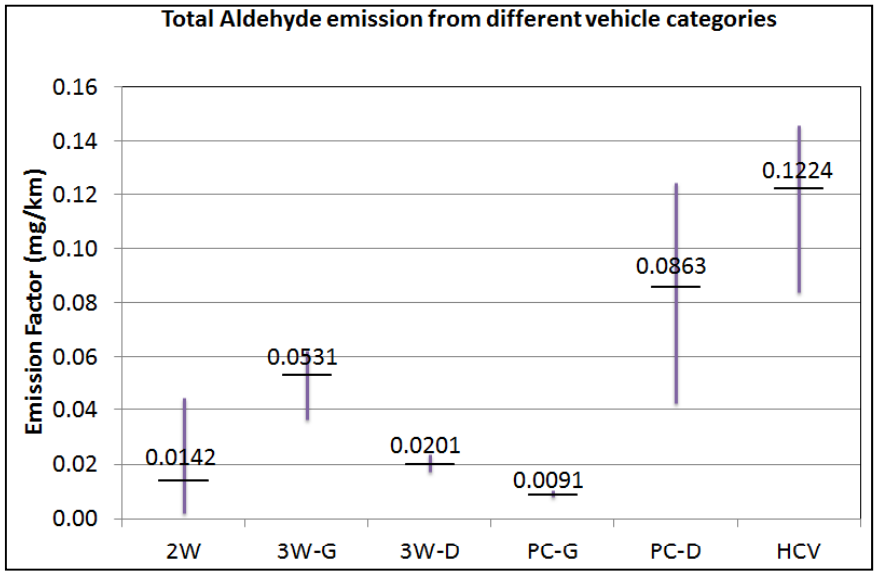
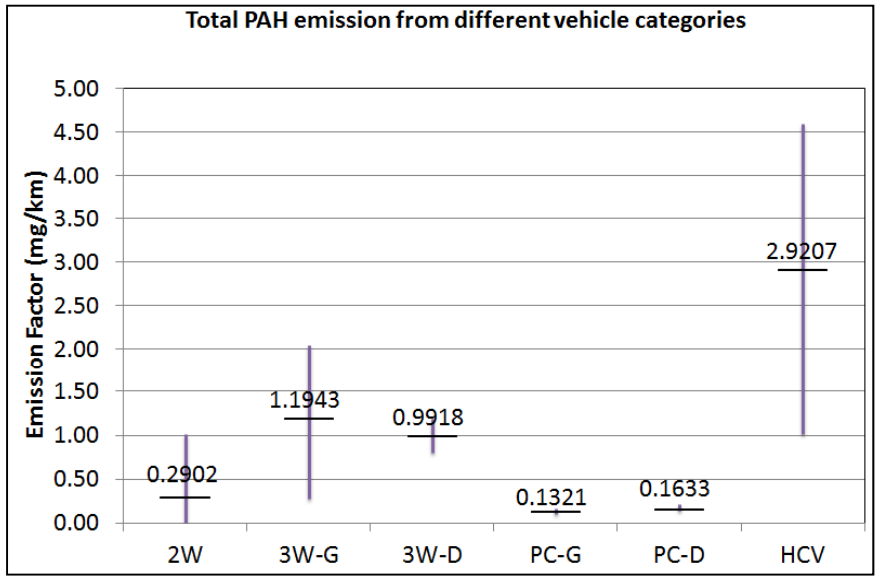
Non-regulated Pollutant Emission Factors









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Way Forward…

- The sample size is limited and there is a need to test more number of vehicles.
  - More emission factors for BSIII technology and BS IV technology vehicles of four wheelers need to be developed
  - BSIII technology of two/ three wheeled vehicles need to be developed.

- Vehicular emission factors need to be evolved on a continuous basis for regulated, non-regulated and greenhouse gases.

- Vehicular Non- exhaust emission profiles generation for in use vehicles need to be undertaken.
  - Brake Pad
  - Tyre Wear

Way Forward…

- Establish EF on city specific Driving Cycles
  - Continuous change in the road traffic pattern.

- Use of PEMS to evolve real world emission data from various vehicle categories across selected cities in the country.

- Since activity of data collection for mobile source is resource intensive, tool for advanced methodology for simpler and quicker approach needs to be worked out ???

Thank You

Air Quality Management Project

The project consists of three major sub-components as below:

1. Development of emission factors for Indian vehicles
2. Vehicle source profiling
3. Ambient air quality monitoring, Emission Inventory and Source Apportionment

On-Board Emission Measurement System

- Typical applications
- Compliance of in use vehicles for prevalent emission norms
- Monitoring of exhaust emissions from in use vehicles
- On road performance evaluation of vehicles; evaluation of exhaust emissions w.r.t. to other engine / vehicle parameters viz.; gear position, throttle, acceleration, clutch, brake, etc.
- On vehicle / on road engine / ECU calibration

Salient Features

- The facility will be based on the test set up recommended by GRPE- PMP group, which includes mainly, dilution tunnel with PCF (Pre-classifier) to cut down exhaust particles below 2.5 µm and HEPA (High Efficiency Particulate Filter) to provide dilution air with filtering efficiency 99.99%, VPR (Volatile Particle remover) and CPC (Condensation Particle Counter)

- In addition to this certification setup, it includes Engine Exhaust Particle Sizer (EEPS) for online nano particle measurement for its number, surface area and size distribution pattern which will be useful for research and development

- Solid Particle Measurement from 23 nm to 2.5 µm as per EURO V/EURO VI

- Nano Particle size range between 5.6 nm to 560 nm on Transient Cycle for On-Line Measurement

- Unique Facility at National level for measuring particle number, size, surface & volume

- Useful for Export Homologation as per Euro V /VI and for R&D

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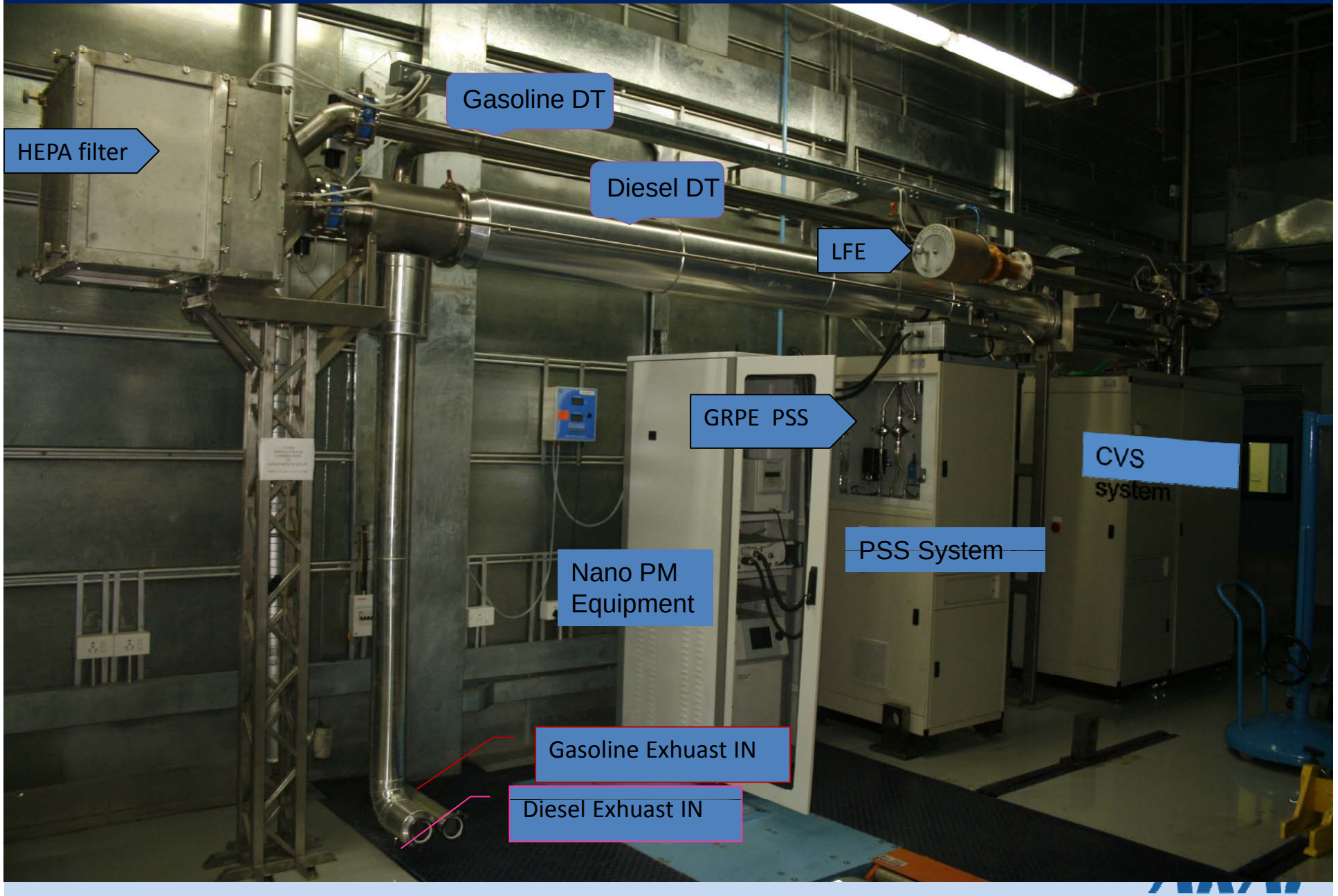
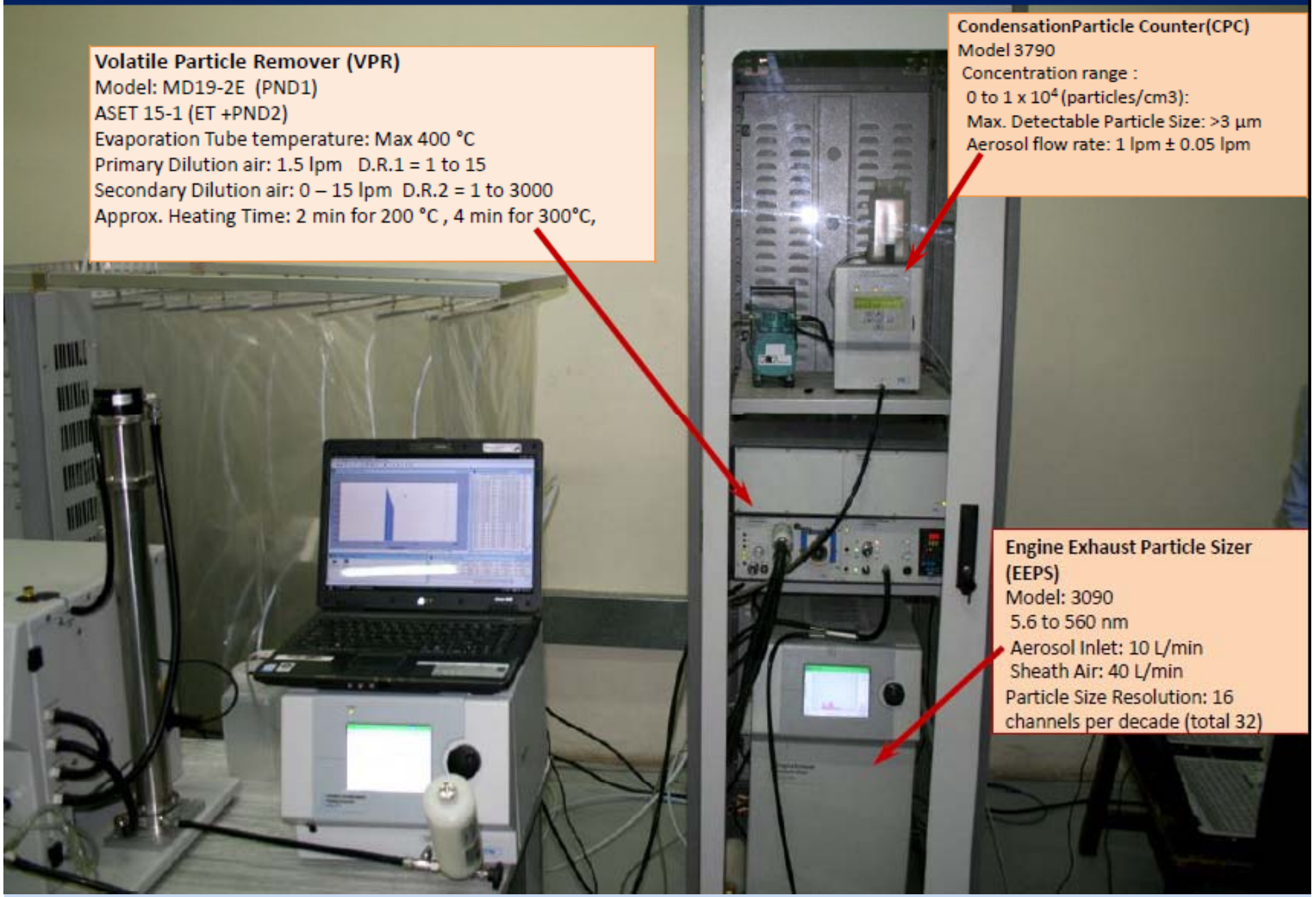
Nano Particle Measurement Equipment Setup



Nano Particle Measurement Setup



New Emission Test Facilities under NATRiP

- Transient Engine Dynamometers with Full Flow Dilution Tunnel (220 kW & 500 kW)
- 4 X 4 Chassis Dynamometers for Emissions
- Climatic 4 X 4 Chassis Dynamometer with Solar Simulation
- 4 X 4 Chassis Dynamometers for Mileage Accumulation
- SHED for Gasoline Evaporative Emissions

4 X 4 Chassis Dynamometer for Emission:

- **All chassis dyno Facilities will be ready In 12-18 months**
- **Conforming to Euro V**
- **2 Axle with 150 kW 2 Nos.AC motor**

Climatic chamber 4 X 4 Chassis Dynamometer with Solar simulation:

Climatic Chamber Conditions: - 30°C to +55°C

4 X 4 Chassis Dynamometer with Robot for Mileage Accumulation:

New Emission Test Facilities under NATRiP

Transient Engine Dynamometers with Full Flow Dilution Tunnel (220 kW & 500 kW)

- **Broad Specifications :**
  - **Heavy Duty Transient Dynamometer :** 500kW @ 1600 to 3200rm, 3000 Nm @ 800 to 1600 rpm.
  - **Heavy Duty Transient Dynamometer :** 220kW @ 2200 to 4500rm, 960 Nm @ 1000 to 2200 rpm.
  - **Emission Analyser :** Suitable for measurement up to Euro V.

Useful for :

- Automotive BSIV, BSIII
- Tractor Trem IIIA
- CEV BSIII
- Export Homologation
- High Altitude Simulation
- Friction Mapping testing
- Vehicle Simulation

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New Emission Test Facilities under NATRiP

Full Flow Emission Measurement facility for Transient Engine Dynamometers

❑ Emission & Particulate Measurement Details

CO (L) NDIR Analyser Range	**50 to 5000 ppm**
THC HFID Analyser Range	10 to 5000 ppmC
CH4/ THC HFID Analyser Range	10 to 5000 ppmC
NO/ NOx HCLD Analyser Range	10 to 5000 ppm
CO2 NDIR Analyser Range	0.5 to 6 % Vol
NH3 HCLD Analyser Range	10 to 1000 ppm
Model	Full Flow Particulate Measurement
Make	HORIBA, Japan
Full flow dilution tunnel diameter	ϕ 18”
Secondary dilution tunnel diameter	ϕ 5”
Filter Holder Size	ϕ47mm & ϕ70mm
Suitability	BSIII & BSIV ESC as well as Transient testing

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National Ambient Air Quality Standard (CPCB)(16thNov.09)

Sr No	Pollutants	Time Weighted Average	Concentration in Ambient Air					Method of measurement
			Induatrial, Residential ,Rural and Other Area	Indutrial Areas	Residential Area	Ecologically Sensitive Area (notified by Central Govt.)	Sensitive Area	
1	Sulphur Dioxide (SO_2), µg/m3	Annual	50	80	60	20	15	Improved West and Gaeke Method
		24 hours	80	120	80	80	30	- Ultraviolet Fluorescence
2	Nitrogen Dioxide (NO2) , µg/m3	Annual	40	80	60	30	15	Modified Jacob & Hochheiser Modified
		24 hours	80	120	80	80	30	(Na-Arsenite) Method
								- Gas Phase Chemiluminescence
3	Particulate Matter (size less than 10 µm) or PM 10 µg/m3	Annual	60	120	60	60	50	Gravimetric / TEOM / Beta Attenuation
		24 hours	100	150	100	100	75	
4	Particulate Matter(size less than 2.5 µm) or PM2.5,	Annual	40	NA	NA	40	NA	Gravimetric / TEOM / Beta Attenuation
		24 hours	60			60		
5	Ozone (O_3), µg/m^3	8 hours	100	NA	NA	100	NA	- UV Photometric technology
		1 hour	180			180		- Chemiluminescences
								Chemical Method
6	Lead (Pb), µg/m3	Annual	0.5	1	0.75	0.5	0.5	AAS /ICP Method after sampling using EPM 2000 or equivalent
		24 hours	1	1.5	1	1	0.75	ED XRF using Teflon Filter
7	Carbon Monoxide (CO) mg/m3	8 hours	2	5	2	2	1	Non Dispersive Infra Red (NDIR) Spectroscopy
		1 hour	4	10	4	4	2	
8	Ammonia (NH3) , µg/m3	Annual	100	100	100	100	100	-Chemiluminescence
		24 hours	400	400	400	400	400	- Indophenol- blue method
9	Benzene(C6H6), µg/m3	Annual	5	NA	NA	5	NA	Gas Chromatography based continuous analyzer,
								Adsorption and desorption followed by GC analysis
10	Benzo a Pyrene (BaP) (particulate phase only), ng/m3	Annual	1	NA	NA	1	NA	Solvent extraction followed by HPLC/GC analysis
11	Arsenic, ng/m^3	Annual	6	NA	NA	6	NA	AAS /ICP Method after sampling using EPM 2000 or equivalent
12	Nickel, ng/m^3	Annual	20	NA	NA	20	NA	
Note :-				New NAAQ Standards				
				Old NAAQ Standards				

Inertia setting for different categories of vehicles

For the purpose of mass emission testing and constant speed emission testing, the following inertia setting for the dynamometer was used.

Veh. Cat	Inertia Setting
2 wheeler	ULW +75 kg
3-wheelers gasoline	225 kg (3 passengers X 75)
3-wheeler diesel	GVW
Passenger cars	ULW+225 kg (3 passengers X 75 kg)
Multi Utility Vehicles	ULW+450 kg (6 passengers X 75kg)
LCV: Bus	ULW + 1500 kg (equivalent to 20 passengers of 75 kg weight each)
LCV: Trucks:	GVW (As specified by the vehicle manufacturer)
HCV: Bus	ULW + 4500 kg (Equivalent to 60 passengers of 75 kg each)
HCV: Trucks	GVW (To be limited to 20 ton max. for GVW > 20tons. If GVW is less than 20 tons, Inertia set to the maximum specified GVW)

Emission Factors for Indian Vehicles

1. Methodology:

The vehicle categorization is given in the table below:

<table>
<tr><th>Fuel
Vehicles type</th><th colspan="2">Gasoline</th><th colspan="2">Diesel</th><th colspan="2">CNG</th><th colspan="2">LPG</th></tr>
<tr><td rowspan="4">Two wheeler</td><td>Two Stroke</td><td>Four Stroke</td><td>Two Stroke</td><td>Four Stroke</td><td>Two Stroke</td><td>Four Stroke</td><td>Two Stroke</td><td>Four Stroke</td></tr>
<tr><td>Less than 80CC; and</td><td>Less than 100CC;</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td></tr>
<tr><td>above 80CC</td><td>100 – 200CC; and</td></tr>
<tr><td></td><td>Above 200CC</td></tr>
<tr><td>Three wheeler</td><td>Less than 200CC</td><td>Less than 200CC</td><td>-</td><td>Upto 500CC; and
Above 500CC</td><td>-</td><td>Less than 200CC; and Above 200 cc</td><td>-</td><td>Less than 200CC; and Above 200 cc</td></tr>
<tr><td rowspan="2">Four wheeler (Car + multi-utility vehicles)</td><td colspan="2">Less than 1000CC;</td><td colspan="2">Less than 1600CC;</td><td colspan="2" rowspan="2">Less than 1000CC; 1000 – 1400CC; and Above 1400CC</td><td colspan="2" rowspan="2">Less than 1000CC; 1000 – 1400CC and Above 1400CC</td></tr>
<tr><td colspan="2">1000 – 1400CC; and Above 1400CC</td><td colspan="2">1600 – 2400CC; and Above 2400CC</td></tr>
<tr><td rowspan="2">LCV</td><td colspan="2" rowspan="2">-</td><td colspan="2" rowspan="2">Less than 3000CC; and Above 3000CC</td><td colspan="2">Less than 3000CC; and</td><td colspan="2">Less than 3000CC; and</td></tr>
<tr><td colspan="2">Above 3000CC</td><td colspan="2">Above 3000CC</td></tr>
<tr><td>HCV</td><td colspan="2">-</td><td colspan="2">Above 6000CC</td><td colspan="2">Above 6000CC</td><td colspan="2">-</td></tr>
</table>