3rd AAI Summit, Bangkok (Thailand)

Hotel Novotel IMPACT (Room Jupiter 6)

Technical Session : Fuel Economy & Emission

Road Map of Fuel Efficiency and Emissions in India

Neelkanth V. Marathe

Senior Deputy Director & Head

Power Train Engineering

Automotive Research Asso of India

ARAI, Pune (India)

3rd December 2014

PRESENTATION OUTLINE

- Quick statistics about India
- Need of Emission and Efficiency Road map
- Status of Emission norms : Road vehicles and Non-road vehicles
- Status of Fuel efficiency norms
- Efficiency labeling
- Air Quality Controls
- Alternate fuels
- Closing Remarks

1

Quick statistics about India

THE INDIA

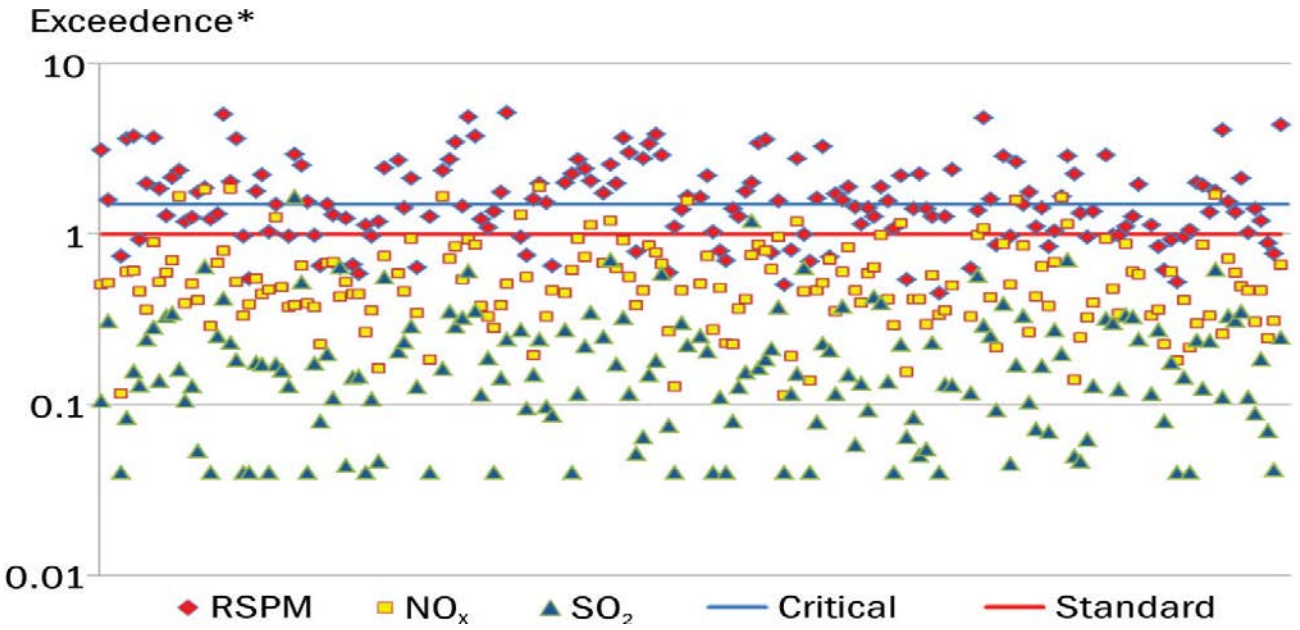
- India is the 7th largest country in the world covering an area of 3.5million square kms
- India has a population of 1.2 Billion.
- India is 3rd largest economies in the world by purchasing power parity.
- 30 percent of India population (Census 2011) live in urban areas and the rate of urbanisation is growing steadily.
- The automobile population in India has increased from a mere 0.3 million in 1951 to more than 141 million in 2013. The growing cities have generated high levels of demand for travel by motor vehicles in the cities.
- The increasing in purchasing power of the individuals and easy loan from the banks to buy automobiles has resulted in tremendous increase in the population of automobiles in the cities.
- Due to higher income levels and greater needs for mobility in the urban areas, more automobiles are owned and operated by individuals. This trend is backed by the development of better quality road network connecting rural areas.

- The Indian Auto Industry is harmonizing both Safety & Emission regulations with International Standards for sustained growth of the Industry for combating the environment and become a global export hub.
- The Safety Regulations are being aligned with the ECE regulation and the Road Map prepared by SIAM envisages alignment by 2010.
- In India, the vehicle population is growing at rate of over 5% per annum and today the vehicle population is approximately 40 million. The vehicle mix is also unique to India in that there is a very high proportion of two wheelers (76%).

Ambient Air Pollution in India

- Eighty per cent of Indian cities already violate the National Ambient Air Quality Standards (NAAQS) for Respirable Suspended Particulate Matter (RSPM) concentrations. Concentration of oxides of nitrogen (NO_x) in Indian cities are close to the standards and are expected to exceed in future.

- Not just big cities, but many smaller cities are also critically polluted, with exceedance levels1.5 times more than the norm for RSPM.



Annual air pollutant concentrations in Indian cities (2010) with respect to prescribed standards

Source: CPCB (2012)

Impacts

- Ambient air pollution has been identified as the fifth biggest cause of mortality in India.
- Fine particulate matter from diesel engine exhaust, has been linked with increasing risk of lung cancer (WHO 2012).
- Air pollutants such as Ground Level Ozone (GLO) which are formed by the reactions of precursors like NOX and Volatile Organic Compounds (VOCs) caused an estimated loss of about 5.6 million tonnes in the yields of wheat, rice, cotton, and soybeans in India in 2005. This amounts to approximately USD 1.3 billion of economic loss (Ghude *et al*., 2014).
- Black carbon (a dominant part of the particulate matter from diesel engines exhausts) is now known to have the second highest radiative forcing (Bond *et al*., 2013).
- Growing air pollution has made the capital city of Delhi rate among the top polluted cities of the world.
- Transport sector is one of the prime contributors to air pollution in cities.

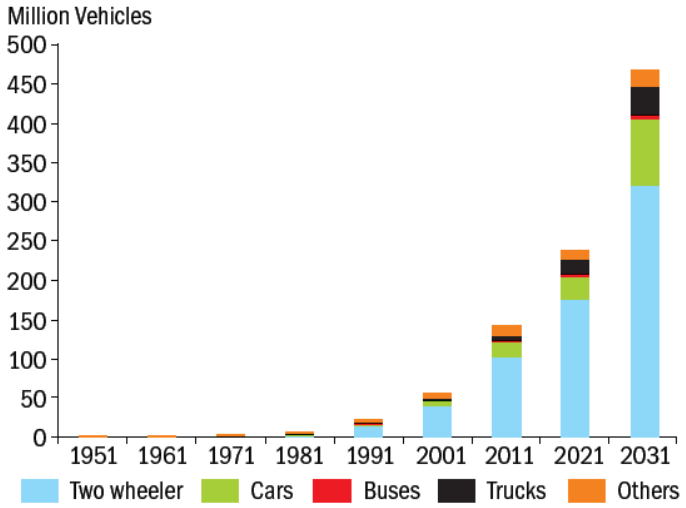
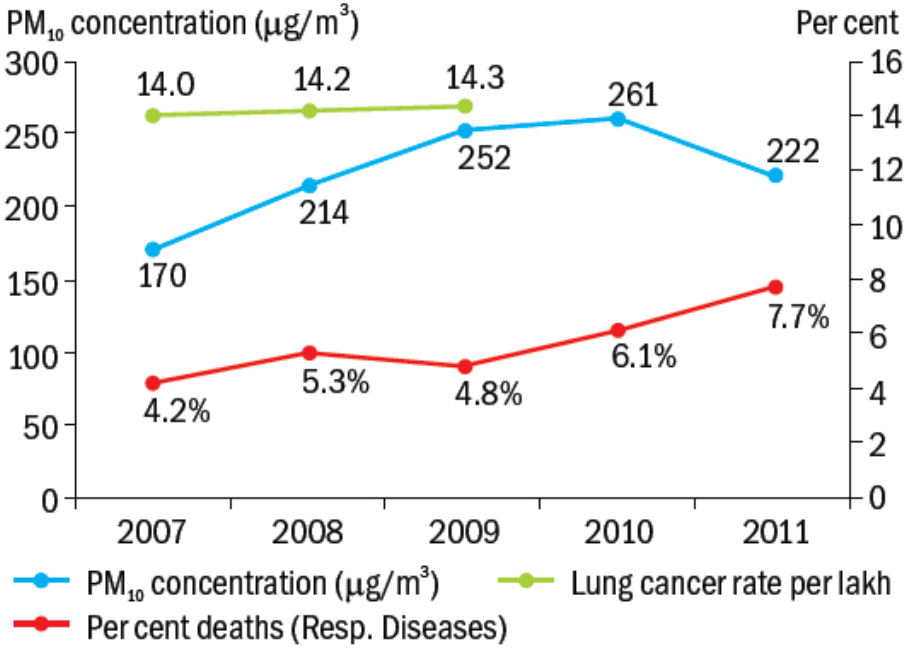
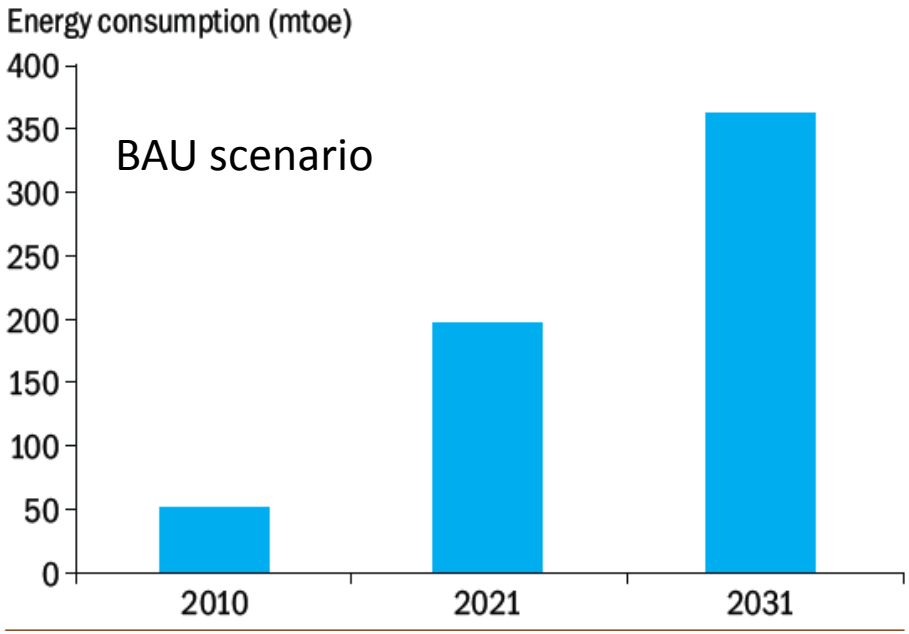


Figure 4: Growth of vehicles in India (1951–2031)
Source: MoRTH (2013), TERI (2014)



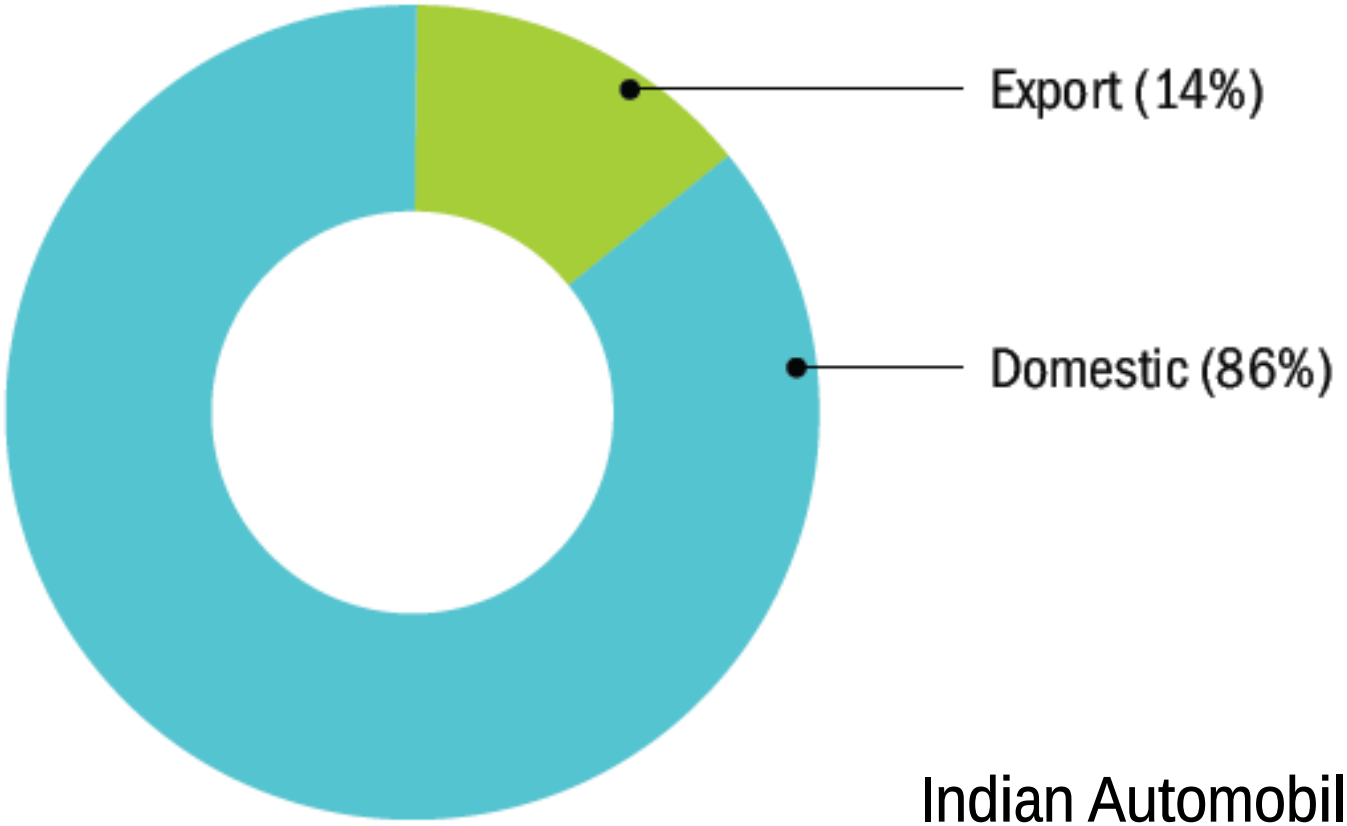
Status in Delhi (CPCB 2014), ICMR 2013), (GNCTD 2013)



Energy Consumption
in the road transport sector in India
(MoRTH 2013), (TERI 2013)

Share of domestic and export vehicles in India

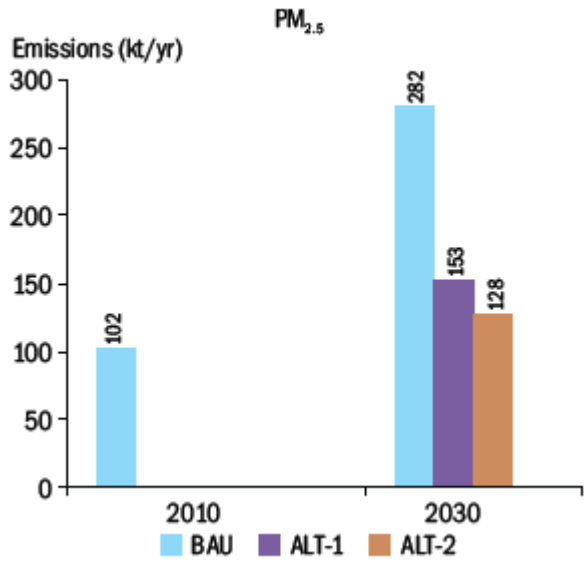
(SIAM 2013)

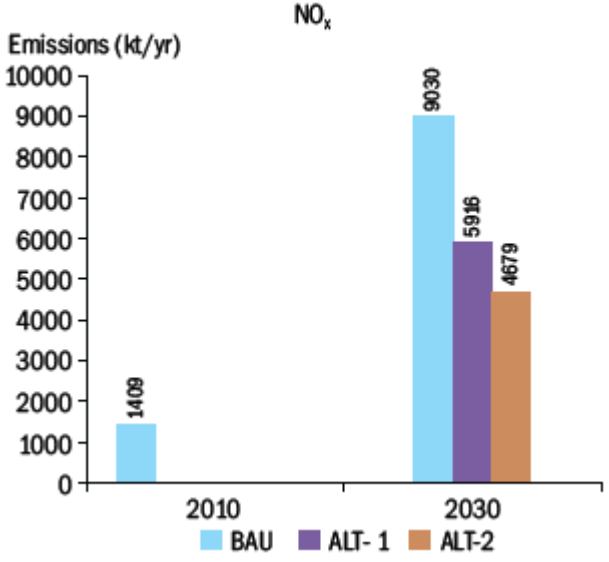


Indian Automobile Industry Growth

- Domestic growth : 12%
- Export growth : 25%

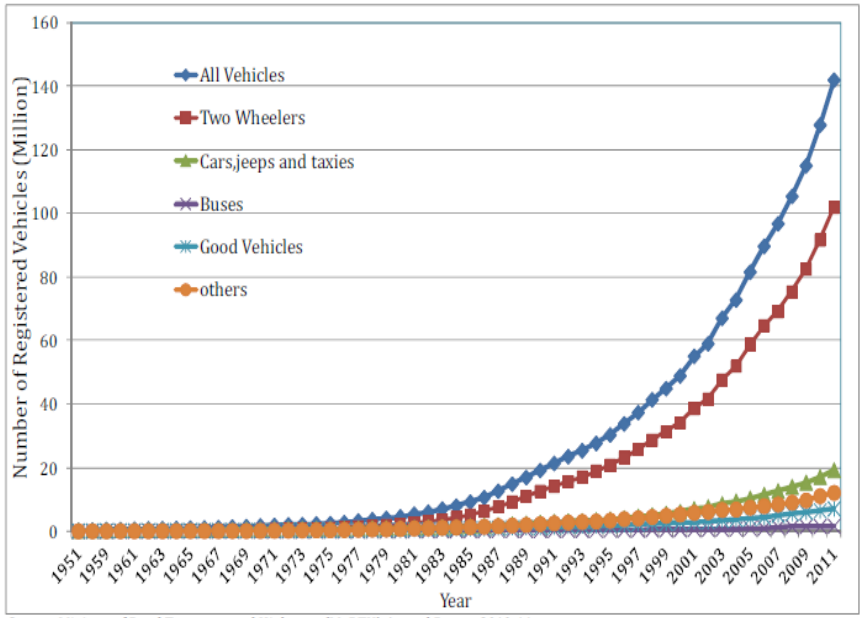
PM and NOx emission reduction in different scenarios





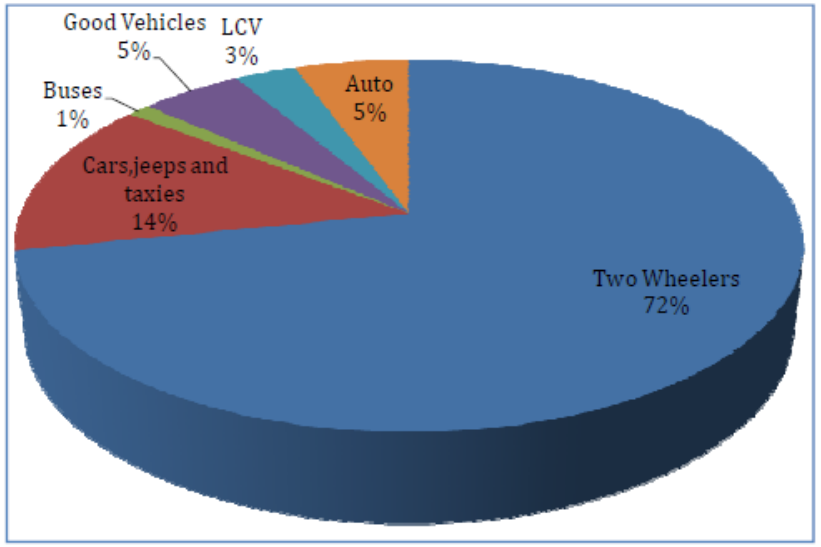
Scenario	Description
BAU	Based on current plans and policies of the government (BS-III all across the country and BS-IV in 13 cities)
ALT-1	BS-IV all across the country by 2015 and BS-V in 2020
ALT-2	BS-IV all across the country by 2015, BS-V fuel by 2018 and BS-VI emission norms in 2020

- An advancement to BS-V standards by 2020 (ALT-1) can result in significant emission benefits (46 per cent).
- However, introduction of BS-VI emission standards (ALT-2 scenario) by 2020 which involve the use of advanced tail-pipe treatment devices can reduce the PM emissions to lowest possible levels.



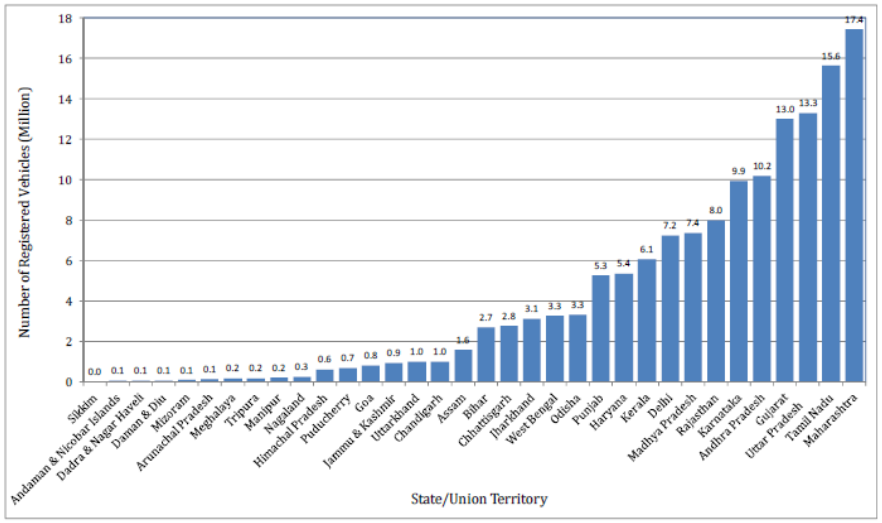
Source: Ministry of Road Transport and Highways (MoRTH) Annual Report 2010-11

Total number of registered vehicles in India



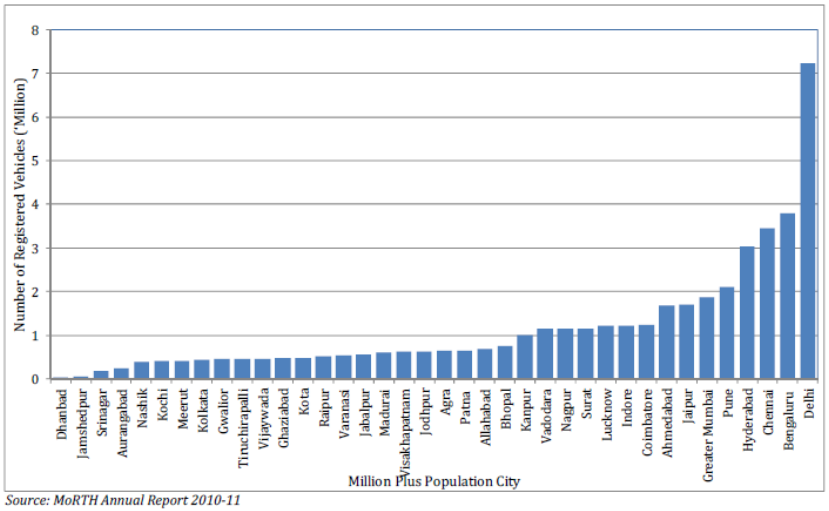
Source: MoRTH Annual Report 2010-11; Note: LCV-Light Commercial Vehicles (up to 7 Tonne load carrying capacity)

Composition of total number of registered vehicles in India



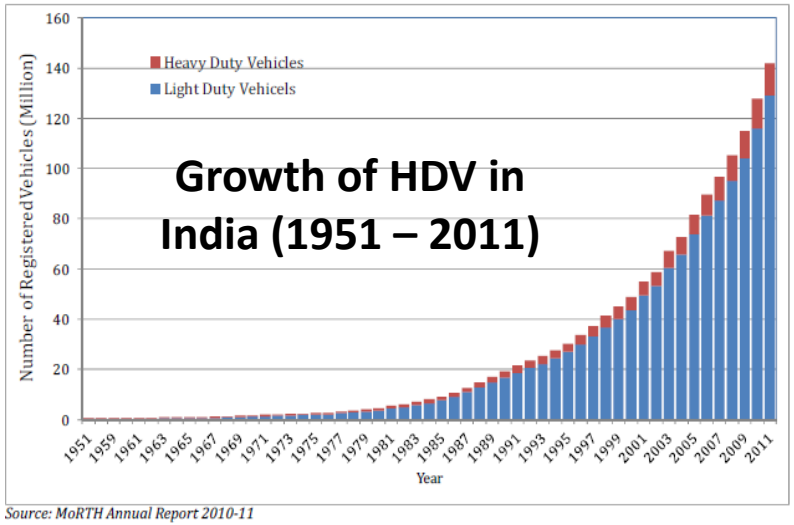
Source: MoRTH Annual Report 2010-11

Total number of registered vehicles – State & UT wise



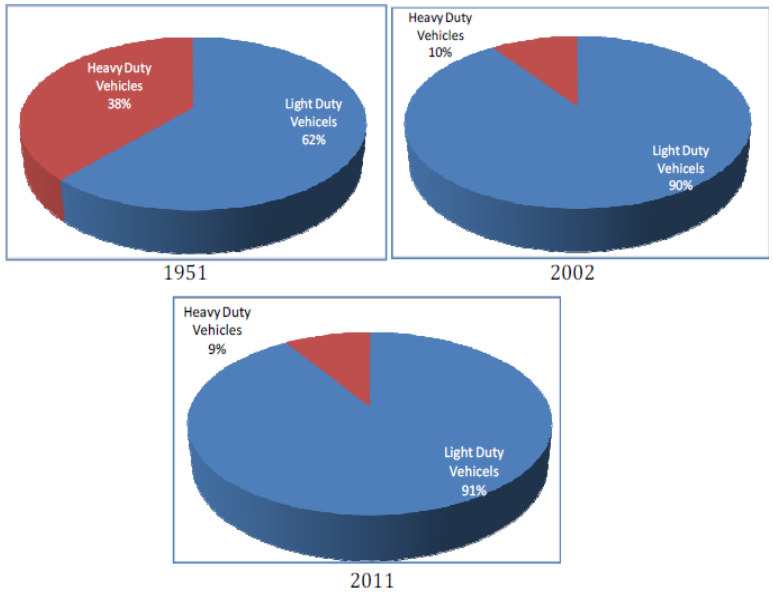
Source: MoRTH Annual Report 2010-11

Total number of registered vehicles in Metro cities (1million plus) in India



Source: MoRTH Annual Report 2010-11

- Absolute number of HDV was increased. Increase in LDVs was more.
- HDV composition reduced from 38 % (1951) to 10 % (2002) and further to 9% (2011).
- Increased competition among the road and rail mode for goods transportation.
- Resulted in increased pressure on existing road network - increase in growth of the different commercial vehicles and also average daily kilometers travelled

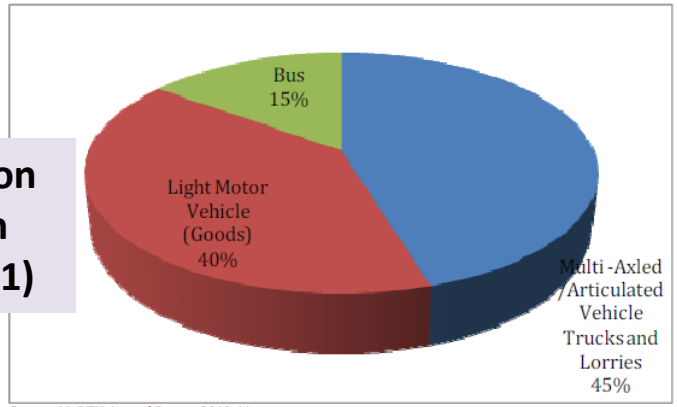


Change in composition in India – HDV vs LCV (1951 – 2011)

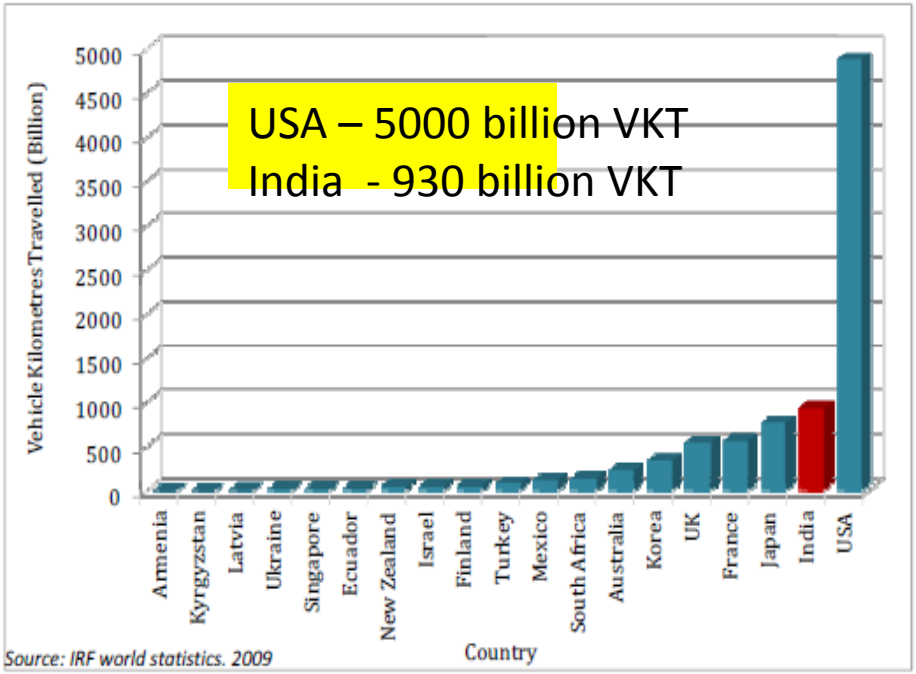
HDV composition (2011)

- Light Commercial Vehicle (LCV) - 40 %
- Heavy Commercial Vehicle (HCV) and Multi-Axle, Commercial Vehicles (MAV) ~45%
- Buses ~15 %

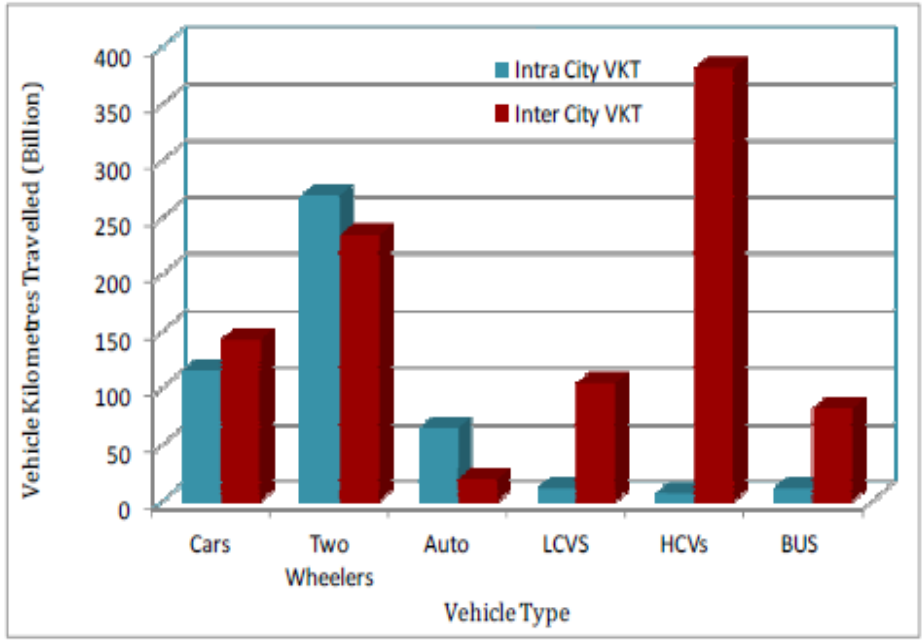
Composition of HDV in India (2011)



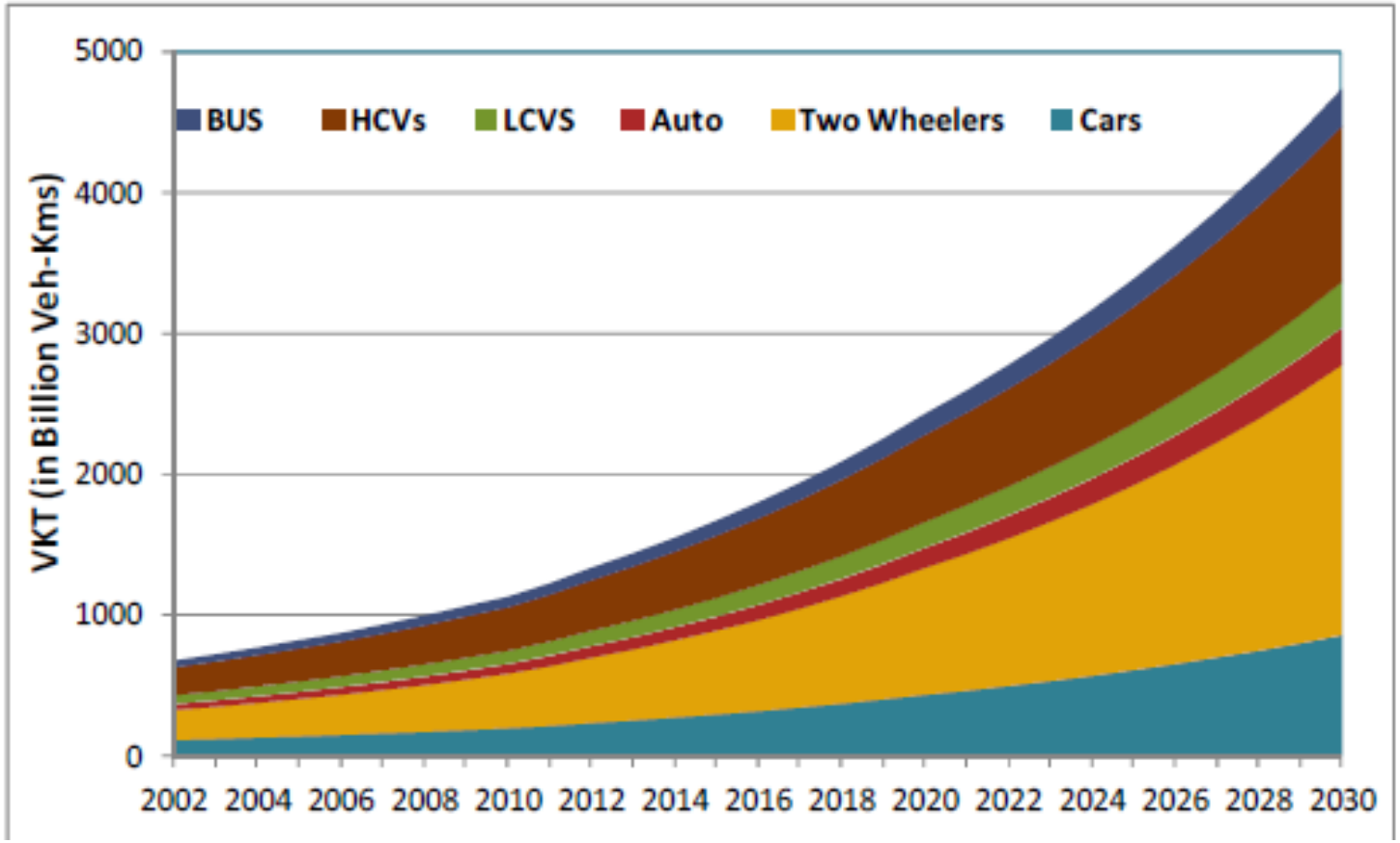
Source: MoRTH Annual Report 2010-11



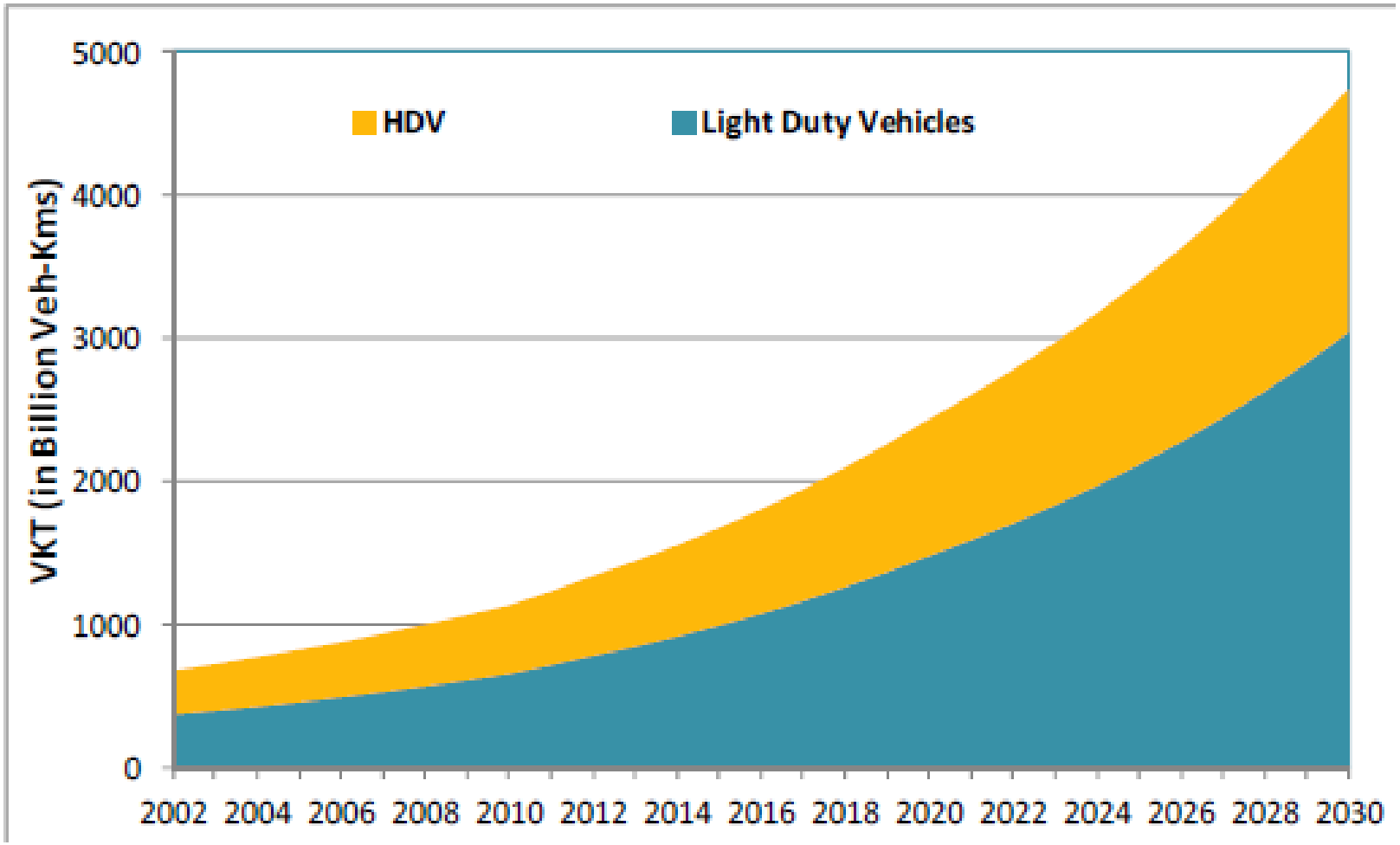
Vehicle kms travelled in selected countries (2007)



Annual vehicle kilometers travelled by different vehicles



Growth of Vehicle kms travelled at National Level (2002 – 2030)



Growth of Vehicle kms by HDV and LDVs at National Level (2002 – 2030)

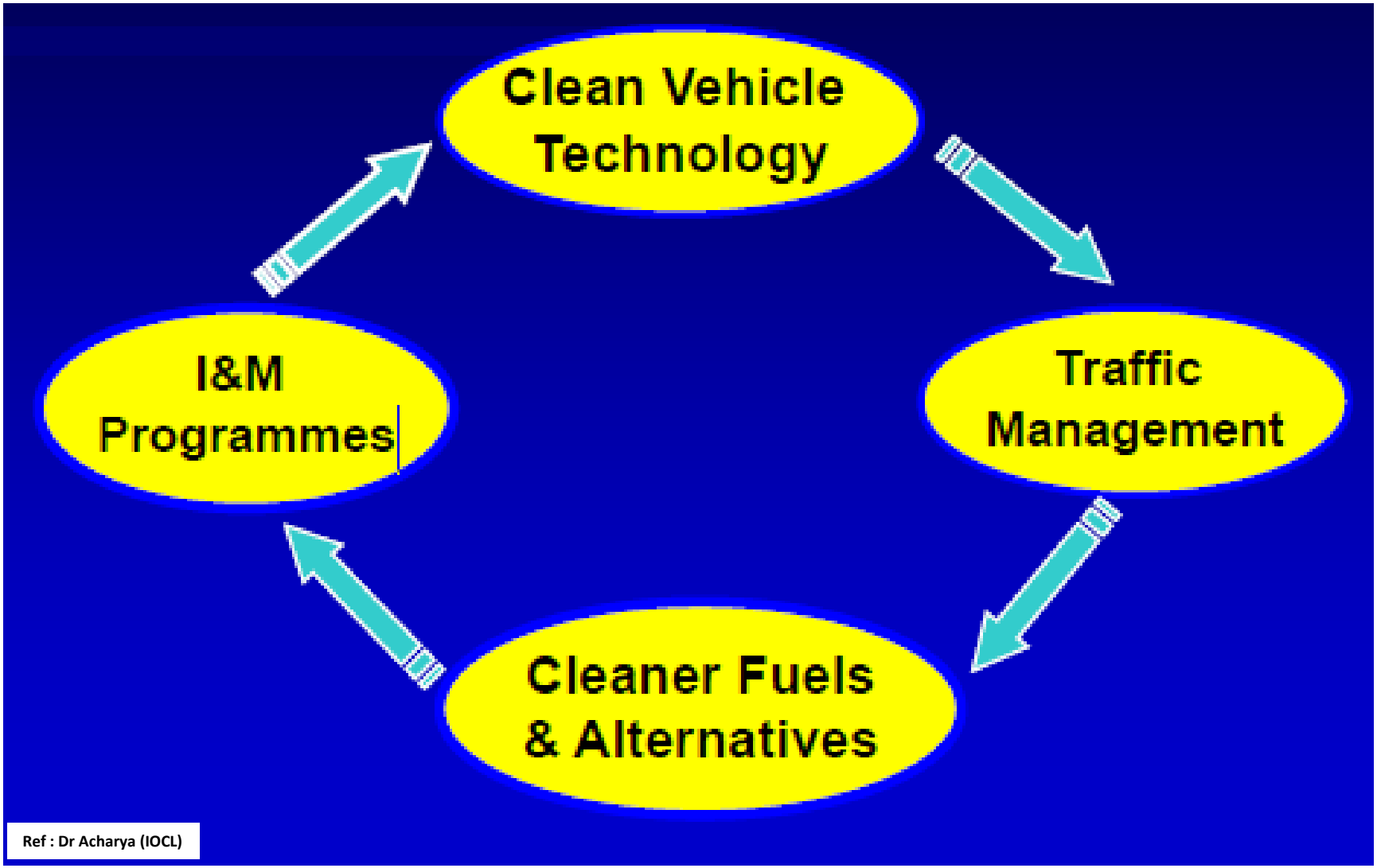
2

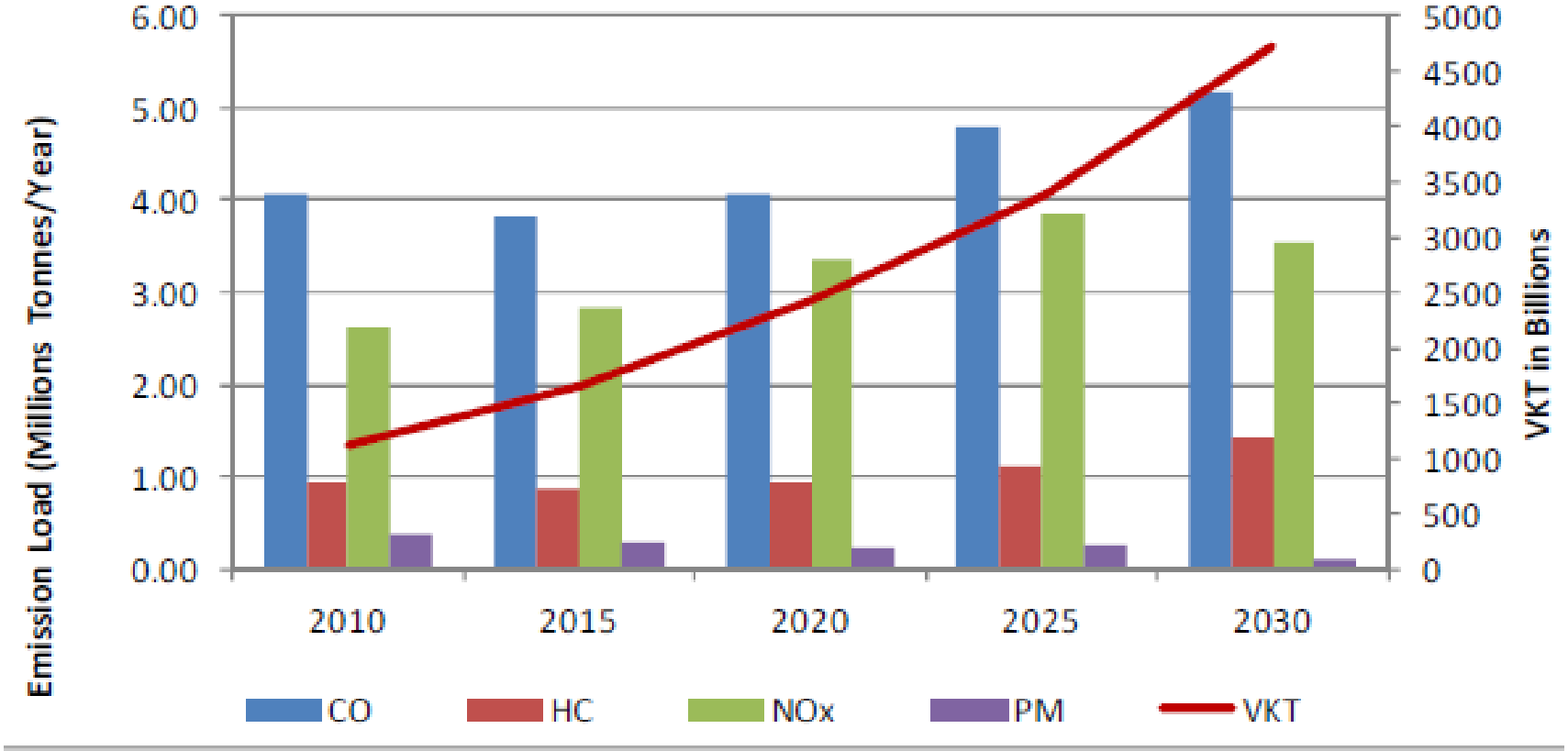
Need of Emission and Efficiency Road map

World Class Vehicle Emission and Fuel Efficiency Norms. WHY ??

- Increasing air pollution has become a great health hazard and is responsible for increase in respiratory and cardiovascular diseases in the urban areas.
- The Government's policy of gradually withdrawing the subsidy on diesel may have only a marginal impact on GHG emissions as most of the diesel consumption is by commercial vehicles, where a switchover to any other form of fuel is not possible.
- The use of diesel by private cars and SUVs may reduce on account of the increasing consumer prices.
- It is, therefore, a need for stricter fuel emission norms in order to bring a drastic reduction in fuel usage and as well as air pollution.

Major Factors affecting Energy Efficiency in Transport Sector





Vehicle Emission Loads with proposed emission norms (2010-2030)

Diesel most consumed in domestic market

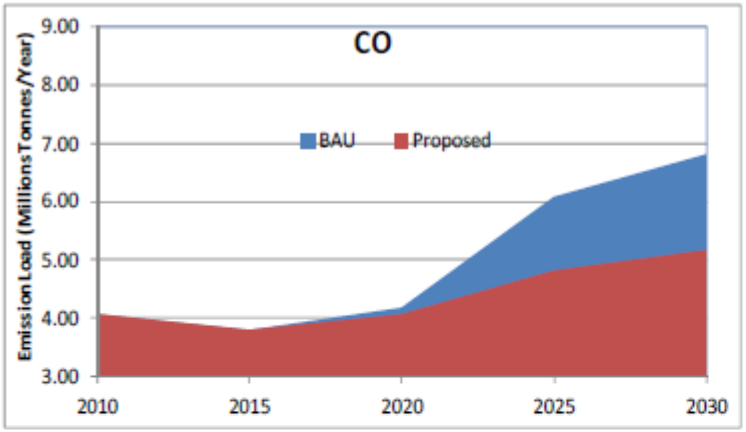
- Diesel accounts for over 43% of 158.2 million tonne of petroleum products consumed in 2013-14

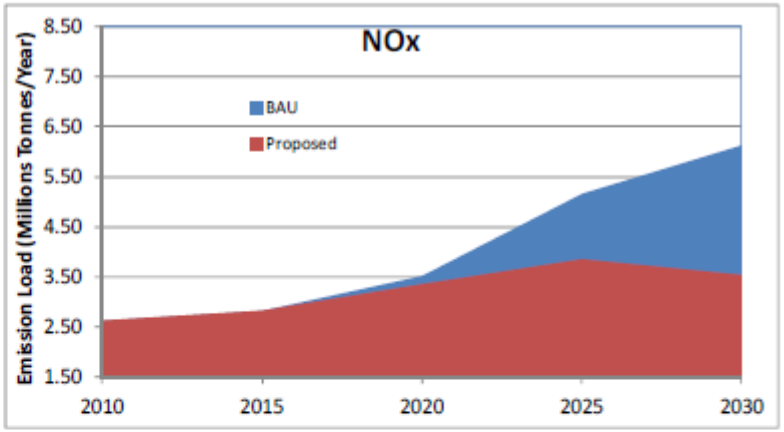
- Crude oil prices are rising.

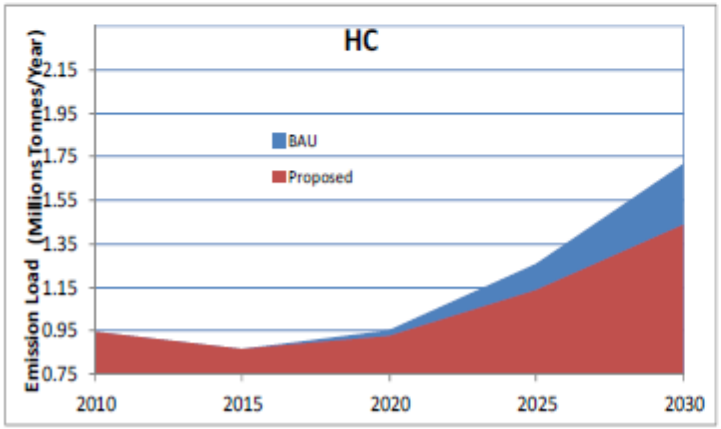
- This can hurt India tremendously as it imports nearly 80 per cent of its crude oil needs.

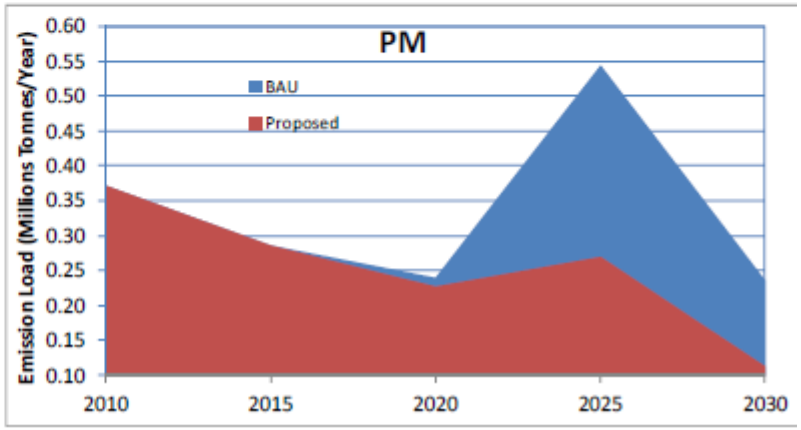
- According to the International Energy Agency, cars will be one of the primary drivers of energy demand in the transport sector in the coming decades.

India needs effective fuel economy targets and strictly enforceable regulatory design for passenger cars.

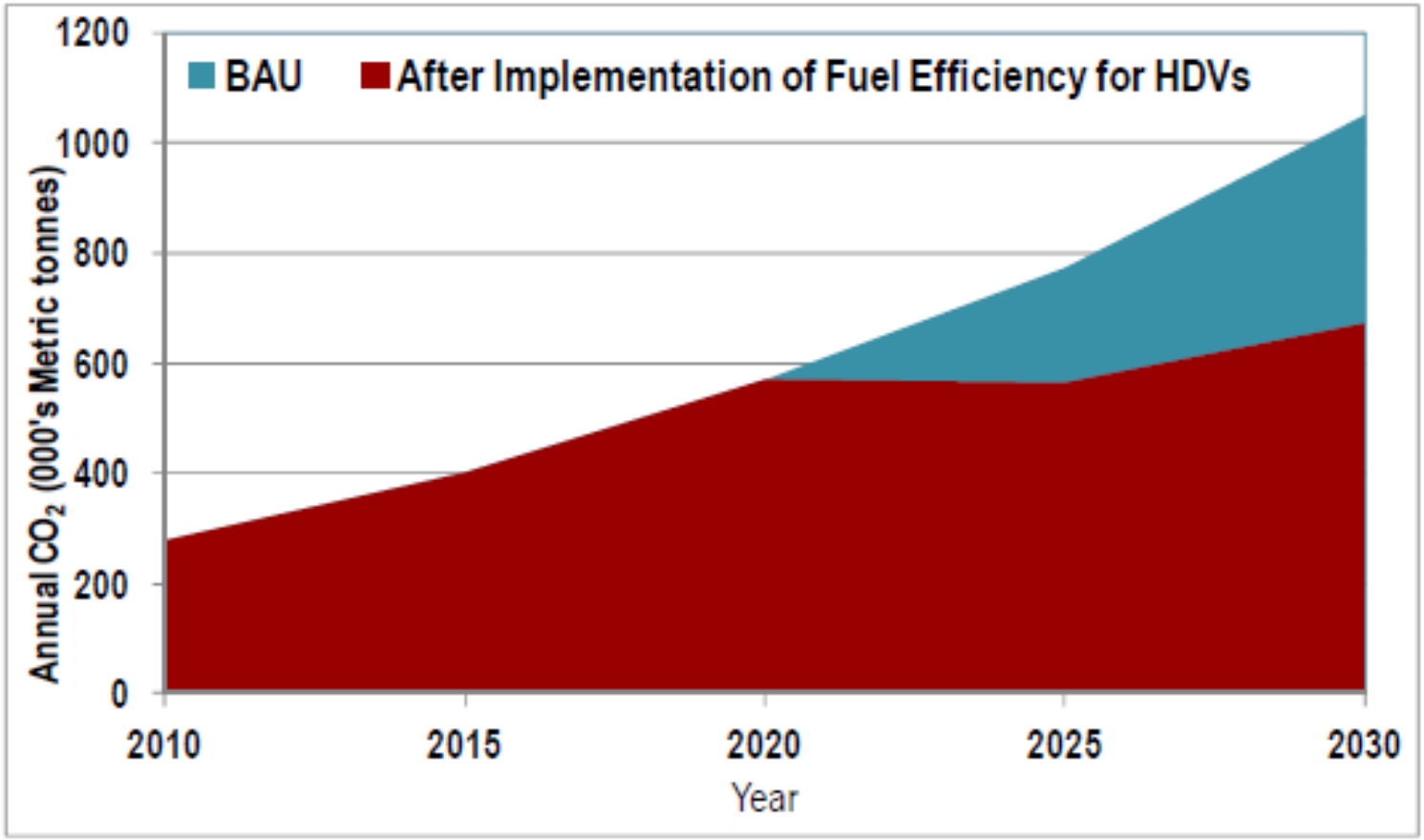








Projected annual emissions with proposed policy action (2010 – 2030)



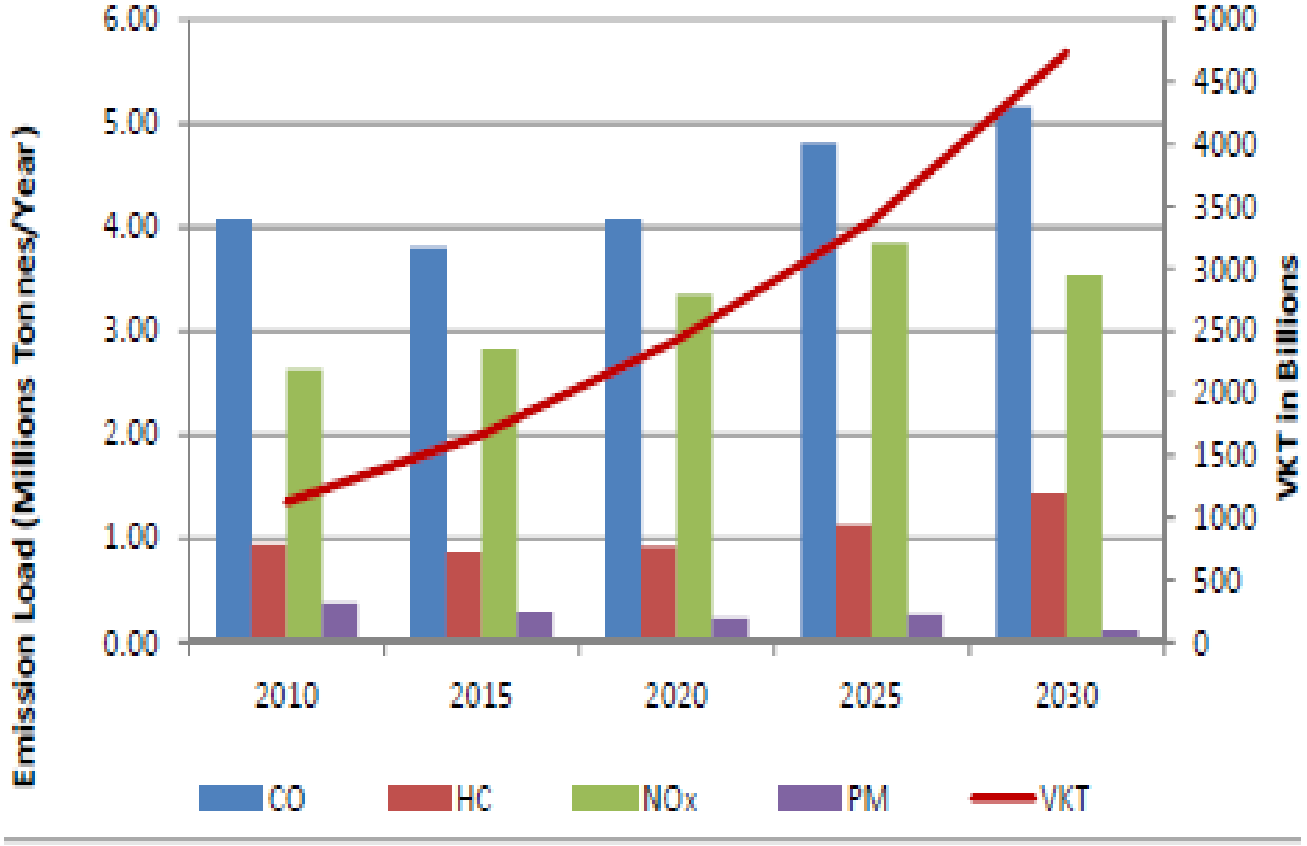
Annual CO2 emission from HDVs considering implementation of all modes and Fuel efficiency policy

Vehicle Emission Norms (India)

- Vehicle population in India has grown tremendously since the year 1951.
- Number of vehicles registered in 28 states and 7 union territories of India ~ 141 million (2011).
- Vehicle Kilometres travelled increased from 673 Billion (2002) to 4733 Billion (2013).
- The Auto Fuel Policy -2003 laid down a road map for vehicular emission and fuel quality standards for the remainder of the new century's first decade. This road map has been largely implemented.
- In 2010, Bharat IV fuel quality standards and vehicle emission standards for four-wheeled vehicles were implemented in 13 major cities, while Bharat III standards took effect in the rest of the country. As of January 2013, Bharat IV standards had been expanded to about ten more cities, most of which are along fuel supply routes. For two- and three-wheelers, India followed an independent path and regulated emissions in a different manner than Europe and China.
- This first phase of emission reductions from all on-road vehicular sources represents great progress.
- Further due to congestion in the road network and in absence of proper polices to tackle the Vehicle kilometres Travelled by the vehicles, marginally reduced the benefits gained

(CRRI, 2009)

Estimation of Vehicle Emission Loads



Vehicle emission loads with proposed emission norms in India (2002-2030)

3

Status of Emission norms : Road vehicles and Non-road vehicles

DRIVING FORCE

- The health impacts of the deteriorating ambient air quality in urban cities worldwide are of serious concern.
- According to the World Health Organisation (WHO), one of the top ten causes of death is attributed to air pollution (WHO, 2010); diesel engine exhaust, for instance has been linked with increased lung cancer risk (WHO, 2012).
- Motor vehicles are one of the major sources contributing to air pollution at local, regional and global scale.
- India, which has the largest number of megacities in the world, is facing serious air quality problems in its urban areas.
- India's transport sector is the fastest growing consumer of energy. Recognising these adverse environmental effects, the Government of India has taken several policy measures to bring down the pollution levels due to vehicular sources.

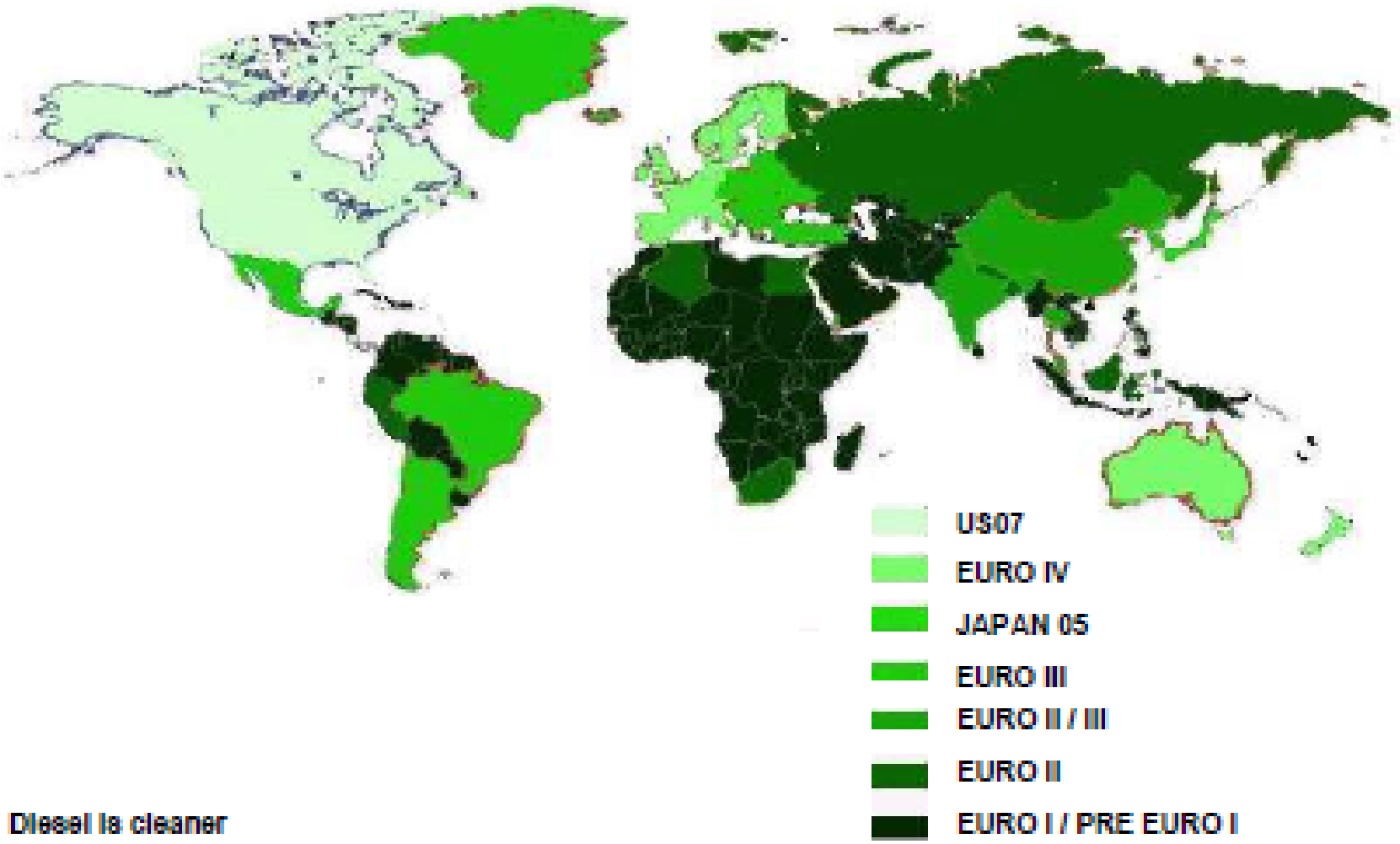
DRIVING FORCE

- Improvement in vehicular technology and the quality of fuel aimed at reducing tail-pipe emissions from vehicular sector are significant interventions amongst several others.

- While the developed world has moved to the stricter Euro-V/VI emission norms, the developing countries like China and India have only reached the level of Euro-III equivalent norms across the country.

- It may be noted that in India there is only one set of ambient air quality standards applicable for the whole country, however, two different vehicle emission/fuel quality standards exists for different regions.

Current status of emission standards worldwide



EMISSION REGULATIONS IN INDIA

- 2 wheelers
- 3 wheelers
- Passenger cars, LMV, SUVs
- HCVs – truck and buses
- Agricultural Tractor
- CEVs (Construction equipment Vehicles)
- Diesel Generator Engines
- Petrol Generator Engines

Overview of the emission norms in India

- **1991** – Idle CO Limits for Gasoline Vehicles and Free Acceleration Smoke for Diesel Vehicles, Mass Emission Norms for Gasoline Vehicles.
- **1992** – Mass Emission Norms for Diesel Vehicles.
- **1996** – Revision of Mass Emission Norms for Gasoline and Diesel Vehicles, mandatory fitment of Catalytic Converter for Cars in Metros on Unleaded Gasoline.
- **1998** – Cold Start Norms Introduced.
- **2000** – India 2000 (Equivalent to Euro I) Norms, Modified IDC (Indian Driving Cycle), Bharat Stage II Norms for Delhi.
- **2001** – Bharat Stage II (Equivalent to Euro II) Norms for All Metros, Emission Norms for CNG & LPG Vehicles.
- **2003** – Bharat Stage II (Equivalent to Euro II) Norms for 13 major cities.
- **2005** – From 1 April Bharat Stage III (Equivalent to Euro III) Norms for 13 major cities.
- **2010** – Bharat Stage III Emission Norms for 4-wheelers for entire country whereas Bharat Stage – IV (Equivalent to Euro IV) for 13 major cities. Bharat Stage IV also has norms on OBD (similar to Euro III but diluted)

Data Source: Wikipedia.org

BHARAT STAGE IV EMISSION STANDARDS FOR TWO-WHEELERS IN INDIA

- India finalized the fourth stage of emission standards for motorized two-wheeled vehicles on July4, 2014.

- The Bharat Stage (BS) IV standards will go into effect for type approval of new motorcycle models in April 2016, and for all motorcycle models in April 2017.

- The Bharat Stage IV standards cover motorized two-wheeled vehicles with engine displacement volume above 50 cc and a maximum design speed above 50 km/h (Vd > 50 cc, VMax > 50 km/h).

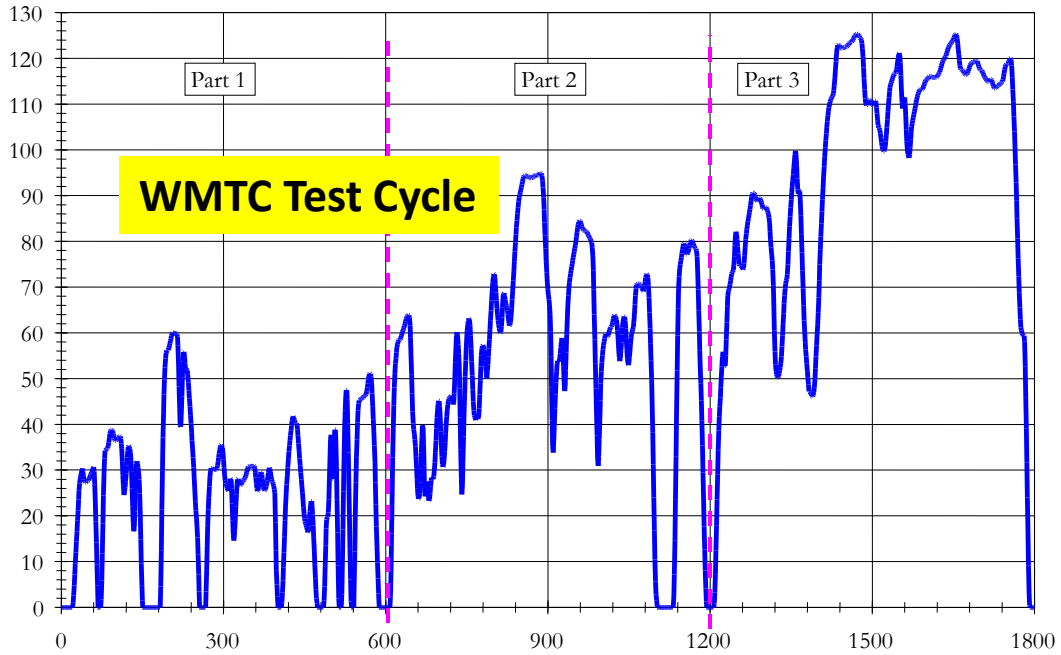
Highlights of proposed BS(IV) :

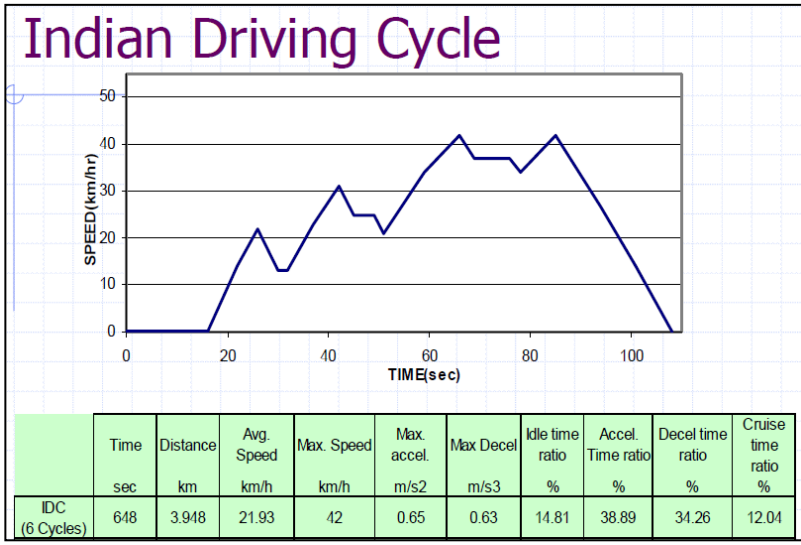
- new standards tighten the HC+NOX emission limits by 23%–60%, depending on motorcycle category. Independent NOx standard in addition to HC+Nox.
- adoption of the Worldwide Harmonized Motorcycle Test Cycle (WMTC) as the mandatory test cycle. India has now harmonized the testing cycle as well as the definition of motorcycle categories as per United Nations Economic Commission for Europe (UNECE) Global Technical Regulation 2 (GTR-2).
- establishes the first evaporative emission standards for two-wheelers in India.
- BS IV standard prohibits release of crankcase emissions form BS IV motorcycles into the atmosphere.

BHARAT STAGE IV EMISSION STANDARDS FOR TWO-WHEELERS IN INDIA

The WMTC better reflects real driving conditions, with higher maximum speed and steeper acceleration ramps than the IDC.

Another significant change is that BS IV defines independent NOX standards, in addition to the combined HC+NOX limits. This requirement will force manufacturers to adopt technology that specifically targets NOX, including electronic fuel injection, better designed three-way catalyst systems, and, very likely, oxygen sensors.





	Time	Distance	Avg. Speed	Max. Speed	Max. accel.	Max Decel	Idle time ratio	Accel. Time ratio	Decel time ratio	Cruise time ratio
	sec	km	km/h	km/h	m/s2	m/s3	%	%	%	%
IDC (6 Cycles)	648	3.948	21.93	42	0.65	0.63	14.81	38.89	34.26	12.04

BHARAT STAGE IV EMISSION STANDARDS FOR TWO-WHEELERS IN INDIA

Table 1 Emission standards for two-wheelers, India and Europe

Emission Standard for 2-W	Motorcycle Class	Emission Limits (g/km)[1]			
		CO	NO_x	$HC+NO_x$	
				If Evap. Test ≤ 2.0 g/test	If Evap. Test ≤ 6.0 g/test
Bharat III (2010) IDC	All 2-W	1.0	-	1.0	1.0
Bharat IV (2016 TA; 2017 AV)	Class 1 and Subclass 2-1	1.403	0.39	0.79	0.59
	Subclass 2-2	1.970	0.34	0.67	0.47
	Subclass 3-1 and 3-2	1.970	0.20	0.40	0.20
European Standards – WMTC testing					
Euro 3 (2006)	V_{max}<130km/h	2.62	0.17	0.92	0.92
	V_{max}≥130km/h	2.62	0.22	0.55	0.55
Euro 4 (2016 TA; 2017 AV)	V_{max}<130km/h	1.14	0.07	0.45	0.45
	V_{max}≥130km/h	1.14	0.09	0.26	0.26

[1] Test procedure and driving cycles according to WMTC GTR-2 regulations, incorporating amendment 2, with preconditioning soaking and colds starts. Emission sampling starts at t=0 seconds.

BHARAT STAGE IV EMISSION STANDARDS FOR TWO-WHEELERS IN INDIA

Motorcycle Class	Emission Limits (g/km)	
	CO	$HC+NO_x$
$V_d \leq 50$ cc and $V_{max} \leq 50$ km/h	0.75	0.75

BS IV emission standards for small 2-W vehicles
IDC test cycle

BHARAT STAGE IV EMISSION STANDARDS FOR TWO-WHEELERS IN INDIA

- The BS IV standards give manufacturers some flexibility by allowing certification under
- two different sets of evaporative and tailpipe emission limits.
- The alternative evaporative emission standards allowed in Bharat IV are 2 or 6 grams of hydrocarbons (HC) emitted during the sealed housing for evaporative determination (SHED) test.
- Manufacturers can elect to deploy vehicle designs able to meet the lower evaporative emission standard (e.g., sealed fuel systems) and rely less on tailpipe HC emission controls, or opt for the higher evaporative emission standard and employ engine and after-treatment systems to achieve lower tailpipe HC emissions.
- Currently only China, Taiwan Province of China, Thailand and the United States have adopted evaporative emission standards for motorcycles, typically at 2 g/test. Europe will implement this requirement by 2016–2017.

For the SHED test the vehicle is placed in a sealed, temperature-controlled chamber and evaporative hydrocarbon emissions are measured while the temperature within the chamber is varied to reflect variation in ambient temperatures over the course of a day.

In contrast to the EU, where durability is defined for 50,000 km, the Indian regulation sets the durability requirement for only 30,000 km.

Emission Standards in India for On-Road Diesel – CNG HDV engines (GVW > 3.5 t)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
India(LDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			
India-Cities (LDV)	Bharat IV							Bharat IV+					Bharat V					Bharat VI			
India (HDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			

Recommended Vehicle Emission Standards in India (ref : Auto Fuel Policy)

Emission Standards in India for On-Road Diesel – CNG HDV engines (GVW > 3.5 t)

BS III

Steady State

NOx g/kW-h	CO g/kW-h	NMHC g/kW-h
5	2.1	0.66

BS IV

Transient

NOx g/kW-h	CO g/kW-h	NMHC g/kW-h	Methane g/kW-h
3.5	4	0.55	1.1

OBD for Diesel as well as CNG will be implemented from 1-Apr-2013 on BS-IV engines / vehicles.
Its is similar to Euro-V OBD-Stage 2 regulations

DF

Engine Type	Test Cycle	NOx	HC	NMHC	CO	PM	CH4
Diesel Engine	ESC	1.05	1.05	---	1.10	1.10	---
Diesel Engine	ETC	1.05	1.05	---	1.10	1.10	---
CNG, LPG or Gaseous Engine	ETC	1.05	1.05	1.20	1.10	---	1.20

Emission Standards in India for Agricultural Tractor Engines

Bharat (Trem) Emission Standards for Diesel Agricultural Tractors

Engine Power	Effective from	CO	HC	HC + NOx	NOx	PM
kW		g/kW-hr				
Bharat (Trem) Stage I						
All	1999.10	14	3.5	-	18	-
Bharat (Trem) Stage II						
All	2003.06	9	-	15	-	1
Bharat (Trem) Stage III						
All	2005.06	5.5	-	9.5	-	0.8
Bharat (Trem) Stage III A						
P < 8	2010.10	5.5	-	8.5	-	0.8
8 ≤ P < 19	2010.10	5.5	-	8.5	-	0.8
19 ≤ P < 37	2010.10	5.5	-	7.5	-	0.6
37 ≤ P < 75	2011.10	5	-	4.7	-	0.4
75 ≤ P < 130	2011.10	5	-	4	-	0.3
130 ≤ P < 560	2011.10	3.5	-	4	-	0.2

Emission Standards in India for Power Tiller engines

Category	Test Cycle	Previous Norms - Trem II			
		Effective from	CO	HC + NOx	PM
			g/kW-hr		
-	ISO 8178-4 "C1" 8 Mode cycle	01-Oct-06	9.00	15.0	1.00
Category	Test Cycle	Current Norms - Trem III			
		Effective from	CO	HC + NOx	PM
			g/kW-hr		
-	ISO 8178-4 "C1" 8 Mode cycle	01-Apr-08	5.50	9.50	0.80

Emission Standards in India for CEV engines

Limit Values for Type Approval (TA) as well as for Conformity of Production (COP)

Bharat Stage II (CEV) Category	Effective from	CO	HC	NOx	PM
		g/kW-hr			
kW < 8	1st October, 2008	8.0	1.3	9.2	1.0
8 ≤ kW < 19	1st October, 2008	6.6	1.3	9.2	0.9
19 ≤ kW < 37	1st October, 2007	6.5	1.3	9.2	0.9
37 ≤ kW < 75	1st October, 2007	6.5	1.3	9.2	0.9
75 ≤ kW < 130	1st October, 2007	5.0	1.3	9.2	0.7
130 ≤ kW < 560	1st October, 2007	5.0	1.3	9.2	0.5

Bharat Stage III (CEV) Category	Applicable with effect from	CO	HC + NOx	PM
		g/kW-hr		
kW < 8	1st April, 2011	8.0	7.5	0.8
8 ≤ kW < 19	1st April, 2011	6.6	7.5	0.8
19 ≤ kW < 37	1st April, 2011	5.5	7.5	0.6
37 ≤ kW < 75	1st April, 2011	5.0	4.7	0.4
75 ≤ kW < 130	1st April, 2011	5.0	4.0	0.3
130 ≤ kW < 560	1st April, 2011	3.5	4.0	0.3

03-Aug-2011

For reference only. Please refer concerned ministries for

DF

Engine Type	NOx	HC	CO	PM
Diesel Engine	1.05	1.05	1.10	1.10

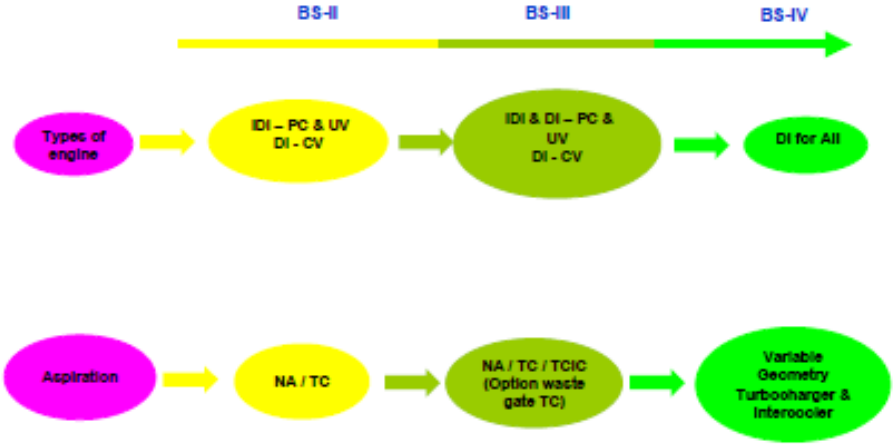
Emission Standards in India for Diesel Genset Engines upto 800 kW

Category	Effective from	NOx + HC	CO	PM	Smoke
		g/kW-hr			Light absorption co-efficient m-1 @ full load
0 - 19 kW	01-Jul-2013	7.50	3.50	0.30	0.70
>19 - 36 kW	01-Jul-2013	4.70	3.50	0.30	0.70
37 - 75 kW					
> 75 - 129 kW	01-Jul-2013	4.00	3.50	0.20	0.70
130 - 560 kW					
561 - 800 kW					
Fuel Sulphur	Less than 350 ppm				

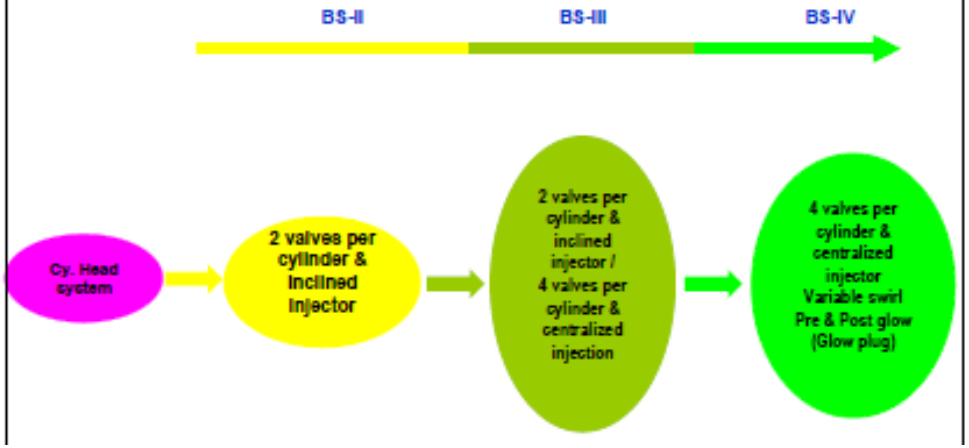
Smoke : Opacity to be measured at each point of the 5 mode test cycle & need to comply with the limits.

Test Cycle : D2-5 Mode cycle specified under ISO 8178

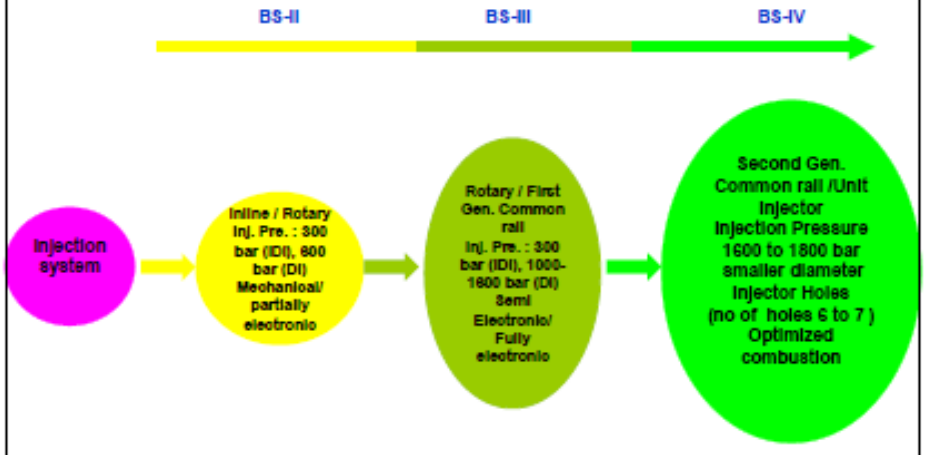
Diesel Engine Technology Movement



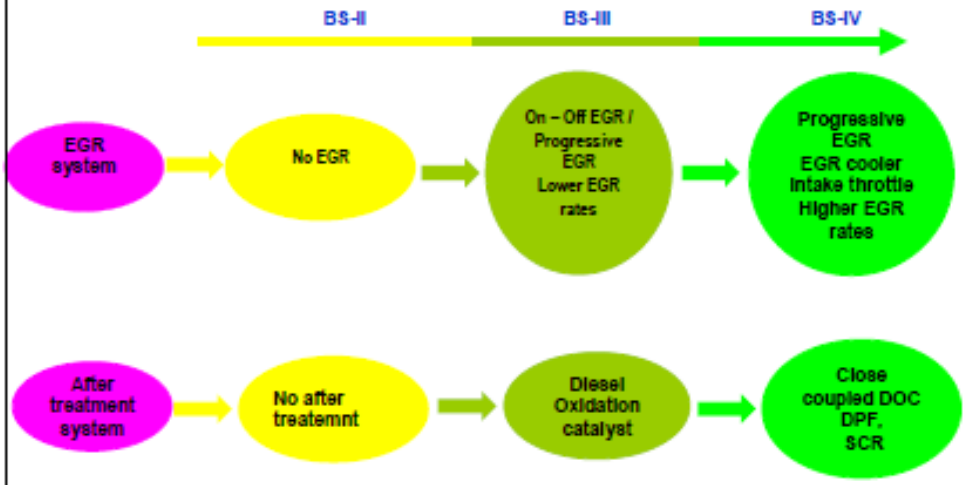
Diesel Engine Technology Movement



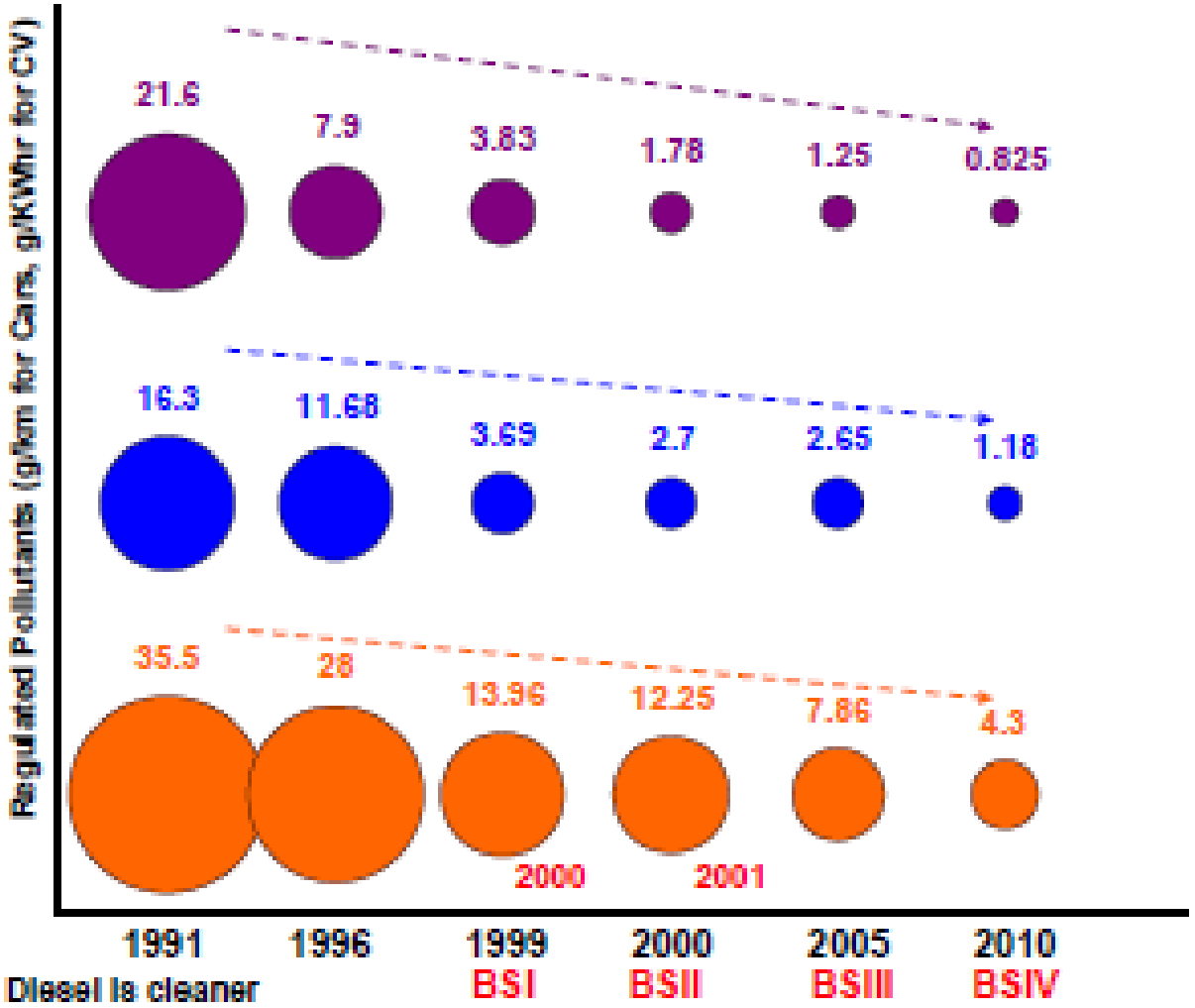
Diesel Engine Technology Movement



EGR & After treatment Technology Movement



Decreasing Pollutant Levels with emission norms



Cars - Diesel

25 fold reduction (96.2%)

Cars - Gasoline

14 fold reduction (92.8%)

Commercial Vehicle

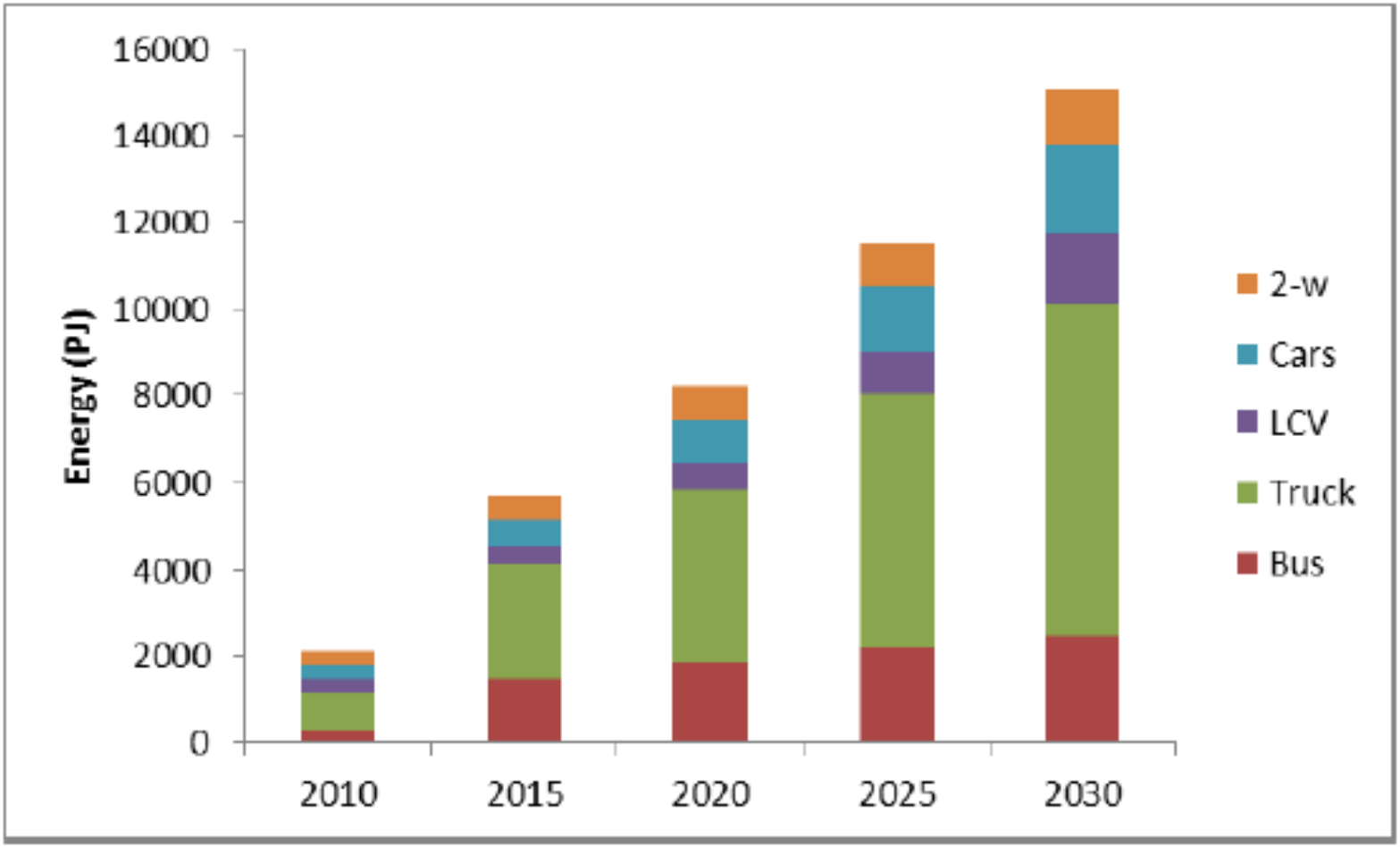
7 fold reduction (86.3%)

Factors other than engine technology influencing emission & fuel economy

- Periodic phasing out of older vehicles
- Infrastructure development
  - ✓ Improved roads / express highways / ring roads etc
  - ✓ Removal / reduction of traffic congestions inside city
  - ✓ Synchronization of traffic signals to have least stoppages at signals
- Fuel quality improvement

4

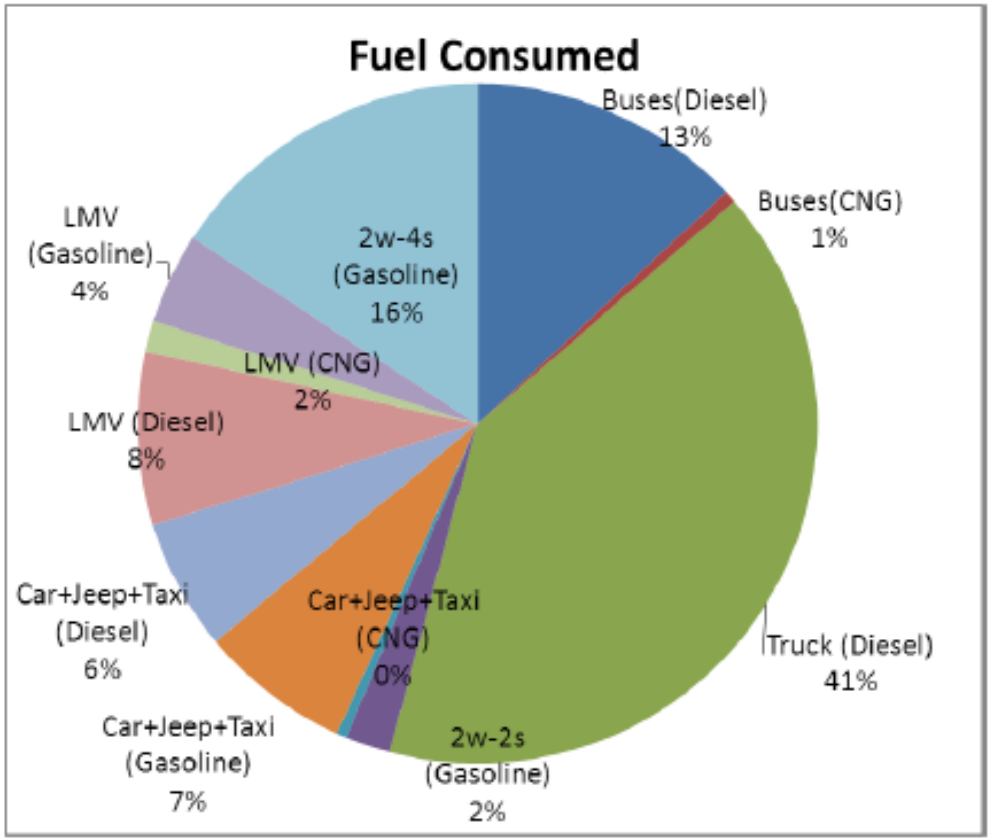
Status of Fuel efficiency norms in India



Projected growth of Vehicle category-wise energy use in India (2010 – 2030)

With commercial vehicles and buses guzzling more than a third of all diesel consumed in India, the Indian government has constituted a high-level committee to develop fuel economy norms for heavy-duty vehicles.

The committee will develop “a road map for fuel efficiency norms for heavy duty vehicles (trucks and buses) in India".

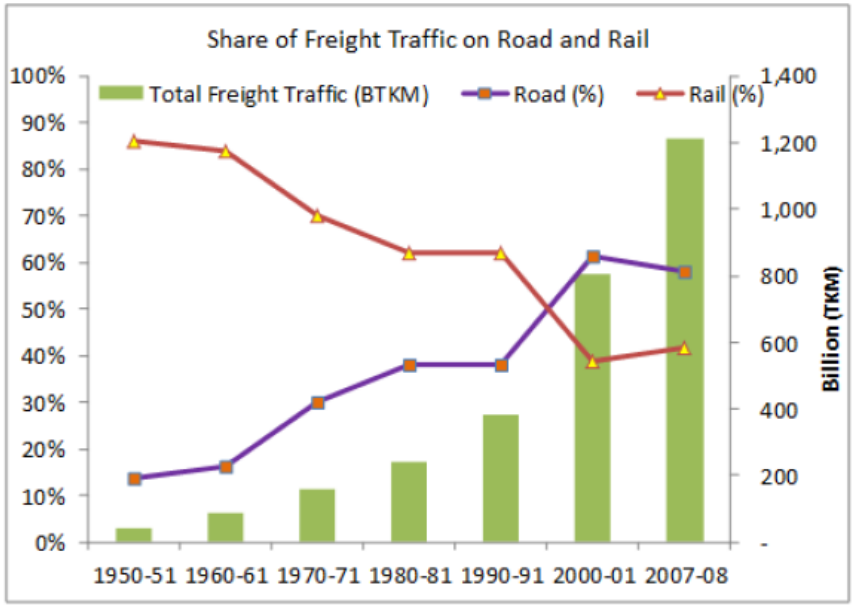


Vehicle category and fuel-wise distribution of energy used in India (2010)

- 10% fuel efficiency improvement from 2020 and 15 % from 2025, can taper the growth trajectory of diesel consumption significantly.
- This could lead to a saving of diesel annually by the year 2030 amounting to about 5000 billion INR.
  (based on 65 Rs/litre)
- This clearly emphasizes the need for stringent fuel efficiency norms in the country, which will not only lead to reduction in fuel consumption, but will also reduce import dependency in the future.

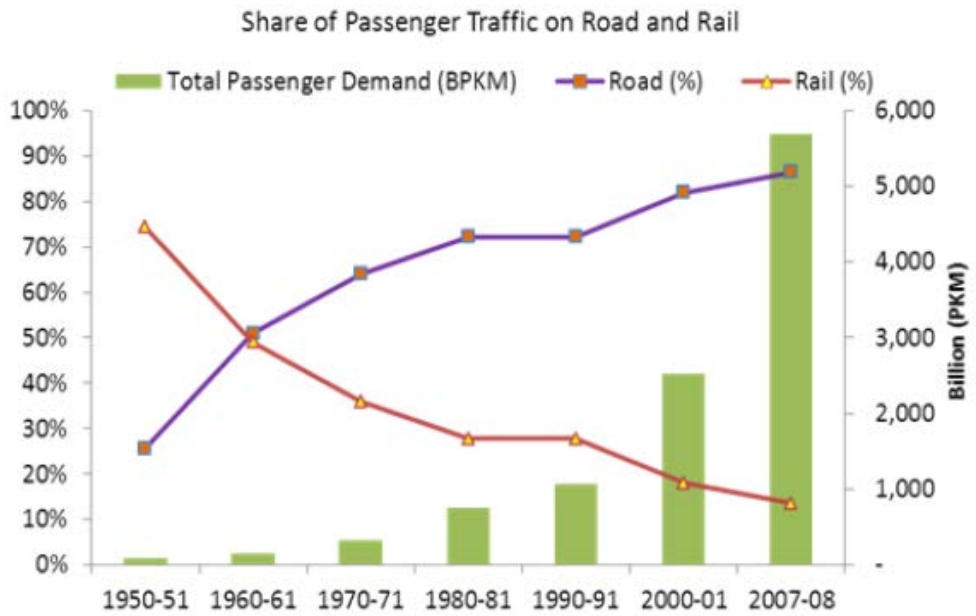
HDV sector in India

- There has been a sharp increase in energy demand from the HDV sector in India, mainly because of the increased transport demand and continuous erosion in the share of railways in freight movement and increase in share of less fuel efficient road transport.
- Road transport is the most dominant mode of transport with over 50 % of the freight.



Source : RITES 2014, PC, MoR 2012

Share of different modes in freight movements in India (1950 – 2008)



Share of different modes in passenger movements in India (1950 – 2008)

- Highest consumption of diesel is by commercial vehicles i.e 26.75 per cent, followed by 10.75 per cent by buses/state transport undertakings

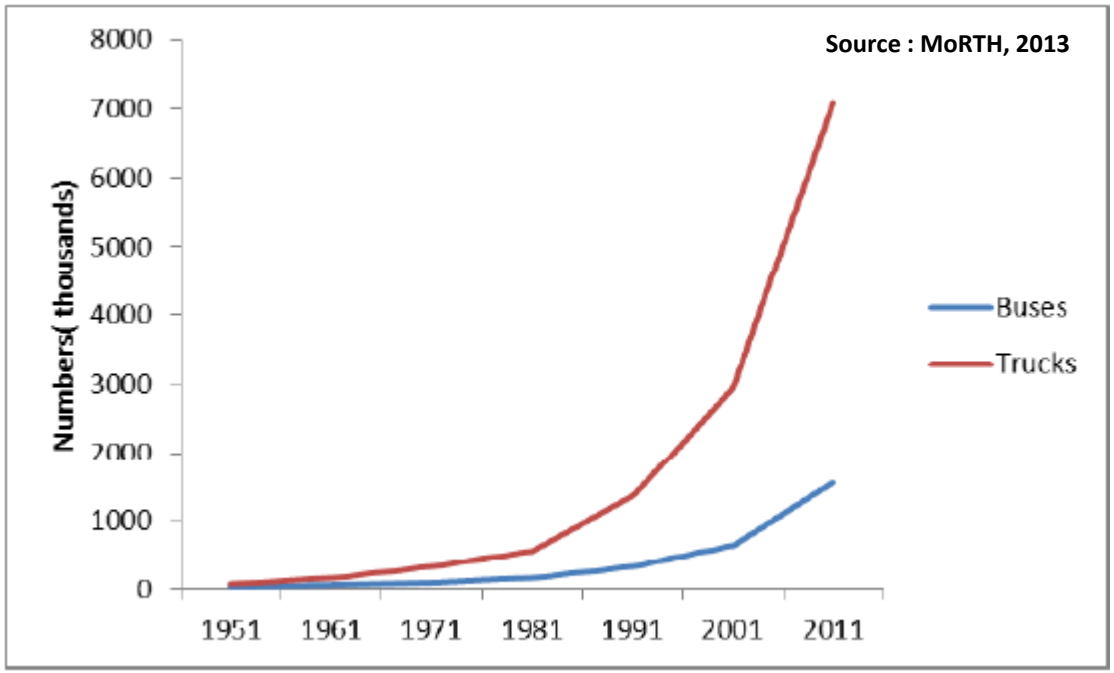
- Diesel is the most consumed fuel in the country, accounting for over 43 per cent of 158.2 million tonnes of petroleum products consumed in 2013-14. Diesel consumption was 68.37 million tonnes in the last fiscal.

- examine incentives for phasing out old and inefficient commercial vehicles and suggest a road map for their replacement, the order said.

Indian market is dominated by low-cost light trucks.

Vehicle Registration in 2011 :

- 7 million trucks
- 1.5 million buses



Number of registered HCVs in India during 1951 - 2011

Developing pathways for fuel efficiency improvements in HDV sector in India
(ref : TERI report)

- In the last two decades, India grew unprecedentedly in different sectors. With urbanization and industrialization, the energy consumption has increased multi-folds. Growing mobility, demands for passenger and freight movement have increased the consumption of petroleum products in the road transport sector.
- Transport sector presently accounts for 17 percent (72 million tonnes of oil equivalent) of the total energy consumed in the country.
- This is the second largest consumer of commercial energy after the industry sector. The share of transport is largest in consumption of diesel (~70 %) and petrol (~95 %).
- There is a continual shift in the share of railways in freight movement to less fuel efficient road transport mode.
- Presently, road transport is the most dominant mode of transport with over 50 percent of the freight movements.
- In passenger transport also, the road-based mobility is the most dominant mode amounting to about 90 percent share in 2010-11.

State of Fuel Efficiency Standards (FES) at global level

- Fuel efficiency standards for HDVs are significantly more challenging to adopt because of the presence of diverse fleets in terms of vehicle size and configuration as well as usage patterns.
- Many countries in the world have made progress and adopted fuel efficiency standards for these vehicles.
- Japan was the first country to introduce such standards in 2005, to be in effect fom 2015.
- US adopted HDV efficiency standards that will apply to vehicles starting in the model year 2014.
- Canada has standards equivalent to the US.
- Europe initiated research work on heavy-duty commercial vehicle CO_2 emission regulations and plans to complete CO_2 emissions testing regulations at the end of 2013, and shall perform certification of the European heavy-duty vehicle CO_2 emissions at the beginning of 2016.
- China adopted an "industry standard" for HDVs in 2011 and has proposed a national fuel consumption standard for HDVs (Zheng, 2011).
- Mexico is in the process of developing heavy-duty fuel efficiency standards.

Ultra-low sulfur diesel and advanced emissions technologies are the pre-requisites as fuel efficiency improvements rely on these technologies.

State of Fuel Efficiency Standards (FES) in India

India

The recently introduced corporate average fuel consumption (CAFC) standards in India for cars are based on the corporate average kerb weight (CAKW) of the vehicles sold by the manufacturers. These mandatory CAFC for 2015-16 standards for cars is calculated as per the formula described below:

$$CAFC = 0.0025 * CAKW + 3.171$$

While, the standard for 2020-21 (assuming availability of Euro V fuel) is:

$$CAFC = 0.0023 * CAKW + 2.753$$

However, this proposal has been met with criticism from various quarters stating that it is too weak both in terms of international standards and in terms of improvements already anticipated in the automobile industry in India. It is expected that the industry will make enough autonomous improvements to surpass the prescribed standards.

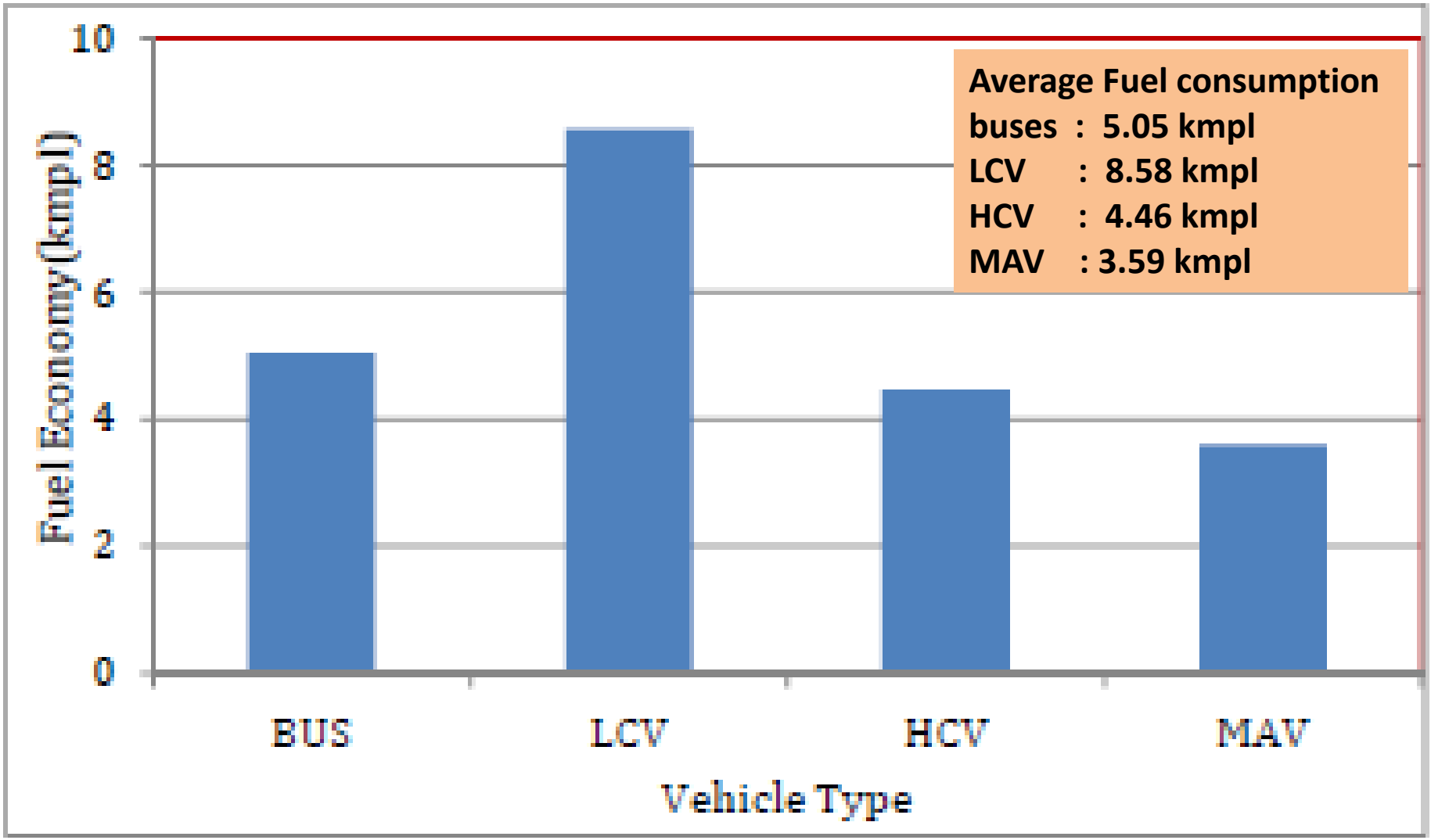
DEFINITION of FUEL CONSUMPTION

- The terms “fuel economy”, “fuel efficiency”, and “fuel intensity” are used interchangeably to mean the amount of fuel consumed by a vehicle over a distance driven.
- The metrics used to measure it differ by region and can be litres per 100 kilometres (l/100 km) (in Europe, China, South America, Australia), kilometres
- per litre (in Japan, Chile, Mexico) and miles per gallon (mpg) (in the united states and the united Kingdom.
- Sometimes CO2-equivalent emissions per km are measured instead of fuel economy, typically by EU.
- Improving fuel economy means that Lge/100 km and gm of CO2 per km (gCO2/km) decline; the fuel efficiency is better; and fuel intensity is lower.

Policies Adopted to Improve the Fuel Efficiency / Reduce the CO_2 Emissions of HVDs

The policy needed to improve vehicle fuel efficiency comprises three main components which should be considered as policy options in an integrated vehicle fuel efficiency :

- Information and Labelling
- Regulatory actions; and
- Fiscal measures



Average Fuel Economy of HDVs in India

Proposed improved Fuel Efficiency norms for HDVs in India by 2020

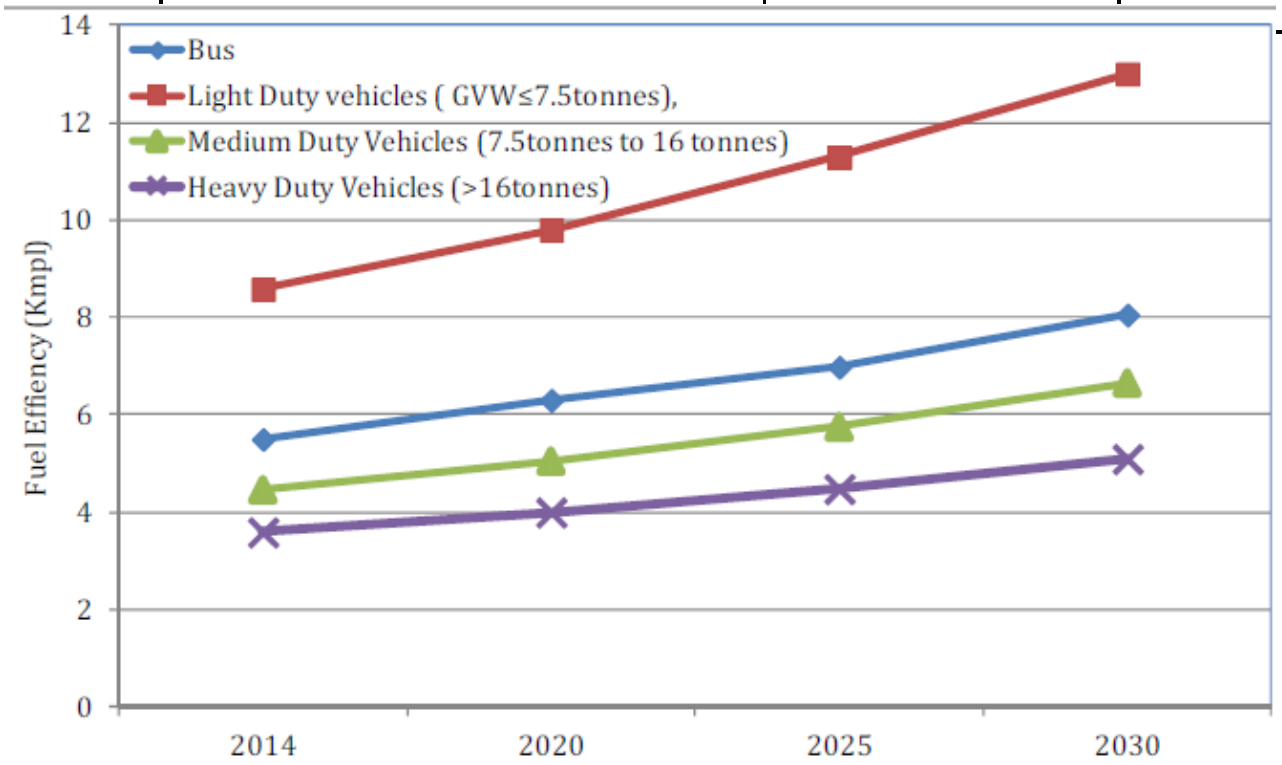
Category	Base Year fuel Efficiency (Kmpl)	Proposed target fuel Efficiency (Kmpl)	Improved Ratios of Fuel Efficiency (%)
Buses	5.5	6.3	14.55
Light Duty vehicles (GVW≤7.5tonnes),	8.58	9.8	14.22
Medium Duty Vehicles (7.5tonnes to 16 tonnes)	4.46	5.05	13.23
Heavy Duty Vehicles (>16tonnes)	3.59	4.0	11.42

Proposed improved Fuel Efficiency norms for HDVs in India by 2025

Category	Base Year fuel Efficiency (Kmpl)	Proposed target fuel Efficiency (Kmpl)	Improved Ratios of Fuel Efficiency (%)
Buses	6.08	6.98	14.80
Light Duty vehicles (GVW≤7.5tonnes),	9.8	11.3	15.31
Medium Duty Vehicles (7.5tonnes to 16 tonnes)	5.05	5.75	13.86
Heavy Duty Vehicles (>16tonnes)	4.0	4.48	12.00

Proposed improved Fuel Efficiency norms for HDVs in India by 2020

Category	Base Year fuel Efficiency(Kmpl)	Proposed target fuel Efficiency(Kmpl)	Improved Ratios of Fuel Efficiency (%)
Buses	6.98	8.05	15.33
Light Duty vehicles (GVW≤7.5tonnes),	11.3	13.0	15.04
Medium Duty Vehicles (7.5tonnes to 16 tonnes)	5.75	6.65	15.65
Heavy Duty Vehicles (>16tonnes)	4.48	5.1	13.84



Proposed Fuel Efficiency (kmpl) for HDVs in India

Comparison of emission (CO_2gm/km) target in key vehicle producing regions		
Countries	**2010**	**2020**
European Union	145	95
United States	187	121
China	179	117
Japan	130	105
India	141	122 (original proposal)

Technologies to improve fuel efficiency

- There are several technologies available for improvement in fuel economy in HDV sector.
- The technologies can be grouped into categories of Power Train improvements and technologies for reducing load specific fuel consumption.
- There are technologies for improving the efficiency of diesel engines and technologies for transmissions and drive axles.
- Hybrid power train technologies can reduce fuel consumption in HDVs.
- The vehicle technologies for reducing Load-Specific Fuel Consumption mainly focus to reduce vehicle engine losses which happen mainly due to heat transfer to the coolant and exhaust heat loss. The rest is used to power the vehicle and auxiliaries.
- The main areas of energy losses are aerodynamics, auxiliary loads, rolling resistance, vehicle mass (weight), and idle reduction. Significant research has happened over the years across the world to improve aerodynamics, reduce vehicle weight, and improve tire quality.

Table 5 summarizes the technologies that can be applied in improving the fuel economy in HDV sector.

Factors causing energy loss in HDVs

- The factors which defines the fuel consumption depend on actual road load driving conditions.
- force or power required to propel a vehicle is broadly comprised of four terms describing tire rolling resistance, aerodynamic drag, acceleration, and grade effects:

$$FRL = mg.Crr + 0.5Cd.A.\rho a.V2 + m(dV/dt) + mgsin(\theta)$$

Where,

mg is vehicle weight,
Crr is tire rolling resistance,
A is the frontal area,
Cd is a drag coefficient based on the frontal area,
ρa is the air density,
V is the vehicle velocity,
m is vehicle mass,
t is time, and
θ is the road gradient (uphill positive).

Energy loss in vehicles caused due to various factors and potential energy savings

Types	Urban / Intercity (percent)	Potential of energy savings(percent)
Engine losses	60	28
• *Heat rejection*	26	
• *Exhaust heat*	24	
• *Gas exchange*	4	
• *Friction*	1.5	
• *Engine accessories*	2.5	
Aerodynamic losses	4–10 / 21	11.5
Drivetrain losses	5–6 / 2	7
Braking losses	15–20 / 0-2	
Auxiliary loads	7–8 / 4	
Rolling resistance	8–12 / 13	11

Source : NRC, 2010

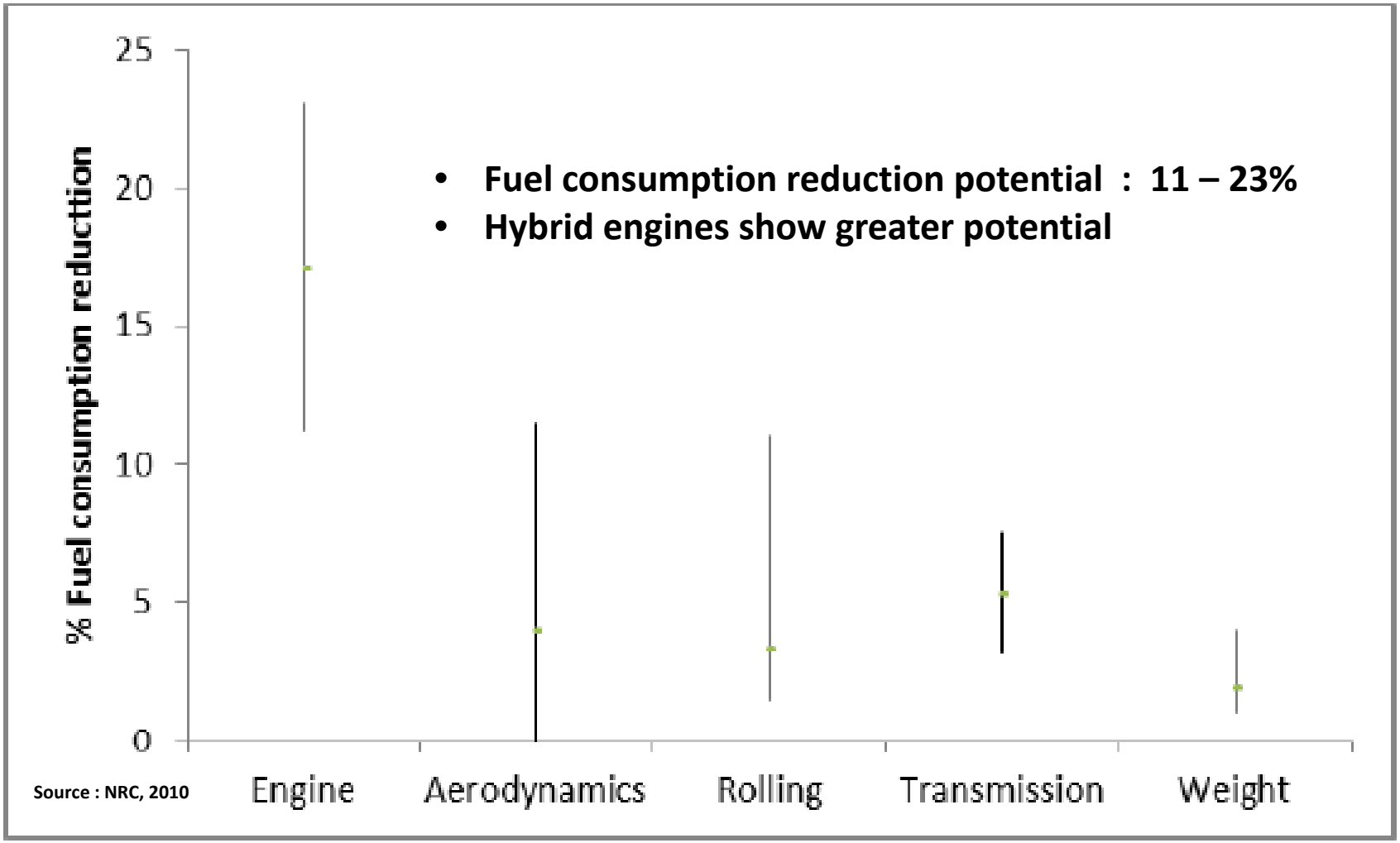
Technologies to improve fuel efficiency

S.No	Technology type	Intervention	Description
1	Power Train Technologies	Turbochargers	Turbochargers (turbines and compressors with improved efficiencies) Dual-stage turbocharging with inter-cooling Mechanical Turbocompound (by employing a power turbine to the exhaust stream to extract wasted energy) Electric Turbocompound (similar to mechanical turbocompound where the power turbine drives an electrical generator to supplement the engine output for electrical accessories or can be used to charge a hybrid system battery.
		Low-Temperature Exhaust Gas Recirculation	Exhaust Gas Recirculation (EGR) reduces NOx formation and leads to more advanced injection timing and increases engine efficiency
		Electrification of Engine-Driven Accessories	Conversion of engine driven accessories to electric power. (more effect in short-haul/ urban applications and lesser in line-haul applications)
		Engine Friction Reduction	Friction reduction in some cases may develop issues with durability/ performance. Friction losses could be more during cold starts and under light load operation. ,
		Improved Work Extraction from Combustion Process	Improved combustion processes (involving improvements in compression ratio, expansion ratio, combustion chamber shape, injection spray pattern, injection pressure, injection timing, injection rate shaping, air/ fuel mixing, peak cylinder pressure limit, air/ fuel ratio, and EGR rate). Improved combustion chamber design, and improved

Technologies to improve fuel efficiency

			materials can allow more precise control of rate of heat release (combustion) as well as higher combustion temperatures, resulting into improved thermal efficiency. More accurate and timed injection of fuel and increase in injection pressure.
2	Vehicle Technologies for Reducing Load-Specific Fuel Consumption	Aerodynamics	Day cab roof deflector (4-7 percent) Sleeper roof fairing (7-10 percent) Standard Chassis skirt (3-4 percent) Cab extender (2-3 percent)
		Auxiliary loads	Improved auxiliary systems Use of electric drives instead of direct mechanical drives
		Rolling resistance	Improved Tires Tire Pressure Maintenance and Effects Tire/ Wheel Alignment
		Vehicle mass (weight)	Lightweight materials and structures (Aluminium composite panels)
		Idle reduction	Automatic Shutdown/ Startup Systems Battery-powered idle reduction systems
3	Driver support systems		Eco-Roll for taking advantage of the vehicle's kinetic energy during downhill driving

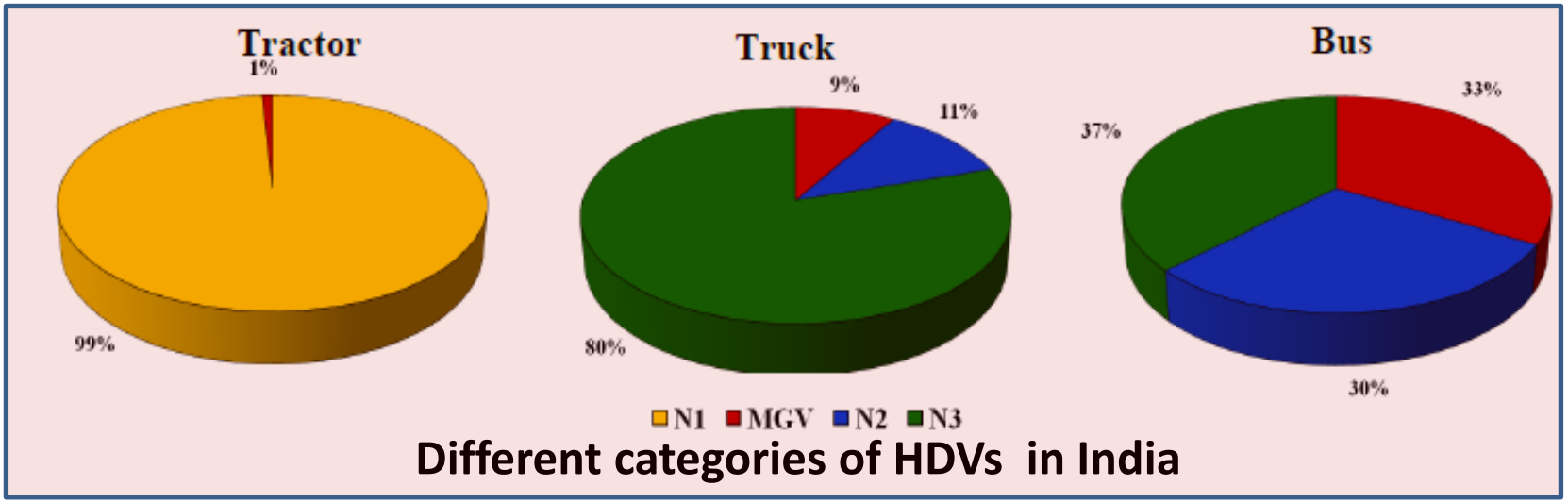
Technologies to improve fuel efficiency



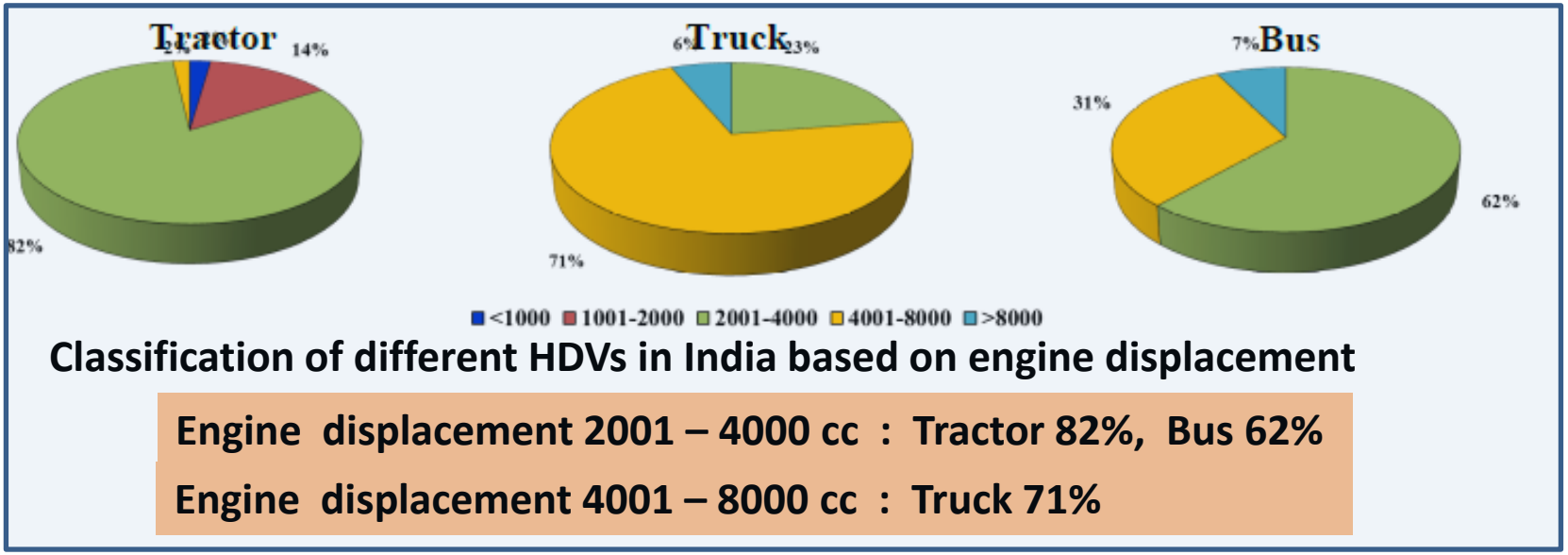
Possible fuel consumption reduction through various technologies in HDVs

Survey of HDV industry in India

HDV includes Tractor, truck & Bus



Different categories of HDVs in India

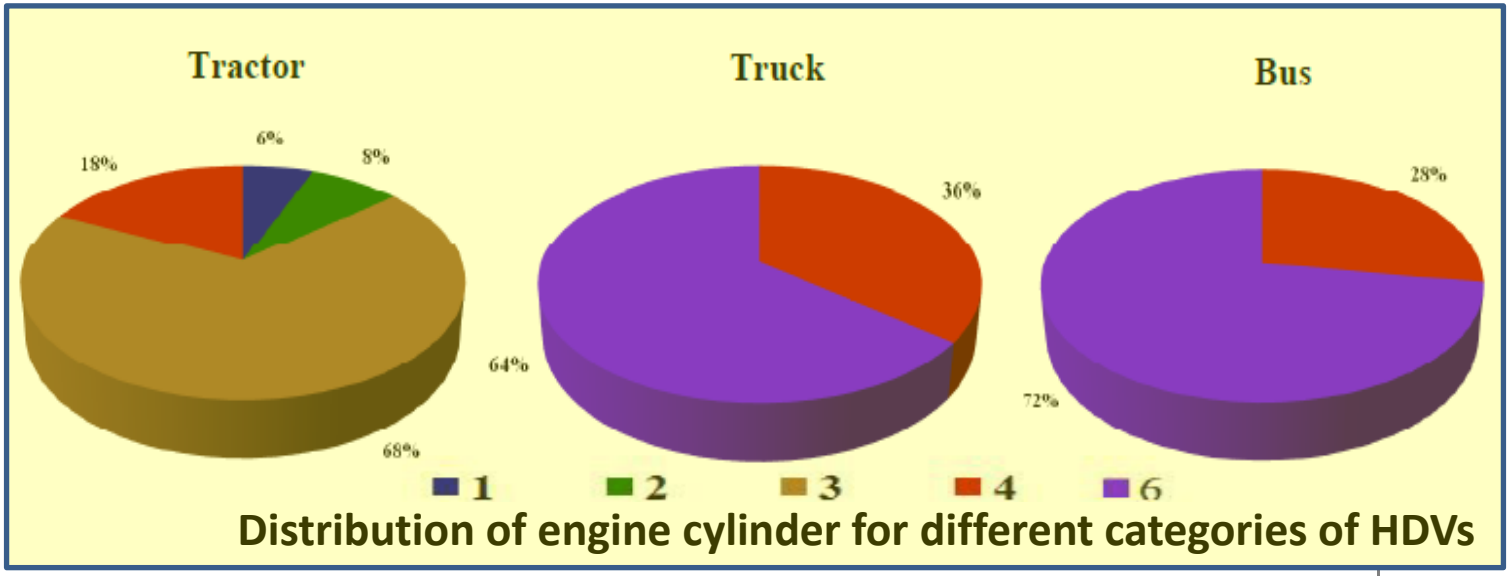


Classification of different HDVs in India based on engine displacement

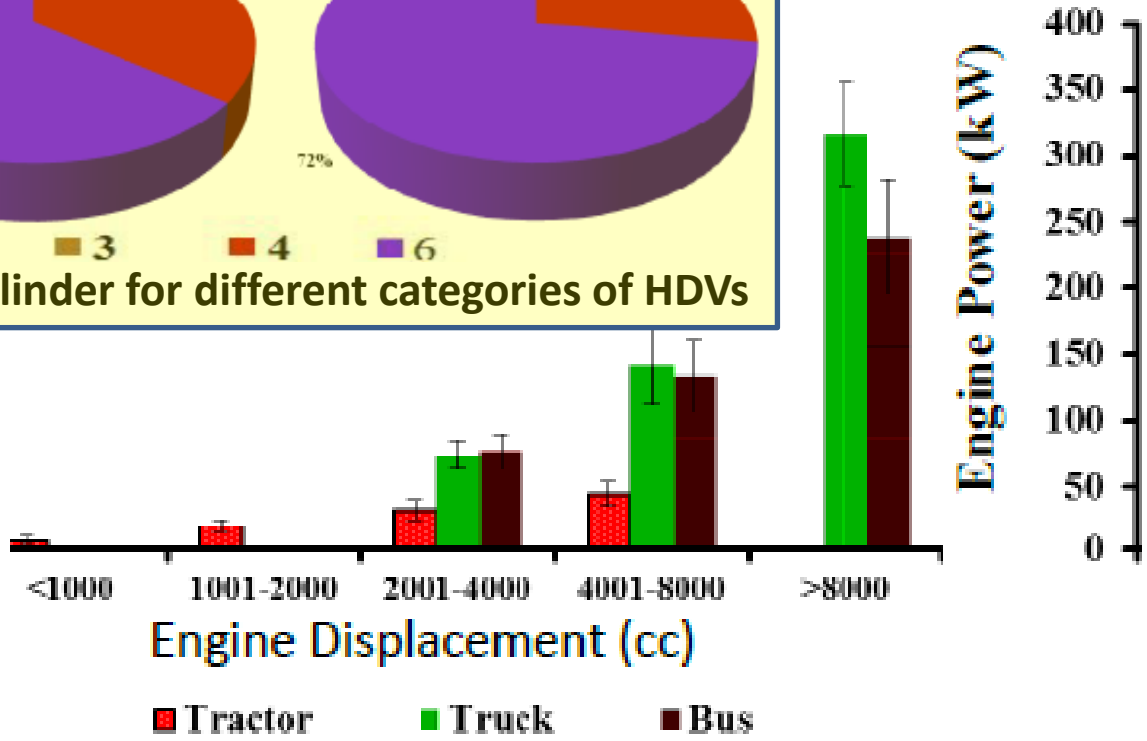
Engine displacement 2001 – 4000 cc : Tractor 82%, Bus 62%

Engine displacement 4001 – 8000 cc : Truck 71%

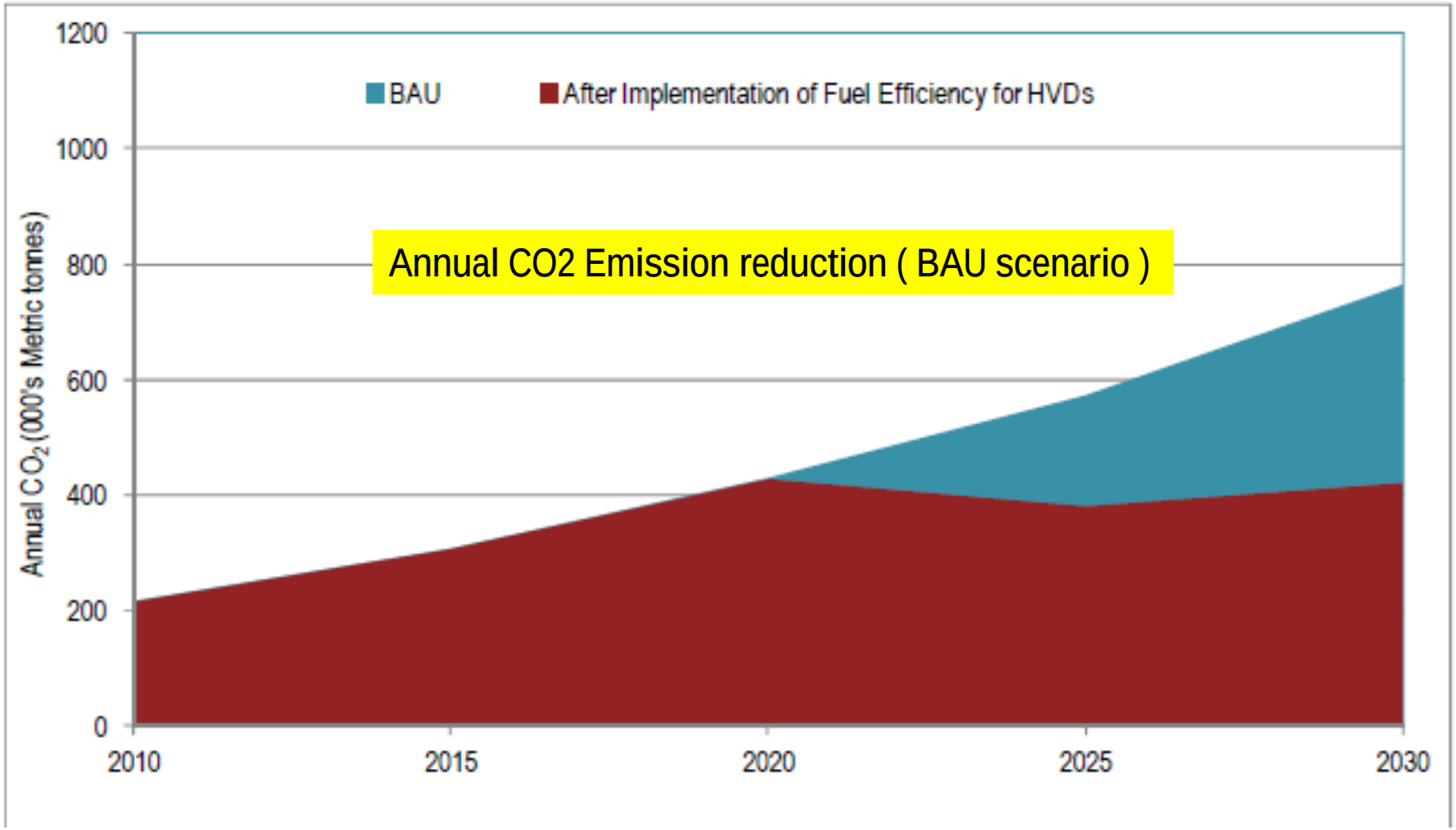
- Maximum numbers of tractor models (68%) are 2V configuration with 3-cylinders (12 – 56 kW) and with 4-cylinder (22 – 62 kW)
- Most of the truck (64%) and bus (72%) models are with 6-cylinders and of 4V configuration. Truck engines (52 – 382 kW), Bus engines (62 – 315 kW)



Distribution of engine cylinder for different categories of HDVs

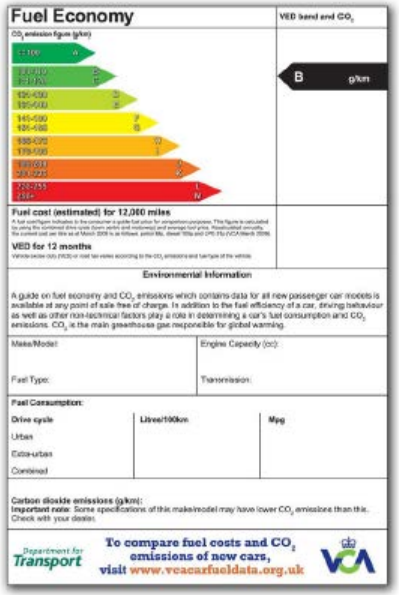


Impact of proposed fuel economy standards in India



5

Efficiency labeling



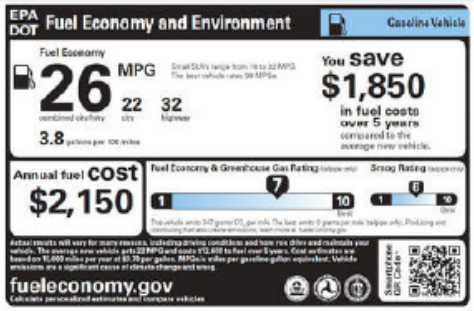
Source: VCA, 2012.

Figure 8.1: Graphical rating label: UK

Direct information disclosure label: China fuel economy label

Source: New Zealand Transport Agency, 2012

Figure 8.5: New Zealand fuel economy label

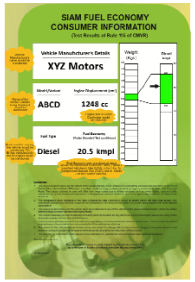


Source: EPA, 2012

.2: Direct information disclosure label: US EPA fuel economy label

Source: MLIT, 2010a.

Figure 8.4: Relative vehicle performance label: Japanese fuel economy label



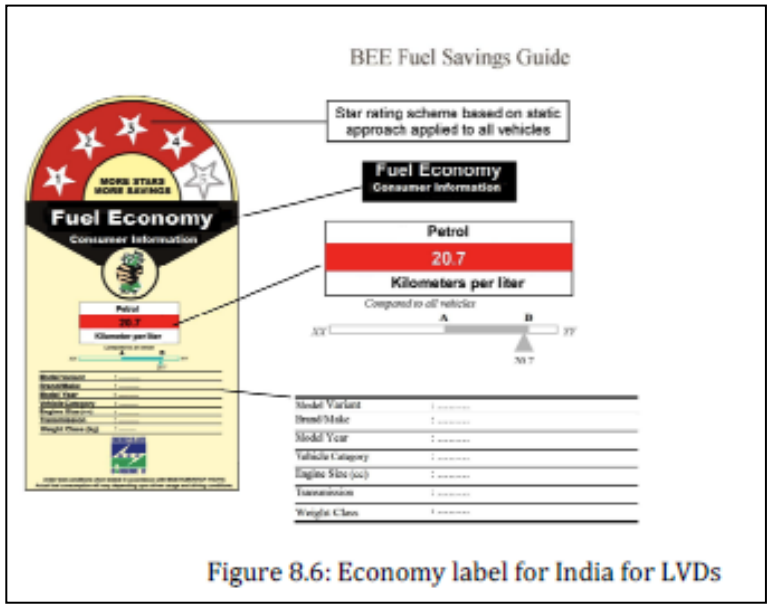


Figure 8.6: Economy label for India for LVDs

FE Information Labelling

examples

SIAM Labelling

FUEL ECONOMY
CONSUMER INFORMATION

(Test Results of Rule 115 of CMVR)

Vehicle Manufacturer's Details

XYZ Motors Ltd.

Model /Variant	Engine Displacement (cm³)
ABCD CDI XS	1850

Fuel Type	Fuel Economy (Over Urban and Test Cycle)
Petrol	16.8 km/l

6

Air Quality Controls

Need for in-use vehicles management

- On-road vehicles emit much higher levels of pollutants during their lifecycle as compared to the limits set during their certification stage.
- This might be attributed to deterioration due to wear and tear, lack of proper maintenance, engine faults or misuse by driver.
- Therefore, robust emission control policies are required for in-use vehicles to bring about a significant reduction in the overall emissions.
- Air pollution is continuing to be a serious health concern in all major cities of India. It is imperative to curb harmful emissions from the vehicles on road and ensure that they are not emitting more than the stipulated norms.

Need for in-use vehicles management

- Despite stringent emission norms at the vehicle certification stage, diesel vehicles have shown higher PM, CO, and HC emissions, particularly before the advent of strategies such as diesel particulate filters (DPF), exhaust gas recirculation (EGR), selective catalytic reduction (SCR), and lean NOx traps (LNT) even in the US.
- In India, as in other countries, new vehicles have to meet emission standards and set deterioration rates at the manufacturing stage. New vehicles are tested during the type approval procedure.
- Type Approval involves durability testing of anti-pollution devices as well. Deterioration rates apply for the useful life of these vehicles, and allow for a slight deterioration in vehicle emissions with use. Still, vehicles are expected not to emit more than they are designed to over a set durability period, taking into account their original emission norms and deterioration rates.

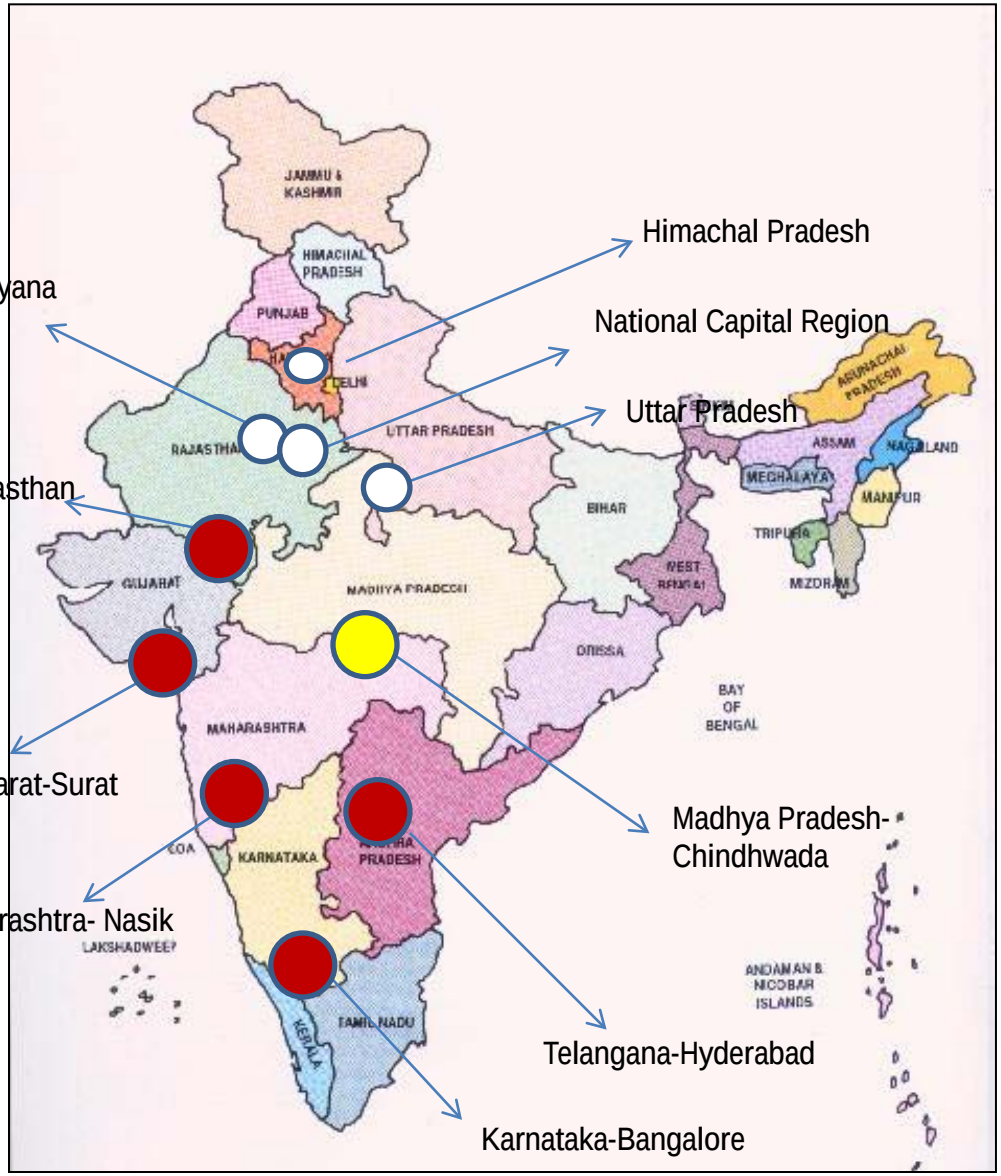
Practices for transportation sector for better air quality

- Periodical Introduction of stricter emission norms
- Advanced technology for the automotives
- Availability of clean fuel
- Extensive use of alternate fuels
- Transport planning and travel demand management is a key component of a comprehensive strategy to reduce emissions from motor vehicles
- Strengthening vehicle Inspection & Maintenance

INSPECTION & MAINTENANCE (I&M) OF IN-USE VEHICLES

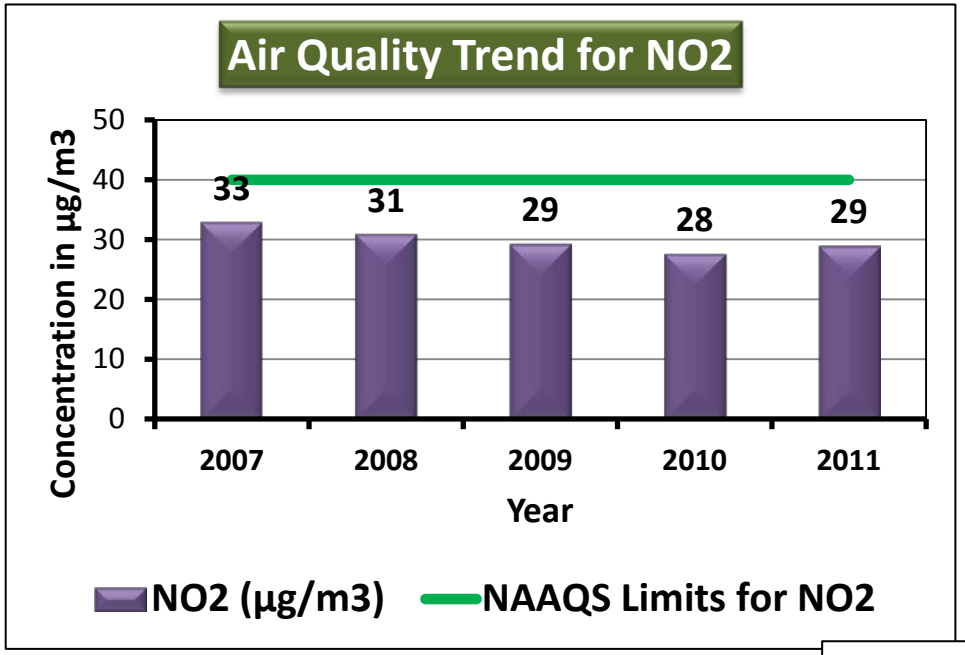
- It has been estimated that at any point of time, new vehicle comprise only 8% of the total vehicle population.
- In India, currently only transport vehicles are required to undergo periodic fitness certification. The large population of personalised vehicles are not yet covered by any such mandatory requirement.
- In most countries that have been able to control vehicular pollution to a substantial extent, Inspection & Maintenance of all categories of vehicles have been one of the chief tools used.
- Developing countries in the South East Asian region, which till a few years back, had severe air pollution problem have introduced an I&M system and also effective traffic management.

Establishment of Inspection and Maintenance Centers

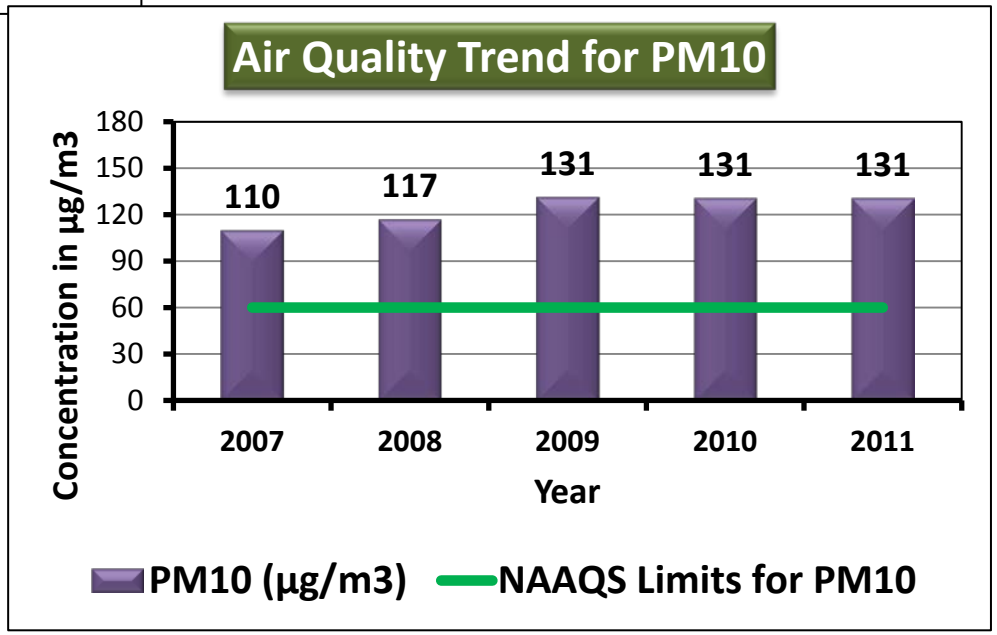


MoRTH Initiative :

10 Model Test Centers are being established in India in different states



Status of Ambient Air Quality in Indian cities



Source: CPCB ENVIS Air Data

Further expansion – Role of ARAI

- Providing consultancy to set up optimal sized test centers based on the vehicle fleet expected and land availability
- Turnkey test center establishment from green field
- Auditing of the test center operation
- Training motor vehicle inspectors and operators

ARAI is currently engaged by several organizations to provide above services

7

Alternate fuels

CNG -STATUS IN INDIA

- CNG stations in India -510.
- 17 companies to supply natural gas for CNG / PNG usage in 42 cities
- Total estimated NG consumption 3.2 MMSCMD gas for CNG purpose and 5 MMSCMD as PNG
- India with 8 Lakh Natural gas vehicles ranks 5thin the world

Status -LPG as Auto Fuel

- LPG notified as transport fuel by MoRT&H –2000
- BIS issued specification of Auto LPG –2001
- Total no. of Auto LPG stations -573
  - ❖IOCL-232 Stations
  - ❖BPCL-74 Stations
  - ❖HPCL-150 Stations
  - ❖Others-227 Stations

FUTURE is HYBRID !!!!

- The Government of India has also launched National Electric Mobility Mission Plan (NEMMP), which aims at selling 6-7 million electric vehicles in the country by 2020.
- The initial cost of electric vehicles being higher than the petrol vehicles, a support mechanism of subsidy and incentives will have to be put in place to achieve the mission's target.
- Electric vehicles are highly suitable for last mile connectivity as shown by the advent of e-rickshaws in Delhi, which are multiplying day-by-day.
- The introduction of stricter fuel emission norms will also bring down the energy consumption in the country.
- A recent study done by TERI revealed that energy consumption can decline by 17 per cent by 2032 if stricter fuel efficiency norms of BS-V and BS-VI are introduced.

8

Closing Remarks

Durability Limits for different types of vehicles in India

Vehicle category	Durability (km)
Two- and three-wheelers	30,000
LDVs	80,000
N1 w/GVW* ≤ 3,500 kg	100,000
N2 w/GVW <12,000 kg	125,000
N3 w/GVW < 16,000kg	125,000
N3 w/GVW > 16,000kg	167,000
M2 w/GVW < 5,000kg	100,000
M3 w/GVW 5,000–7,500kg	125,000
M3 w/GVW > 7,500kg	167,000

Source : MoSRTH, CMVR, 2008, GSR 522(E)

Vehicle categories :

N1: Means a vehicle used for carriage of goods and having a GVW not exceeding 3.5 ton

N2: A vehicle used for the carriage of goods and having a GVW exceeding 3.5 ton but not exceeding 12 ton

N3: Means a vehicle used for the carriage of goods and having a GVW exceeding 12 ton

M2: A vehicle used for carriage of passengers, comprising nine or more seats in addition to the driver's seat, and having a maximum GVW not exceeding 5 ton

M3: A vehicle used for the carriage of passengers, comprising nine or more seats in addition to the driver's seat and having a GVW exceeding 5 ton

Closing Remarks

The automobile industry has to address globally, the following issues at all the stages of vehicle manufacture :

- Environmental Imperatives
- Safety Requirements
- Competitive Pressures and
- Customer Expectations

There is a strong interlinking amongst all these forces of change, influencing the automobile industry. These have to be addressed consistently and strategically to ensure competitiveness.

Since pollution is caused by various sources, it requires an integrated and multidisciplinary approach. The different sources of pollution have to be addressed simultaneously in order to stall widespread damage.

Closing Remarks

The automobile industry has to address globally, the following issues at all the stages of vehicle manufacture :

THE PARAMETERS DETERMINING EMISSION FROM VEHICLES

- Vehicular Technology
- Fuel Quality
- Inspection & Maintenance of In-Use Vehicles
- Road and Traffic Management

While each one of the four factors mentioned above have direct environmental implications, the vehicle and fuel systems have to be addressed as a whole and jointly optimised in order to achieve significant reduction in emission.

Closing Remarks

ROAD & TRAFFIC MANAGEMENT

- Inadequate and poor quality of road surface leads to increased Vehicle Operation Costs and also increased pollution.
- It has been estimated that improvements in roads will result in savings of about 15% of Vehicle Operation Costs.

- Fuel quality plays a very important role in meeting stringent emission regulations.
- Global alignment of fuel specifications will be an helpful scenario as regards ensuring robust performance guarantee
- Use of alternate fuels and power train systems are required to be promoted
- Immediate future is Hybrid (combustion engine + electric motor)
- Long term future is Electric vehicles
- Long term future is carbon-free Hydrogen vehicles

Closing Remarks

- Indian emission regulations are tightest amongst emerging nations for some category of engines / vehicles.
- Diesel engines are becoming more popular worldwide because of high fuel efficiency (reduced green house gas emissions) & increased performance with new technologies.
- Infrastructure required for availability of urea to introduce SCR technology.
- Phasing out of older vehicles, infrastructure development & Fuel quality improvements will also play important role in clean environment and improvement in fuel economy.

ARAI will be pleased to cooperate in the area of
Fuel efficiency improvement and Emission reduction programmes
by way of dealing in the area of advance power train design and development
- Combustion Engines, Hybrids , Electric vehicles, alternate fuels, etc. -

Thank you

Contact :

NEELKANTH V. MARATHE

Senior Deputy Director

Power Train Engineering (PTE)

AUTOMOTIVE RESEARCH ASSOCIATION OF INDIA (ARAI), Pune 411038 (India)

Email : nvmarathe.edl@araiindia.com; Phone(desk) : 0091 20 30231430

Website : www.araiindia.com