DAIMLER

Emission Control Technologies - Conference
Insight and Best Practices of EU Nations / Adoption for BS VI

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Daimler AG

New Delhi, 2016, Nov. 9

Daimler Trucks

FREIGHTLINER

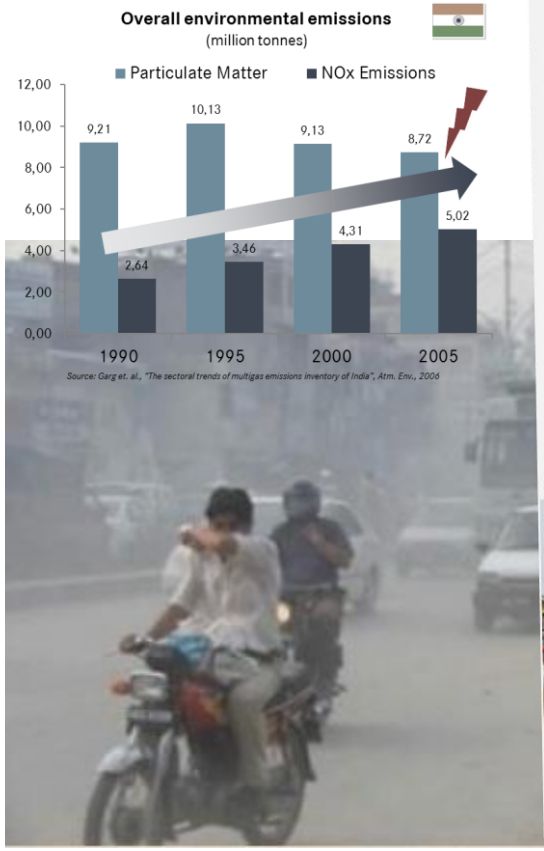
FUSO

WESTERN STAR

Thomas BUILT BUSES

BHARATBENZ

SIAM principally supports the introduction of Bharat VI but has major concerns



INDUSTRY NEWS

This edition presented by FASCHING safety belts

Indian auto industry ready for BS-VI challenge

The Indian auto industry is committed to meet the challenge of achieving to BS-VI emission norms by 2020. The target is very stiff but the auto industry has accepted the challenge in view of the rising concerns on vehicular pollution, especially in the urban metros, stated Mr. Vinod Dasari, SIAM President, at a press briefing in the country's capital.

"India has been the fastest at adopting new safety and emission norms. This leap-frog would make India the first country in the world to accomplish such an accelerated progression in vehicular emission norms", said Mr. Dasari. "This would not only entail a significant telescoping of long term investments into a much shorter timeframe of 3-4 years, but also deployment of a much larger technical resource drawn from world over to enable compression in the time taken for technical development, testing and validation of the vehicles in Indian conditions", he added.

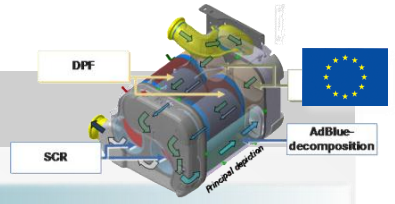
The SIAM President however cautioned that once the industry has chosen to go down the path of leap-frogging the emission norms, this roadmap should not be changed or delayed midway for any reason. He hoped that the oil sector would fulfil its role by making the required fuel available on a country wide basis as per the new timeline and have testing fuel available a year sooner. He said that the exemptions given to oil companies in some of the fuel specifications will make it even more difficult for the auto industry to meet other mandatory norms like on fuel efficiency. Also for two-wheelers, even the Euro 5 emission norms (equivalent to BS-VI) in Europe is not yet finalised. This is a matter of concern for the two wheeler industry, as our regulation will be ahead of even Europe.

Mr. Dasari also stated that the industry is fully committed and ready for implementing BS-IV across the country on April 1, 2017 and is now waiting for the fuel availability on a pan-India basis.

Mr. Vinod Dasari, SIAM President

10 | MOTORINDIA • October 2016

Euro VI 'behind the scene'



Durability procedures
- 700.000km (Euro V: 500.000km)

Onboard Diagnosis
- SCR (inducement measures)

Off Cycle Emissions (NTE limit)
- Approval by WP29 as gtr n° 10 in June 2009

Particle Measurement Procedure Validation
- very complex and expensive testing

World Heavy Duty Cycle (WHDC)
- First world-wide harmonized test-cycle mainly driven by Daimler
- Test cycle will be applied to Euro VI standard

In Service Conformity
- Checking customer vehicles for emissions conformity with portable measurement systems

- **Euro VI is more than just tight limits – there are technical issues which are usually seen on the surface**

A successful introduction of a challenging emission legislation needs to reflect the needs of society, customers and industry

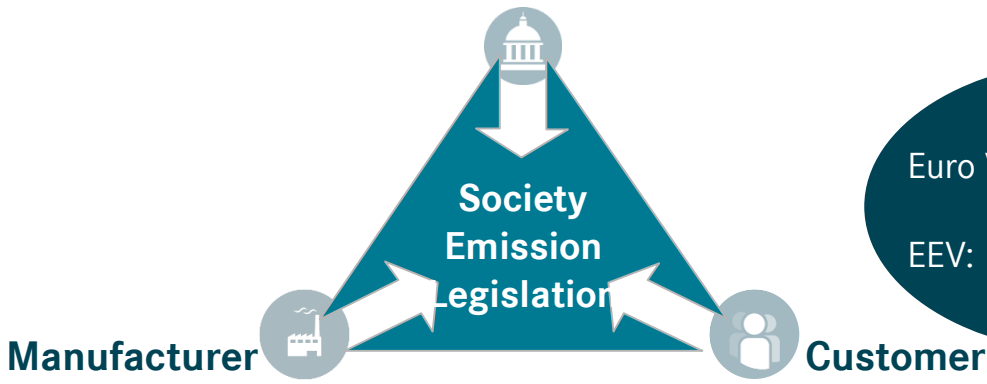
Impact assessment as basis for finding optimum situation / acceptable compromize

Interest of Stakeholder

Regulating Body
Improvement of air-quality (Reduction of PM, NO_x, O_3)

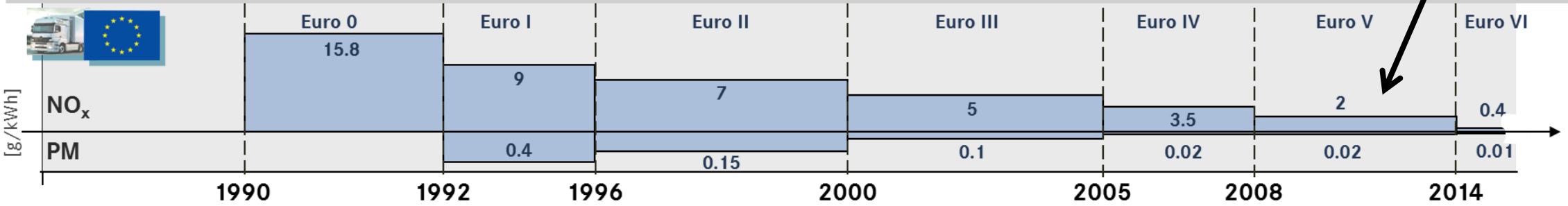
Customer
Long-Term and Future-orientated Solutions

Manufacturer
Targets should be achievable through short&medium term and sustainable measures



PM:
Euro V: ESC:0.02 g/kWh
ETC: 0.03 g/kWh
EEV: ESC: 0.02 g/kWh
ETC:0.02 g/kWh

Euro I emits 20times more particulates than Euro V/EEV



‘Clean Air for Europe (2005)’ paved way for better air: Progress with regards to NO_x and PM in emission reduction

Combined efforts of all contributors

power plants

industry

commercial and households

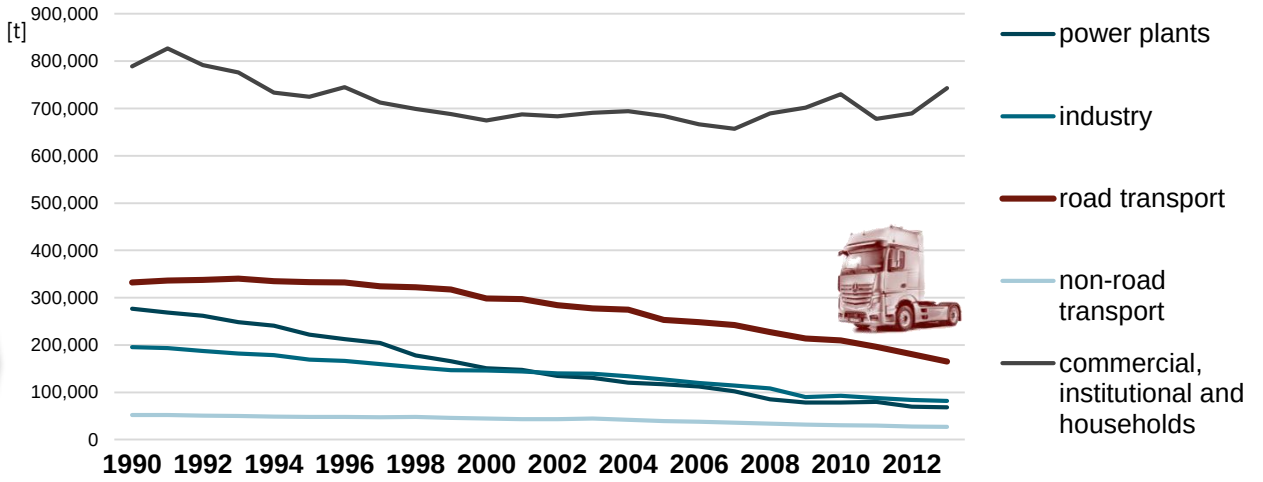
EU: mostly clean air already achieved

road traffic

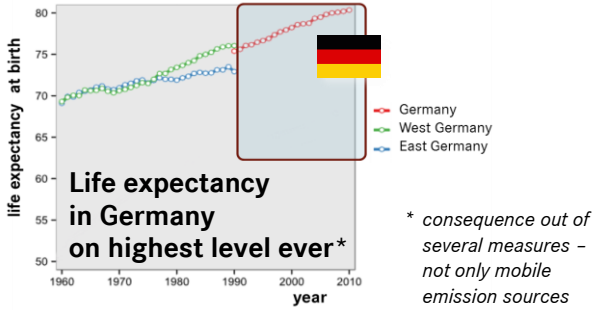
road transport with positive effects of Euro IV/V and EEV

example: Heavy-Duty commercial vehicles in Germany

Emissions trends in EU since 1990 - example $PM_{2.5}$



- Overall significant reduction of PM emissions from all sources
- Transport emissions clearly reduced with Euro IV/V and EEV - even with increase in transportation performance



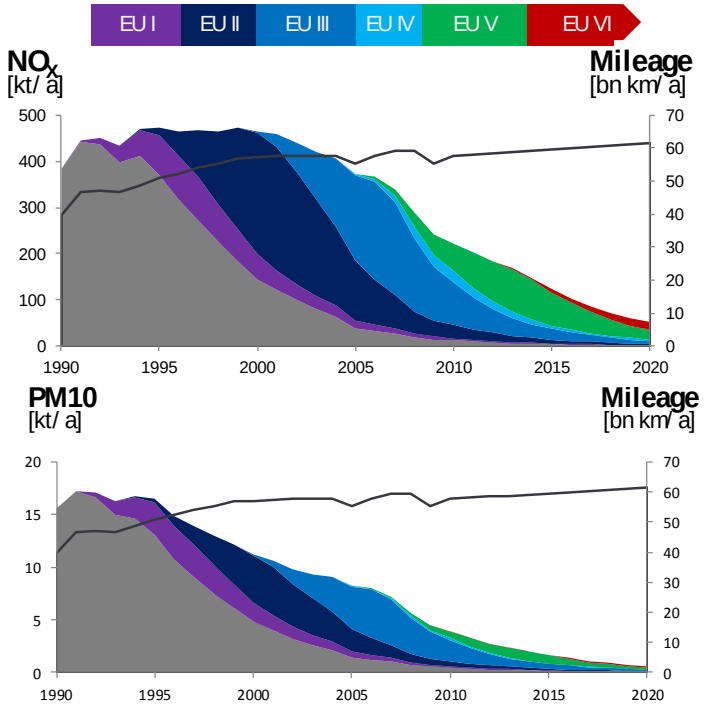
* *consequence out of several measures – not only mobile emission sources*

- **Governmental regulations pushed all sources of emissions, mainly power generation, building heating systems and road transportation.**
- **Euro V and EEV for HDV are effective and achieved significant improvements, Euro VI will further contribute.**

Air quality in Germany: Significant reduction of NO_x and PM emissions due to the introduction of Euro IV/V/EEV

HD commercial vehicles in Germany

Simulation of NO_x and PM development of HDV

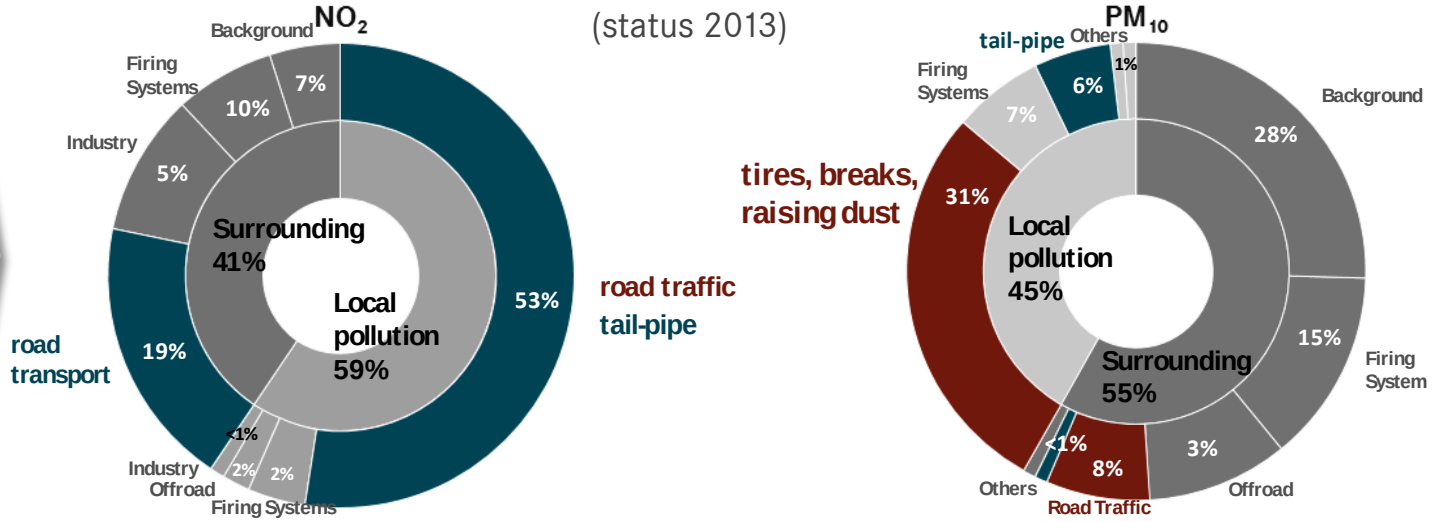


Source: Daimler calculation with TREMOD 5.25c, "Basis", inland; own assumptions for mileage 2011-2020; Heavy-Duty Commercial Vehicles: Tucks, Buses

Air Quality in cities: Determined by many factors

Various pollutants under observation but Diesel exhausts only one source

Example: Stuttgart Neckartor
(status 2013)

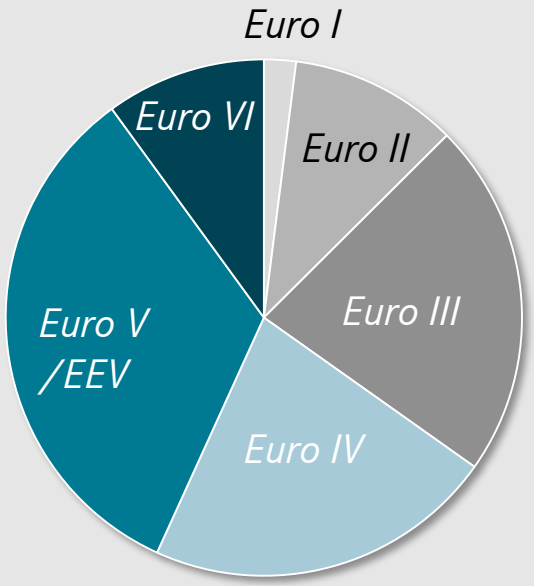


- **NO_2 reduction only in the long-term** due fleet renewal with new trucks
- **Tailpipe PM_{10} with a minor amount (6%),** much less than brakes, tires (31%) and other sectors (63%).

- **SCR technology as game changer in the emissions of NO_x and PM.**
- **Successful market uptake decisive.**

The economic power has essential impact on the fleet emission standard distribution

Europe

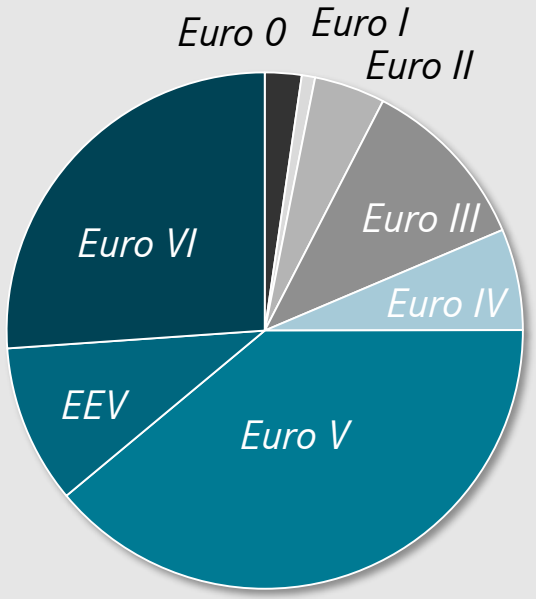


Vehicle population: ~6,9 mio.
Vehicle weight >3.5t
Date: 2015

Source: ACEA, TREMOVE, Daimler

GDP per capita: US$ 37,852 (PPP, 2015)

Germany

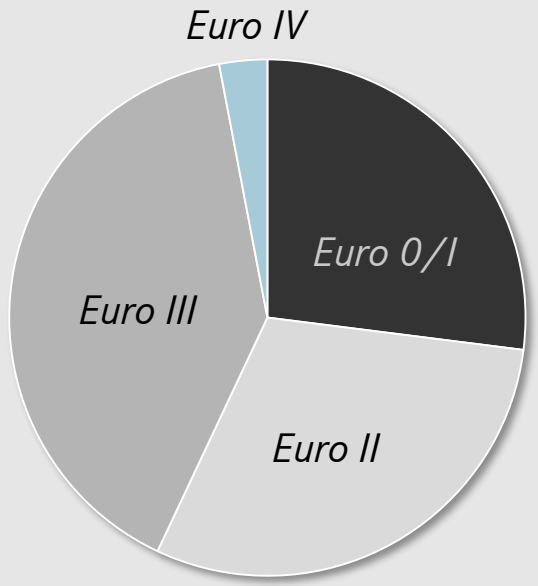


Vehicle population: 474000
Vehicle weight >7.5t
Date: 01.01.2016

Source: KBA, Daimler

GDP per capita: US$ 47,033 (PPP, 2015)

India



Source: OICA, 2015; SIAM 2015/16

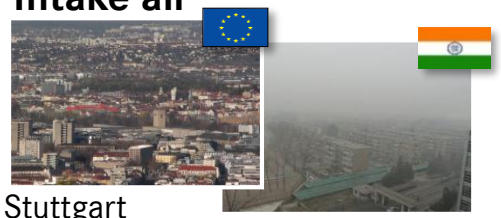
GDP per capita: US$ 1806 (PPP, 2015)

- **Currently air quality in Europe is determined by Euro V / EEV standard. Euro VI still plays a minor role.**
- **Germany is the only European country with substantial stimulation for Euro VI (highway toll !)**
- **India mainly on Euro I/ II level (Euro I: PM: 0.4g/kWh vs. Euro V-EEV: 0.02g/kWh)**

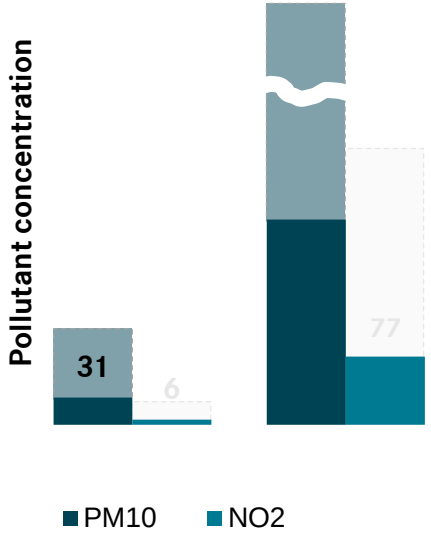
Euro VI requires by far the most complex technology but India today is mainly on Euro 0 to Euro III level

Development of technologies to reach exhaust gas emission limits – example PM and NO_x

Intake air



Stuttgart New Delhi



Euro III

- improved turbocharger
- engine internal measures

regular resonator

Exhaust gas

NO_x
PM_{10}
...

Euro IV/V/EEV

- increased injection pressure

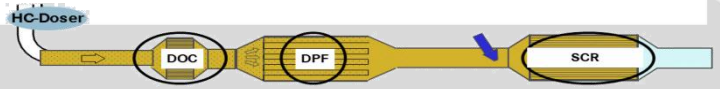
+ SCR system / AdBlue

Exhaust gas

< NO_x
< PM_{10}
...

cost increase

Euro VI



New engine generation

- increased max. peak pressure
- Common-Rail injection
- Exhaust Gas Recirculation (EGR)

SCR system / AdBlue
+ EGR cooling
+ HC-Doser
+ DOC

Exhaust gas

<< NO_x
<< PM_{10}
...

cost increase

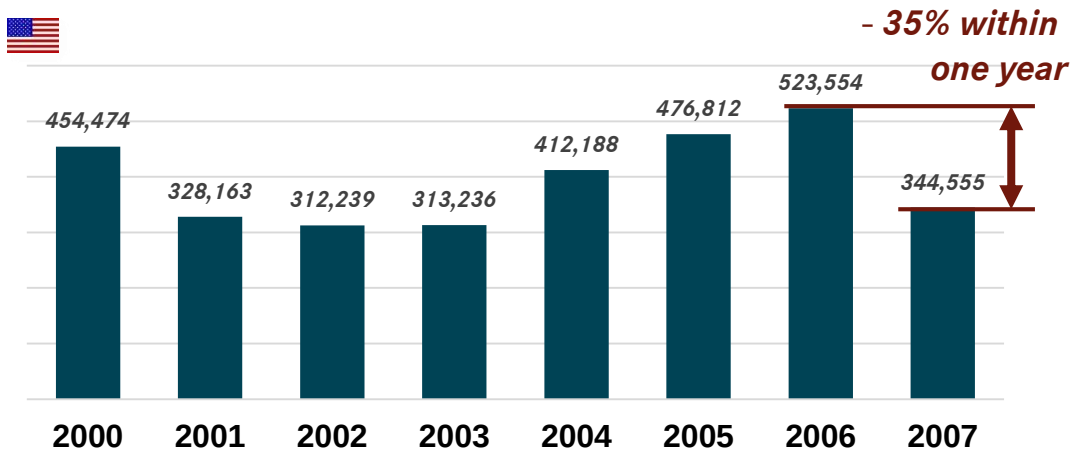
- **Only with costly measures in engine and aftertreatment systems Euro VI can be fulfilled.**
- **Will the Indian heavy duty vehicle market be ready for a costly and complex technology?**

SCR: Selective Catalytic Reduction EGR: Exhaust Gas Recirculation DOC: Diesel Oxidation Catalyst DPF: Diesel Particulate Filter

When markets weren't ready: Radical changes caused harmful effects – examples: EPA07 in USA (2007) and Euro V in Brazil (2012)

Introduction EPA 07 for HD commercial vehicles, USA

Registration of Cl. 6/7/8-CV in USA from 2000 to 2007 [units]



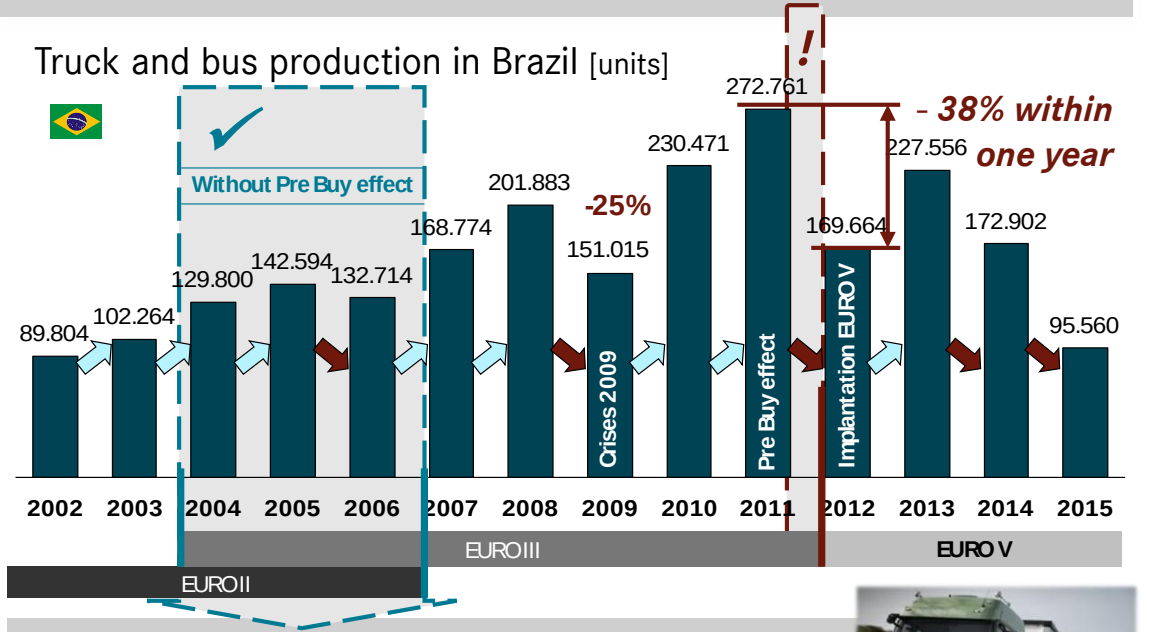
Customer cost situation

- **EPA07 vehicles with higher sales price**
- **EPA07 versus EPA04: disadvantage in fuel consumption of 3 to 7%** (introduction of DPF)

Diesel Particulate Filter (DPF)

Introduction Euro V for HD commercial vehicles, Brazil

Truck and bus production in Brazil [units]



Social and economic effects

With **incremental implementation** of new limits:

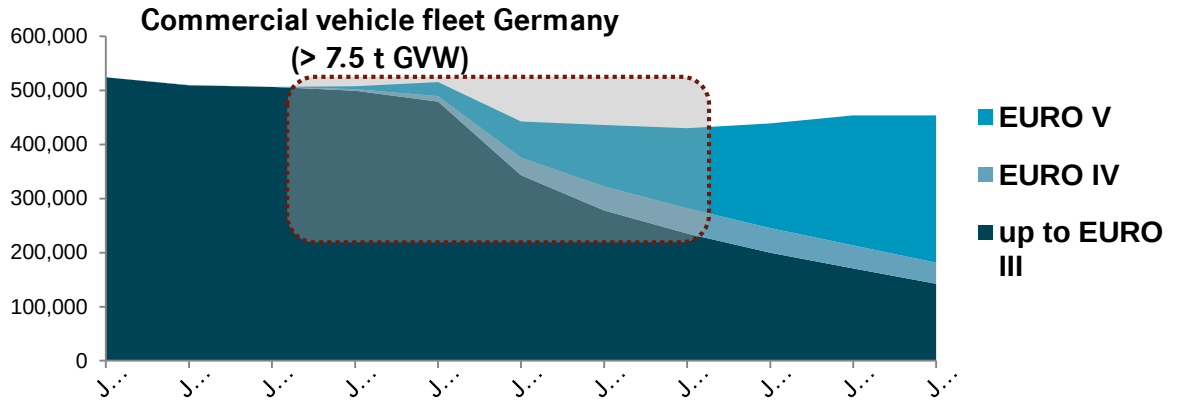
- **No risk** of economic crisis by the effects of 'pre buy'
- Can be made **regardless of** government changes or **economic swings.**

- **Pre-buy effects with dramatic consequences for truck manufacturers and economy, along with negative impact on environment!**

Introduction of Euro V in Europe
A success story

Winning parties at all shareholders

Winning: Customers ✓



High acceptance

- **Efficient vehicles**: efficiency of Euro V engines improved by 4%
- **Less emissions**
- **Reasonable** increase in **costs**
- **Robust** and **economic** technology

Winning: Legislation ✓

- Advancement of Euro V technology – e.g. by low toll rates in Germany
- Available AdBlue infrastructure

Winning: Manufacturers ✓

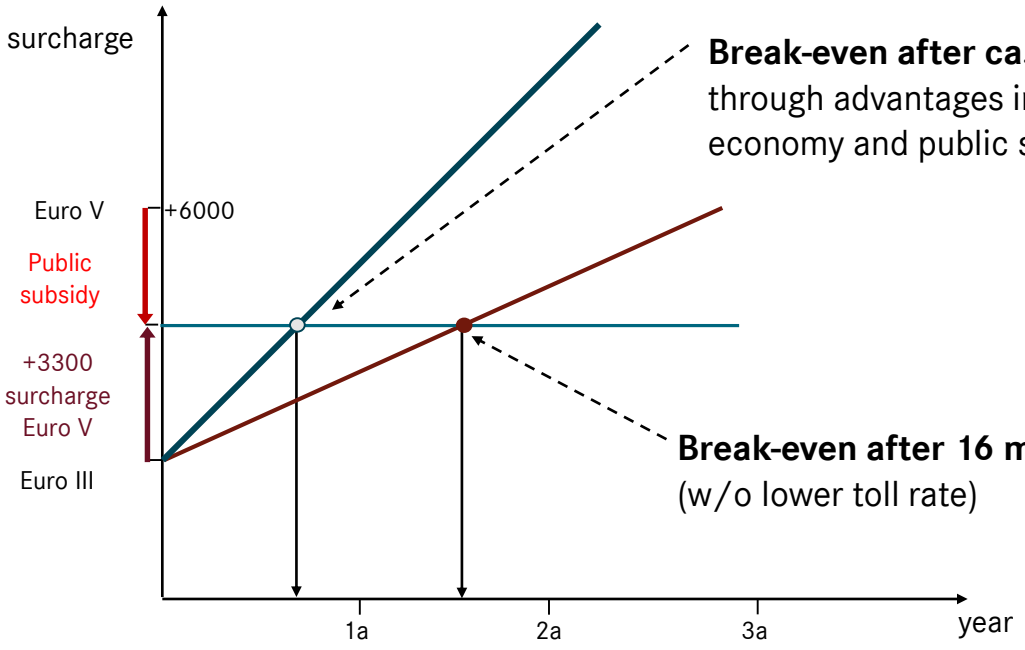
- High request for vehicles from the market
- No buying resistance
- Acceptable cost increase

BLUETEC 5

- **Early market penetration with Euro V vehicles due to motivating governmental incentives.**

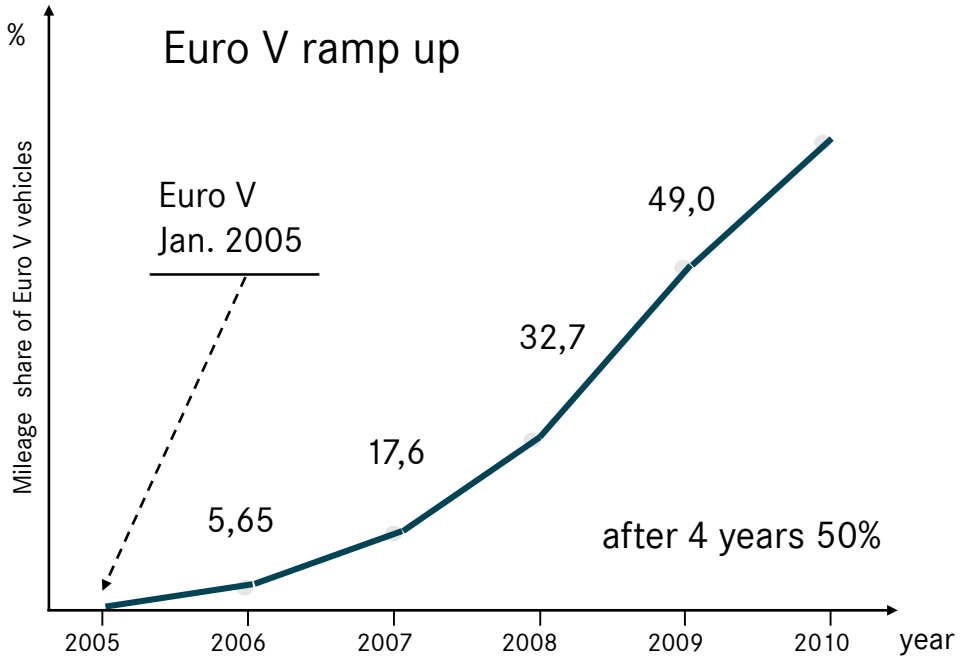
German highway toll system
Supporting the introduction of Euro V emission standard

Lower toll rates for advanced technologies provided for quick market acceptance of Euro V over Euro III / IV



assumptions

- *surcharge Euro V vs. Euro III: 6000€*
- *improved fuel efficiency Euro V vs. Euro III: 4%*

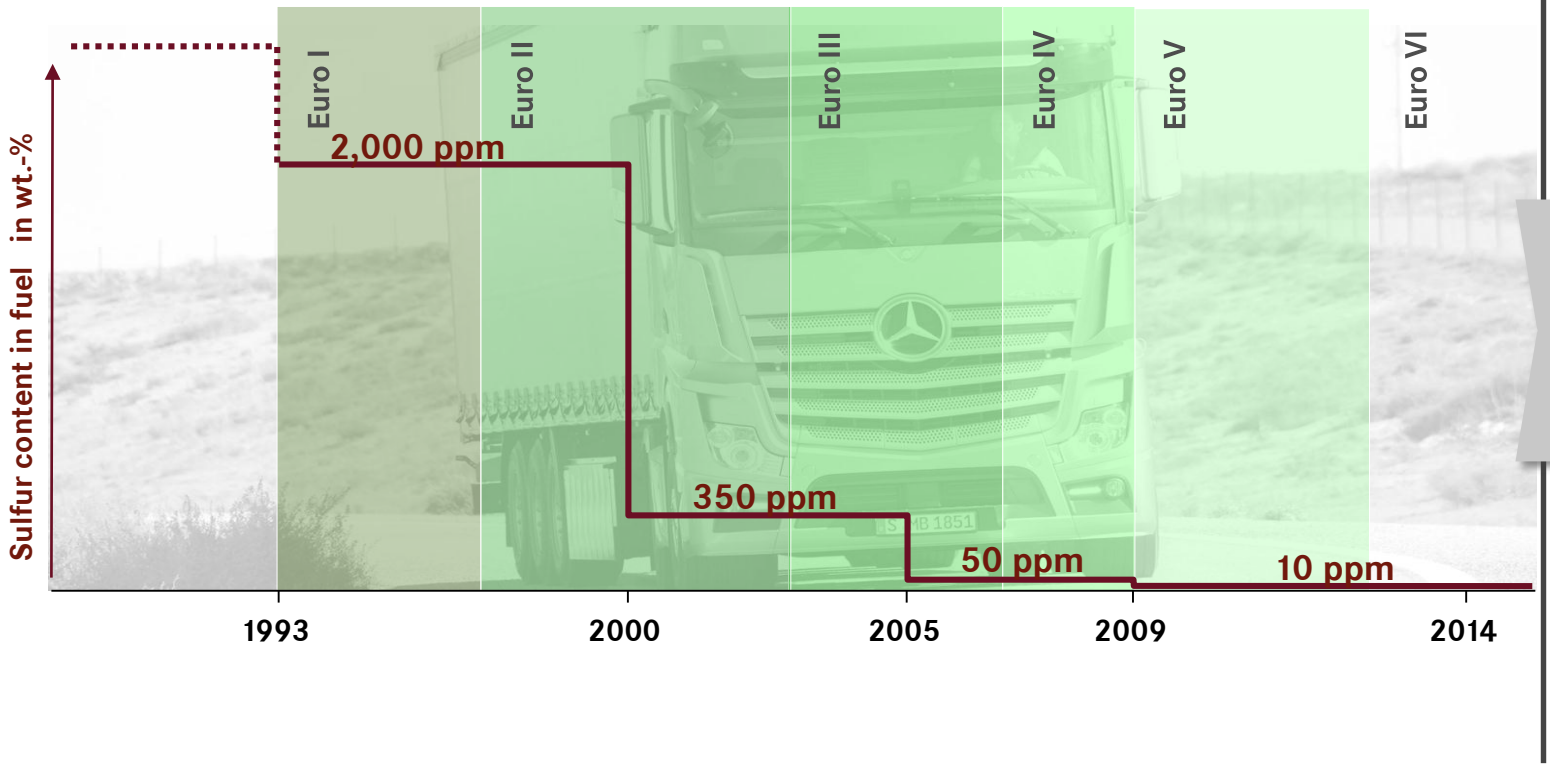


- *Toll rate advantage Euro V vs. Euro III : 2ct/km*
- *Public subsidy: 45% of surcharge*
- *mileage: 100.000km/year; Fuel consumption 33l/100km*

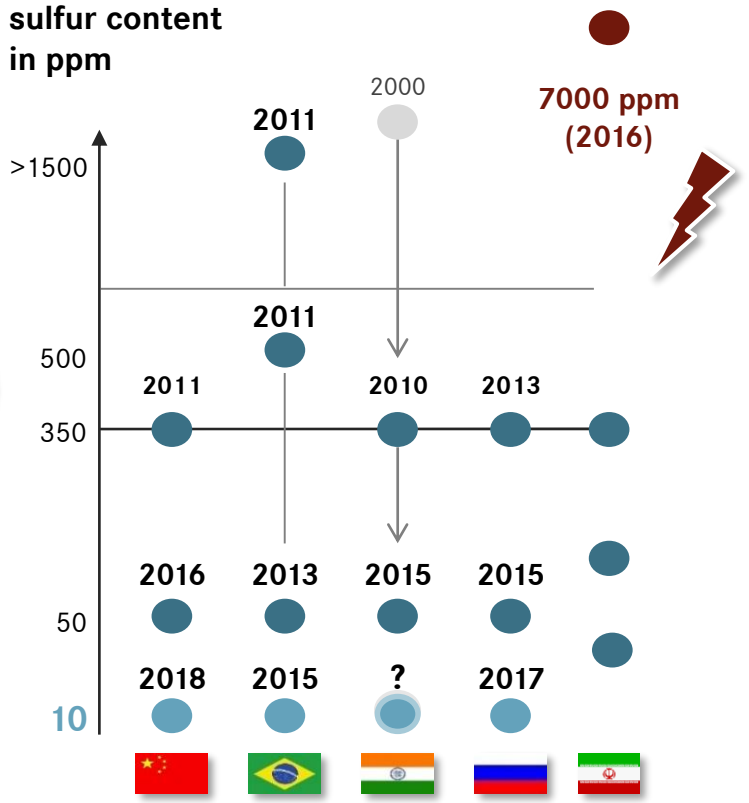
- **Quick market ramp up of Euro V in Germany under unique framework conditions of a win-win-win situation.**
- **Mandatory Euro V as of 2009 – high pre-fulfilment share of next to 50% in first mandatory year.**

Regulatory driven reduction of sulfur content as a prerequisite for introduction of Euro V/VI

Reduction of fuel sulfur level to enable and support emission standards



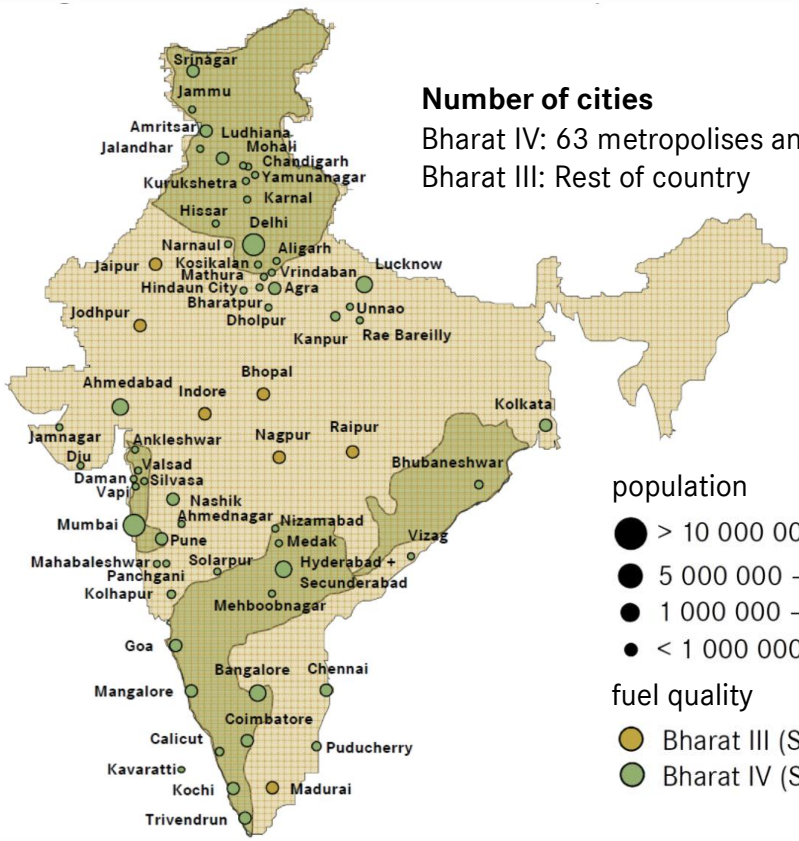
Euro V ff. allow max. 10ppm Sulfur



- Ultra low sulfur fuel is required for Euro V, but SCR more sulphur tolerant (with implications on PM limit)
- High costs and low oil prices have postponed introduction of ultra low sulphur diesel in BRIC countries.

Availability of ultra-low-sulfur fuel (max. 10 ppm, prerequisite for Euro VI) in India still requires lead-time (status July 2016)

Bharat IV fuel (max. 50 ppm sulfur) required to be available all over India in first quarter 2017

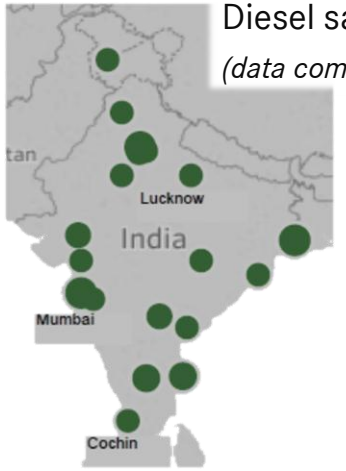


Number of cities
Bharat IV: 63 metropolises and few regions
Bharat III: Rest of country

population
- > 10 000 000
- 5 000 000 – 10 000 000
- 1 000 000 – 5 000 000
- < 1 000 000

fuel quality
- Bharat III (S<350 ppm)
- Bharat IV (S<50 ppm)

Driving improvements in fuel quality:
Staged emissions policy and related fuel standards - requirements regarding sulfur in diesel slowly progressing

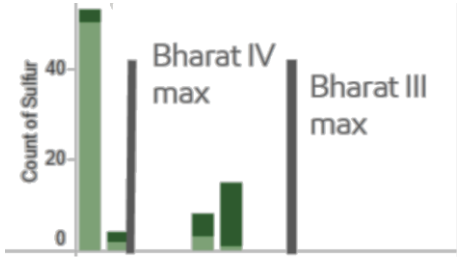


Diesel samples (SGS) / India: 80 (winter 2015-2016)
(data compared against national/local specifications)

Diesel observations regarding sulfur content

Range: 18-297

Average: 98



Source: Exxon Mobile, Fuels Quality in Growth Markets, October 2016

- **Proposal of ‚Expert Committee for Auto Fuel Vision and Policy 2015' taken over by government, notification in Motor Vehicles Act in August 2015.**
- **Improvements towards fuel quality targets, technological/economic factors slowing down change.**

Estimated invest for EURO VI technology and NO_x abatement costs in HD vehicle sector were more than doubled in reality

Impact assessment legislative process

Estimated additional costs for HD CI from Euro IV to Euro VI in 2012
(full cost allocated to emission reduction)

	limits g/kWh ETC*	Engine swept volume (L)	cost (€)		
			low	high	avg
scenario 1	PM: 0,030	6	297	533	415
	NOx:2,00	9	346	935	640
	THC: 0,55	13	428	1287	857
scenario 2	PM: 0,015	6	1131	1753	1442
	NOx:1,00	9	1632	2315	1973
	THC: 0,55	13	2116	3080	2598
scenario 3	PM: 0,015	6	1631	1853	1742
	NOx: 0,50	9	2332	2415	2373
	THC: 0,55	13	2816	3180	2998
scenario 4	PM: 0,025	6	2559	3255	2907
	NOx: 0,40	9	3189	4218	3703
	THC: 0,20	13	3778	5251	4515
scenario 5	PM: 0,010	6	3355	3553	3454
	NOx: 0,40	9	4318	4615	4466
	THC: 0,16	13	5351	5780	5566
scenario 6	PM: 0,020	6	3753	3753	3753
	NOx: 0,20	9	4815	4815	4815
	THC: 0,55	13	5980	5980	5980

* NH3 10 ppm CO 4,0 g/kWh

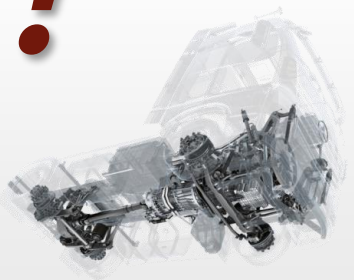
selected scenario

Source:
TNO report, 2006
Euro VI technologies and costs for Heavy Duty vehicles

Effective abatement cost (per vehicle)

2006: **Assumed average costs** of **5,600 Euro** for vehicle invest
(considering emission improvement ***starting at Euro IV level***)

2013: Approximately **12,000 Euro additional cost** for vehicle invest for Euro VI technology
*(considering additional costs **starting at Euro V level**)*



Assumptions:

average consumption HDV EURO V	33	l/100km
consumption penalty due EURO VI	2	%
mileage lifetime	700,000	km
vehicle effectiveness	40	%
Euro V	2	g/kwh output power
Euro VI	0.4	g/kwh output power
avoided NO_x due Euro VI	1.6	g/kwh output power
additional costs EURO VI technology	12,000	Euro/HDV
calorific value	9.8	kwh/l
average diesel price (VAT excl.)	1.21	Euro/l

Avoided NO_x (reg. veh. lifetime): 1,45 t
Additional costs: 17.583 Euro/HDV lifespan
Abatement costs 12.136 Euro/t NO_x

- **Even after intensive investigations in preparation of legislation, investment costs for EURO VI technology are far higher than expected during legislative process in 2006.**
- **As a result, abatement costs per t NO_x are significant.**

BS V – EEV: A viable 2nd option to India's BS VI requirements

Overview on main arguments for a Euro VI implementation beyond 2020

Strategy position and issues to argue for

Recommendation for a successful implementation in India

- **Euro V –EEV to be allowed parallel to BS-VI till 2022 (all vehicle classes)**
- **Further improvements: Incremental introduction starting with city buses earlier**
- **Make improvements in infrastructure based on BS-V EEV experience**

Customers

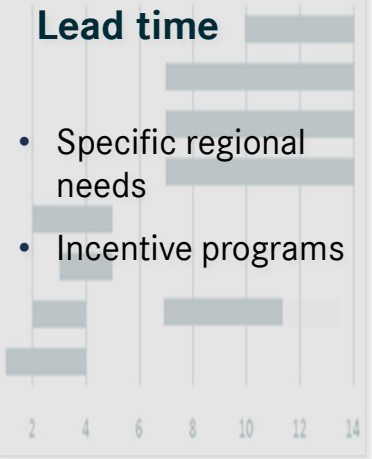
- Due to high prices and unknown technologies customers will continue to operate old vehicles

Economic Development

- Higher vehicle costs
- Robust economic growth needed
- Jobs at risk if customers won't buy

Lead time

- Specific regional needs
- Incentive programs



Environmental Impact

- Impact of BS V limits
- Fleet emission reductions

Fleet Renewal

- Market penetration
- Average age

Fuel and AdBlue Quality

- Ultra-low-sulfur fuel availability with consistent quality
- Technology intolerant to adulteration of fuel

Based on the experiences in all other markets:

- **It is unlikely that the uptake rate of Euro VI will be high in the first years.**
- **Therefore an unbalanced introduction of Bharat VI will not lead to the desired improvements of air quality.**

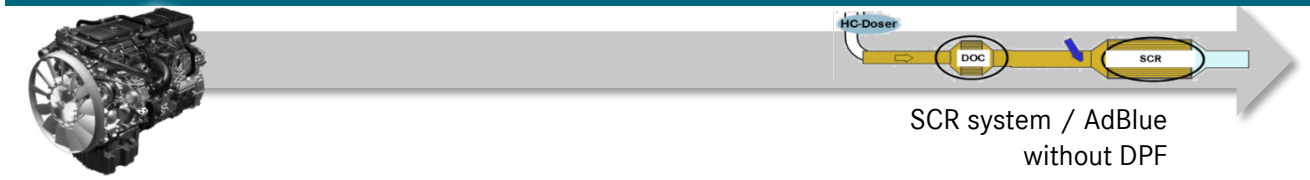
Summary: India should consider EEV as a 2nd option for a 2020 HDV emission standard

- Euro IV and V have been fully accepted by customers and therefore created a win-win-win situation in Europe
- No_x , PM and CO_2 emissions significantly reduced through the introduction of Euro V/EEV – and Euro IV/V based on SCR created the way to Euro VI
- Governmental incentives (toll charge discounts, taxation, technology subsidies, exclusion from driving bans) are a very important basis for a smooth ramp-up of new technologies
- Prepare the markets: Involve customers, oil companies, AdBlue distributors, political parties
  Make sure that acceptable fuel quality is available countrywide
- Industry, suppliers and customers together built up an affordable AdBlue infrastructure
  - IBC (bulk) solutions play the major role in the market
- The introduction of a challenging emission legislation can be a success story for all relevant players, if the timeframe for a solid marketing preparation is sufficient

Backup

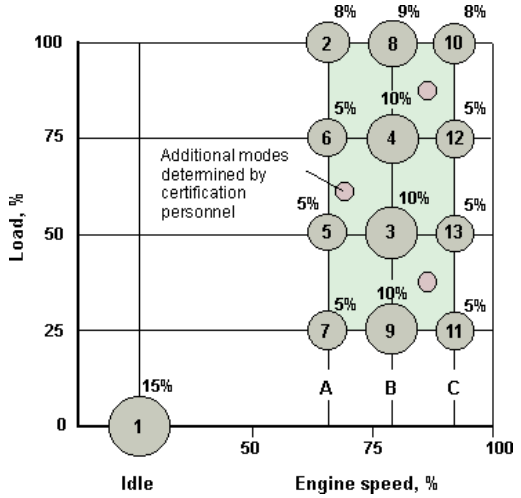
Alternative option: Euro V / EEV as ideal bridging technology paving the way towards medium-term Euro VI introduction

Euro V

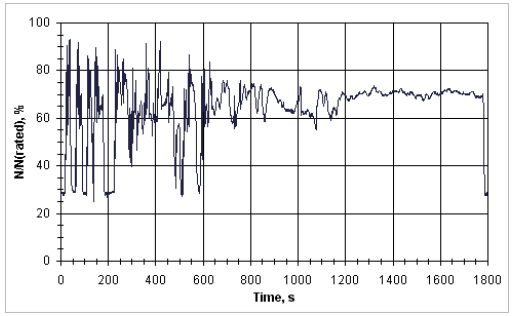


SCR system / AdBlue
without DPF

ESC test cycle



ETC test cycle



Test Cycle		Euro EEV WHSC	Euro EEV WHTC
NO_x	[g/kWh]	2.0	2.0
PM mass	[g/kWh]	0.02	0.02
CO	[g/kWh]	1.5	3.0
HC [c]	[g/kWh]	0.25	
smoke	[m^{-1}]	0.15	
NMHC	[g/kWh]		0.4 [d]
NH_3	[ppm]	25	25
Part. number	[#/kWh]		
CH_4	[g/kWh]		0.5

c For diesel engines only
d For gas engines only

Euro V/EEV

defined in
European Directive
2005/55/EC

Expected/required lifespan

Aftertreatment system:
500 tkm
Engine :
700 tkm

- **Based on the difficult sulfur situation still in Indian diesel it would be pragmatic to propose a solution on the basis of Euro V/EEV (European Dir. 2005/55/EC) as the best compromise**

Euro-V EEV is a smart approach of transition to Euro-VI from Euro-IV. Reduction of PM is close to Euro VI

	NOx (g/kWh)	PM (g/kWh)	THC (g/kWh)	CO (g/kWh)	Ammonia slip (ppm)	Particle number
ESC EU IV	3.5	0.02	0.46	1.5	25	-
ESC EU V - EEV	2.0	0.02	0.25	1.5	25	-
WHSC EU VI	0.40	0.01	0.13	1.5	10	8 E 11

	NOx (g/kWh)	PM (g/kWh)	THC (g/kWh)	CO (g/kWh)	Ammonia slip (ppm)	Particle number
ESC EU IV	3.5	0.03	0.55	4	25	-
ETC EU V - EEV	2.0	0.02	0.40	3	25	-
WHTC EU VI	0.46	0.01	0.16	4	10	6 E 11