Why are we discussing BSVI today?

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CSE Round Table
BSVI Readiness and Roadmap
New Delhi, April 8, 2019
A long journey… A recap

More than 20 years of Right to Clean Air campaign
- Campaign for clean fuels and technology
- Campaign for clean diesel and to curb dieselisation

Strategic intervention accelerated pathways
But stepped introduction weighed down progress
- 2000: Delhi Euro II; Nation-wide: Euro I
- 2005: Euro III major cities; Euro II: Nation-wide
- 2010: Euro IV major cities; Euro III: Nation-wide
- 2017: BSIV nation-wide

The big leap:
2020: BSVI nation-wide
Our first leapfrog

CNG Bus Emissions in 2004

- Bharat stage II Diesel Bus (500ppm max. sulfur) - 0.32
- Bharat stage II Diesel Bus + CRT (50ppm max. sulfur) - 0.009
- Bharat stage II CNG Bus + 3 way catalyst - 0.007

Source: Teri
Why leapfrog? To stay ahead of the pollution curve

- 80% of cities are critically polluted; 95% of Indians breathing unsafe air
- India motorising and dieselising rapidly
- Vehicles responsible for high level of exposure – In Delhi responsible for 40% of particulate pollution inventory
- Diesel emissions responsible for high health impact (ICCT).
- Delhi early signs of stabilisation – but long way to go

Source: 2016, Road Transport Yearbook, MoRTH
Motorization: High growth rate across Cities

Trend in total registered vehicles and average annual growth rate in the 14 cities (2006–16)

- Mega cities have very high vehicle stock; Delhi highest
- Metropolitan cities with smaller base have recorded very high growth rate

Source: MoRTH statistics
How much vehicles contribute to particulate pollution?
PM2.5 Emission inventory

**SAFAR/IITM**

- Transport: 39%
- Industry: 22%
- Wind Blown: 18%
- Residential: 6%
- Power: 3%
- Others: 12%

**TERI- ARAI**

- Transport: 39%
- Road Dust: 18%
- Construction: 8%
- Waste Incinerators: 6%
- Others: 6%
- Refuse Burning: 4%
- Landfill Fires: 5%
- Power Plants: 11%
- Residential: 6%
- Industries: 3%

Source: 2018, SAFAR High Resolution Emission Inventory of Delhi City, Indian Institute of Tropical Meteorology

Note: Others i- agricultural burning, crematoria, restaurant, airport, waste incinerators, Source: August 2018, Source Apportionment of PM2.5 & PM10 of Delhi NCR for Identification of Major Sources, Prepared by ARAI and TERI
PM2.5
Source apportionment

Summer
- Secondary: 17%
- Vehicle: 18%
- Dust + Construction: 34%
- Industry: 11%
- Biomass: 15%
- Others: 5%

Winter
- Secondary: 25%
- Vehicle: 23%
- Dust + Construction: 16%
- Industry: 11%
- Biomass: 21%
- Others: 4%

Source: August 2018, Source Apportionment of PM2.5 & PM10 of Delhi NCR for Identification of Major Sources, Prepared by ARAI and TERI
How much pollution we breathe while travelling?

Source: Based on CSE exposure monitoring and DPCC data for ambient levels.
Bharat Stage VI roll out begins
April 1 milestones…..

April 1: 2018: Delhi got Bharat Stage VI (BSVI) compliant 10 ppm sulphur fuels

April 1 2019: NCR to get BSVI fuels

April 1, 2020: The big leap
• Entire country will move to BSVI emissions standards for vehicles and BS VI compliant fuels
Clean fuel helps.....

- **On-road vehicles will spew less particles**: Sulphur contributes to formation of particles.

- **Sulphur dioxide emissions**—a deadly gas, is also directly proportional to the amount of sulphur in fuel.

- 10 ppm sulphur fuels allow emissions control systems of on-road diesel vehicles to perform more efficiently.

- Less engine wear-and-tear for all that can reduce emissions.

- **Petrol vehicles will also benefit**: Sulphur reduces the efficiency of catalysts and adversely affects heated exhaust gas oxygen sensors.

- Opens up opportunity for retro-fitment of advanced emissions control systems.
2005-2020: Deep cuts

Petrol cars-- NOx

Diesel cars-- PM

HDV-- NOx

HDV-- PM

Source: DieselNet.com Emission standards- India
Why BSVI is disruptive?

- **India to come close to fuel neutral standards** as the difference between petrol and diesel emissions will narrow down substantially.

- Not only the total mass of PM emissions from diesel vehicles will be weighed and regulated but also particle numbers will be counted to ensure effective emissions control devices are adopted.

- **Vehicles will be tested for real world emissions** – monitor emissions portable emissions monitors over the driving pattern of vehicles on the road.

- Two wheeler standards will become significantly more stringent. For the first time Nox and hydrocarbon will be regulated separately; evaporative standards; OBD.
Automobile industry

April 1, 2020, all vehicle models to meet BSVI; No extra time for older models (Supreme Court)

New investments: SIAM: Economic burden on automobile manufacturers significant; Many new technologies to be developed

Paradigm shift in diesel emissions control system: Diesel particulate filters (DPF) for PM control; lean NOx traps (LNT), and selective catalytic reduction (SCR) and exhaust gas recirculation (EGR) for Nox control

Higher incremental cost for diesel vehicles: Small diesel cars will be challenged

Big impact on emissions control component industry
Oil industry

Clean fuels by 2020 has enabled BSVI leapfrog

- Upgrading refinery technology
- 12th 5-year plan (2013-2017) public sector refinery investments:
  - Much of low sulphur investment included in 12th five-year plan
  - Investment from private sector as well

- Capital costs -- Annual capital charges associated with investments
- Operating costs
  - Cost of additional hydrogen supply
  - Cost of replacing lost product yield
  - Cost of maintaining other aspects of fuel quality
  - Other operational costs

More economical to leapfrog than clean up incrementally.
Benefits much higher than the costs

280,000 cumulative avoided deaths by 2030 from fuel and emissions standard roadmap

Source: International Council On Clean Transportation
Global learning curve: Huge risks if not done properly…
Europe: Challenge of real world emissions

NO\textsubscript{x} EMISSIONS FROM EU CARS: REAL-WORLD VS OFFICIAL VALUES

Eliminate gap between certification and real world vehicular emissions

Diesel cars: Nitrogen oxide (NO\textsubscript{x}) emissions (in g/km)

Euro 3 (MY 2000–2006)


Euro 5 (MY 2009–2015)

Euro 6 (MY 2014–2017)

Petrol cars: Nitrogen oxide (NO\textsubscript{x}) emissions (in g/km)

Euro 3 (MY 2000–2006)


Euro 5 (MY 2009–2015)

Euro 6 (MY 2014–2017)

Source: FIA Foundation
Unacceptably high emissions from diesel cars in Europe

Real world NOx emissions of Euro 5 vehicles

Real world NOx emissions of Euro 6 vehicles

Source: April 2016, Vehicle Emissions Testing Programme, Secretary of State Transport, UK
Real world emissions from Euro IV cars in Europe (gm/km)

Source: Anon 2015, Driving away from diesel, Reducing air pollution from diesel vehicles, London Assembly, Environment Committee.
Global action on diesel cars
Diesel car sales down

London: Pre Euro VI cars not to be allowed inside the ultra low emissions zone in Central London.

France: Euro VI diesel cars not to be included in the new category 1 colour coding scheme that classifies vehicles according to how much they pollute. French government to “progressively” ban diesel vehicles.

Paris: To phase out pre-2011 diesel cars by the end of the decade.

Madrid: To ban polluting diesel cars from the city centre from 2020.

Netherlands: In 1998 the Third National Environment Policy targeted to reduce diesel share to only 5% in 2010. Dutch registration and circulation taxes for diesel cars are close to prohibitive. Kept share of diesel cars in Netherland lower than EU average.

Brazil: Sales of diesel passenger cars and commercial vehicles below 1,000 kg are banned.

Beijing has banned diesel cars as a pollution control measure. China has the lowest diesel car penetration at less than 1%. China taxes do not differentiate between petrol and diesel fuel.

Sri Lanka has imposed several times higher duties for diesel cars compared to petrol cars and have reduced diesel car sales.
What happened in Europe after that?
Focus shifts to real world emissions
Euro VI+ strategy
Spate of regulatory reforms

Four packages of additional reforms to tighten lab tests and real world monitoring

**Package one: RDE Act 1, 2016:** Test procedure with basic features of Realworld Driving Emissions (RDE) test for monitoring purposes; Type approval continued as laboratory measurements.

**Package 2: RDE Act 2 – September 2017:** RDE testing included in type approvals. RDE measurements of NOx made compulsory for new car models from September 2017, and for all from September 2019. Conformity factor for Nox emissions.

**Package 3 - RDE Act 3:** RDE testing included Particle Number emissions for all new vehicle types by September 2017 and for all by September 2018. Real-world emission performance of a car disclosed by manufacturers -- transparent to all citizens and public authorities. RDE test are compliant if distance-specific mass emissions are below No to Exceed Emission Limit (NTE) limit. PEMS test procedure for particle number and Conformity Factor for particle number.

**Package 4 - RDE Act 4 - 2020:** Type approval authorities to check each year the emissions of vehicles already in circulation ("in-service conformity" testing). Authorities and independent parties to perform tests through accredited testing centres. Reduce conformity factor in RDE measurements, from 1.50 to 1.43 (for Nox). Mat further reduce to 1 by 2023.
More reforms…..

Changed the test cycle -- Worldwide Harmonised Light Vehicle Test Procedure (WLTP):

In-service conformity (ISC) tests for after market vehicles: Part of this responsibility to shift to respective type-approval authorities, which will perform WLTP and RDE tests. All parties to report results in an electronic platform to coordinate in-service conformity testing.

New type approval: European Commission may have power to carry out its own verification testing; initiate & monitor vehicle recalls. EC can impose fines of up to 30,000 EUR per noncompliant vehicle on manufacturers.

Independent market surveillance: Perform tests on vehicles already in the market to ensure vehicles meet emission limits. Market surveillance authority independent of the type approval authority.

Enforcement mechanisms: Member states will be allowed to restrict or prohibit the usage of affected vehicles or require actions by the manufacturer.

Fuel consumption meter: From January 2020 onwards manufacturers to determine
AIS 137 -- India poised for further reforms in 2023: Get it right

Heavy-duty vehicles

- 1st April, 2020, emission measurement on vehicles using portable emissions measurement systems (PEMS) to be carried out on road for data collection

- 1st April, 2023 in-service conformity factor shall be applicable.

- 1st April 2023: For PEMS demonstration test at type approval, vehicle shall meet the requirements of in-service compliance from 1st April, 2023.

- World Not-To-Exceed (WNTE) Off-cycle laboratory testing limits for gaseous and particulate exhaust emissions limits are given in BS VI notification

Light duty vehicles

- **In-Service Conformity:** In service compliance of vehicles shall be as per procedure laid down in AIS137 and as amended time to time.

- **RDE:** From 1st April, 2020, real world driving cycle emission measurement using PEMS shall be carried out for data collection and from 1st April, 2023 real world driving cycle emission conformity shall be applicable.

- **Not-to-exceed Emission Limits:** to be prescribed based on conformity factors to be assessed by 2023

Missing links in India

Align with the latest package in Europe to narrow down the gap between laboratory and on-road emissions performance of vehicles

**Light duty:** Need in-service compliance for light duty vehicles; No confirmatory factor yet

**Market surveillance and an independent verification testing and inspection by regulatory authorities of in-use vehicles and components.** Makes testing authorities responsible for testing. Also adopt PEMS testing for in-service Conformity test

**WLTP not yet adopted – RDE testing should be validated against WLTP; MIDC is weak**

**Public disclosure:** AIS 137 says - manufacturer shall ensure that information is made available on a publicly accessible website without costs. But government and testing agencies should also release data

**Define test trip on roads.** Adopt total NOx emissions as per the package 4 of Europe or increase the weighing factor in the urban driving category. Will promote in-cylinder or EGR based NOx reduction strategies at low load, which the SCR system will not reduce.
Conformity factors for 2023 yet to be decided

Need effective confirmatory factor. Committee to decide for 2030 timeframe. Need at CF=1.43 and CF=1.0. More lenient margin will lead to compromises and high real world emissions.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Maximum allowed conformity factor</th>
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<tbody>
<tr>
<td>CO</td>
<td>XX</td>
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<tr>
<td>THC (1)</td>
<td>XX</td>
</tr>
<tr>
<td>NMHC (2)</td>
<td>XX</td>
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<tr>
<td>CH4(2)</td>
<td>XX</td>
</tr>
<tr>
<td>NOx</td>
<td>XX</td>
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<tr>
<td>PM mass</td>
<td>XX</td>
</tr>
<tr>
<td>PM Number</td>
<td>XX</td>
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</tbody>
</table>

Notes:
1. For compression ignition engines
2. For positive ignition engines
3. Applicable with effect from 1st Apr 2023 as notified in notification G.S.R. 889(E) dated 16th September 2016 published by MoRTH

Note: The conformity factors to be decided based on recommendations of HDV in-service conformity committee.
Public Information system in Europe: Access to Euro 6 RDE data

European automakers are publically disclose data

Real World NOx emissions from light duty vehicles in Europe

Real-World NOx Emissions Euro 6 diesel cars (published in 2016)*

February 2019: the German automobile club ADAC published on-road emission results for 26 diesel and gasoline cars. NOx emissions far below the regulatory limit.

Source: * ICCT 2016, NOX emissions from heavy-duty and light-duty diesel vehicles in the EU: Comparison of real-world performance and current type-approval requirements  
Understanding implications for I/M regime and on-road surveillance...
On-road emissions management

PUC is not relevant for new generation emissions control technologies.

Global trend

Tightening of in-use inspection: UK: If DPF fitted vehicles emit smoke of any colour it is considered a major defect. The UK has even lowered smoke limit to 27 HSU in 2014.

Checklist for physical checks: To check if any emission control equipment fitted by the manufacturer is missing, modified or defective. This is categorized as a major defect. This includes Diesel Particulate Filters (DPF), Oxidation Catalysts and Selective Catalyst Reduction (SCR) valves.

OBD integration: Integrated on-board diagnostic systems with I/M programme. MIL is now part of the test and will be a major defect if it is inoperative or indicates a malfunction. Also checking if OBD is working (US)

Remote sensing measurements
8.2.2 Compression ignition engine emissions

8.2.2.1 Exhaust emission control equipment

This inspection is restricted to components that are readily visible and identifiable, such as a diesel oxidation catalyst, diesel particulate filter, selective catalytic reduction valve etc.

*Diesel particulate filters* (DPF) should be checked for evidence that the DPF has been removed or otherwise tampered with. Where a DPF canister has clearly been cut open and re-welded, it should be rejected unless evidence can be provided that the canister was cut open for legitimate reasons, such as filter cleaning.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Category</th>
</tr>
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<tbody>
<tr>
<td>(a) Emission control equipment fitted by the manufacturer missing, obviously modified or obviously defective.</td>
<td>Major</td>
</tr>
<tr>
<td>(b) An induction or exhaust leak that could affect emissions levels.</td>
<td>Major</td>
</tr>
<tr>
<td>(c) Evidence that the diesel particulate filter has been tampered with.</td>
<td>Major</td>
</tr>
</tbody>
</table>
China:
- Remote sensing in use since 2005. There are 22 removable remote sensing devices and 27 fixed remote sensing devices in Beijing. Vehicles that exceed the remote sensing standard needs to go to smog station for retest; it will be fined if it exceeds again.

- Remote sensing method for HDV is used to analyze and evaluate the vehicle.

- For compliance Government is revising local law to require that driving a HDV with visible smoke once photographed by the camera will be fined directly.

Europe: True initiative:
- Three-colour system based on remote sensing monitoring has been developed.
Remote sensing initiative in Europe

- Three-colour system
- Green – good - lowest available in-use emissions
- Red – poor - emissions are 3 times or more than the latest emission limits.
- Informative for consumers, policymakers and manufacturers

Fleet profiling

- NOx emissions are systematically much higher for diesel cars, even for the newest Euro 6 models
- All Euro 6 diesel models exceeded the Euro 6 diesel NOx emissions type-approval limits
- Remote sensing results are consistent with laboratory testing conducted by Transport for London

Source: The Real Urban Emissions Initiative (TRUE) March 2019,
Beijing: Remote sensing and roadside inspections

• In 2017, Beijing local standard Rapid Testing of NOx and Limit Value Method for Heavy-Duty Vehicles came into effect.

• The in-use vehicles that fail to meet the NOX emission standard are punished according to law, and the PEMS inspection carried out.

India
Remote sensing monitoring in Kolkata

Delhi: ICAT pilot; MORTH-ARAI to develop guidelines
To develop threshold limit to pull out gross polluters
How to use this for compliance
Centralised inspection test centers

10 Model I&C Test Centers being established..

- Haryana
- Himachal Pradesh
- National Capital Region
- Rajasthan
- Uttar Pradesh
- Gujarat – Surat
- Maharashtra – Nasik
- Madhya Pradesh – Chindhwara
- Telangana – Hyderabad
- Karnataka – Bengaluru

Centers to be facilitated by ARAI
Centers to be facilitated by iCAT
Center to be facilitated by SIAM

This is not scalable: Leverage them strategically; Need other supportive measures for basic screening

Source: ARAI
How do we operate and maintain this technology?
## Technology options for cars

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<thead>
<tr>
<th></th>
<th>BSIII</th>
<th>BSIV</th>
<th>BSV</th>
<th>BSVI</th>
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<tbody>
<tr>
<td><strong>Gasoline Vehicles</strong></td>
<td></td>
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<tr>
<td>Multipoint Fuel Injection + Closed loop A/F system + 3 Way Catalyst Convertor</td>
<td></td>
<td></td>
<td>Gasoline Direct Injection + Turbocharger + VVT + Controlled EGR</td>
<td>Gasoline Direct Injection + Use of Gasoline Particulate Filter</td>
</tr>
<tr>
<td><strong>Diesel Vehicle</strong></td>
<td>Mechanical FIE system + DOC</td>
<td>CRDi &lt; 1800 bar + DOC POC + EGR + Turbocharger + OBD monitoring</td>
<td>High Pressure CRDi &gt; 2000 bar + SCR + DPF +EGR+ Turbocharger + OBD monitoring</td>
<td>High Pressure CRDi + SCR + DPF +EGR+ Turbocharger + OBD monitoring + Lean NOx Trap (LNT)</td>
</tr>
</tbody>
</table>

Note: GDI is an option as it is likely that only in GDI vehicles GPF would be used.
Diesel emissions control system

National Academies Press
Technology pathways for diesel and CNG

IVECO Stralis Natural Power
Environmental benefits – Simple EATS

L-CNG Euro VI
Lambda Sensor
3 WAY CATALYST
Lambda Sensor
T* sensor
1 element
3 Sensors
45 kg

NOx Sensor
T* Sensor
Diesel Euro VI
PARTULATE FILTER
ADBLUE INJECTOR
ADBLUE MIXER

5 elements
7 Sensors
≈ 250 kg

AdBlue Pump
Engine Control Unit

NOx Sensor
NH3 Sensor
T* Sensor

1 additive + tank
1 Pump
1 injector
1 mixer
Prevent cheating and tampering

EGR tampering
External zapping device
• External black box plugged behind EOBD socket

Mechanical tampering
• Physical change in engine compartment
• Blocking gas tube with a baffle
• Sealing hose to the vacuum actuator


DPF removed
• Missing part or visible alteration (e.g. welding seam) of exhaust pipe
• Soot in exhaust of a Euro 5/6 vehicle, may indicate DPF removal (an indication, no proof for manipulation)

DPF gutted
• Soot in exhaust of a vehicle, may indicate DPF removal
Prevent tampering

SCR disconnected and ECU emulator

• Reagent tank gauge showing exactly 25%, 50%, 75% or 100%
• Reagent tank empty or level does not correspond with gauge
• Crystallisation and/or rust around the AdBlue tank cap and/or filler pipe when cap removed
• Fuse removed/blown from SCR system
• Modified wires in the harness
• Soldered wires
• Electronic device fitted in OBD-port or with wires spliced into the wiring from SCR ECU may be an emulator

Maintenance challenge

- Expensive after treatment systems; Good maintenance to reduce cost of repair
- Sensitise drivers, mechanics, about DPF and SCR and their working
- Specialised maintenance – maintenance intervals and schedule
- Inspection protocol
- Working of SCR: Frequency of urea refill and cost of urea: Many estimates: AdBlue consumption to vary across models -- A heavy vehicle with a mileage of 5km/litre will need approx. 12 litres of AdBlue per 1,000 km; With truck tank capacity of over 40 litres, to cover approx 3500 km with tank full of AdBlue.
  - Cars?
- Infrastructure for urea - highways
- Quality benchmarks
- Action against tampering and cheating devices
**Way forward**

**National level**
- Align with latest package of Europe to reduce gap between lab and real world
- Further strengthen compliance and testing regulations for effective real-world emissions performance
- In-service compliance programme for LDVs
- Public disclosure and independent verification
- Penalty and warranty

**State level**
- Upgrade vehicle inspection programme
- Automated advanced vehicle testing centres, OBD integration, and guidelines and norms for remote sensing monitoring, physical verification
- Maintenance protocol for bus corporations and truck operations
- Prevent tampering with emissions control system (especially SCR system; Urea refilling infrastructure)
Let’s begin the discussions...