Real World Emissions

An Industry Perspective - Light Duty Vehicles

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India Habitat Center, New Delhi

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Outline

- Global Scenario on Real World Emissions
- Key Insights from EU Experience
- Issues and Concerns in the Indian Context
- The Way Forward

Global Scenario

Our understanding on Global Approaches?

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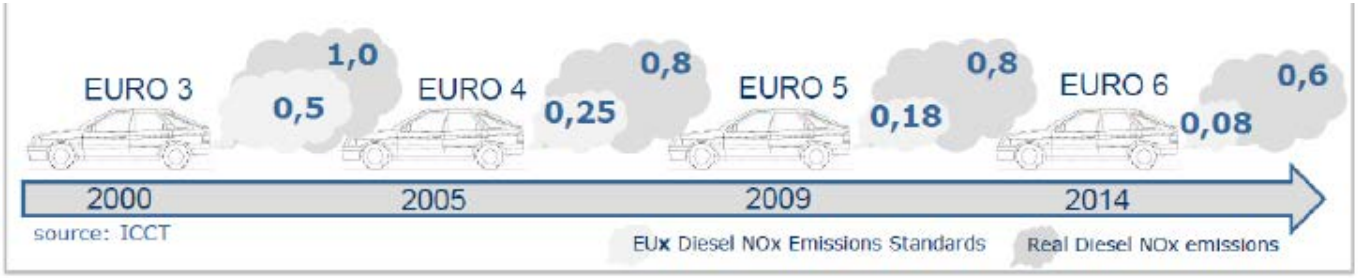
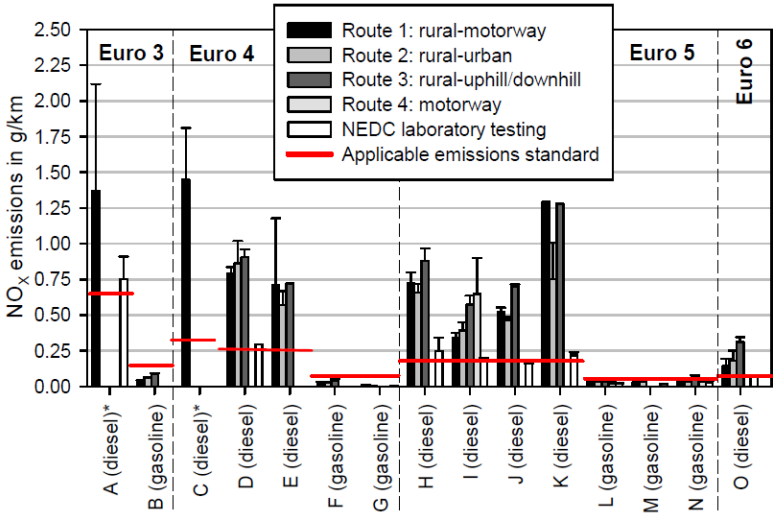
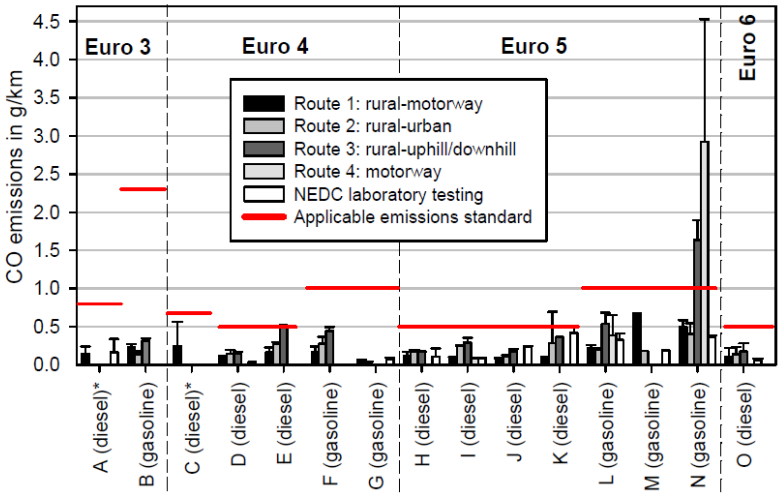
Background



Source: ICCT





Source: JRC Report EUR 25572, 2013

India : BS6 Notification, GSR 889(E), dtd. 16th Sep 16

During type approval and COP applicable 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. The detailed procedure is laid down in AIS137 and as amended from time to time.

There is a need to have Test Protocols for evaluating Emissions in Real World Driving Conditions.

Available Test Protocols

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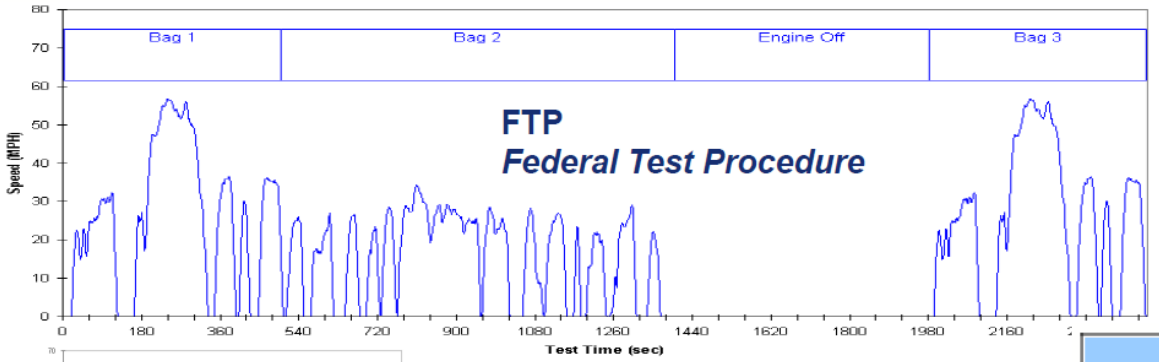
Country	PEMS based Tests	Lab Tests
USA	▪ No regulatory Requirements. ▪ Primarily for research work & emission source modelling.	▪ Supplementary Tests for Light Duty
EU	▪ Monitoring from Jan 2016 for New type-approvals ▪ Compliance from Sep 2017 for new type Approvals from Sep 2017.	▪ No provision
Japan	▪ No Regulatory Requirements ▪ Used for Research Work ▪ Study for suitability of PEMS for defeat device detection.	▪ No provision

Approaches for Light Duty Vehicles :

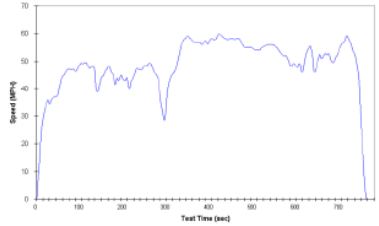
- ❑ On Road using PEMS (**P**ortable **E**mission **M**easurement **S**ystem)
- ❑ Supplementary Tests in Test Lab (In addition to Primary Certification Test)

Globally, two distinct Approaches Available

The US Example



FTP
Federal Test Procedure



HWFET
Highway Fuel Economy Test

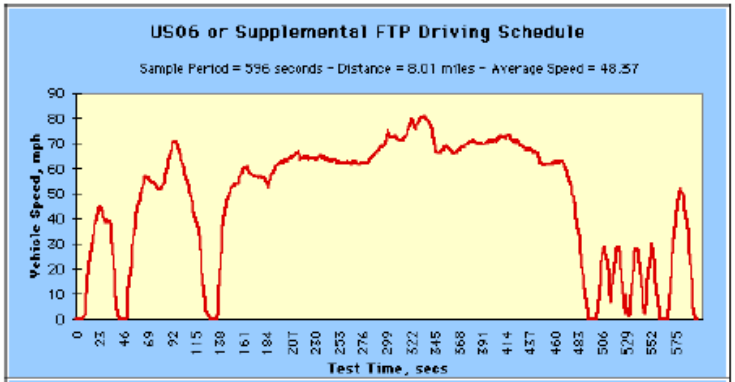
Primary Test Cycles

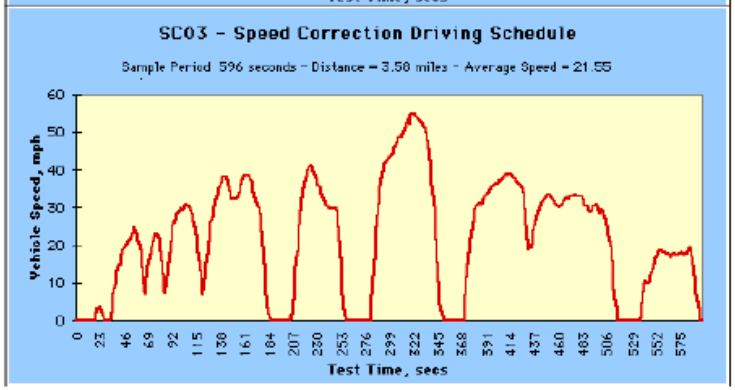
- FTP 75
- HWFET

Supplemental Cycles

- Aggressive driving behavior
- Rapid speed fluctuations
- Driving behavior following startup, and
- Use of air conditioning

US06: High acceleration, aggressive driving
SC03: Hot, city traffic, Air Conditioning on 95F, 40% RH and 850 W/m2solar load





Supplemental Lab Tests for Real World Drive Conditions

EU Experience

- **Drivers in EU**
  - High NO2 levels (Urban hotspots)
  - Correlation established - High Nox from Diesel Vehicles

(*Source: Air quality in Europe - 2015 report, EEA & EUR 25572 EU- 2013 report, JRC)*

- **EU Approach**
  - Data collection & Study done (2011 ~ 2014)
  - Two concepts studied
    - (A) **Random Test cycle (RTC)**
    - (B) **Portable Emission Measurement System (PEMS)**
  - Compliance using PEMS for new Type Approvals from Sep 2017.

6 years of rigorous study leading to a suitable mechanism

EU Road Map

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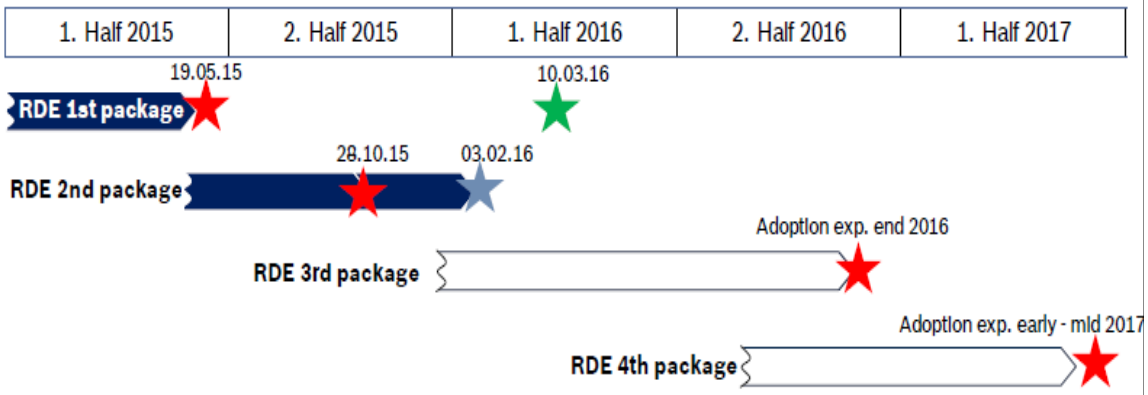
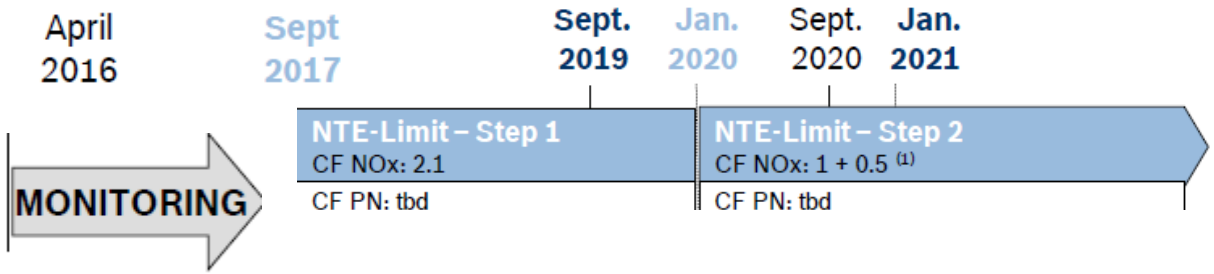
Regulation Development



Pending Items - 3rd & 4th Package

- Cold Start Evaluation
- PN Test Procedure & CF
- Testing of Hybrids
- In-Service Conformity

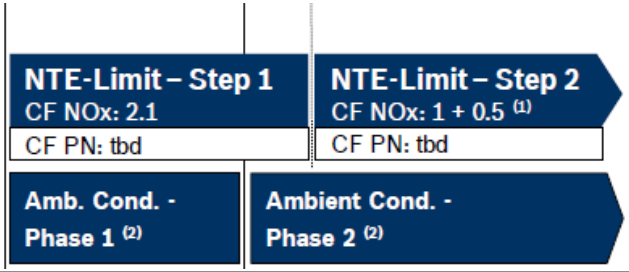
Monitoring and Compliance



New Models

Existing Models

All Types



Regulatory Requirements in EU are still being Finalized.

Key Insights from EU Experience

Our Understanding So Far

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Issues and Concerns

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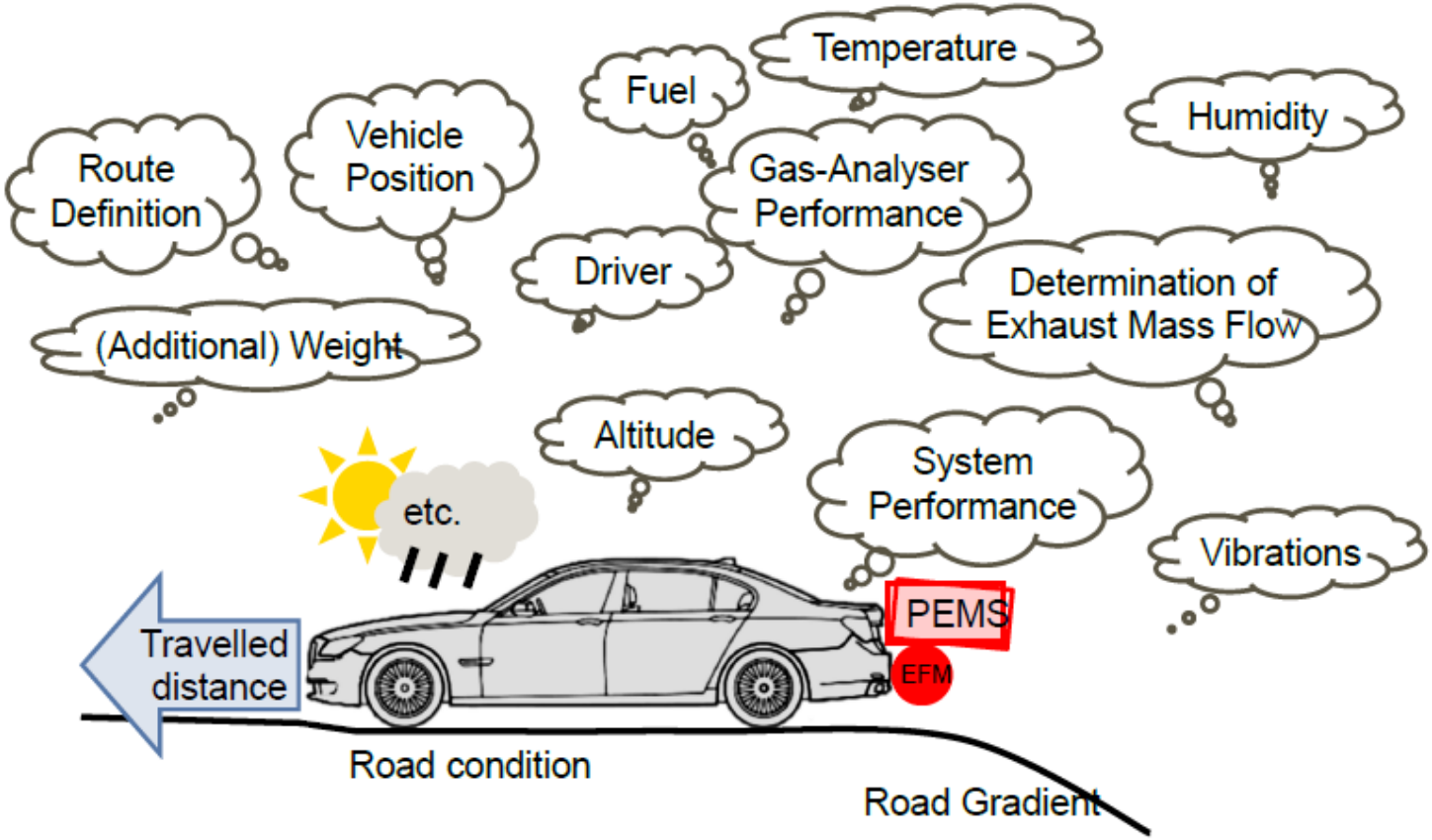

From Test Lab to Road Test , the increase in Complexity is a Challenge for Measurement Accuracy & Repeatability

A Typical EU RDE Test Schedule

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Day 1 – Installation & Verification

- EFM Selection, PEMS installation
- Pre-conditioning (For Correlation check of PEMS & CVS)

Day 2 – Correlation Check with Test Lab.

- PEMS leak check
- Starting and stabilizing PEMS
- Preparing the sampling system & EFM
- Pre-test check & calibration of PEMS
- Cold Emission on WLTC (For Correlation check of PEMS & CVS)
- Post-test calibration check of PEMS analyzer

Day 3- On Road Test including Test Preparation

- PEMS leak check
- Starting and stabilizing PEMS
- Preparing the sampling system & EFM
- Pre-test check & calibration of PEMS
- On-road RDE test (on a pre-decided and agreed route)*
- Post-test calibration check of PEMS analyzer

Day 4 – Test Validity Check & Data Analysis

- Post processing of data (MAW/Power Binning)
- Compliance evaluation

Day 5 – Final Report Compilation

- Final Report generation

Rectify PEMS
If Correlation check is out of permissible tolerances :
CO, THC, NOx: ±15 mg/km OR 15% (Larger)
CO2: ±10 mg/km OR 10% (Larger)

Repeat On Road Test
Trip requirements not fulfilled.
Tool criteria not fulfilled

*** Additional time required for Route definition, if not done earlier.**

A Typical PEMS test may take 5-7 days to complete !!

Trip Requirements

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Trip Sequence = Urban → Rural → Motorway

	Urban	Rural	Motorway
Speeds [km/h]	V ≤ 60 15 < V_{avg} (including stops) < 30	60 < V < 90	V ≥ 90 V > 100 (for at least 5 minutes)
Max. speed [km/h]	❑ V_{max} ≤ 145km/h (may be exceeded by 15km/h for max. 3% of time of motorway driving) ❑ Local speed limits remain in force at a PEMS test, notwithstanding other legal consequences. ❑ Violations of local speed limits per se do not invalidate the results of a PEMS test.		
Min. Distance [km]	16	16	16
Trip duration [min]	90 -120		
Share [of total trip distance]	34% (±10%) ❑Shall never be less than 29%	33% (±10%)	33% (±10%)
Elevation	Start & end point shall not differ in their elevation above sea level by more than 100 m.		
Stop Periods [V < 1km/h]	❑ Shall account for at least 10% of the time duration of urban operation. ❑ Urban operation shall contain several stop periods of 10s or longer. ❑ Shall avoid the inclusion of one excessively long stop period that individually comprises >80% of the total stop time of urban operation.		

Test Route Selection – Vital for ensuring a Valid Test.

PEMS Installations

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In the cabin

On the towing hitch

On the open deck

Picture Courtesy: Millbrook's , JAMA

Issues

- Less Boot Space- Requirement of Towing Hitch.
- Dual Exhaust Vehicles
- Closing of Boot Lid, when installed in the Boot
- Vehicle adaptation needed

Installation of PEMS can be Challenging for some vehicles, requiring Vehicle Adaptation and Customization

The Indian Context

Issues & Concerns

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India Ambient Air Quality – Concerns

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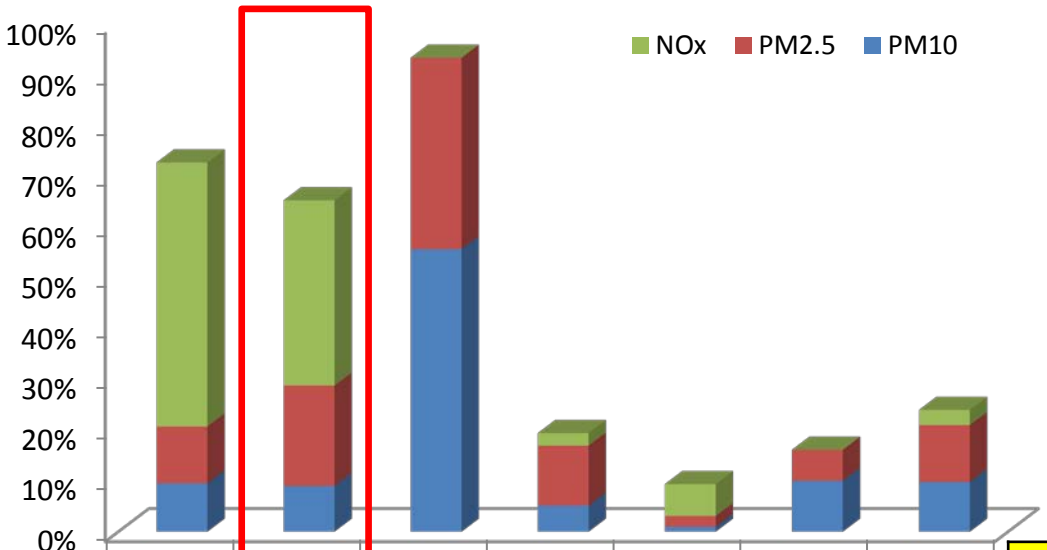
Ambient Air Quality Data



	Industrial Stack	Vehicle	Road Dust	Domestic	DG Set	Concrete Batching	Other sources
NOx	52%	36%	0%	2%	6%	0%	3%
PM2.5	11%	20%	38%	12%	2%	6%	11%
PM10	10%	9%	56%	5%	1%	10%	10%

4W LDV's
6 %
2 %
0.9 %

The End Objective?

1. Air Quality Improvement by Improving 4W-LDV emissions?
2. The Target Pollutant: NOx or PM?
3. To reduce gap between On Road Emissions & Test Cycle (MIDC)?

Source: Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi – Draft Report : IIT Kanpur

Note : The above figures are for the NCT of Delhi. For a more holistic picture for India, more such studies are required for major Cities

The Objective needs to be understood so as to define a Suitable Test Protocol addressing the Objective.

Indian Conditions are Different

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Traffic conditions (Uneven, High density)

Dust, Road Vibration

Ambient Conditions
High temperature , BS II/III fleet

PEMS Installation

- Safety of test vehicle & equipment.
- Reliability of test results due to dust & road vibrations.
- Vehicle speed is often low in India. *(Concern of Pitot tube accuracy at low flow rate)*
- Concern of high ambient ppm levels.*(No adjustment for Background Samples as in Lab Tests)*
- PEMS Equipment installation & operation at high temperatures (>40 deg C).
- Traffic condition demand more battery back up.

EU approach as it is, may not work in India

Selection of EFM

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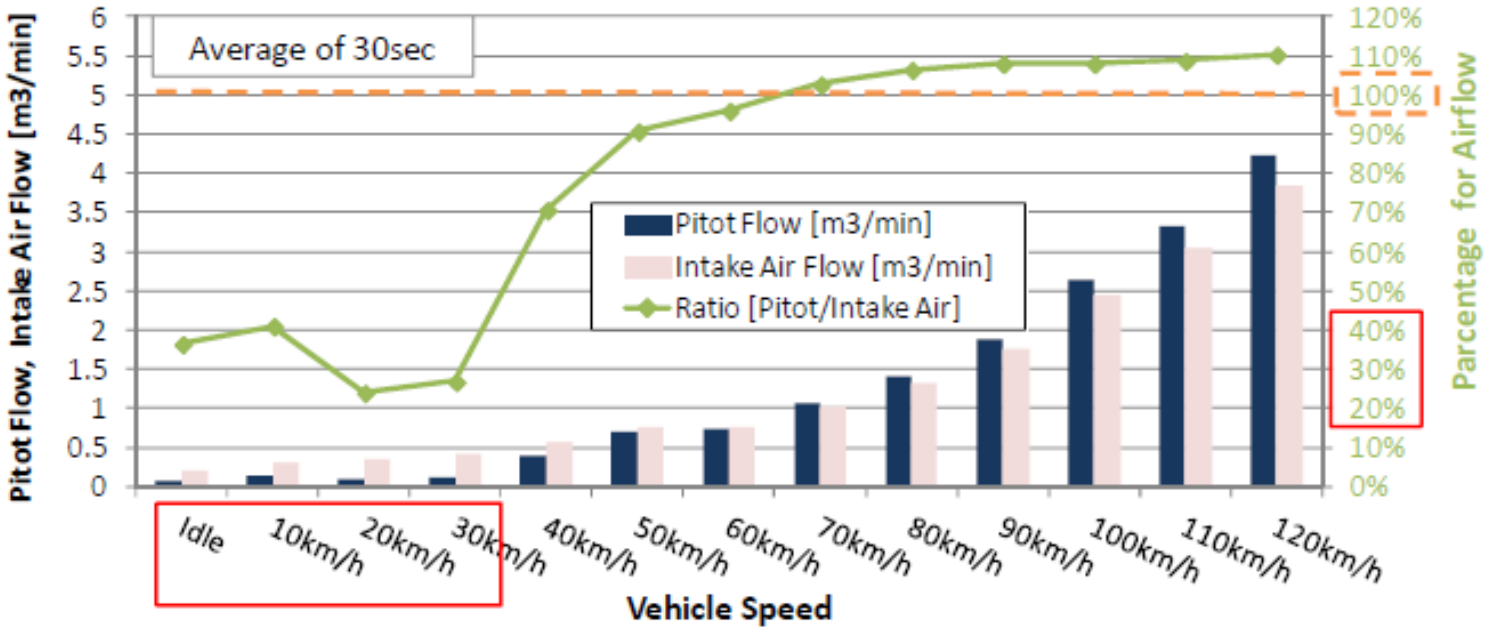
Measurement accuracy is low at low flow rate.
The maximum difference is approx. 75%.

・Chassis dynamometer test (Steady-state condition)



Comparison between Pitot tube-type exhaust gas flowmeter and Intake air flow (ECU)

Source: JAMA, 2016

A Key Concern: EFM Accuracy is very low at lower Speeds.

Vehicle Size Constraints : Instrumentation

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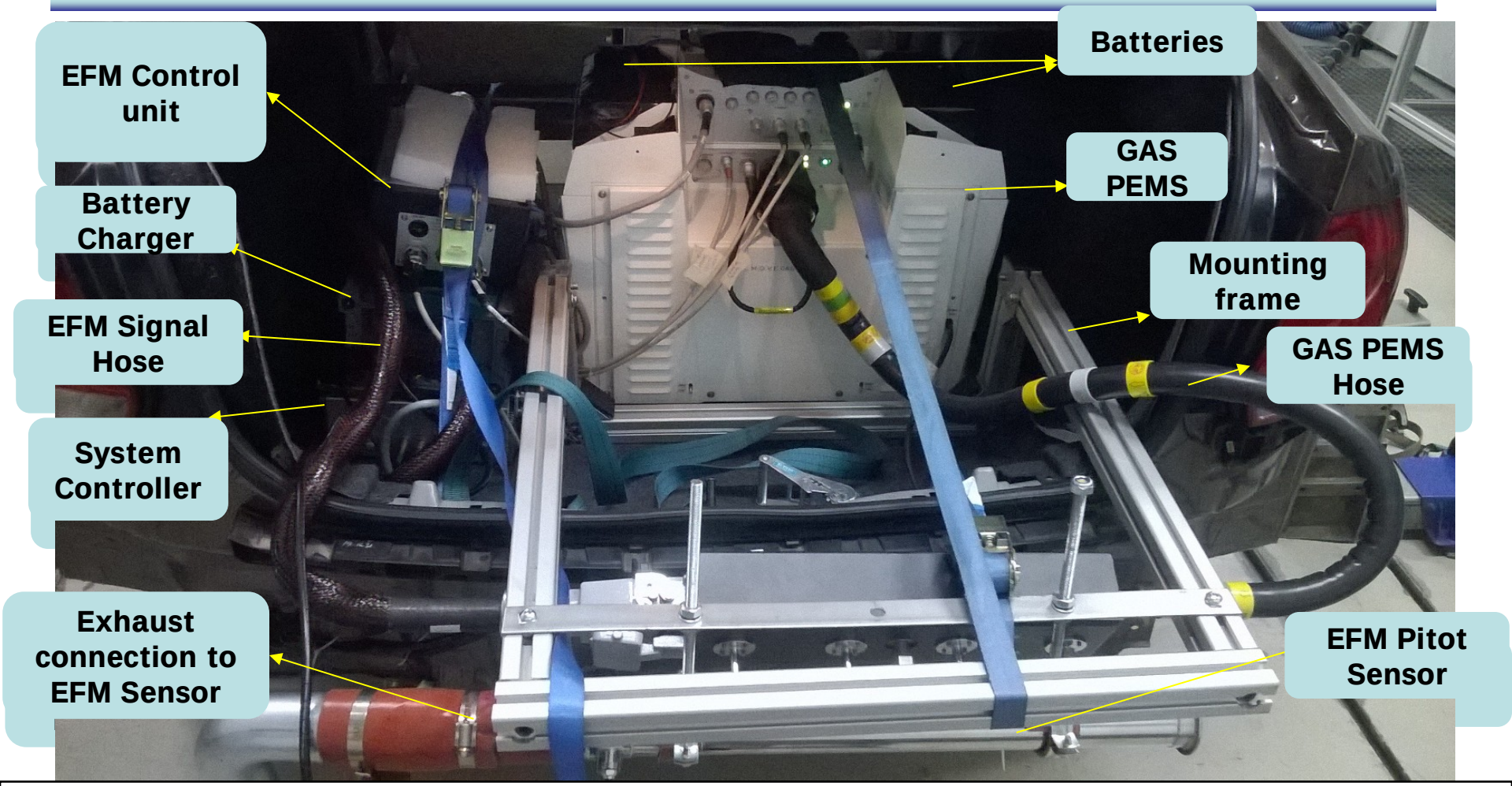
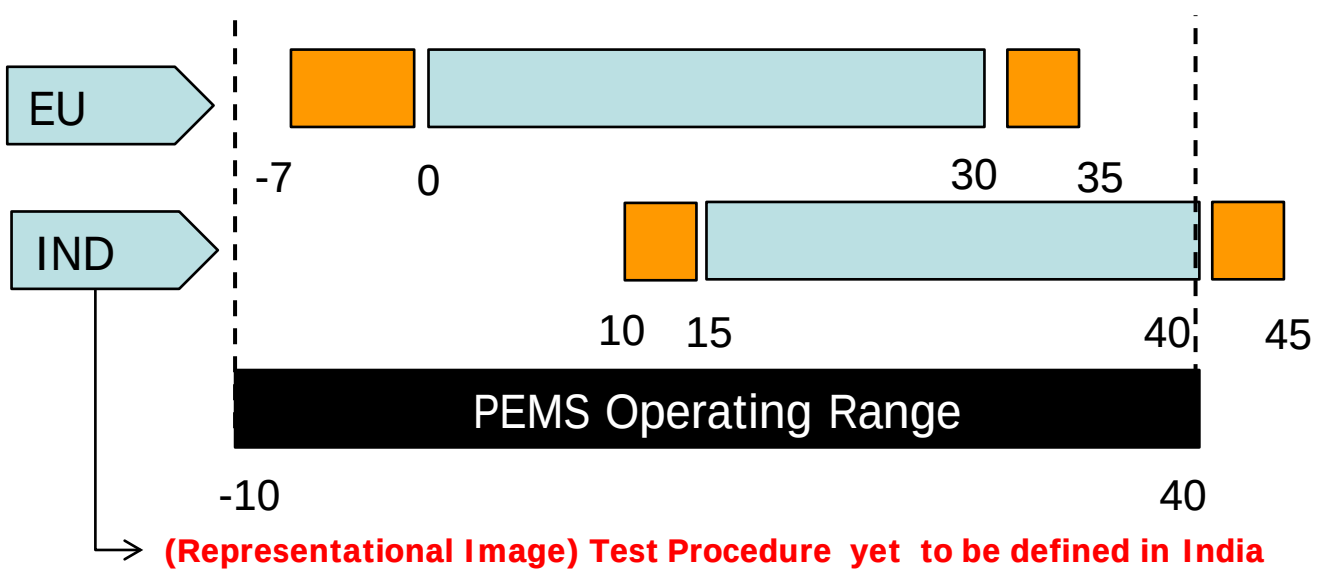


Equipping PEMS in Small Vehicles with Less Space in Rear: May require modification in the Vehicle.

Typical Indian Cars (Sub 4m) have smaller in size with limited space in the rear

Effect of Higher Ambient Temperatures



- As Indian Ambient Temperatures are Higher than EU, there will be a need of changing temperature range for RDE Measurement

- Limitation based on PEMS Operating Range. (Max 40 DegC). For working in extended range the following adaptation may be required:
  1. Internal Temperature Condition Unit→ Increase Battery Drain
  2. PEMS is Cooled by Vehicle AC → Additional Load on Vehicle → Will increase severity for Small Vehicles

Measurements at Higher temperatures may not be representative of Real Drive Conditions (Customer Drive Conditions). Needs further Review

Summary & The Way Forward

Recommendations

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Options - Addl. Emission Test Protocols

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Options	Merits	Demerits
Option1 (PEMS)	▪ On Road Emission Measurement	▪ Test Accuracy, Repeatability & Validity Issues ▪ Equipment Safety and Test Implementation Concerns in Indian Conditions ▪ Testing Time and Effort
Option2 : (Supplemental Tests)	▪ Excellent Accuracy & Repeatability ▪ Existing Test Equipment Can be used (No additional Investment Required) ▪ Efficient, due to less test effort and time	▪ Capturing Indian Driving Conditions, may be a Challenge.

Supplementary Test seems to be a Practical Approach for Implementation as a Part of Vehicle Certification.

Option2 (Supplemental Tests) as a Likely Approach

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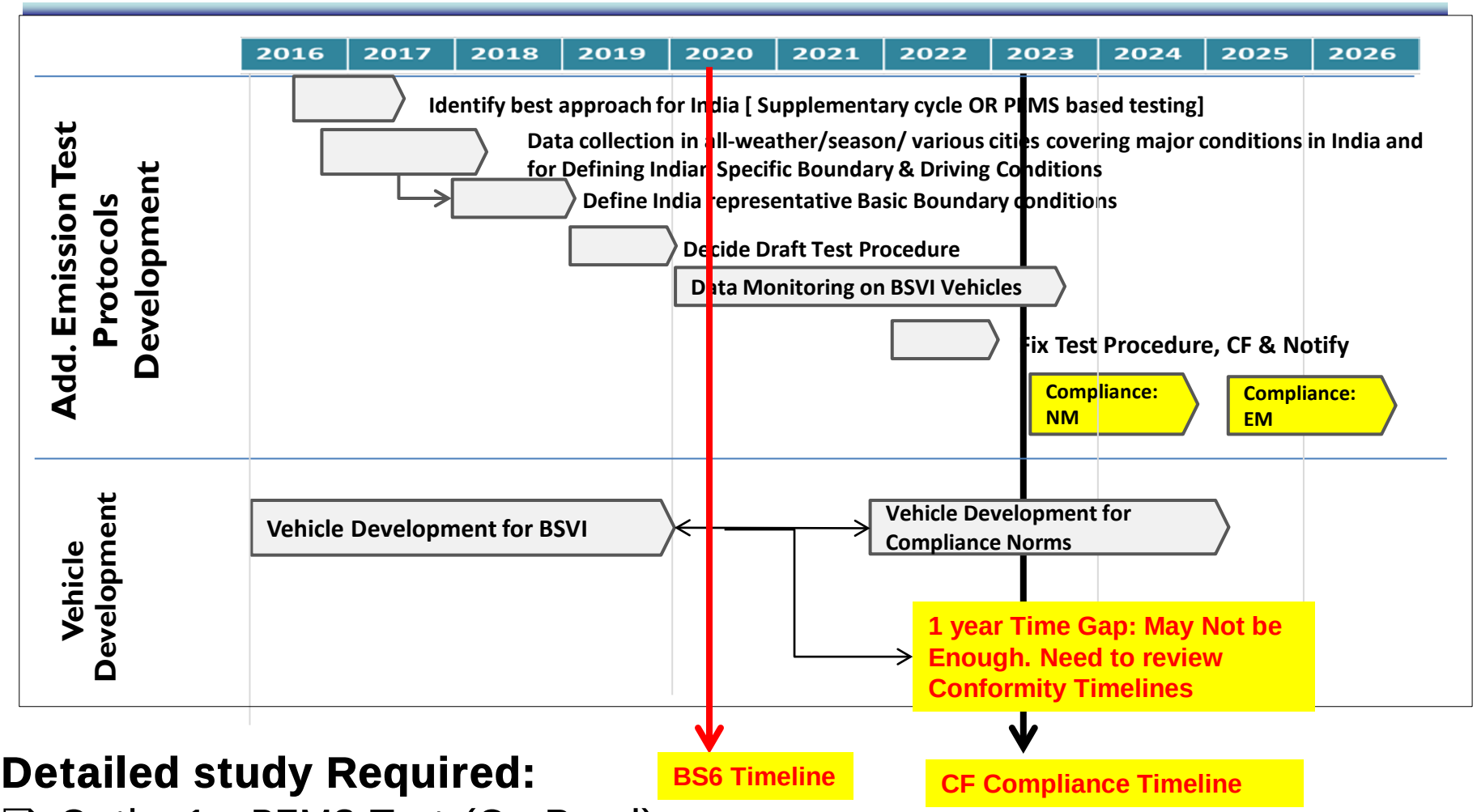
Requirements

Key Factors	On Road Test	Lab Test	Addl. Emission Test in Lab set up
Driving Pattern	Customer pattern	Standard (MIDC)	Possible. Methodology to be established.
Test Method	Varying condition (Cold/Hot conditions)	Cold Start	
Test Environment (Temp./Humidity)	Based on season & Region	20~30 deg C / 5.5 to 12.2. g/kg	Possible. Facility Side Modifications
Road Load Forces	Real road conditions	Based on Coast Down data	Possible, by simulating additional loads
Inertia Weight	2 ~ 4 or more	2 Pax	
Test Fuel	Commercial (available in market)	Reference	Commercial fuel
Use of Accessories	AC/ Blower, Head lamps, etc.	Not Captured	Possible to include.

Indian Conditions to be studied to define the Addl. Emission test protocols in Lab.

The Way Forward (Outline)



Detailed study Required:

- ❑ Option1 : PEMS Test (On Road)
- ❑ Option2 : Supplementary Tests (In Test Lab)

All Stake Holders need to work Together for Defining the Best Approach

Thank you very Much

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