Understanding Bharat Stage VI technologies and on-road emissions management — the global learning curve

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Advancing On-road Emissions Management for being BS VI-ready

Mumbai

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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

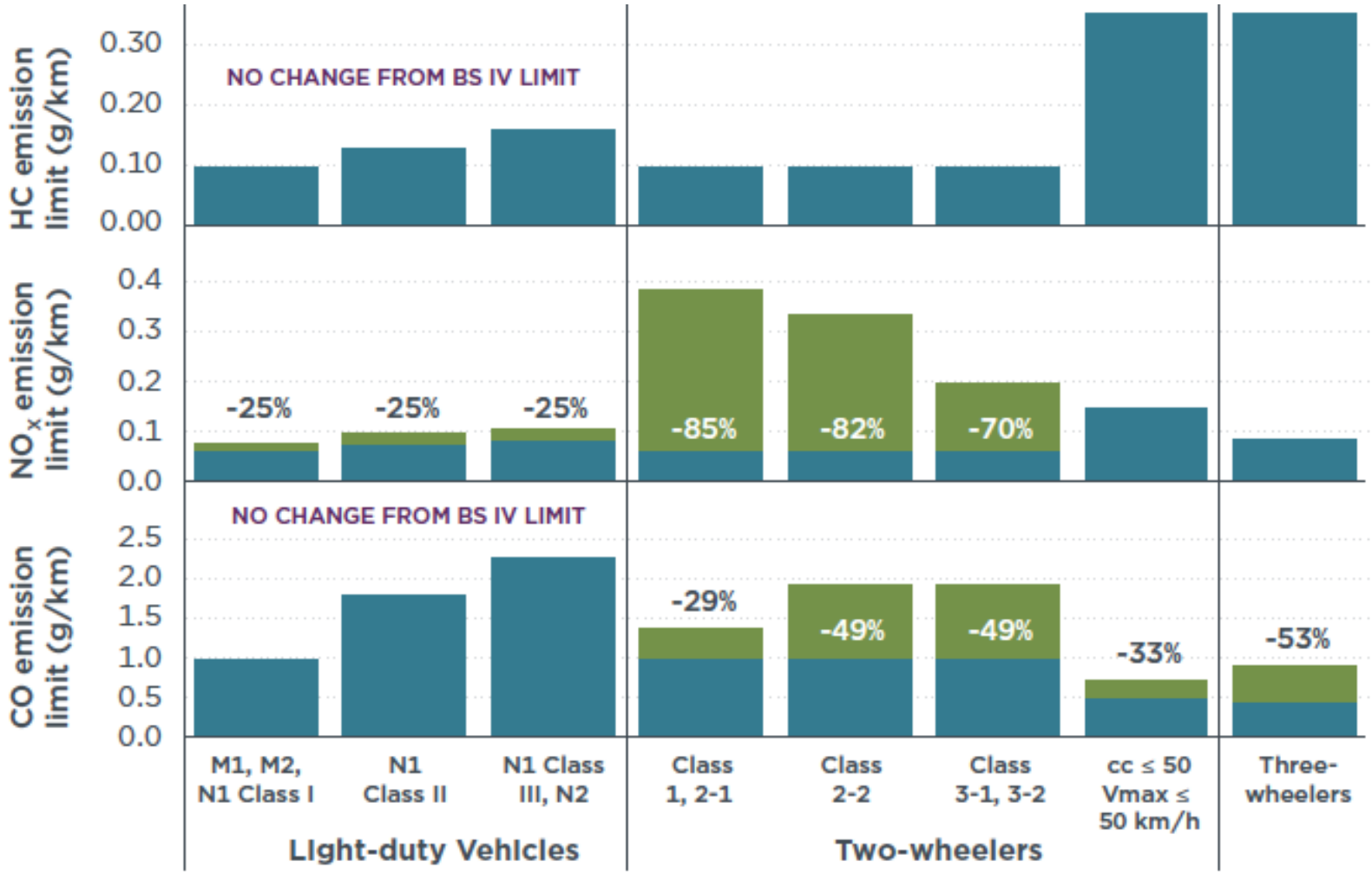
The International Council on Clean Transportation (ICCT)

The mission of ICCT is to dramatically improve the environmental performance and efficiency of cars, trucks, buses and transportation systems in order to protect and improve public health, the environment, and quality of life.

- Non-profit research organization
- Air Pollution and Climate Impacts
- Focus on regulatory policies and fiscal incentives
- Activity across modes including aviation and marine
- Global outreach, with special focus on largest markets
- Offices in Washington D.C., San Francisco, Berlin, Beijing

Bharat VI emission standards will bring about a major change in diesel bus emission controls

BS IV and VI emission limits for petrol/CNG vehicles



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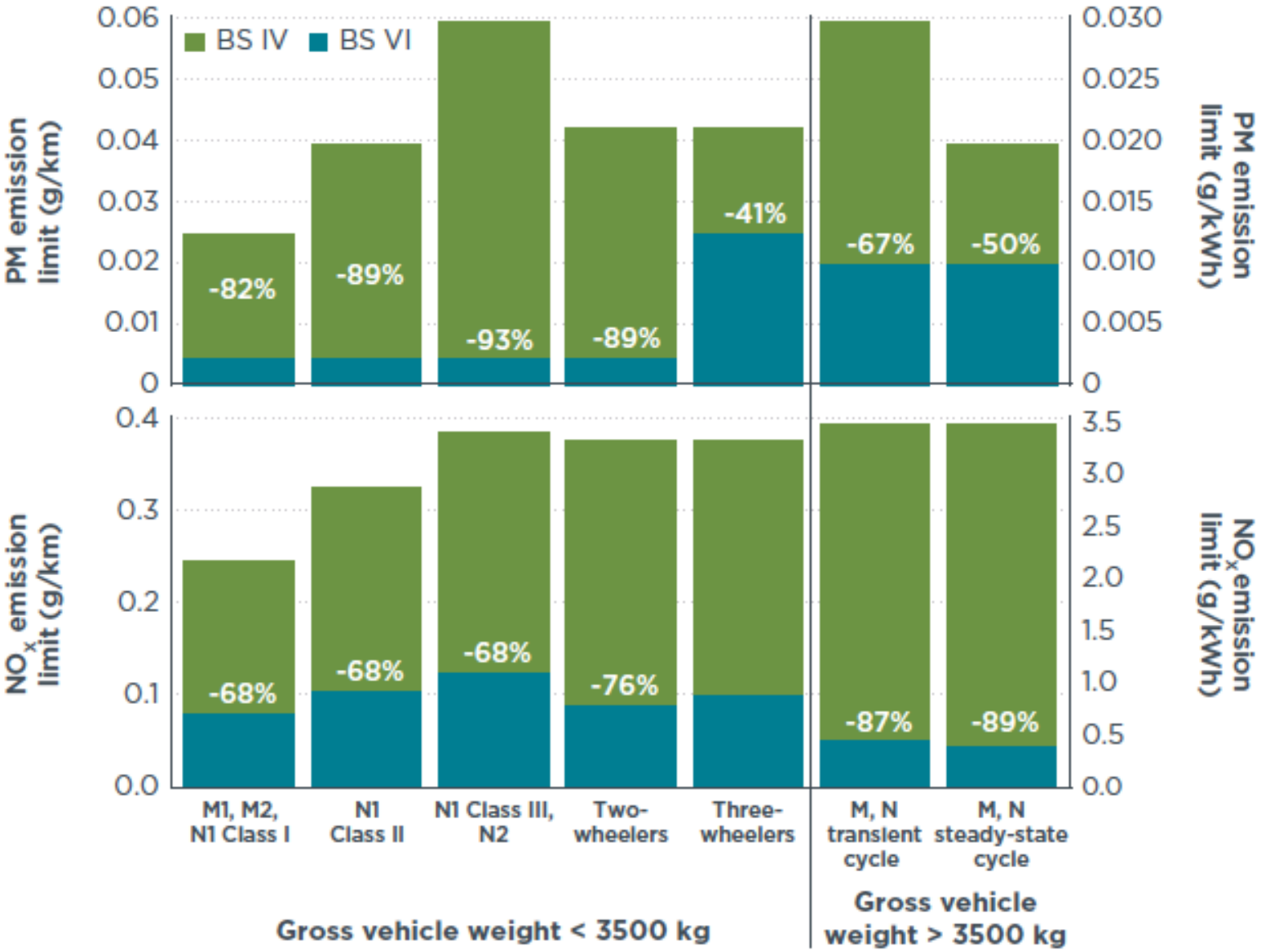
➢ https://theicct.org/publications/india-bharat-stage-vi-emission-standards

BS IV and VI emission limits for diesel vehicles



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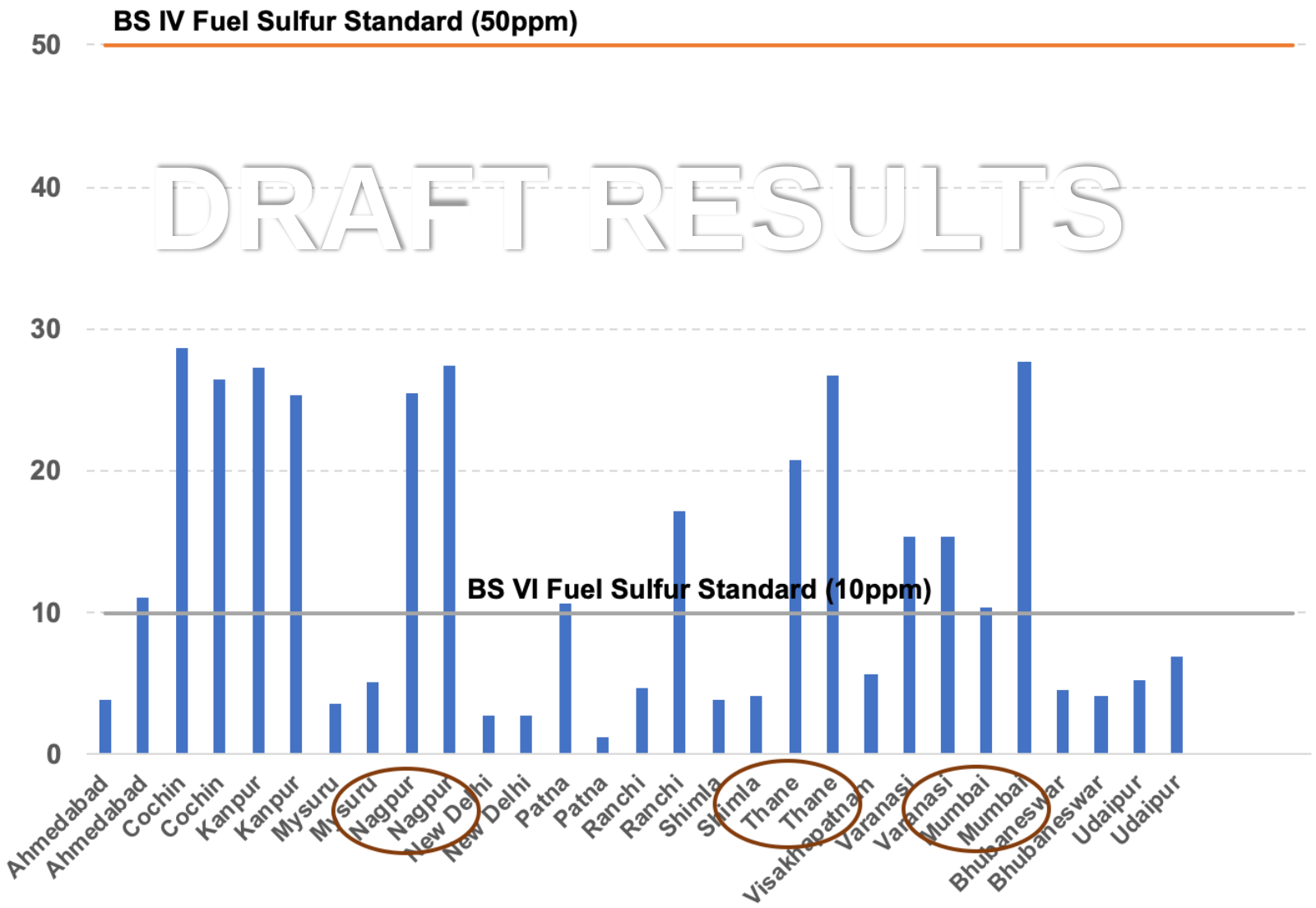
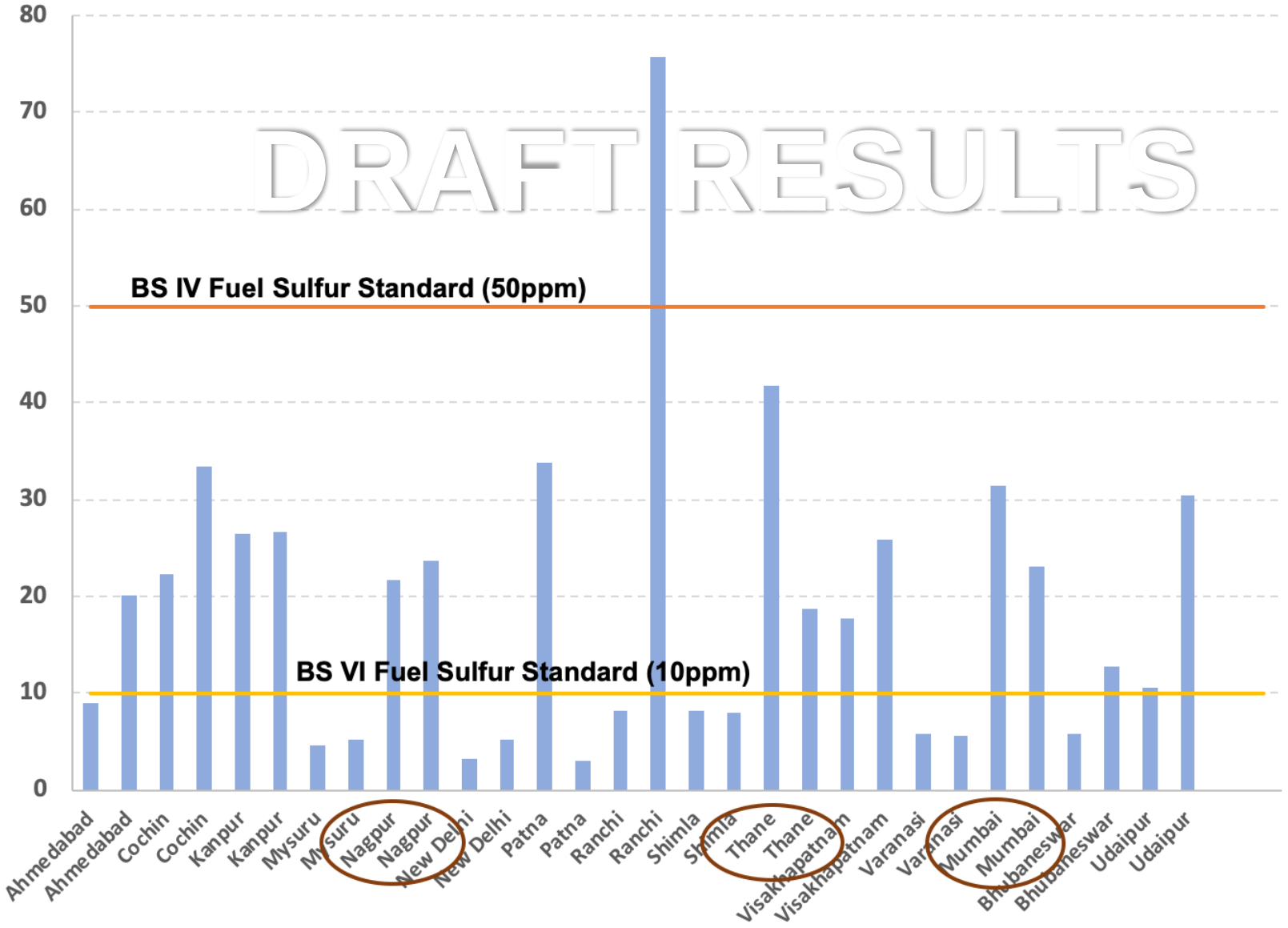
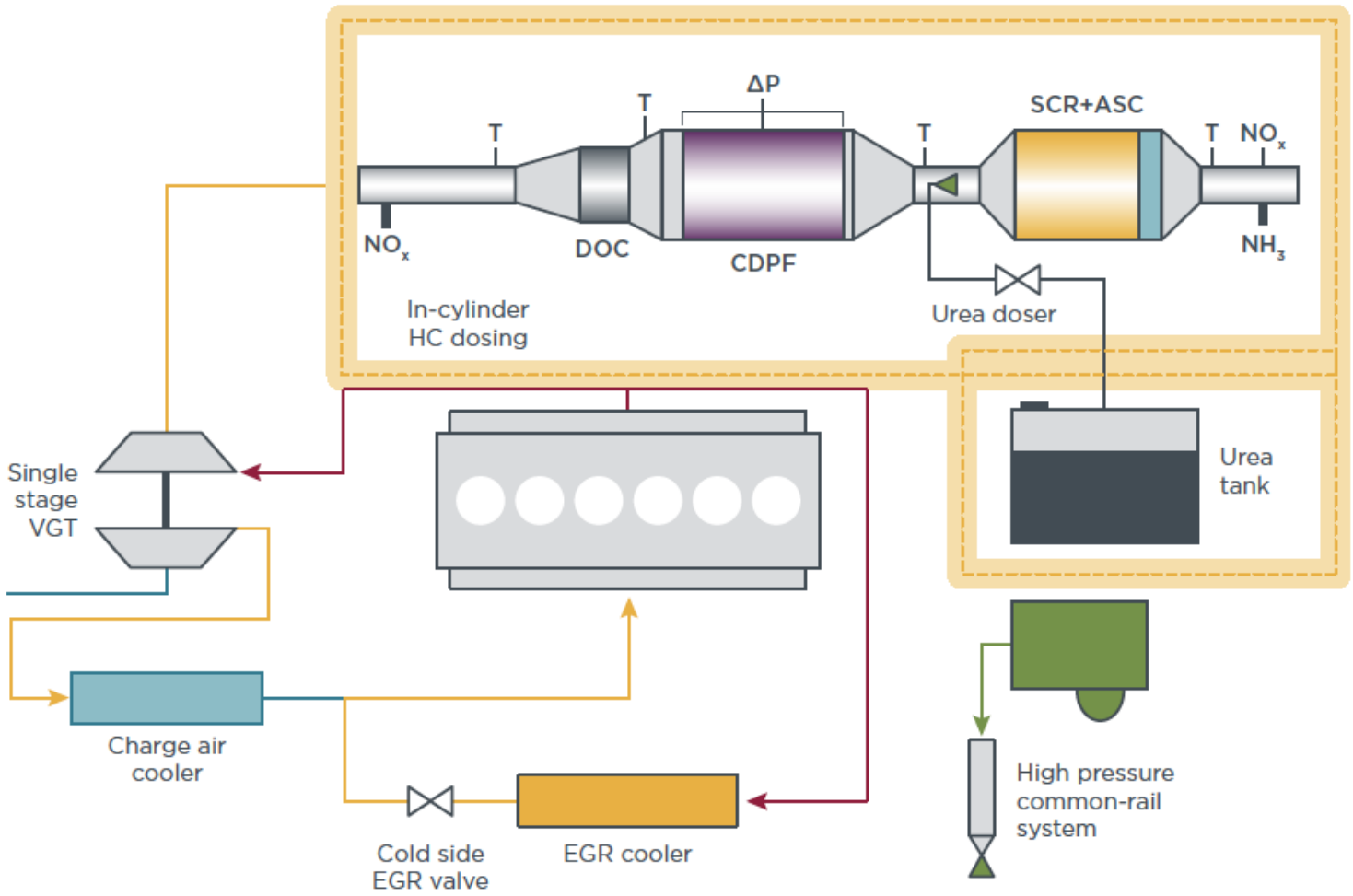
Petrol fuel sulfur evaluation (December 2019)



Diesel fuel sulfur evaluation (December 2019)



Expected BS VI aftertreatment systems for diesel buses/trucks



Expected BS VI aftertreatment systems for diesel buses/trucks

Component addition for BS VI compliance	Associated critical components
diesel particulate filter (DPF)	differential pressure sensor (inlet)
	exhaust temperature sensor (inlet)
	exhaust temperature sensor (outlet)
	fuel injector (inlet)/hydrocarbon doser (usually placed at the pre-diesel oxidation catalyst [DOC] to aid soot oxidation through active regeneration)
	on-board diagnostics (OBD) indicators and warning lights
selective catalytic reduction (SCR)	urea storage tank or aqueous urea solution (AUS) storage tank
	urea injector
	NO_x sensor
	exhaust temperature sensor (inlet)
	on-board diagnostic indicators and warning lights
ammonia slip catalyst (ASC)	—

What should fleet and maintenance managers know?

- Diesel particulate filters (DPFs) may require ”active regeneration” periodically to burn of soot and prevent excessive backpressure.

- Typically, drivers should not inhibit ongoing regeneration; doing so causes unwarranted thermal stress, and an incomplete regeneration process leads to frequent soot and ash buildup.

- Ignoring a request for DPF regeneration for too long can cause backpressure on the engine. A forced or parked regeneration usually results in vehicle downtime.

- Fleet managers should maintain records of all parked regeneration events for all the vehicles in the fleet. This will help identify if there is an increase in frequency, which may be due to poor in-use maintenance or, a DPF failure.

➢ https://theicct.org/sites/default/files/publications/BSVI-DriversOperators_factsheet_22oct2019.pdf

What should fleet and maintenance managers know?

- On-board diagnostics (OBD) related changes in driver console: prepare “cheat sheets” for drivers if needed, and post on dashboard

Possible OBD dashboard indicators	Possible description
	• Warning light for *EGR malfunction* • Warning light for *EGT sensor (exhaust gas temperature)*-relevant malfunctions. • Warning light for high EGT due to active DPF regeneration without enough air flow.
	• Warning light for *tampering*-relevant activity like DPF removal, *operator negligence* in response to malfunctions and OBD requests (e.g., DPF regeneration or AUS refill).
	• Warning light for DPF half full status. • Warning light for *DPF full and ready for regeneration*. This prompts the driver to complete regeneration pre-requisites.
	• *AUS level low* or critically low and requires refill, or *incorrect AUS refilled*.

➢ https://theicct.org/publications/bsvi-guide-fleet-managers-factsheet-20191022

What should fleet and maintenance managers know?

- Maintain a log of aqueous urea solution (AUS) refills: make topping off AUS tanks on a weekly or bi-weekly basis a part of the periodic maintenance routine.

- Engage drivers/operators in training workshops that detail manufacturer recommended maintenance activities and provide a list of dos and don’ts.

- Drivers may experience loss of power, loss of torque, and even vehicle shutdown while driving if maintenance requests are not completed on time and/or they are not appropriately fulfilled.

What additional things should the RTOs know while issuing a fitness certificate?

- Fitness inspector should perform a visual check of:
  - DPF/DOC housing for cracks or holes
  - Presence/absence of a tampering device
  - Presence/absence of urea in urea tank
- Malfunction Indicator Light (MIL) being ON is a sign of a pending maintenance request or an active fault code
- Fitness inspector should know how to operate a standardized OBD reader or diagnostic tool and software capable of reading SAE J1939 or ISO 15765 standard messages

PUC Checks, and the future of Vehicle Inspection

Free Acceleration Test

- With the engine idling, the accelerator control shall be operated quickly, but not violently, so as to obtain maximum delivery from the injection pump. This position shall be maintained until maximum engine speed is reached and the governor comes into action. As soon as this speed is reached the accelerator shall be released until the engine resumes its idling speed and the opacimeter reverts to the corresponding conditions.
-
- The sequence mentioned in above para for complete cycle for measurement can be defined based on time.
  1. Acceleration time from idle to fly up speed :- 5 sec (max)
  2. Stabilising time at maximum speed :- 2 sec (max)
  3. De-acceleration Phase :- Engine comes back to idle speed by its own natural time
  4. Idling Phase :- Operator to start next acceleration within 5 to 20 secs.
  5. Repeat 1) to 4) above.

- The operation described in para above shall be repeated at least six times in order to clear the exhaust system and to allow for any necessary adjustment of the apparatus. The maximum opacity values read in each successive acceleration shall be noted until stabilised values are obtained.

Revision of PUC norms for BS VI vehicles

Sl. No.	Method of Test	Maximum Smoke Density	
		Light absorption coefficient (1/meter)	Hartidge unit
(1)	(2)	(3)	(4)
1.	Free acceleration test for turbo charged engine and naturally aspirated engine for vehicle manufactured as per pre Bharat Stage IV norms	2.45	65
2.	Free acceleration test for turbo charged engine and naturally aspirated engine for vehicle manufactured as per Bharat Stage IV norms	1.62	50
3.	Free acceleration test for turbo charged engine and naturally aspirated engine for 4 wheelers manufactured as per Bharat Stage VI norms	0.7	26
4.	Free acceleration test for turbo charged engine and naturally aspirated engine for two / three wheelers manufactured as per Bharat Stage VI norms	1.5	48”;

Shortcomings of PUC testing, and need to augment it with remote sensing and/or OBD evaluation

- Existing PUC tests
  - Existing PUC tests do not correlate well with dynamometer tests
  - With lower CO and HC values of BS IV and beyond vehicles, the tests are much less reliable indicator
  - Failure to capture NOx emissions that contribute to ozone formation as well as secondary particulate formation

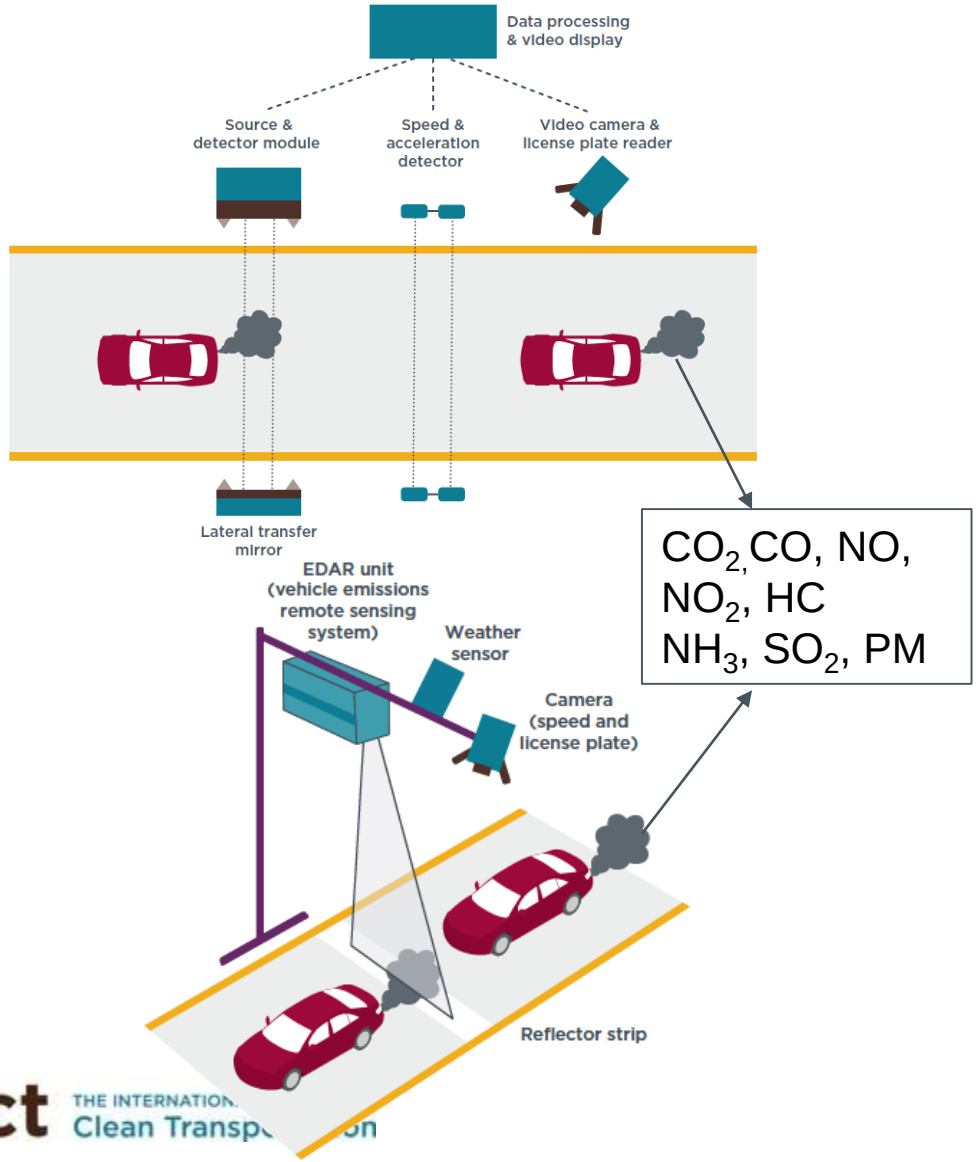
- Loaded Mode Tests
  - Carried out on a dynamometer; take about the same time as PUC tests performed properly
  - More accurate than PUC, but capital equipment is costlier
  - Unlikely to be able to perform loaded mode tests for all vehicles in fleet

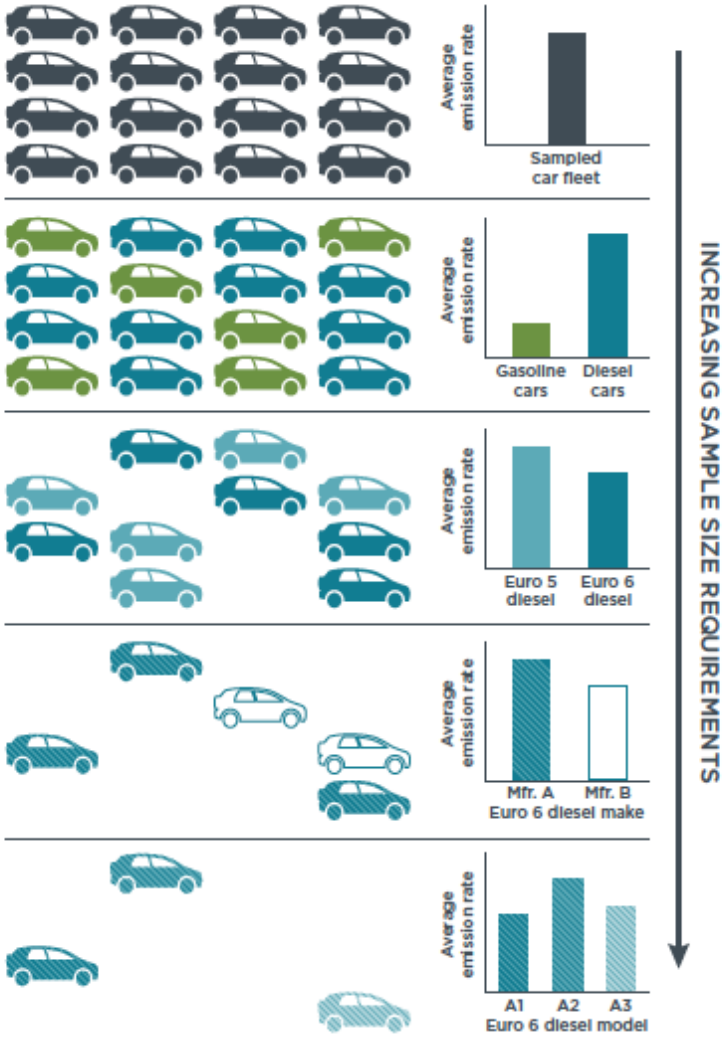
Remote Sensing for measuring in-use emissions

- Carried out in a non-intrusive fashion, and without vehicles having to report to centralized test center or PUC stations
- Same remote sensing setup can be used to measure emissions from different vehicle types
- Can be used to evaluate hundreds to thousands of vehicles each day
- Only a limited number of vehicles identified as high emitters can then be selectively required to report for a loaded test at centralized, and possibly automated testing centers
- A mature remote sensing program can also be used support a “clean screen” program that lets drivers skip a periodic tailpipe emissions recertification test by verifying that their vehicle emissions are within a limit range

How remote sensing technology enables cities to measure and monitor vehicle emissions

Remote sensing capable of evaluating both fleet and model level emissions – thousands of vehicles per day





Remote sensing applications

1. Screen fleet for market surveillance
2. Monitor a single fleet
3. Emission factor development
4. Steer new policies/track policy effectiveness
5. Track technology effectiveness
6. Identification of individual high (or low) emitters
7. Inform purchasing decisions

How remote sensing can be used to track Extreme Polluters

- Possible cut-points for Extreme Polluters

Vehicle Type	CO Percent	HC ppm	NO ppm	UV Smoke
HDV	3.637	2258	3966	1.517
LDV	2.752	1356	2223	0.608

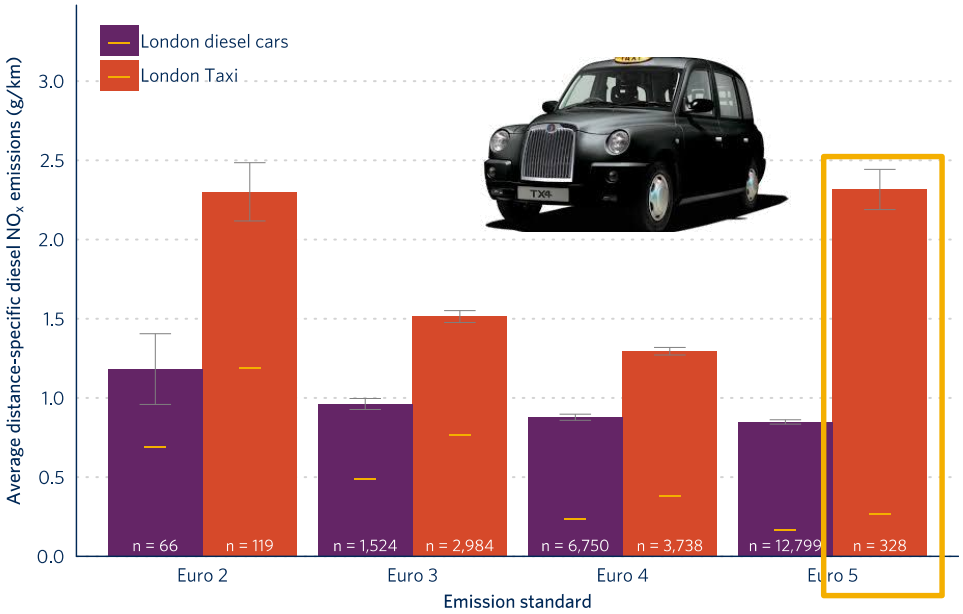
- Possible cut-points for Extreme Polluters

Vehicle Type/Fuel/Bharat Stage	CO Percent	HC ppm	NO ppm	UV Smoke
HDV/Diesel/Bharat St IV	1.377	1104	2685	0.766
LDV/Diesel/Bharat St IV	0.617	385	1508	0.335
LDV/CNG-Petrol/Bharat St IV	1.259	631	1399	0.099
LDV/Petrol/Bharat St IV	0.92	561	766	0.083

TRUE London - spotlights on special fleets

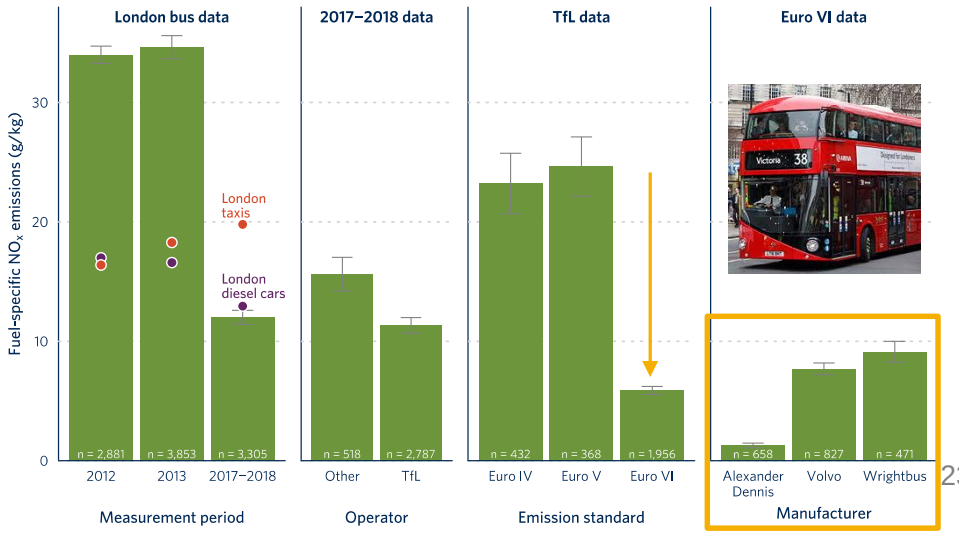
London "black" taxis

- Euro 5 NO_x are as bad as Euro 2…
- …about 10 times its type-approval value
- Similar emission level confirmed by TfL on the "London" test cycle



London buses

- Euro VI brings a 75% NO_x improvement…
- …but that varies by manufacturer
- Euro VI only are exempted from the ULEZ daily charge



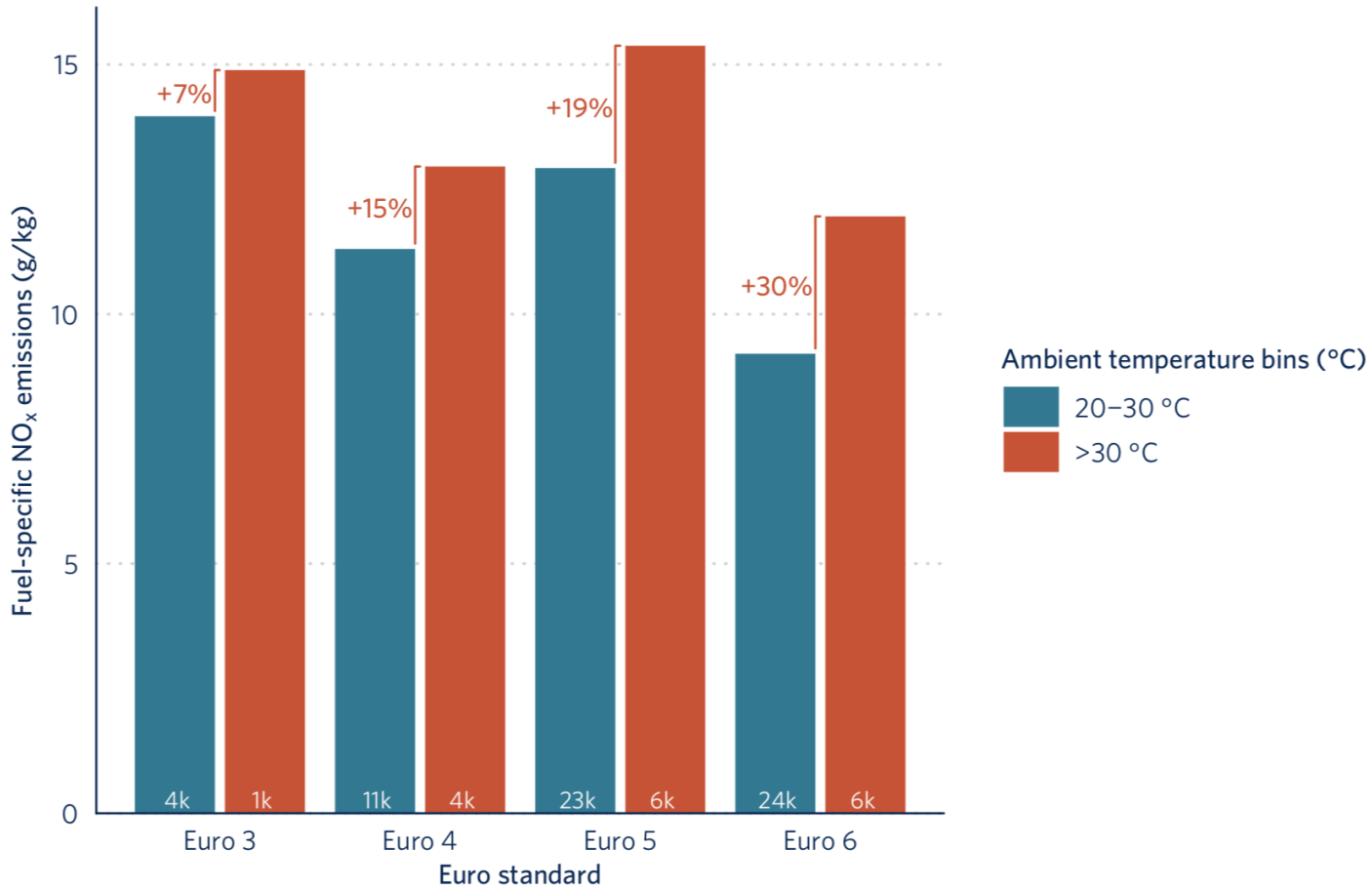
London Mayor Sadiq Khan has announced new plans based on the TRUE study

"We know that dirty vehicles are responsible for half of our NOx air pollution – and this new data from TRUE and ICCT reveals the stark health impact of polluting diesel taxis on our streets."

New measures proposed by the Mayor and TfL:

- An enhanced delicensing fund, providing up to £10,000 for drivers who trade in their older, dirtier vehicles early
- A £2.5M fund to help drivers of newer Euro 5 taxis to convert to much cleaner LPG fuel
- A consultation early next year on a phased reduction in maximum taxi age limits for the dirtiest vehicles from 15 years to 12 years by 2022

NO_x emissions from diesel passenger cars increase significantly above 30℃



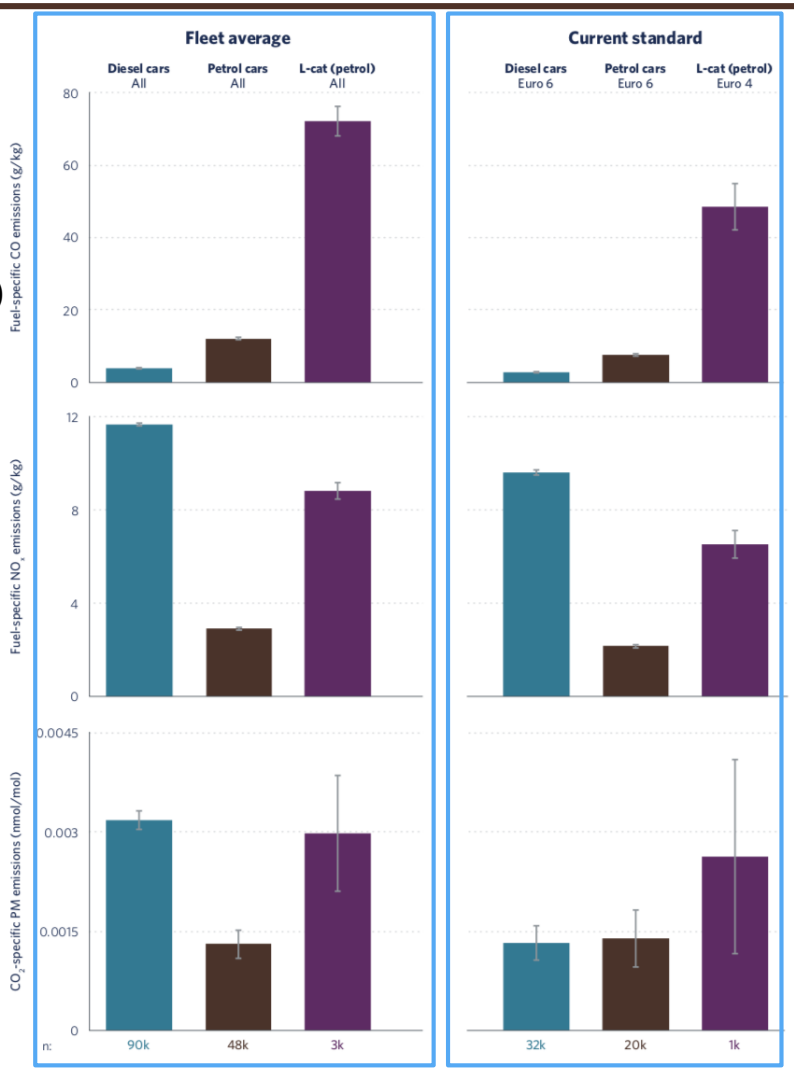
Average NOx emissions from diesel cars, in grams per kilo of fuel consumed. In hot weather, NOx emissions from Euro 6 cars were worse than emissions from Euro 4 cars at milder temperatures. The gap between in-use NOx emissions measured at ambient temperatures between 20 and 30 ˚C, which is the type-approval test range, and above 30 ˚C increases with every Euro standard, as type-approval NOx limits become more stringent.

Pollutant emissions from mopeds, motorcycles, three wheelers, and other category "L" vehicles in Paris

Carbon monoxide (CO)

Nitrogen oxides (NO_x)

Particulate matter (PM)



For a given quantity of fuel burnt

- Fleet-average emissions
  - far exceed those of diesel or petrol passenger cars (PC)
  - for NO_x and PM are closer to diesel PC than for gasoline

- The average emissions of the most recent Euro 4 standard
  - for CO are nearly 10x higher than for Euro 6 PC
  - for NO_x approximately 3x higher than those of gasoline PC

ICCT India Initiative: http://www.theicct.org/india

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A combination of regulatory tools and incentives is necessary to reduce transport emissions

New Vehicle Policies

- ❑ Stringent tailpipe emission standards
  - ✓ BS VI for on-road vehicles
  - ✓ Stage V for non-road vehicles
- ❑ Stringent evaporative emission standards
- ❑ Strong compliance and enforcement program
- ❑ Promotion of electric drive

Clean Fuel Policies

- ✓ Ultra-low sulfur fuels
- ❑ Stage I and II evaporative controls

In-use vehicle emission control

- ❑ On-board diagnostics (OBD) based inspection and maintenance program
- ❑ Remote sensing or other in-use emissions testing program
- ❑ Scrappage of old (especially diesel) vehicles
- ❑ Diesel particulate filter (DPF) retrofits for BS III/IV vehicles

Demand management

- ❑ Restrictions on use of older/more polluting vehicles
- ❑ Additional fees for older/more polluting vehicles
- ❑ Low Emission zones (LEZ)

What is OBD good for?

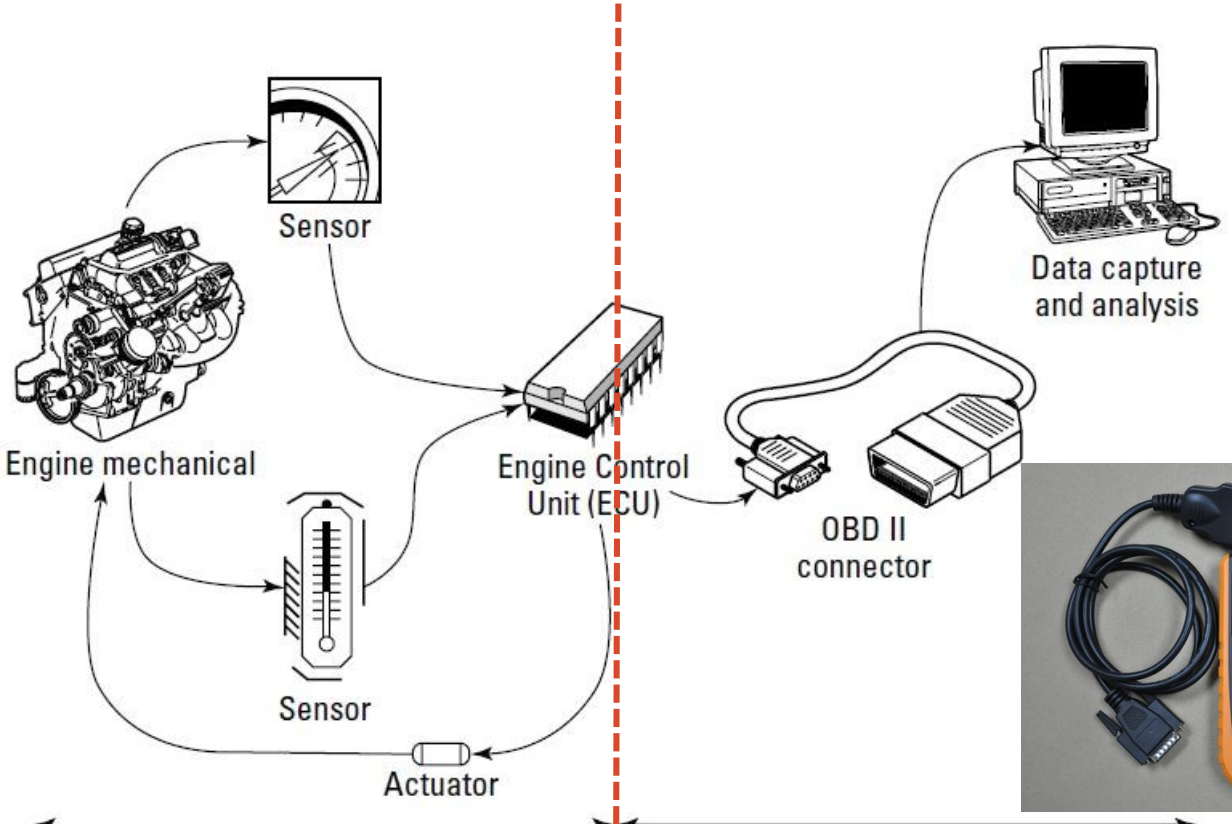

FIGURE 1: On-board diagnostics block diagram

I/M program
In-use emissions monitoring

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http://etechnologytips.com/own-made-automotive-diagnostic/

OBD Based I/M Procedure

1. Does the malfunction indicator light (MIL) work? (Key on engine off)
2. Is the vehicle ready for an inspection?
   - No recent code clearing
3. Is the MIL commanded off?

- If YES to all 3: PASS
- If NO, remedy as necessary:
  - Fix MIL lamp or wiring
  - Conduct more in-use driving and return for re-inspection
  - Fix detected fault and return for re-inspection

Benefits over Tailpipe I/M

- More comprehensive fault detection
  - All emission-related components individually monitored
  - Cold start problems detected
  - Evaporative emission problems detected
  - Broad in-use testing conditions
  - OBD failure rates 2.5X ASM (acceleration test) failure rates
- Convenience
  - Faster (less than 5 minutes)
  - No surprises (MIL off = pass, unless recently serviced)
  - Less expensive
- Nearly every state in the US now conducts OBD only inspection

OBD-based I/M program is possible in India

Improve effectiveness of an OBD based I/M to overcome fraudulent practices by:

- Strengthening the OBD parameters required → Opportunity to include this in AIS 137
- Connecting scanning tool directly to vehicle and computer so that inspector cannot modify data during inspection
- Overcoming code cleaning practices with “readiness indicators”
- Overcoming clean scanning by matching vehicle identification numbers
- Requiring permanent diagnostic trouble codes (DTCs) to prevent tampering → Opportunity to include this in AIS 137