# Cleaner vehicles and fuels:
## Learning from International Best Practices

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**ECMA ECT 2016**

**New Delhi**

**November 9, 2016**

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# Fundamentals of controlling air pollutant emissions from motor vehicles

## New vehicle standards

Technology neutral (but technology-forcing…) emissions standards for new vehicles.

Must consider emissions from all mobile sources: on-road, off-road, marine, locomotives, aviation…

Limit values only as good as:

- Compliance and enforcement
- Real-world performance

## Fuel quality standards

High fuel quality (especially low sulfur levels) enables advanced emission control technologies to be deployed in the fleet.

Fuel quality compliance programs critical to prevent damage to engines and prevent misfueling

**"Systems Approach"**

## In-use vehicle emission control

Clean up legacy vehicles on the roads

Comprehensive program includes:

- Catching gross-emitters (I/M, remote sensing, maintenance, etc.)
- Cleaner fuels
- Scrappage/replacement programs
- Retrofit programs
- Complementary strategies (low emission zones, driver training, etc.)

Not shown but also important: transportation demand management, modal shift, traffic optimization, and more

http://www.theicct.org/global-health-roadmap

http://www.theicct.org/best-practices-emission-control-in-use-hdvs

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# Recent policy developments globally

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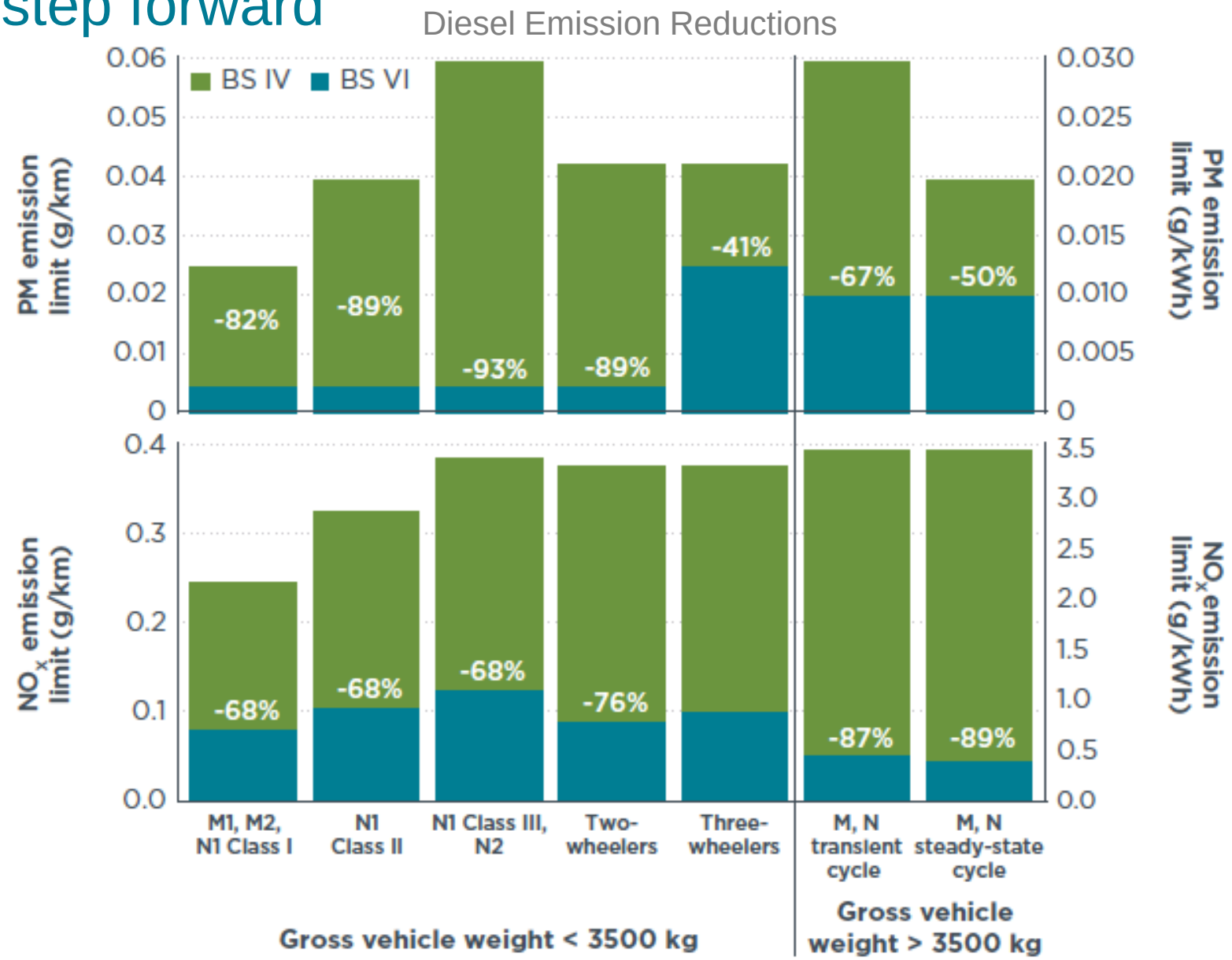
# BS VI standards implementation by 2020 is a major step forward




- http://www.theicct.org/india-bharat-stage-vi-emission-standards

# Summary of major developments globally

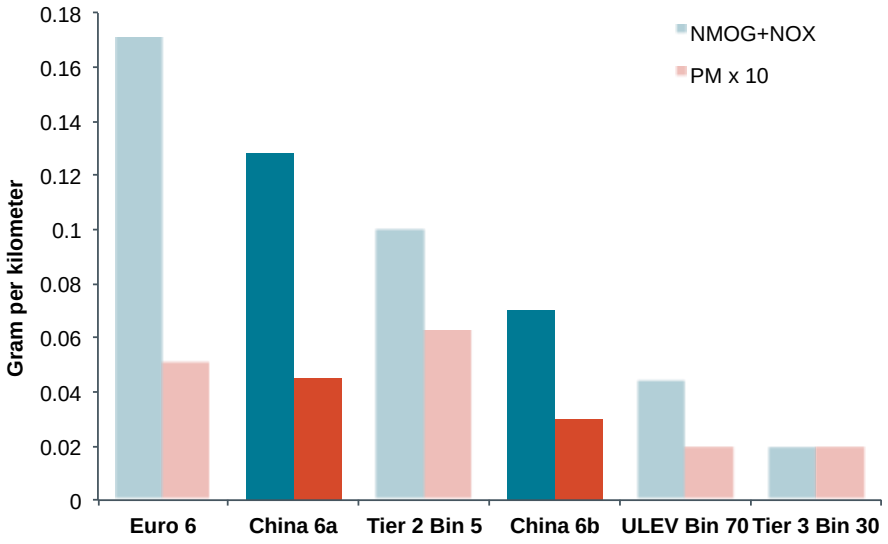
- US implementation of Tier III light-duty emission standards from MY 2017 onwards
- EU adopting real-driving emissions (RDE) test requirements
- EU and Japan adopted World Harmonized Light-duty Vehicles Testing Procedure (WLTP)
- Beijing proposed perhaps the most stringent emission standards in the world
- China proposed China 6/VI emission standards
- EU adopted Stage V emission standards for non-road vehicles

# China 6 emission standards are an ambitious step forward

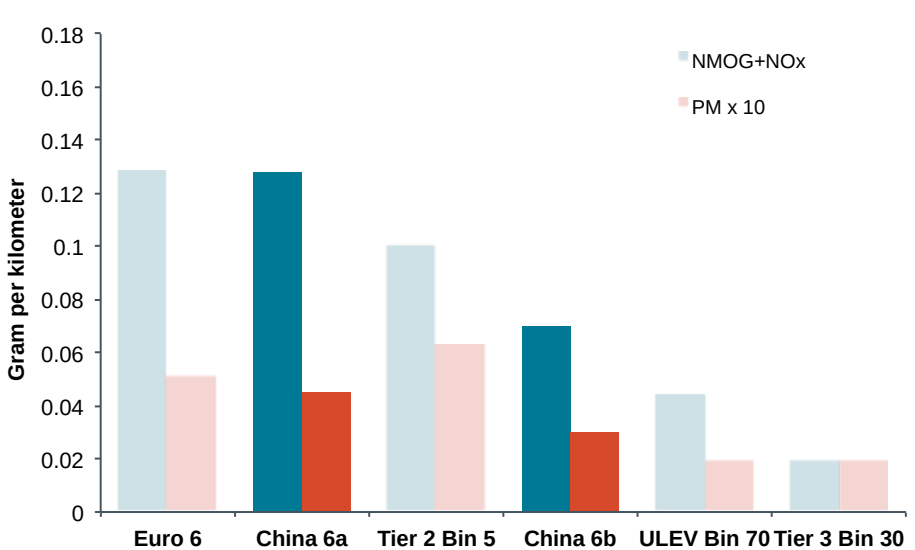
- Emission limits are fuel neutral and more stringent than those in Euro 6
- $N_2O$ emission limits
- Stringent evap. limits, innovative 48-hr test procedure, OBD and ORVR requirement
- OBD provisions largely based on CA OBD II with a few modification
- Modified RDE boundary conditions

# Comparison between China 6 (a and b), Euro 6, Tier 2 and LEV 3 standards

## Diesel Cars




## Gasoline Cars




[1] Emissions limits are those for Type I test (regular temperature, cold start emission test)
[2] For diesel light-duty vehicles, Europe and China regulate HC and NOx, instead of NMOG+NOx
[3] For gasoline light-duty vehicles, Europe and China regulate NMHC and NOx, instead of NMOG+NOx
[4] This analysis simply compares direct emission limits, and does not take into consideration the differences in test cycle and procedures among various regulatory programs

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# Major reform of China Clean Air Law strengthens authority for compliance and enforcement

- Clear authority to enforce standards
  - Recall authority is established for motor vehicles and off-road engines
  - Clear authority of central and provincial environmental agencies (MEP and provincial EPBs) to impose large fines (1-3 times product value) for producing, selling and importing non-compliant vehicles
  - Clear authority of the industry ministry (MIIT) to suspend or discontinue the production of violating vehicles/engines
- Clear authority of environmental agencies to perform compliance testing
  - Authority of MEP and provincial EPBs to investigate and test newly produced and sold vehicles and engines
  - Authority of local EPBs to perform random onsite and roadside emission inspection and testing, including remote sensing tests.
- Highlighted shared burden among government, industry, and consumers
  - Manufacturers of vehicles and engines shall test their products to ensure emission compliance before introducing the products into commerce
  - Manufacturers shall publish their emission compliance test result information to the public
  - Manufacturers shall recall their vehicle/engine products if they are found not in compliance with standards due to design, manufacturing defects
  - Consumers are prohibited from tampering/modifying emission control devises (incl. OBDs)

# Yellow Label Vehicle road restriction plan in Guangdong Province

| | Guangzhou | Shenzhen | Foshan | Dongguan |
|---|---|---|---|---|
| **Starting date** | January 1, 2014 | January 1, 2015 | January 1, 2015 | November 1, 2014 |
| **End date** | Dec. 31, 2018 | N/A | N/A | Dec. 1, 2015 |
| **Restriction Area in 2014 ($km^2$)** | 528 | 841 | 101 | N/A |
| **Jurisdiction constructed area ($km^2$)** | 990 | 841 | 101 | 153 |
| **% Area** | 53% | 100% | 100% | N/A |
| **Restriction time** | All day | All day | All day | Daily 9:00-18:00 |
| **Supervision** | Surveillance cameras, police | Surveillance cameras, police | Surveillance cameras, police | Surveillance cameras, police |
| **Penalty** | 200 RMB and 3 points on license | 300 RMB and 3 points on license | 200 RMB and 3 points on license | 200 RMB and 3 points on license |
| **Exception** | Emergency vehicles*, municipal vehicles, and road maintenance vehicles are not restricted | Emergency vehicles, city buses, passenger vehicles with more than 20 seats, China II diesels with Transportation Permit | Emergency vehicles | Emergency vehicles, China II buses |

* Emergency vehicles usually include: Army, police, fire, ambulance, project emergency.

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- http://www.theicct.org/review-and-analysis-in-use-vehicle-emission-control-programs-guangdong-province

# On year after Dieselgate

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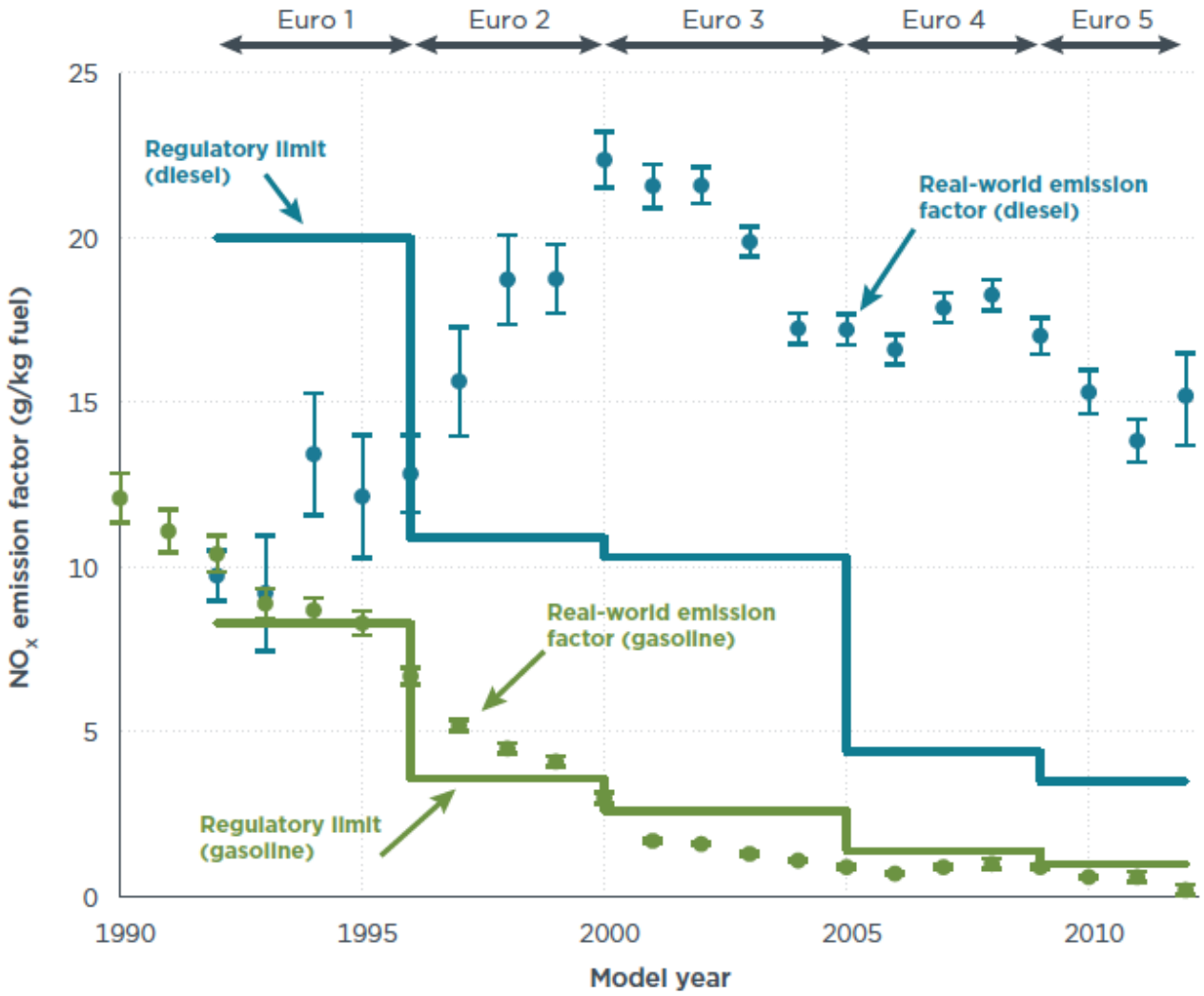
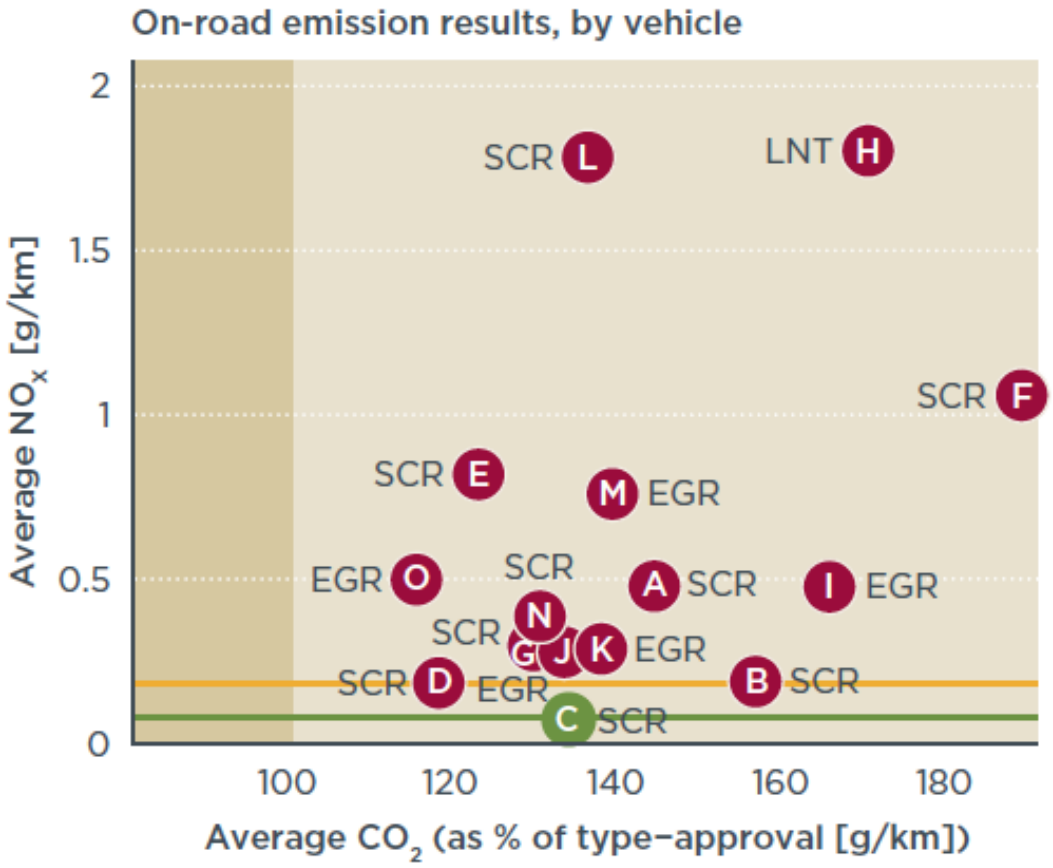
# While emission standards were tightened, real-world $NO_x$ from diesel cars remained high

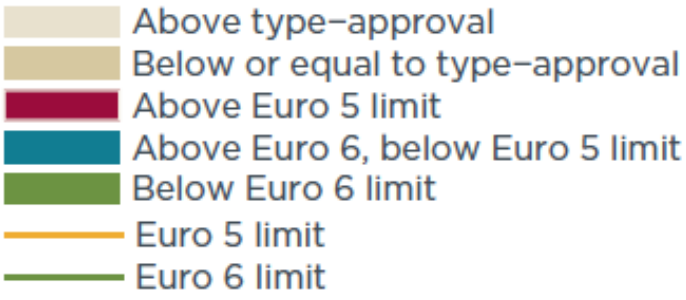





http://www.theicct.org/environmental-risks-diesel-passenger-vehicles-brazil-2016, based on Chen and Borken-Kleefeld (2014)

# On the road, on average, $NO_x$ emission levels of new diesel cars are 7 times the regulatory limit




15 test vehicles in total (6 manufacturers), with different $NO_x$ control technologies:
- 10 selective catalytic reduction (SCR)
- 4 exhaust gas recirculation (EGR)
- 1 lean $NO_x$ trap (LNT)

Average Euro 6 $NO_x$ conformity factors (ratio of on-road emissions to legal limits):
- all cars: 7.1
- best performer (Vehicle C, SCR): 1.0
- bad performer (Vehicle H, LNT): 24.3
- worst performer (Vehicle L, SCR): 25.4

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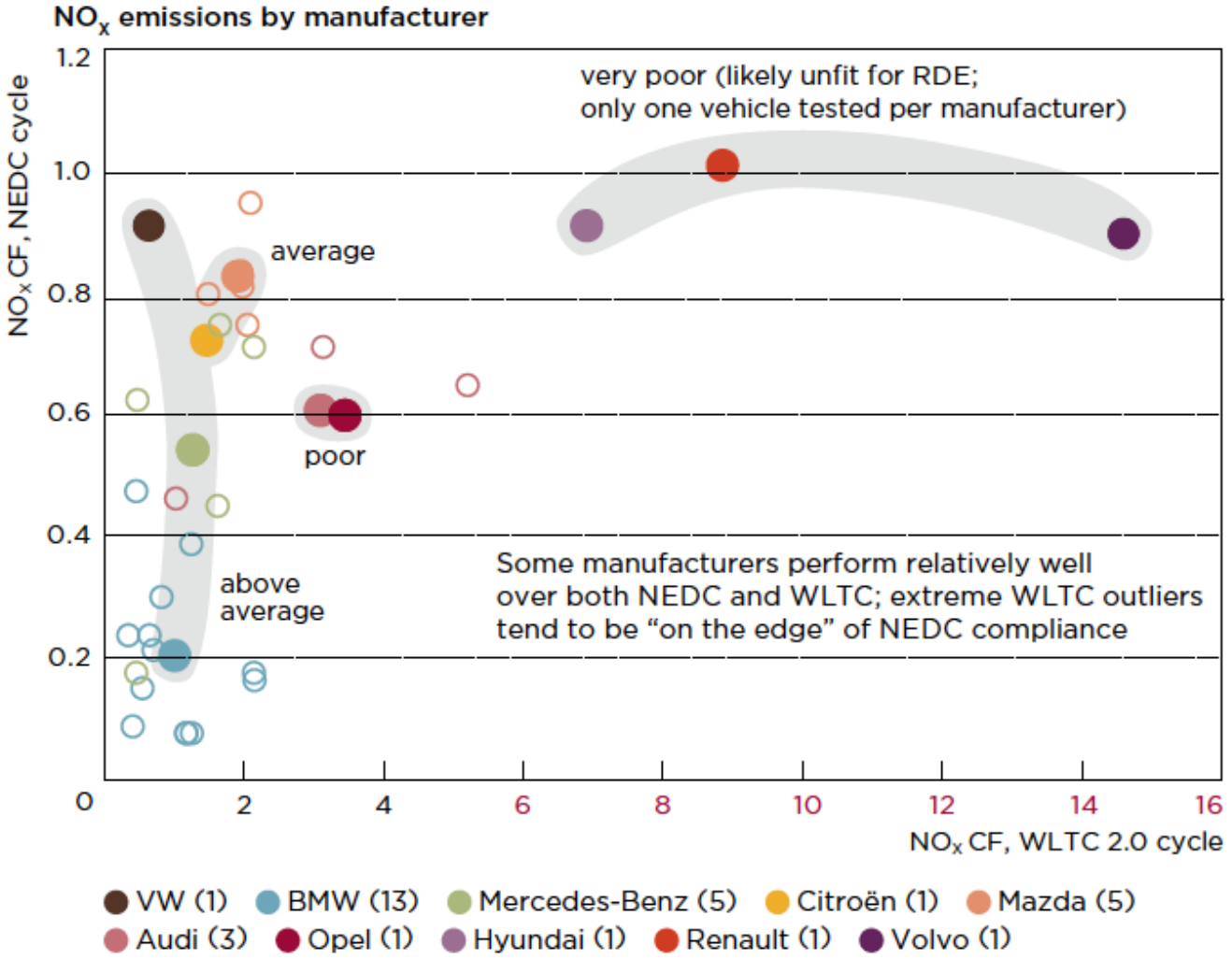
http://www.theicct.org/real-world-exhaust-emissions-modern-diesel-cars

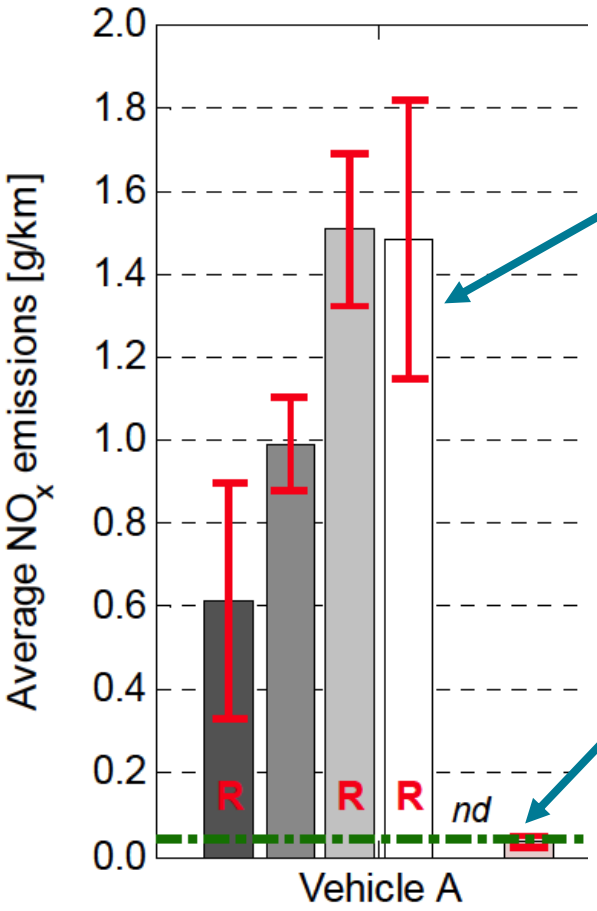
# Even a slight variation in testing conditions can result in drastically high $NO_x$ emission levels




(Solid dots mark the average of the vehicle subset. Numbers in parentheses indicate the number of cars in the subset)

http://www.theicct.org/nox-control-technologies-euro-6-diesel-passenger-cars

# A comparison of laboratory vs. on-road test results for 3 diesel cars in the US triggered “Dieselgate”




On-road test

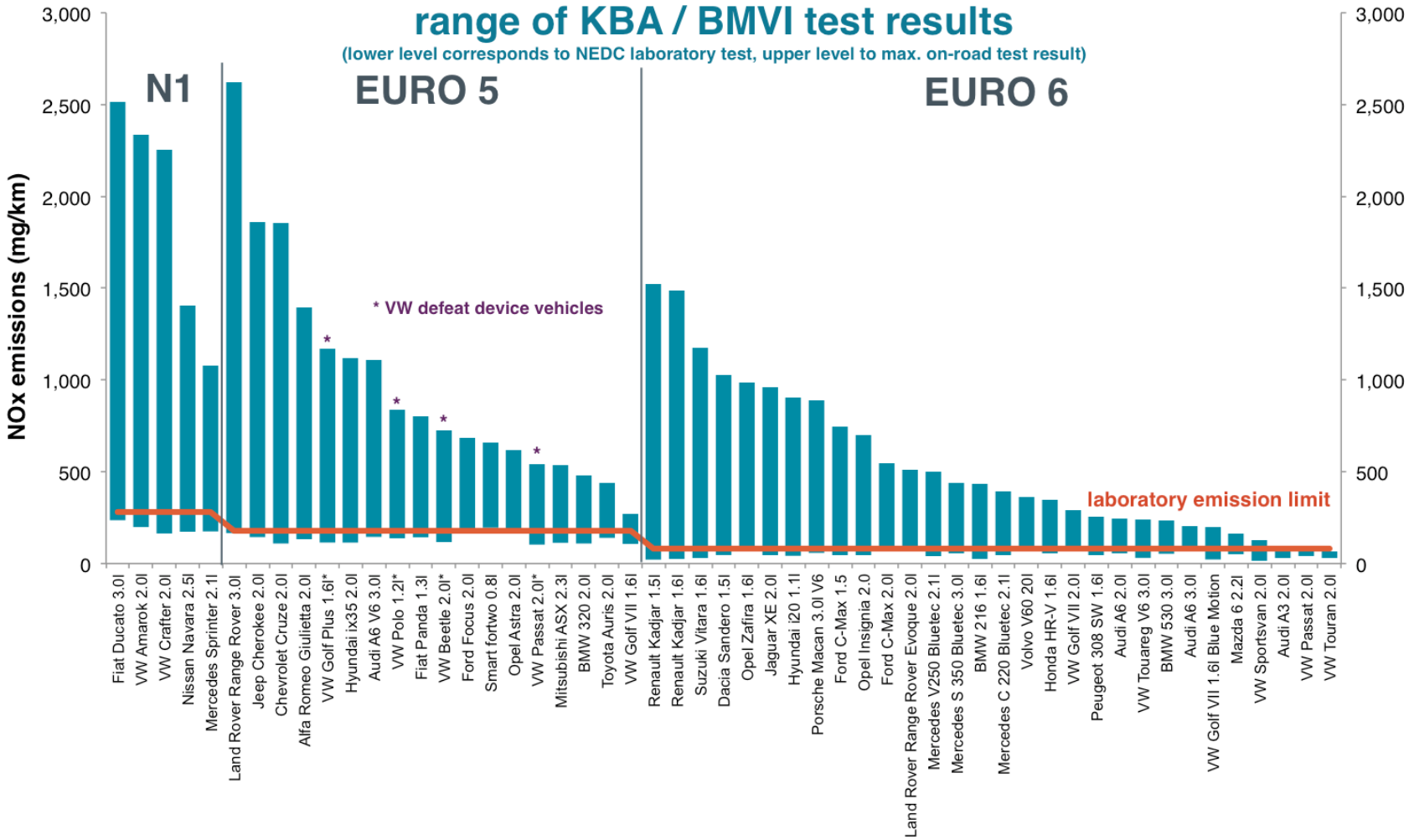
Laboratory test

Source for photos: AVL / ERMES
Vehicles shown on photos are not related to test results shown



http://www.theicct.org/use-emissions-testing-light-duty-diesel-vehicles-us

# Government testing has confirmed earlier findings and points to numerous other defeat devices

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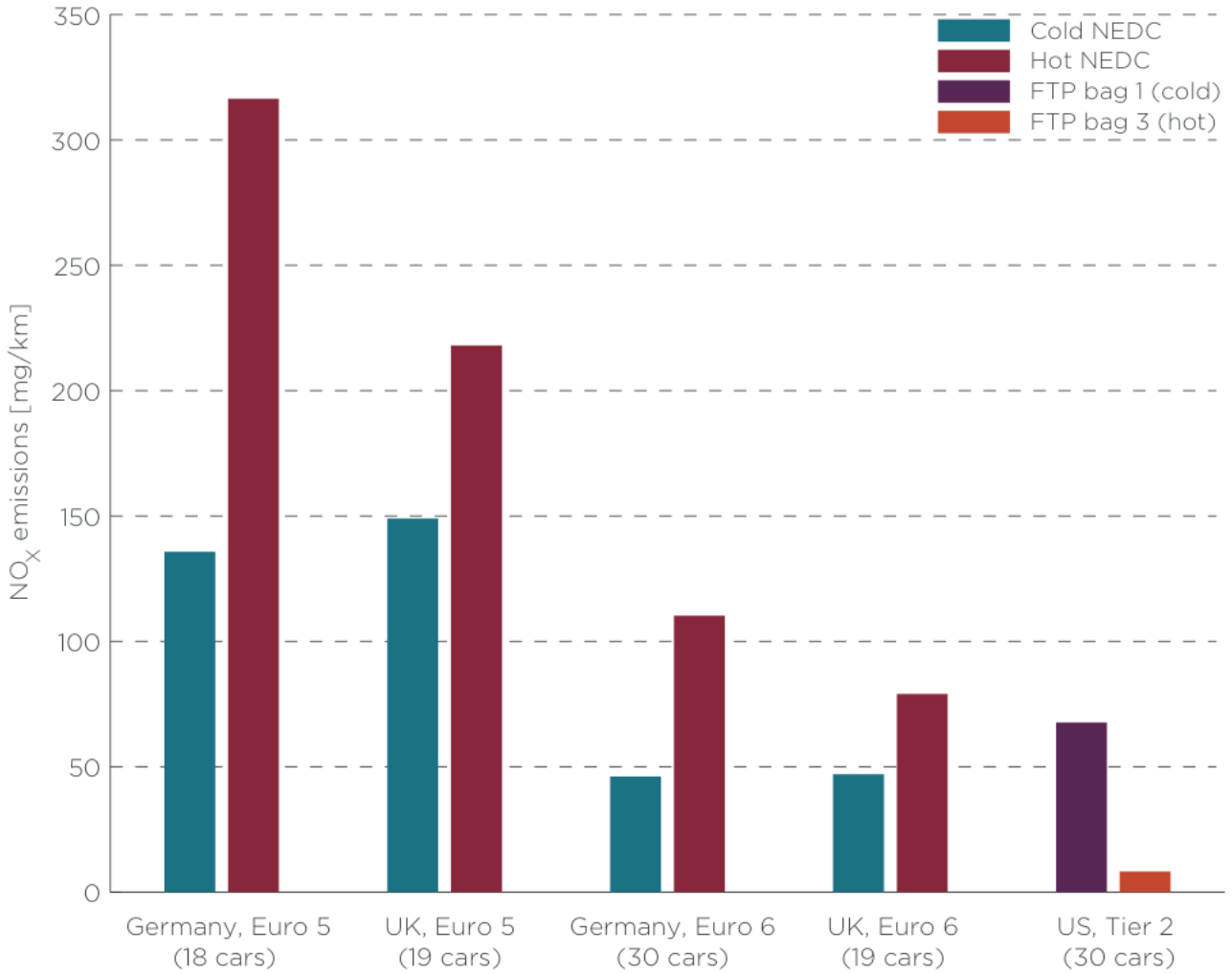
http://theicct.org/blogs/staff/first-look-results-german-transport-ministrys-post-vw-vehicle-testing

# A popular type of defeat device is recognizing cold start conditions as type approval testing

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http://www.theicct.org/blogs/staff/emissions-test-defeat-device-problem-europe-not-about-vw

# Nearly all manufacturers in the EU make use of the “thermo-window” defeat device

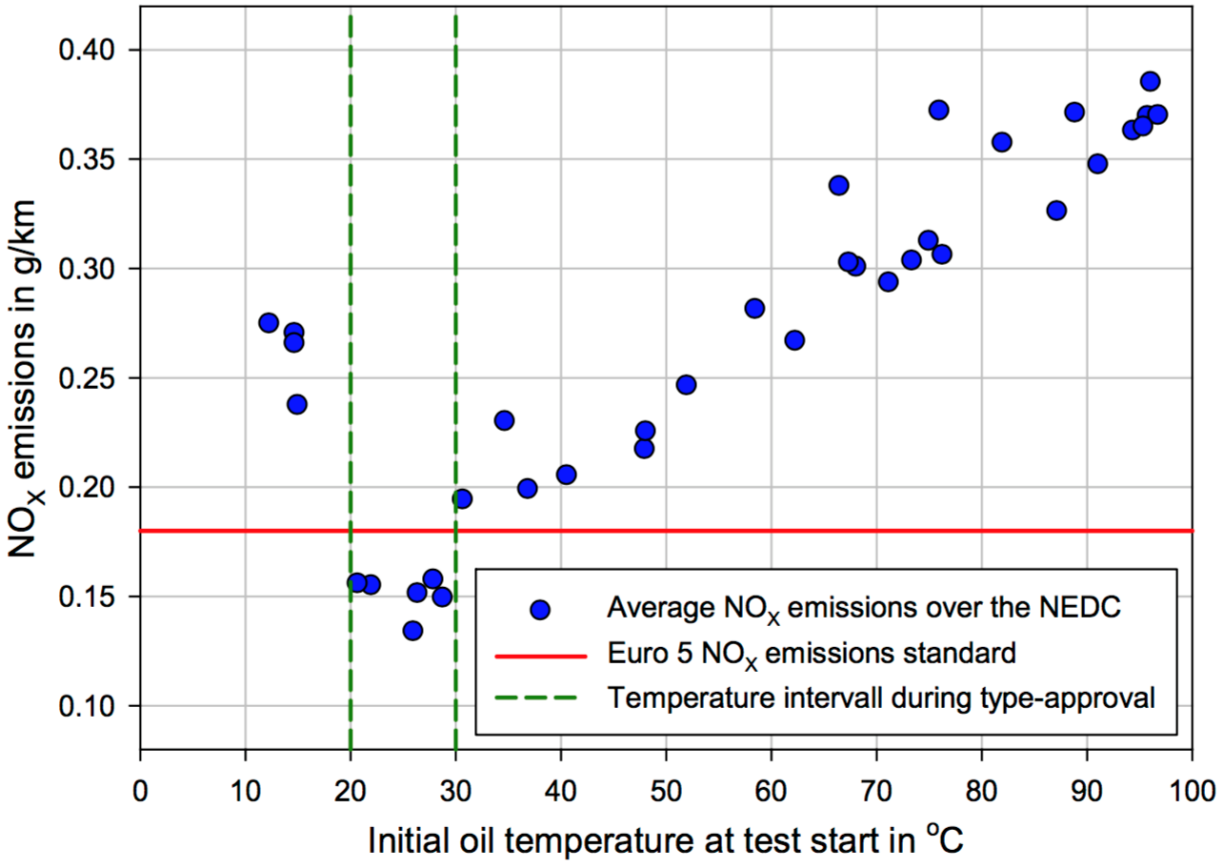


**Figure 9:** Average $NO_X$ emissions of a Euro 5 diesel vehicle over the NEDC at various initial engine temperatures (Data source: Kühlwein, 2012)

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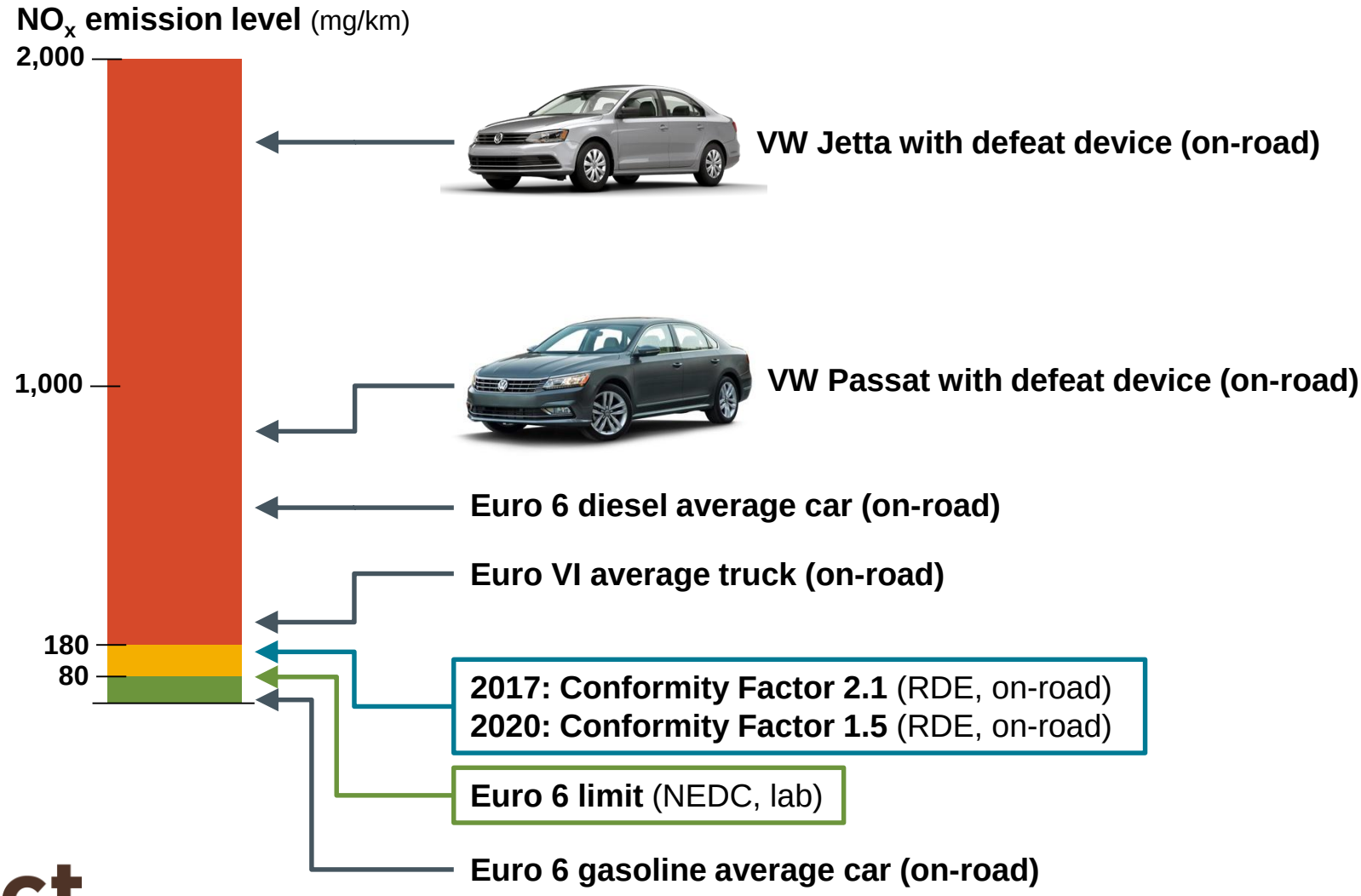
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC75998/ld-na-25572-en-n_online.pdf

# Introduction of new RDE test procedure is an improvement but still masks part of the emissions

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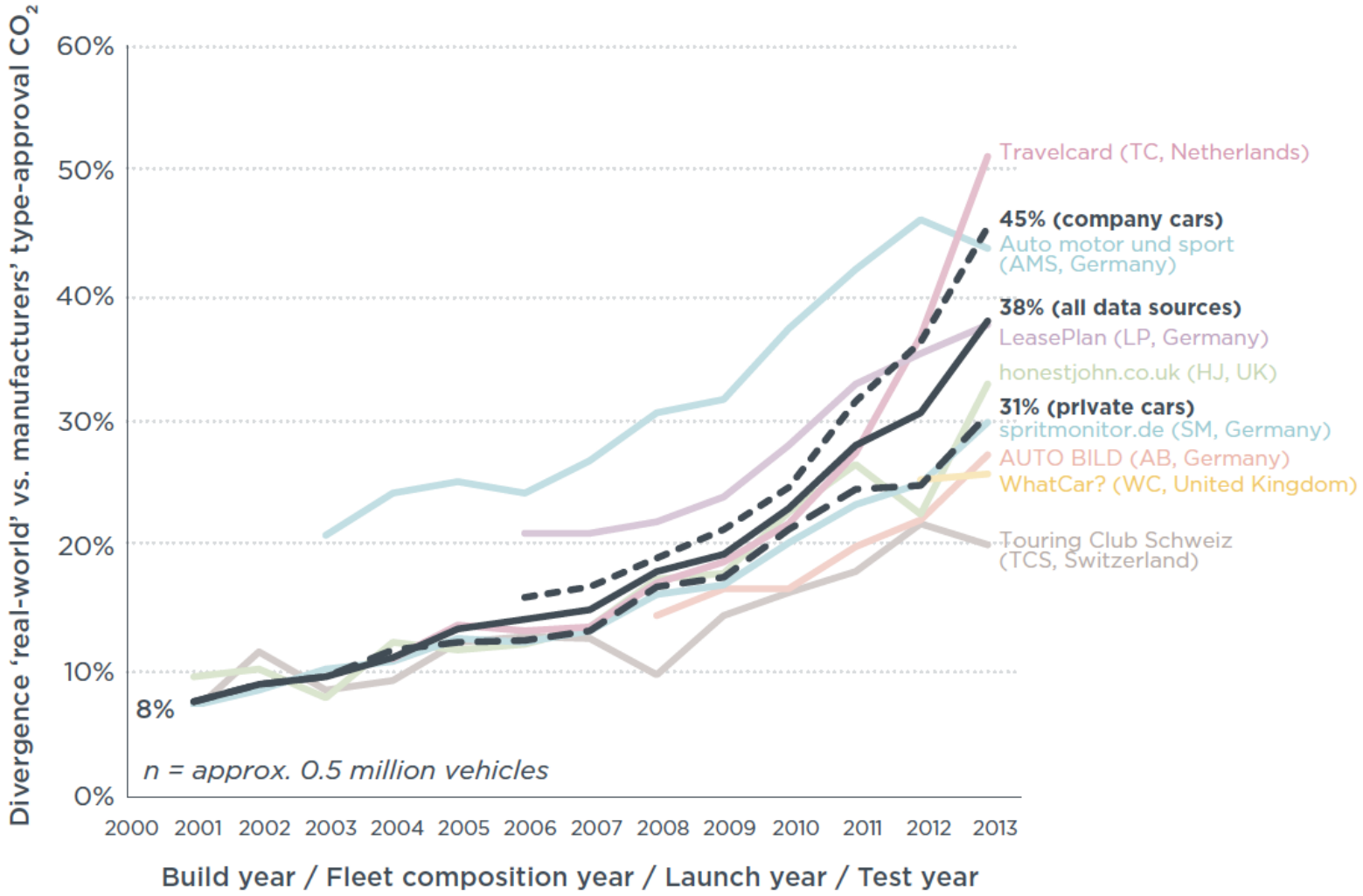
# The difference between laboratory and real-world $CO_2$ emissions increased to 40% in recent years

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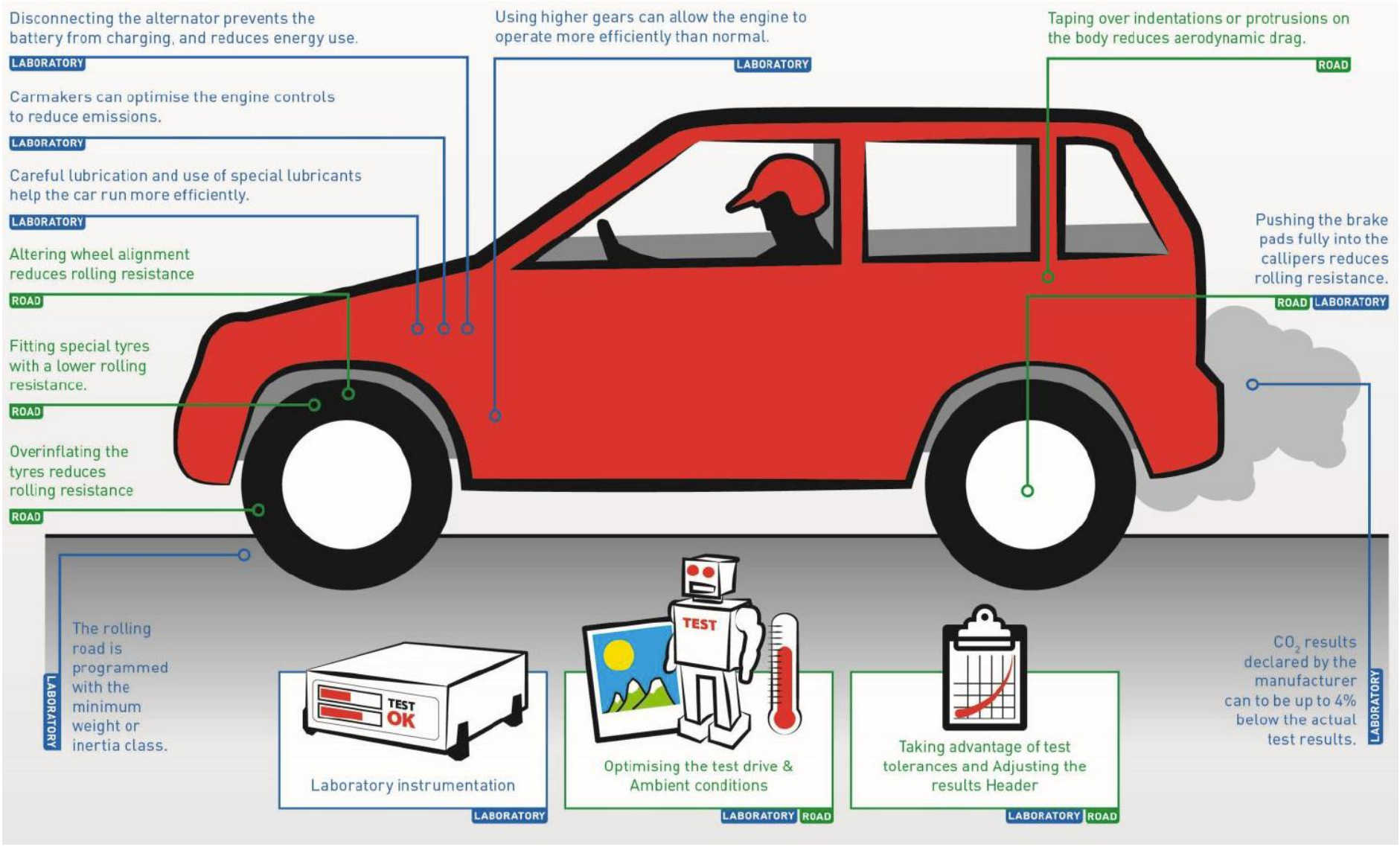
http://www.theicct.org/laboratory-road-2015-update

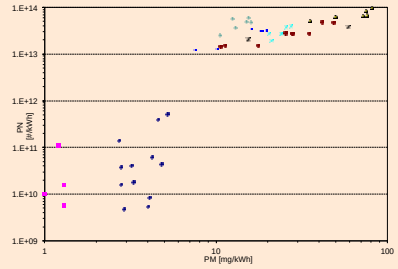
# There are many ways to optimize vehicles for the laboratory testing



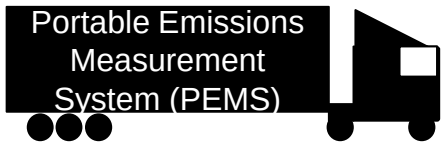
# Implications for India

# Many provisions of BS VI make it a more robust emission standard, but some have been delayed

## Particle number limits




## HDV In-service conformity testing




Delayed until 2023

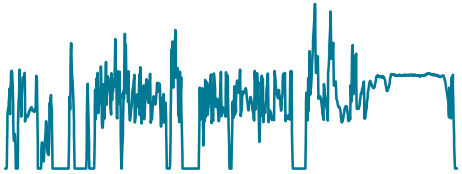
## Real Driving Emissions (RDE) testing

Delayed until 2023

## Enhanced onboard diagnostics (OBD)


OBD delays for 2/3 wheelers

## More representative test cycles



WLTP not adopted

- Extended durability requirements
- Tighter methane requirements for CNG

Lower durability than EU in some cases

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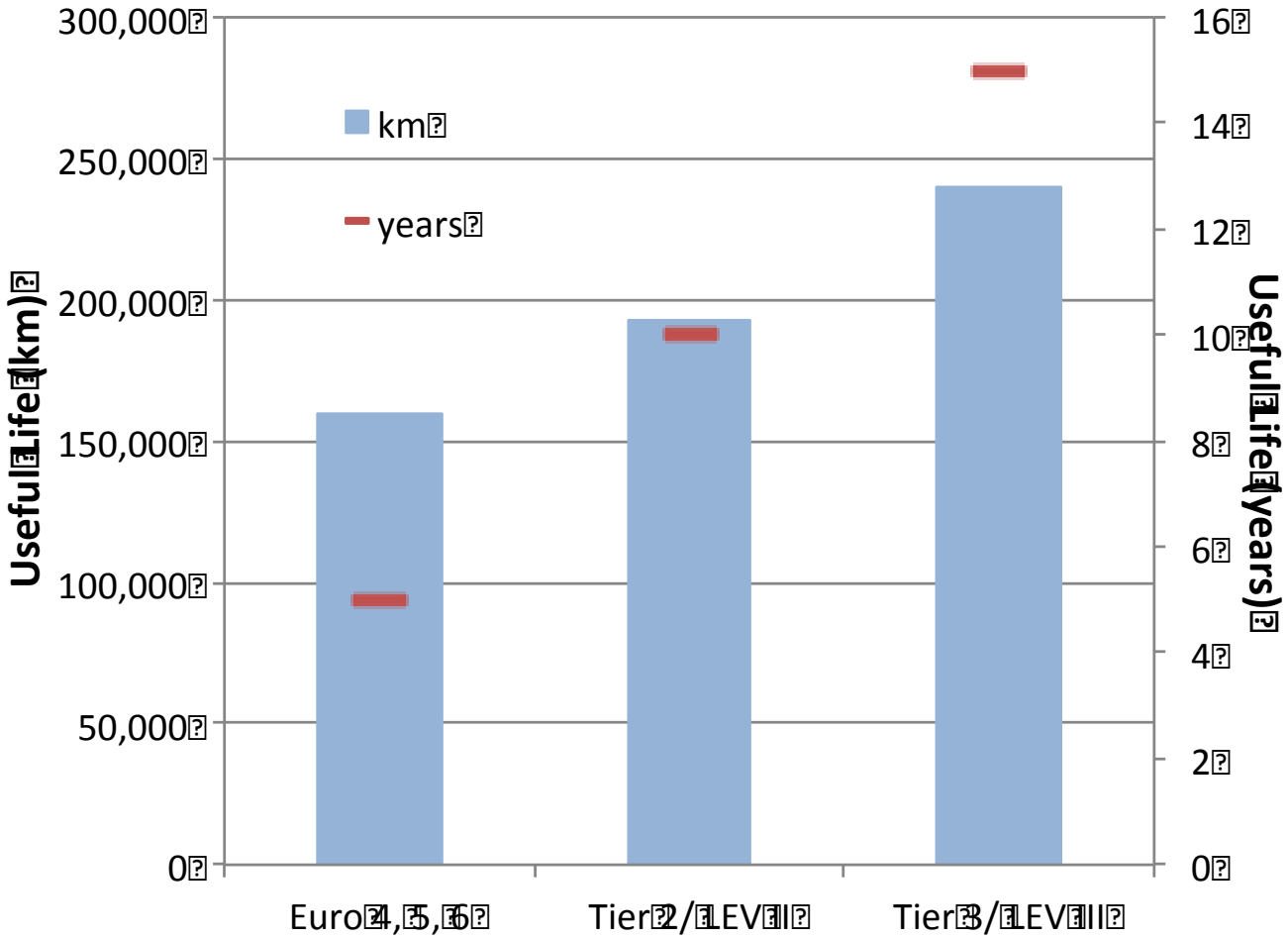
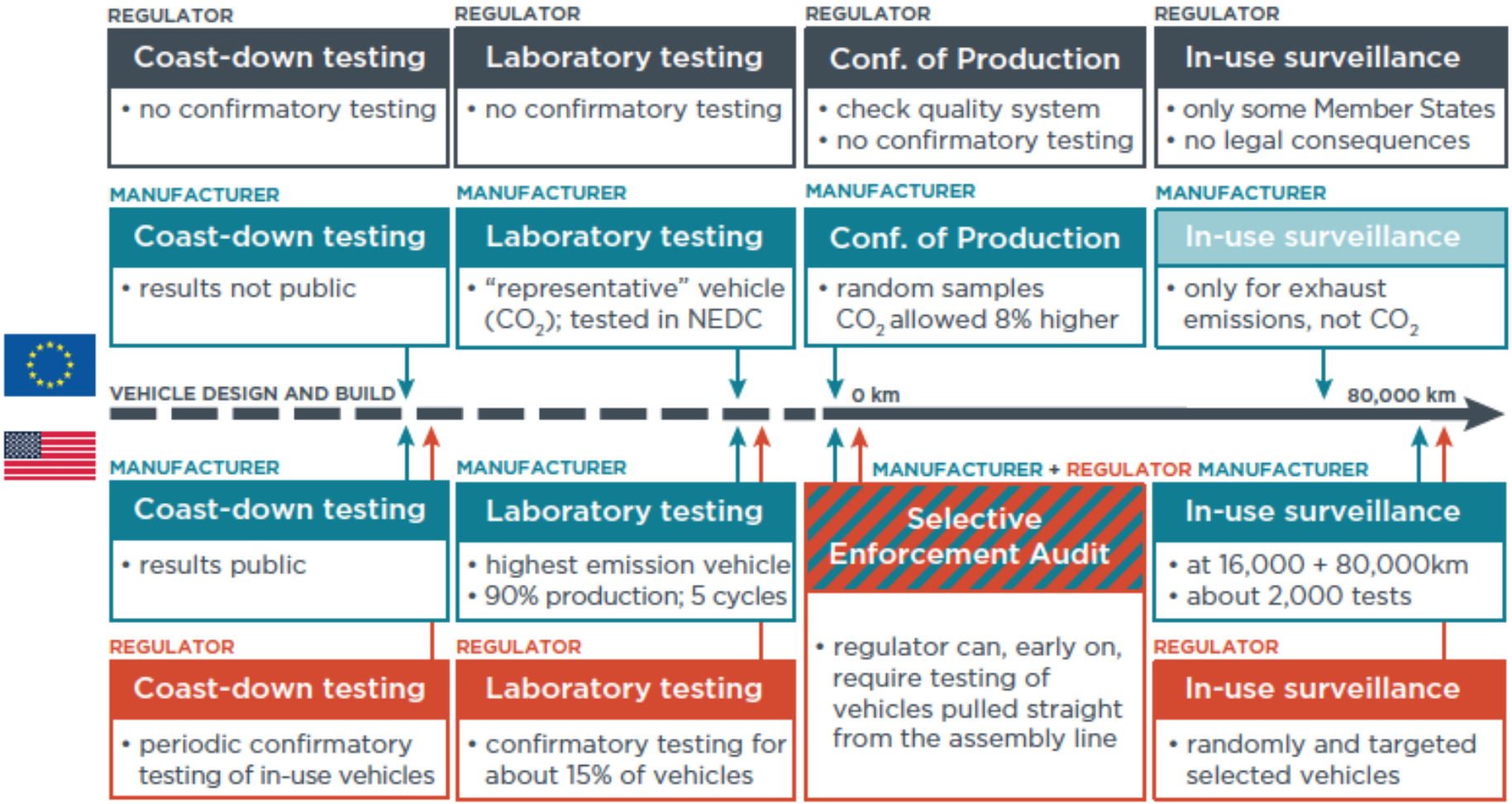
http://www.theicct.org/blogs/staff/india-leapfrogging-an-outdated-standard-to-bharat-stage-VI

# Useful Life of Emissions Control Systems



# In the EU there is a lack of emissions regulation enforcement, resulting in “type-approval tourism”



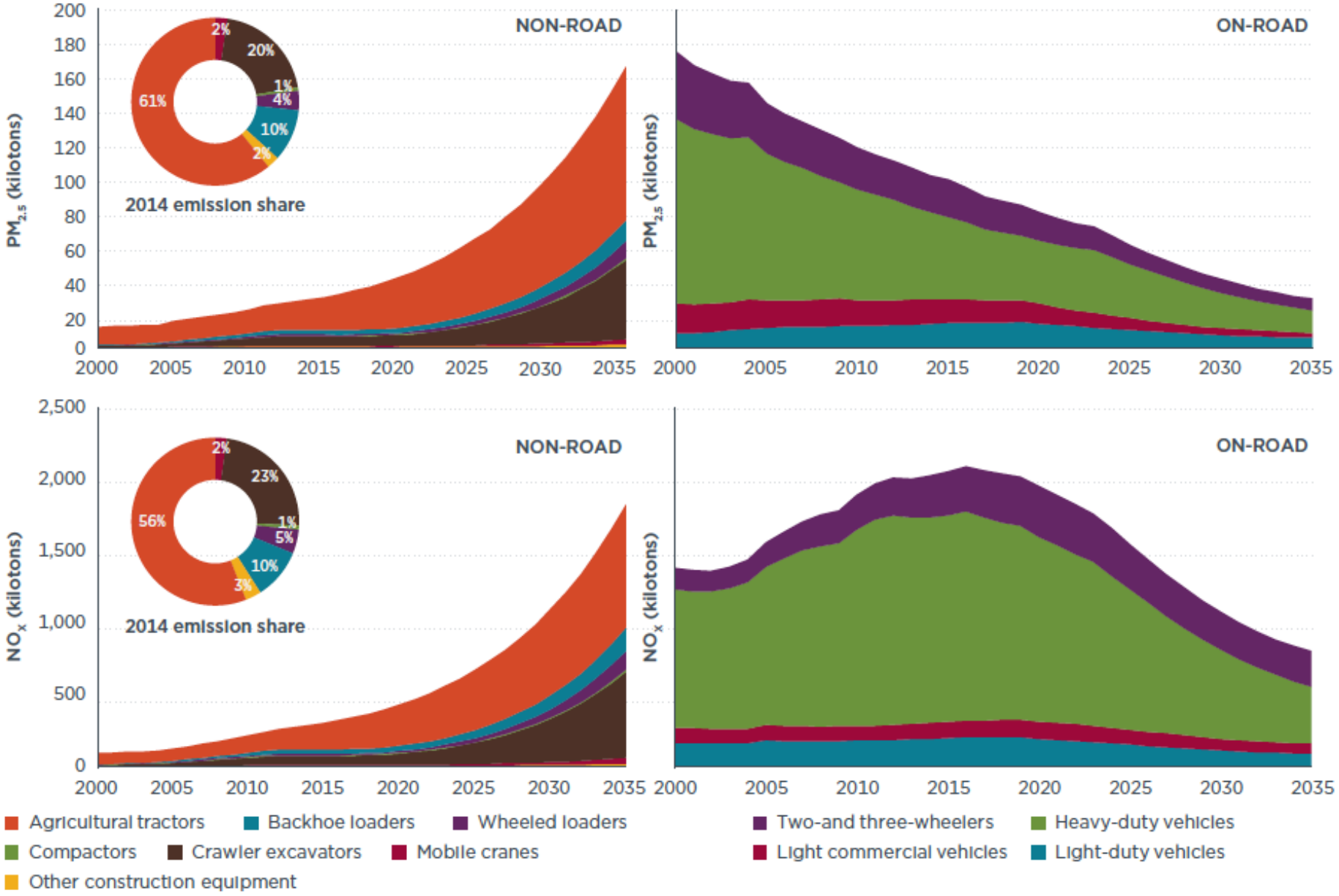



Source: http://www.theicct.org/future-of-vehicle-testing

# India needs to improve both vehicle compliance and Inspection/Maintenance (I/M) programs

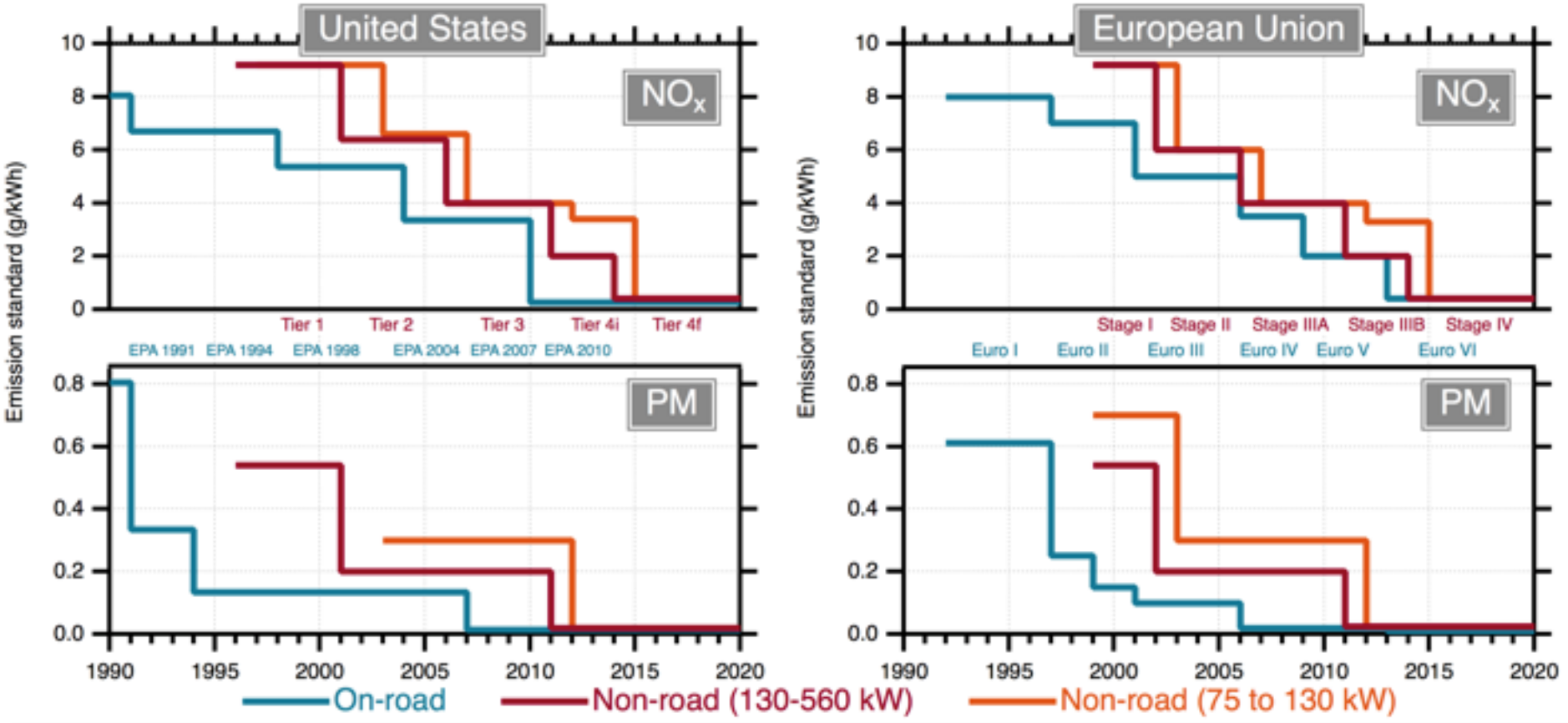
- Suggested improvements in compliance program
  - Vehicle manufacturers should be required to test a select number of low-mileage and high-mileage vehicles manufactured by them (In-Use Verification Program), and report all data to MoRTH
  - Detailed in-use compliance testing (IUCP) should be required if samples fail during IUVP
  - MoRTH, through NATRiP, should conduct in-use surveillance tests
  - MoRTH must have the ability to recall vehicle models failing in the IUCP and/or in-use confirmatory tests

# Importance of reducing non-road emissions in a post BS VI world




- http://www.theicct.org/non-road-emissions-inventory-india

# Comparison of on-road HD and non-road engine regulatory pathways in the U.S. and EU




European Stage V regulation goes further than US Tier 4, and will require a diesel particulate filter on all non-road diesels from 2020 onwards.

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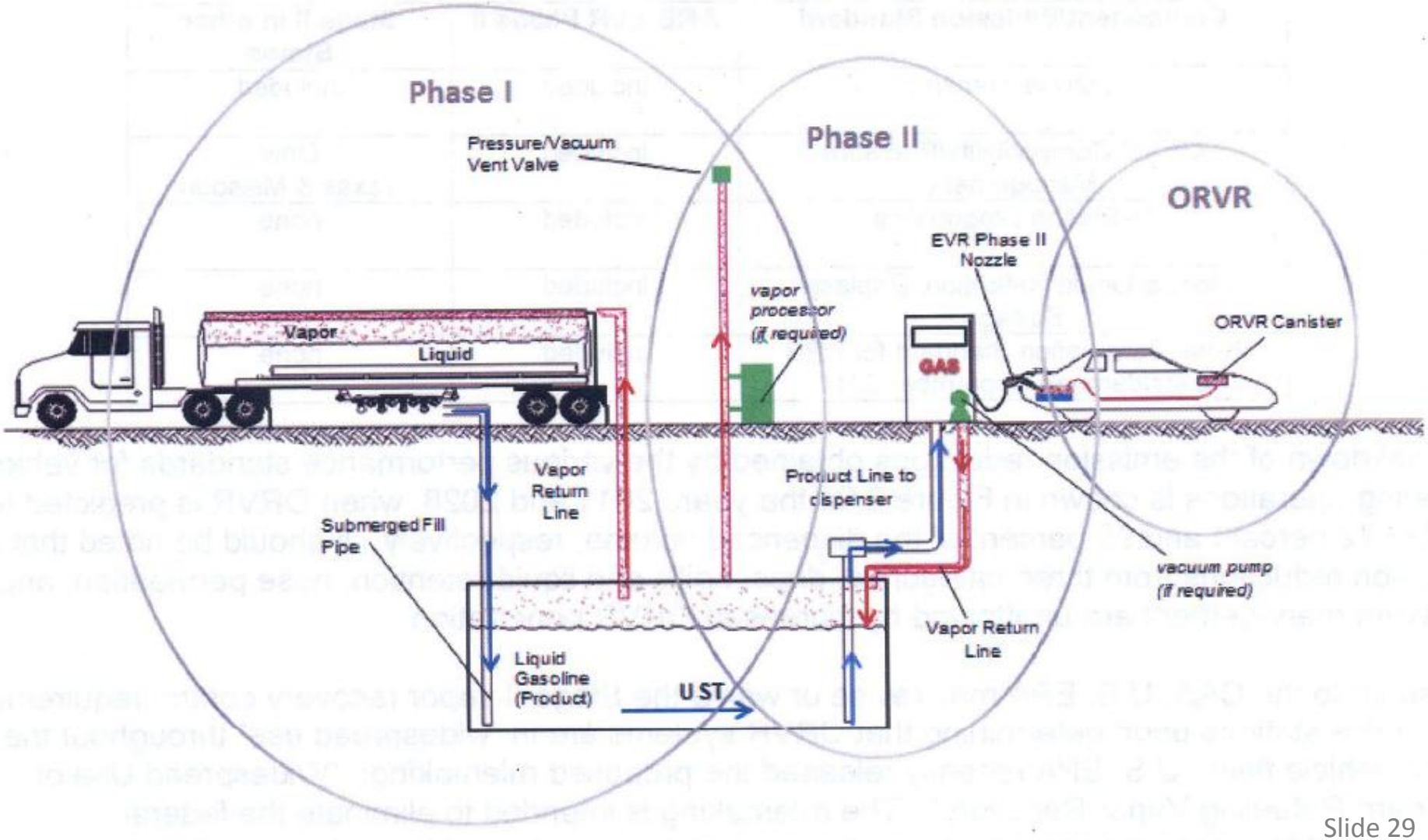
Opportunity for improvement

# Fuel compliance issues

| | India | US | Japan |
|---|---|---|---|
| **Fuel Testing** | Oil industry tests fuel; only one independent fuel testing lab | Oil industry tests every batch; EPA audits industry tests & contracts testing to multiple independent labs across the country | Oil industry testing before sale; METI tests all service stations annually at one of nine NPA labs |
| **Presumptive Liability** | Oil companies not responsible once fuel leaves their depots | All parties in fuel distribution system responsible | All parties in fuel distribution system responsible |
| **Fuel Registration & Tracking** | No centralized or computerized system | Computerized EPA Designate & Track system accounts for all fuel nationwide | All fuel and fuel handlers registered with METI |
| **Penalties** | None to date | Fines and criminal charges against violators | Fines and possible jail time; non-compliant service stations closed |

# Vapor Recovery Options: Stage I, Stage II controls/On-board Vapor Recovery (ORVR)



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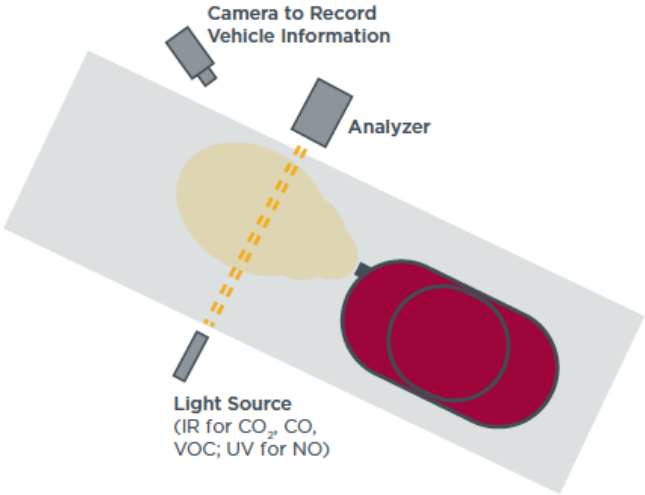
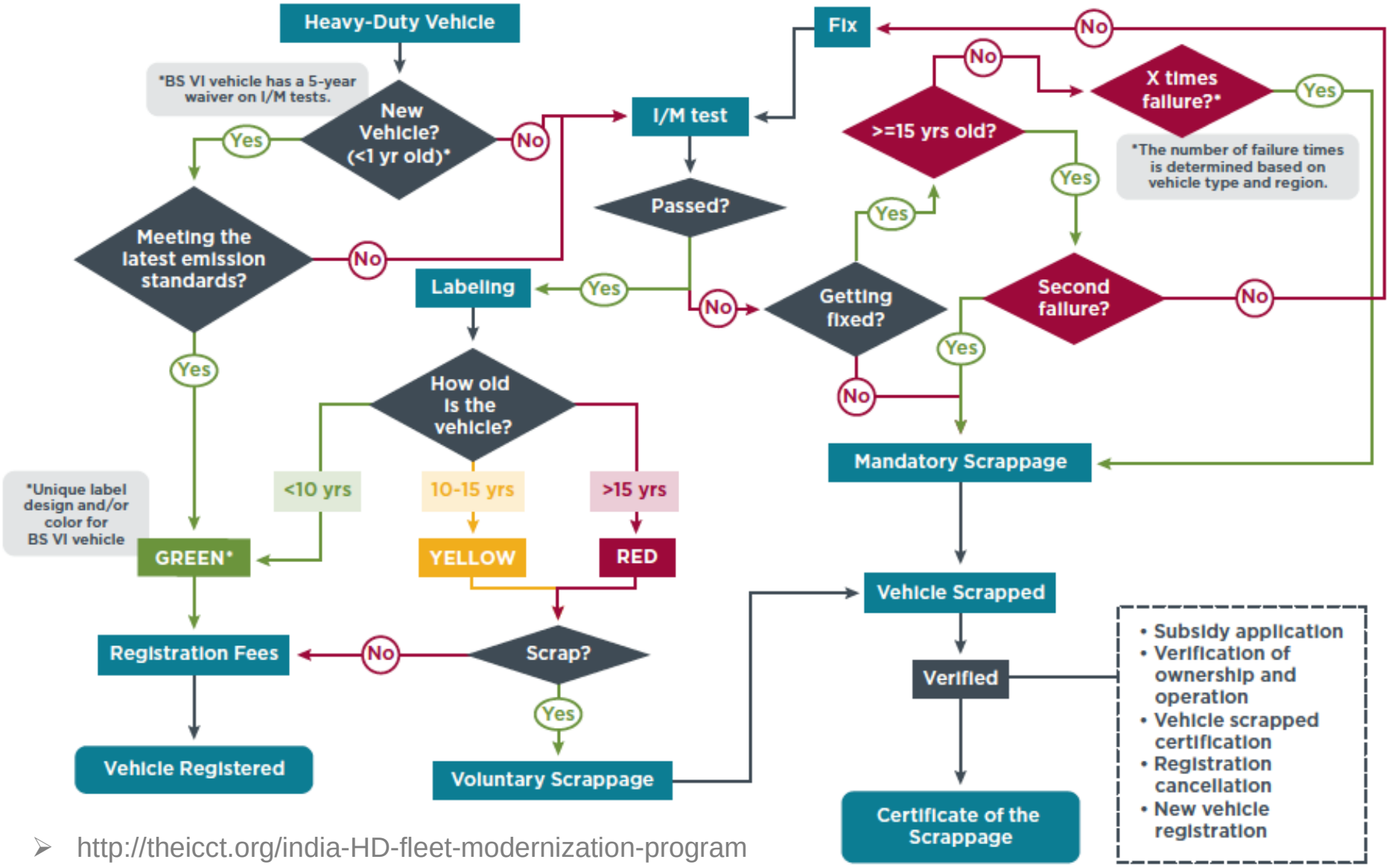
# Remote sensing

- Programs are widespread in Europe and U.S.
- Useful tool for monitoring mean on-road fleet emissions
  - Ensure that new vehicle standards are operating as intended
  - Ensuring the effectiveness of I/M programs, including guarding against corruption in test centers
  - Can be used to better calibrate emissions modeling
- On-road heavy-duty vehicle emissions monitoring system (OHMS)




# Combining a HDV scrappage program with BS VI standards can be a major win-win




- http://theicct.org/india-HD-fleet-modernization-program

# Much cleaner diesel vehicles are possible through stricter standards and/or retrofits

No retrofit system
**Uncontrolled Diesel Exhaust**
(Level 1)

Old technlogy
Little black carbon removal
Little ultrafine PM removal
Does not remove lube oil ash

Retrofitted with
**Diesel Oxidation Catalyst (DOC)**
(Level 1)

Old technlogy
Little black carbon removal
Little ultrafine PM removal
Does not remove lube oil ash

Retrofitted with
**Partial Filter**
(Level 2)

Little black carbon removal
Little ultrafine PM removal
Does not remove lube oil ash

Retrofitted with
**Diesel Particulate Filter (DPF)**
(Level 3)

New Technology
Used on all new trucks since 2007
>85% black carbon removal
>85% ultrafine removal
>85% lube oil ash removal

DPFs are typically installed on new diesel passenger vehicles with Euro 5 standards and on heavy duty vehicles with Euro VI standards, but can be retrofitted to older diesels provided <50 ppm sulfur fuel is available.

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➢ Cleaire Advanced Emission Controls LLC

# 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 vehicles

Demand management

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

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# For more information…

- ICCT India Initiative: http://www.theicct.org/india
- ICCT Heavy-Duty Program: http://www.theicct.org/heavy-duty-vehicles
- Advantages of Euro 6/VI emission standards over Euro 5/V: http://www.theicct.org/briefing-leapfrogging-to-euro-6-vi-mar2015
- Making Bharat VI Affordable: http://www.theicct.org/blogs/staff/making-bharat-vi-affordable
- Survey of best practices in reducing emissions through vehicle replacement programs: http://www.theicct.org/vehicle-replacement-program-best-practices-mar2015

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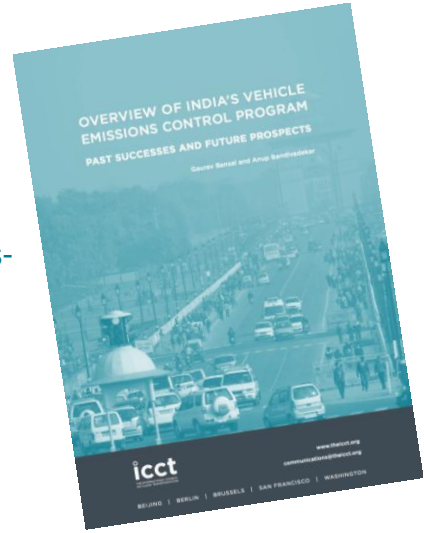
# ICCT's India air quality and HDV emissions-related resources


http://www.theicct.org/briefing-leapfrogging-to-euro-6-vi-mar2015


http://www.theicct.org/comparing-real-world-nox-euro-iv-v-vi-mar2015


http://www.theicct.org/india-bharat-stage-vi-emission-standards

http://www.theicct.org/indias-vehicle-emissions-control-program




http://www.theicct.org/india-HD-fleet-modernization-program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