Technical considerations for transitioning to soot-free vehicle standards and fuels

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Transition to Soot-free Heavy-duty Vehicles and Fuels: Technical Workshop
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CLIMATE & CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

ICCT projects global transport CO_{2e} emissions to grow significantly to 2050 driven largely by emerging economies

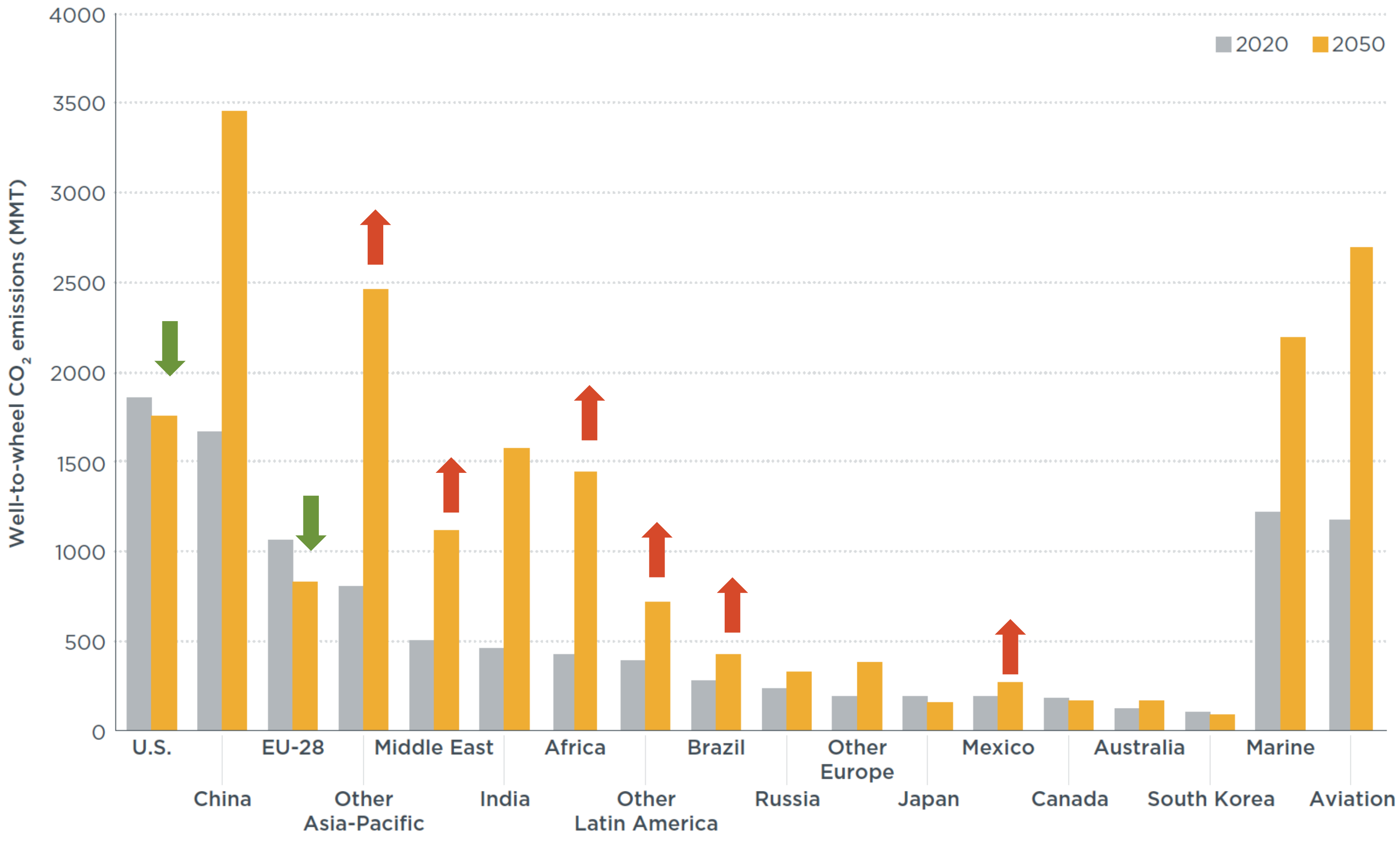
Estimated transport CO_{2e} growth under **adopted policies**

2020: 12 Gt/year

2050: 21 Gt/year

2020: ASEAN is the 4th largest GHG contributor

2050: ASEAN GHG emissions would be second to China.



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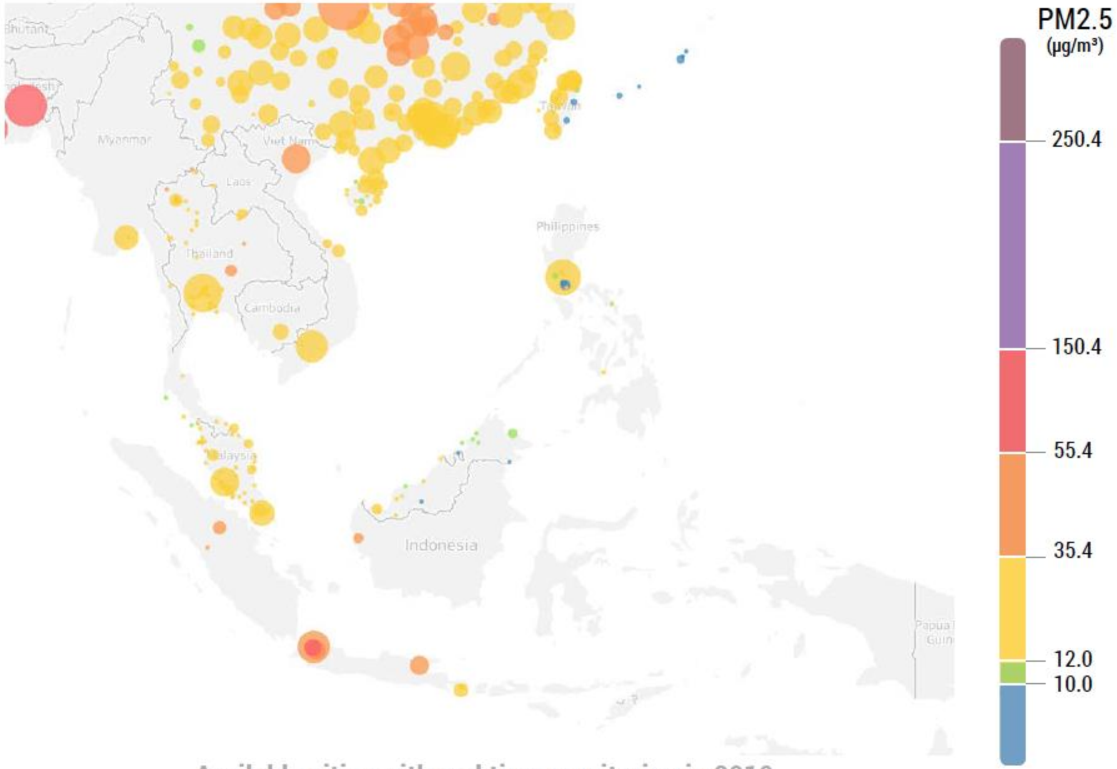
ASEAN cities are struggling with high levels of air pollution

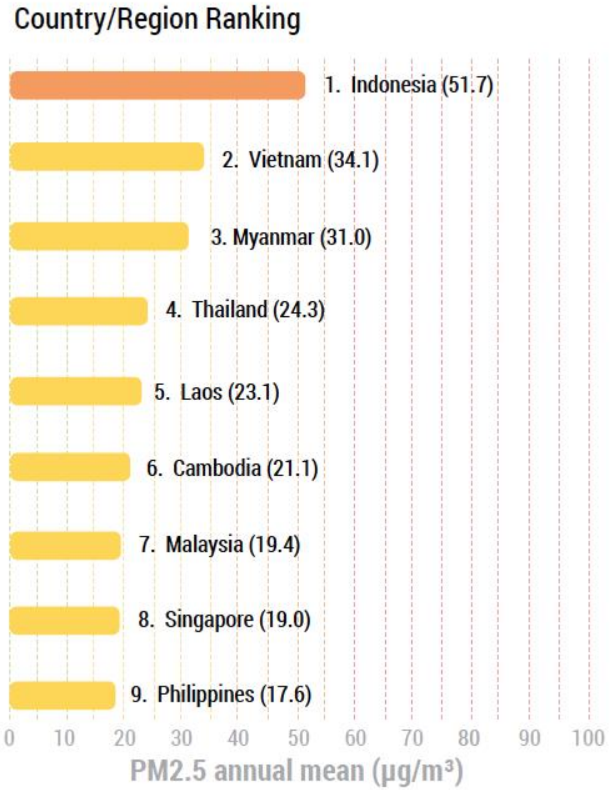
Source: https://www.iqair.com/us/

Most Polluted Regional Cities

Rank	City	2019 AVG
1	South Tangerang, Indonesia	81.3
2	Bekasi, Indonesia	62.6
3	Pekanbaru, Indonesia	52.8
4	Pontianak, Indonesia	49.7
5	Jakarta, Indonesia	49.4
6	Hanoi, Vietnam	46.9
7	Talawi, Indonesia	42.7
8	Nakhon Ratchasima, Thailand	42.2
9	Saraphi, Thailand	41.3
10	Surabaya, Indonesia	40.6



Available cities with real time monitoring in 2019



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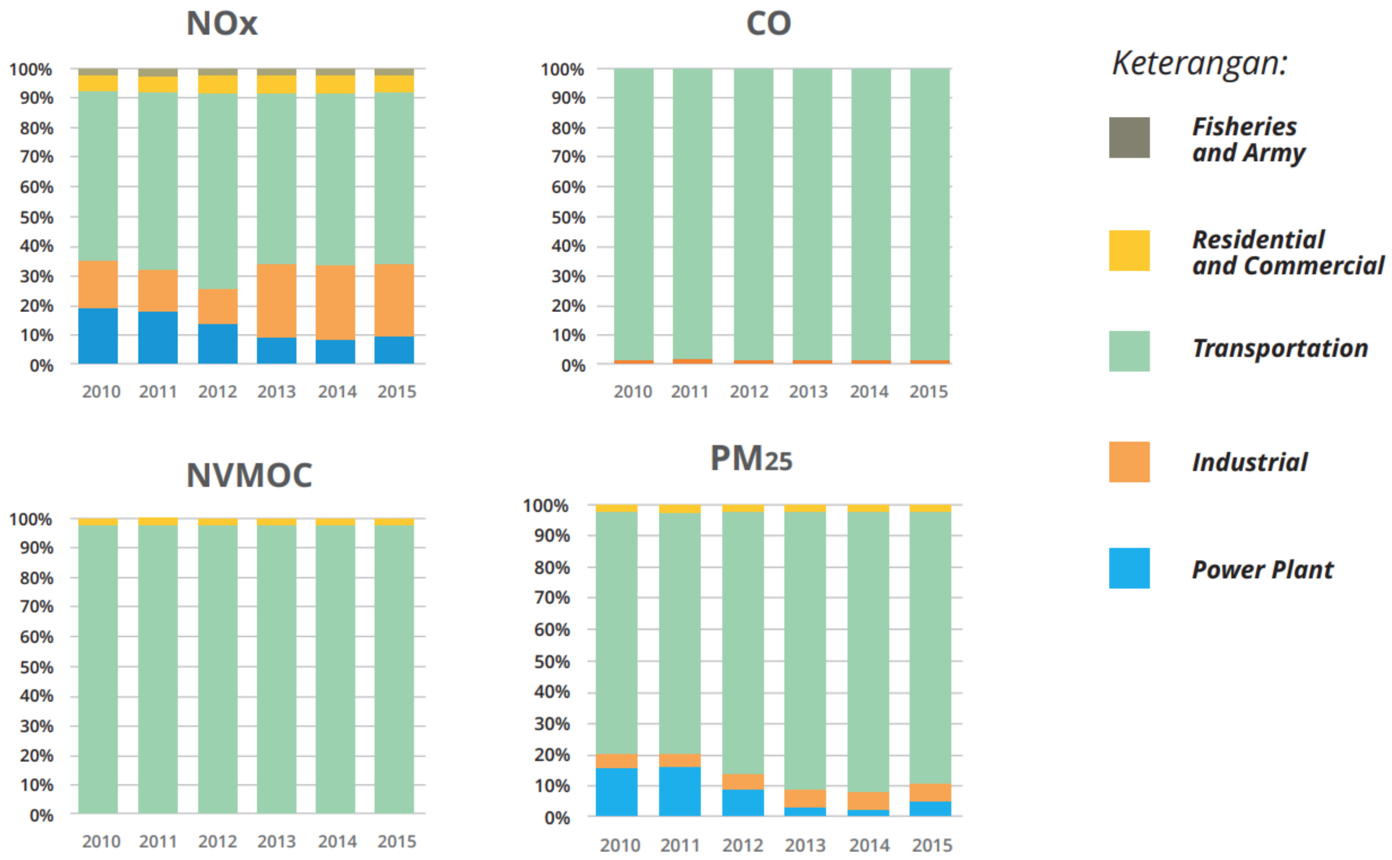
WHO 2020 guidelines: annual average concentration of PM2.5 should not exceed 5 μg/m3, while 24-hour average exposures should not exceed 15 μg/m3 more than 3 - 4 days per year.

https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

Transport is a significant source of pollution is areas with high presence of uncontrolled engines



Jakarta's emissions inventory (2019)

Source: https://icel.or.id/wp-content/uploads/Brief-Inventarisasi-emisi-udara-jakarta-OK.pdf

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What can national regulators do to curb growing vehicle fuel consumption, GHG and pollutant emissions?

Developing vehicle and fuel regulations that promote a **technology transition towards cleaner options**

Reduction of pollution

- N L Fuel quality (S<10 ppm)
- N L Vehicle emission standards
  - Aim for Euro 6/VI
- N L Vehicle replacement
- L Low emission zone

Reduction of GHG

- N Vehicle fuel efficiency standards
- N Efficiency labels
- N Fiscal programs f(CO_2)

Reduce both!

Policies and programs to incentivize adoption of **Zero Emission Vehicles** (EVs and FCEVs)

EV: Electric Vehicle ; FCEV: Fuel Cell Electric Vehicle

Important clarification: Addressing one does not solve the other.
Work in both issues at the same time!!

Toyota Prius

Europe	**California**
Fuel consumption: 20 km/L	Fuel consumption: 20 km/L
CO_2: 120 g/km	**CO_2: 120 g/km**
Emission standards: **Euro 6 – NOx: 60 mg/km**	Emission standards: **SULEV – NOx: 12.5 mg/km**

Global best practices on achieving clean air

1. Fuels and vehicles act as a single system

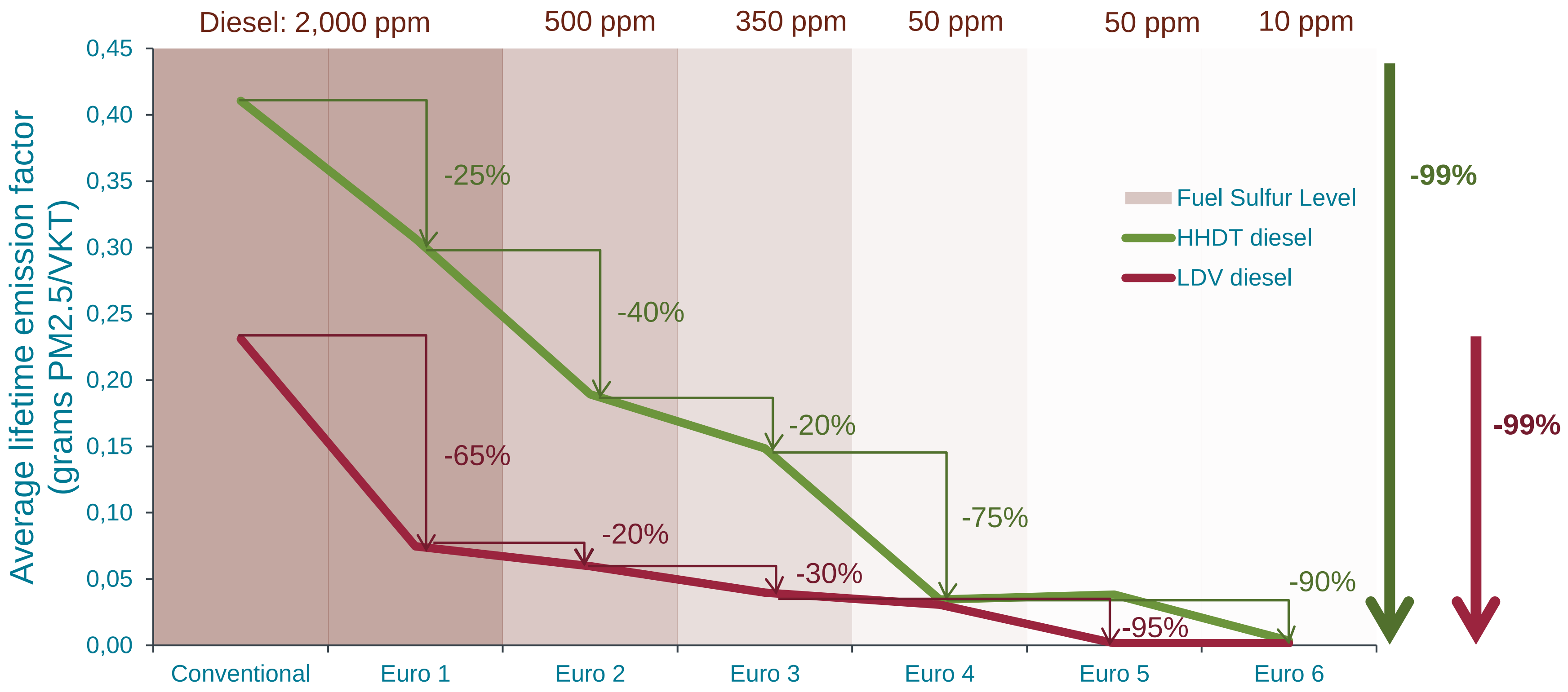
Fuel Quality

Limit gasoline and diesel sulfur to 10 parts per million

Emission Control System

HDV emission standards offer substantial emission reduction levels when paired with proper fuels

- Lower S content enables cleaner technologies for diesel vehicles
- Diesel fuel quality is key



Emission factors from COPERT 4, versión 10.0

Global best practices on achieving clean air

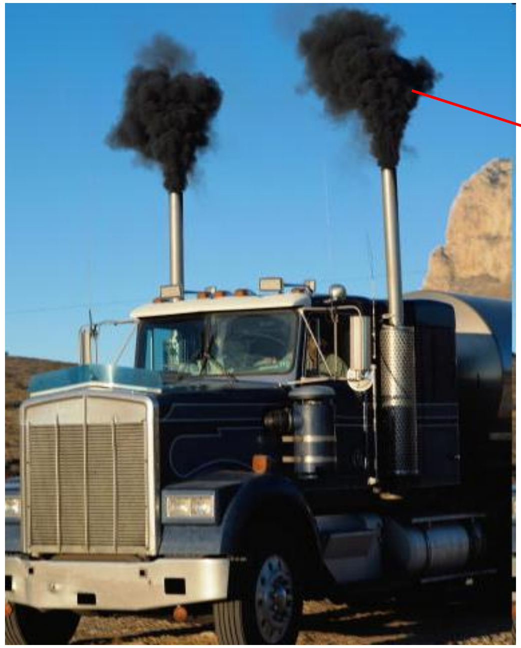
2. New vehicle emission standards:
Controls on new vehicles are the first target

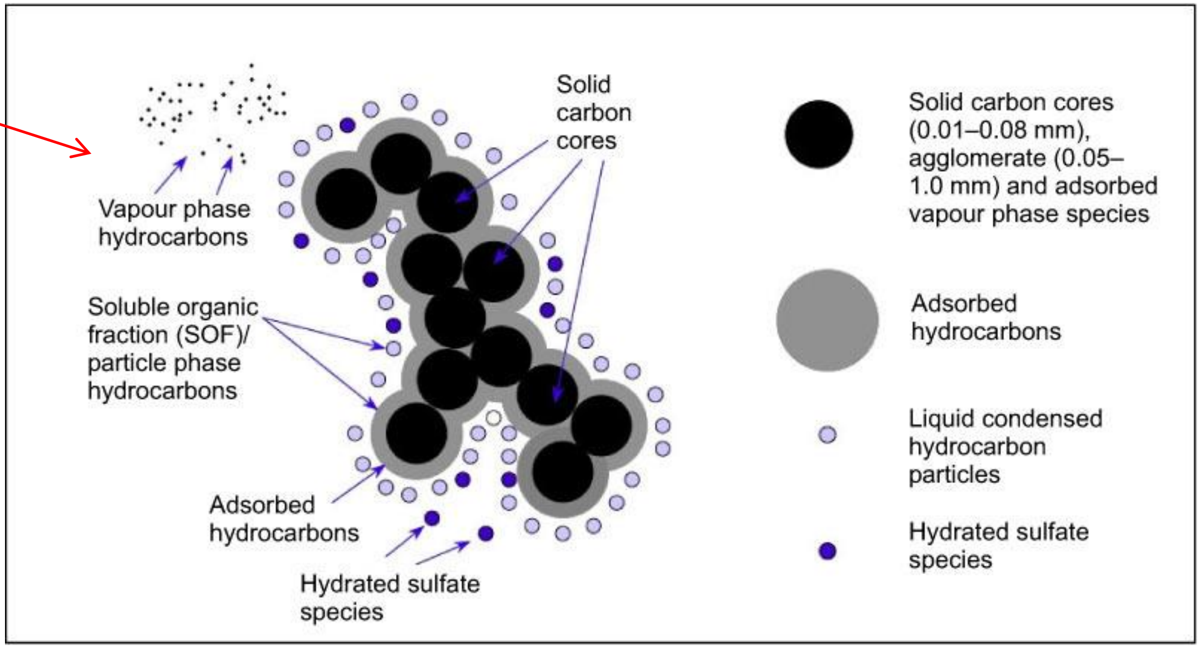
- Fewer actors
- Costs borne by vehicle importers and manufacturers
- Generally, more cost-effective
- Reduces emissions through natural fleet replacement

Key tailpipe pollutants to control from gasoline and diesel vehicles

- Carbon Monoxide, CO
- Hydrocarbons, HC
- **Nitrogen Oxides, NO and NO_2 = NOx**
- **Particulate Matter / Number and Black Carbon (BC)**
  - PM is not a pure substance
  - Low PM emissions shifted the measurement from mass to number

What about CO_2?





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Heavy-duty engine testing for emissions and fuel consumption are measured under laboratory test conditions

Dynamometer (represent the work required second by second)

Engine

Exhaust pipe

Regulated pollutants (per vehicle max or fleet average):
NOx, NMHC, NMOG, HC (EU), CO, PM, PN (EU), HCHO (US)

CO_2 (gCO_2/km)

Fuel Economy (km/L) = f(CO_2, CO, HC,..)

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HDV emission standards limits are the main drivers of emission control technology improvement

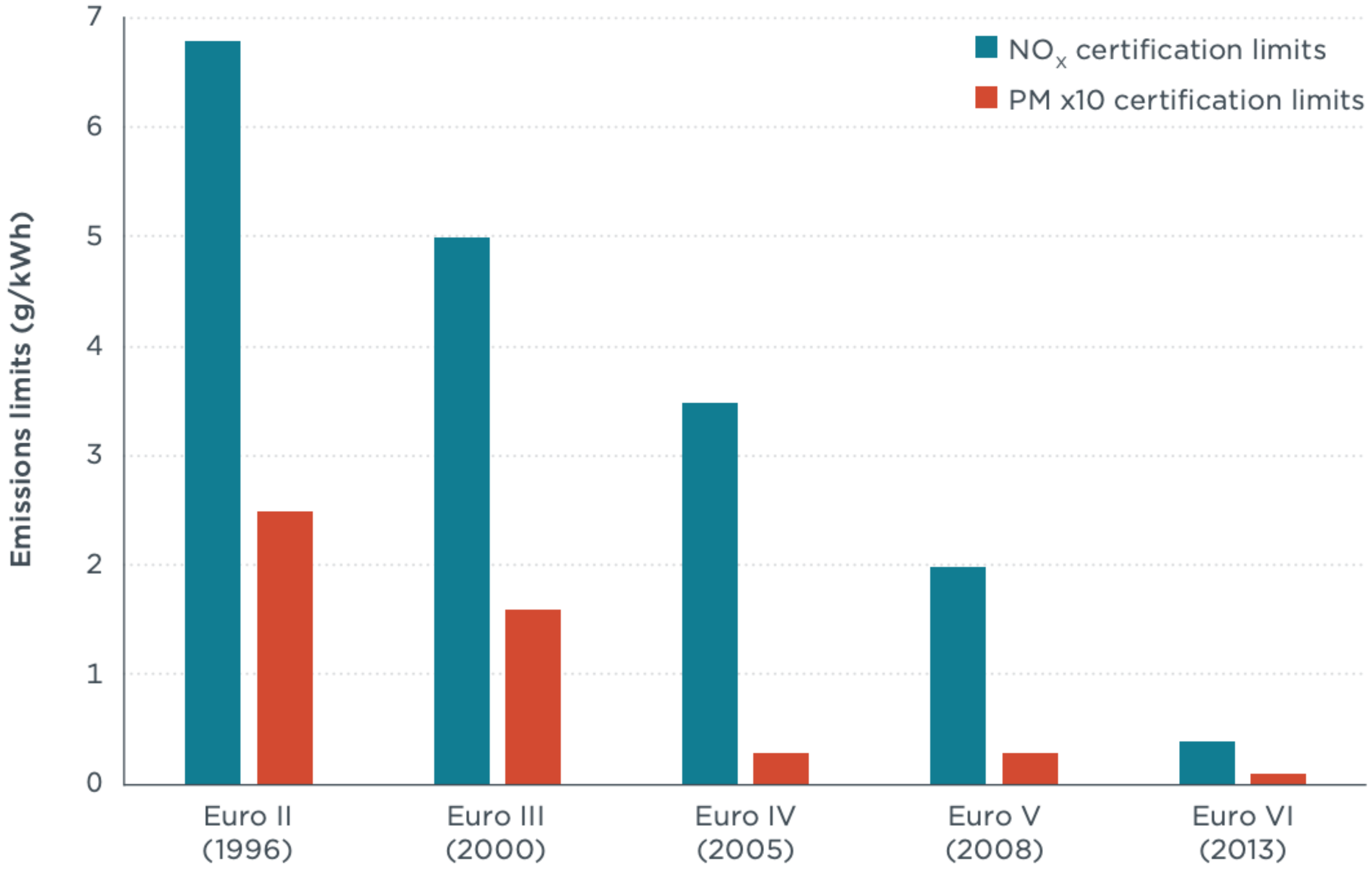

Figure 8. Emissions limits for each stage of the European standards.

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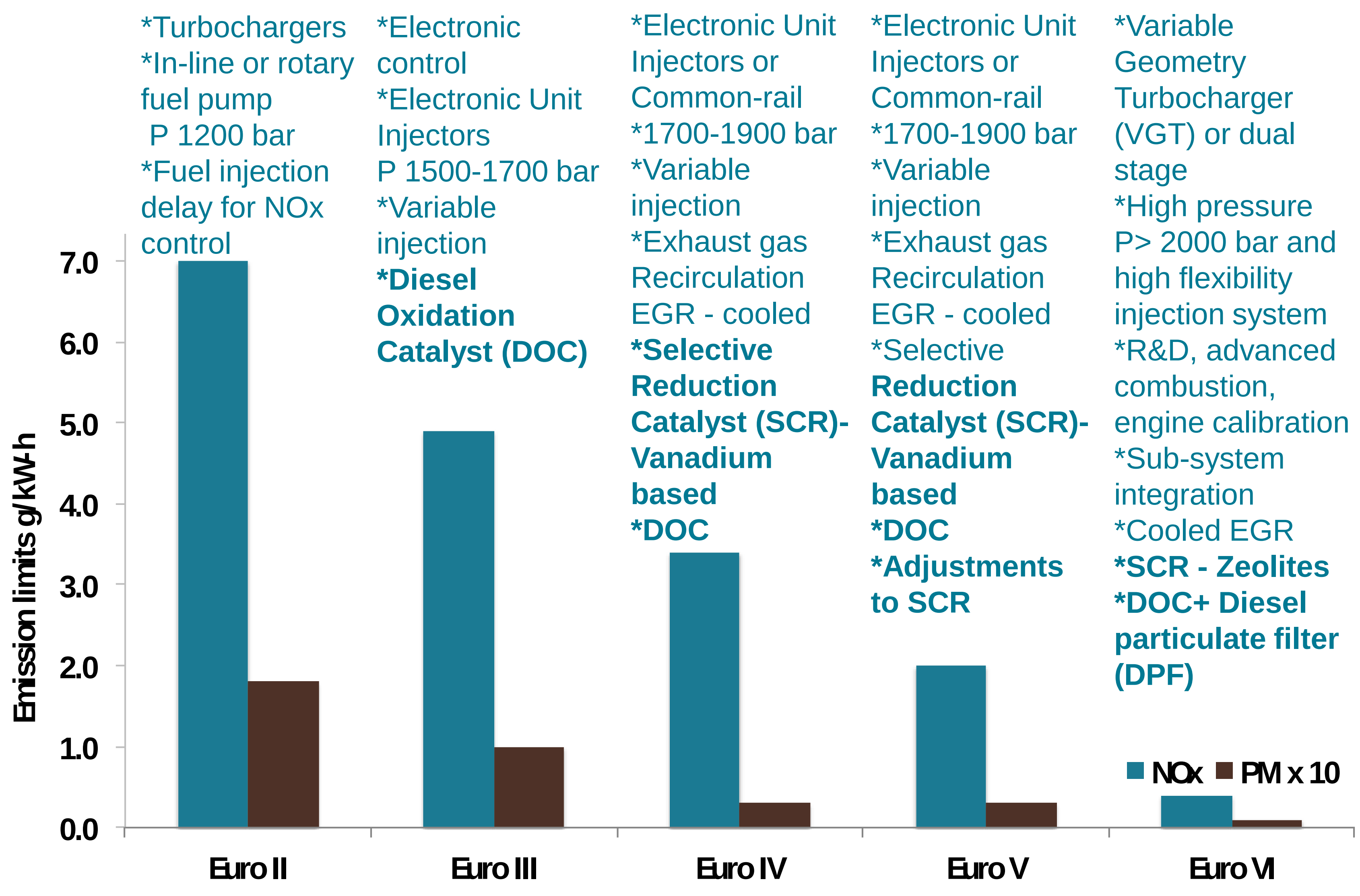
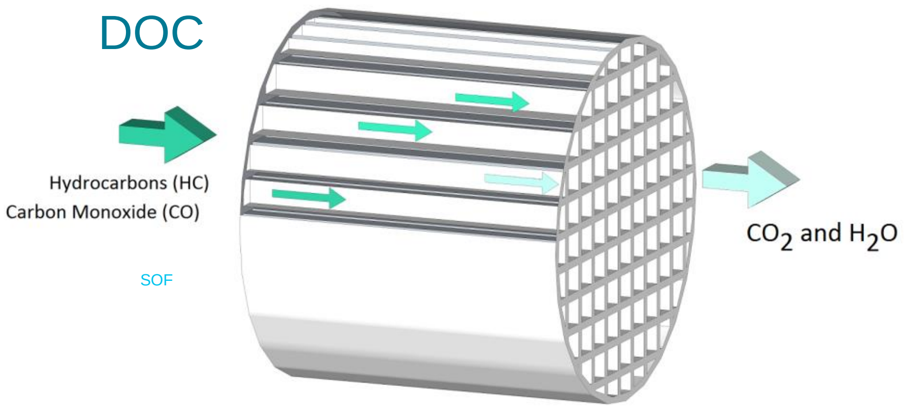
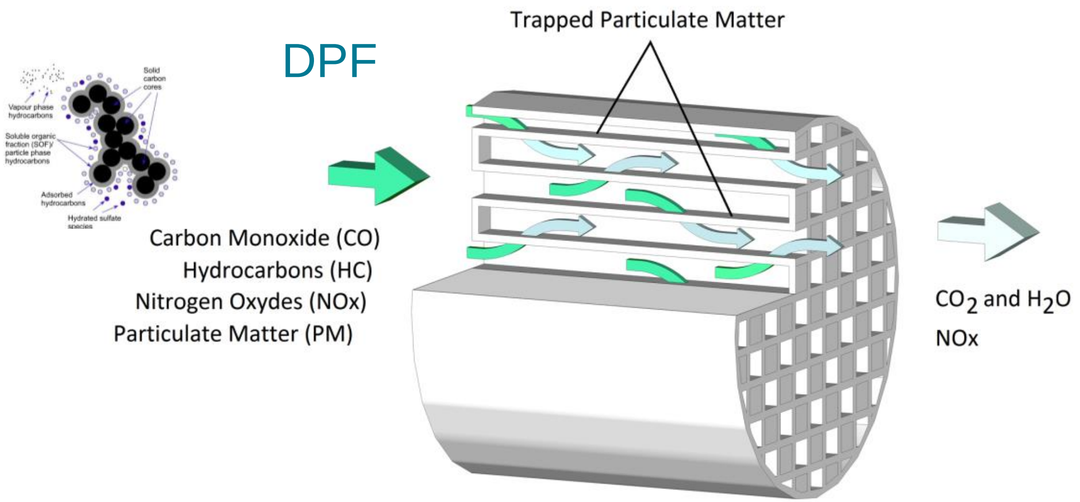
Technology progression for Diesel HDVs under Euro emission standards program



Emission Control Technologies





Aftertreatment

- Diesel Oxidation Catalyst (DOC)
  - CO (90%), HC (70%)
  - SOF fraction of PM (10-50%)
- Diesel Particulate Filter (DPF)
  - PM (95%)
  - PN
- Lean NOx Trap (LNT)
  - NOx (70-90%)
  - Require ULSD
- Selective Catalytic Reduction (SCR)
  - NOx (95%)

PM and BC accumulation in filter

	Material	Wall thickness (µm)	Porosity (%)	Mean pore diameter (µm)
Porous wall A	Cordierite	305	48	12
Porous wall B	Silicon carbide	305	42	14

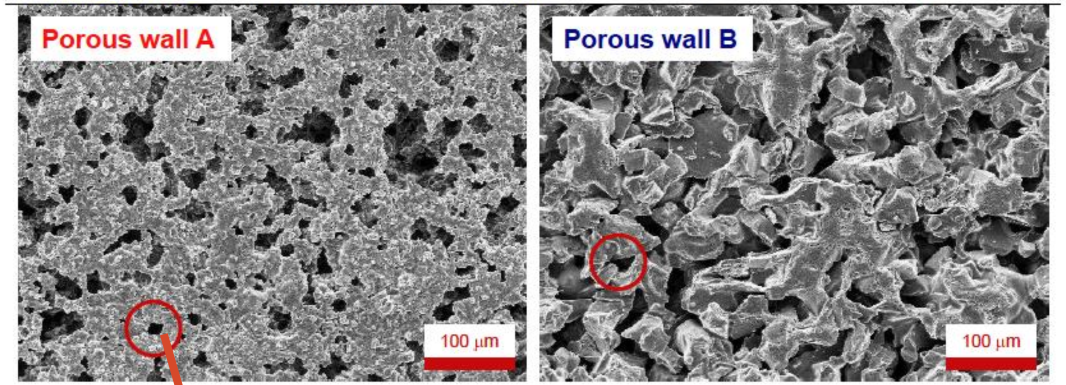
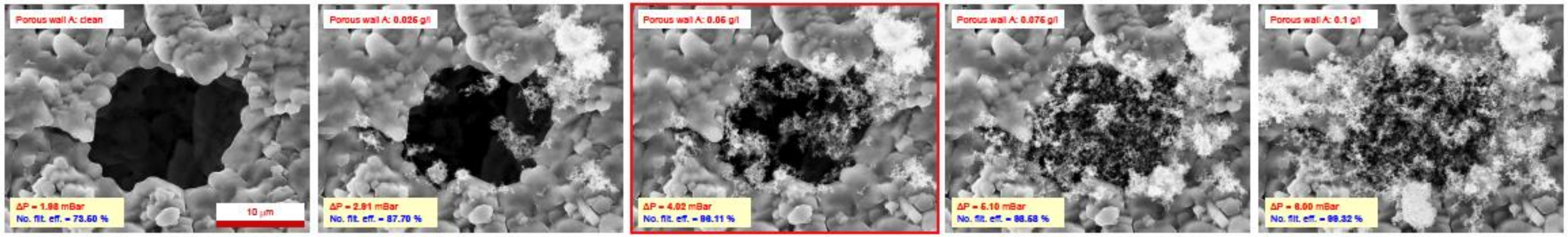
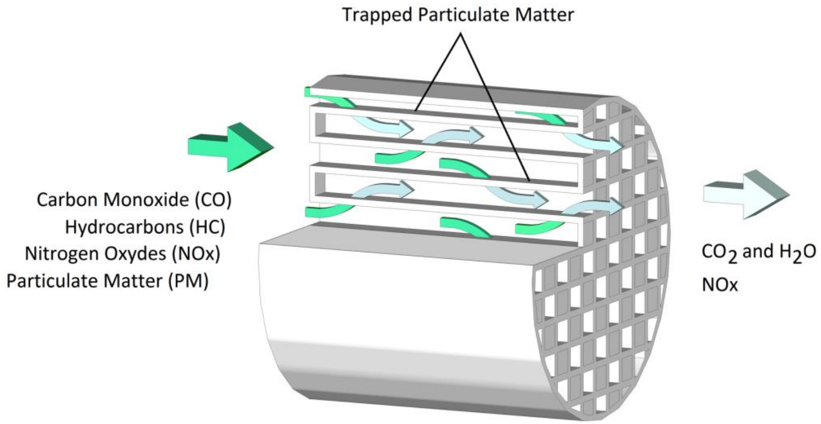
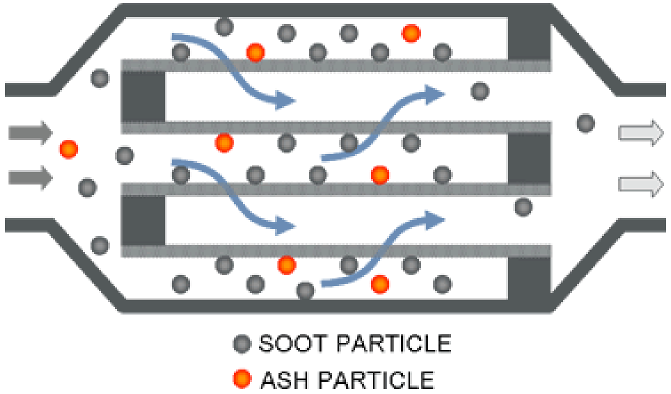


Figure 3: Porous wall parameters and SEM map (PM deposition in circled pore is examined in section below)



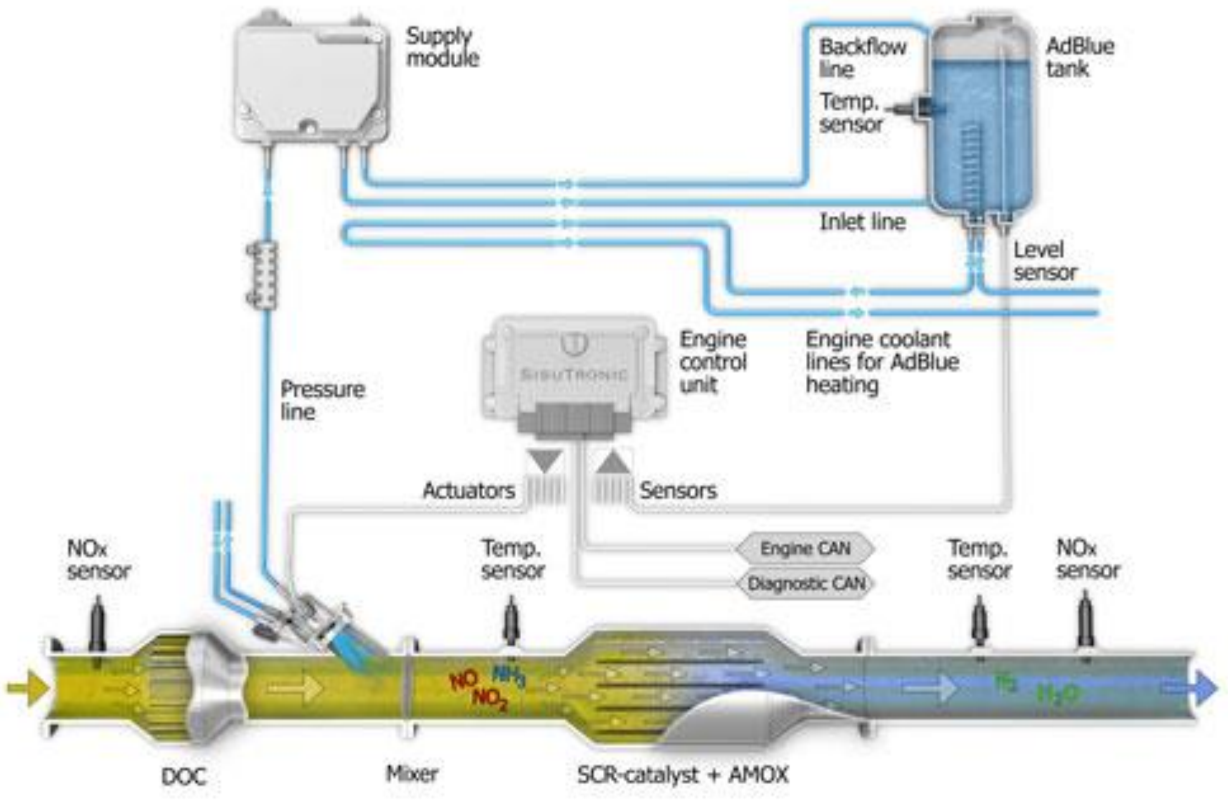




Source: **Simon Payne and Nick Collings, Visualisation and Monitoring of Diesel Particulate Filtration**

Emission Control Technologies

SCR system for NOX control



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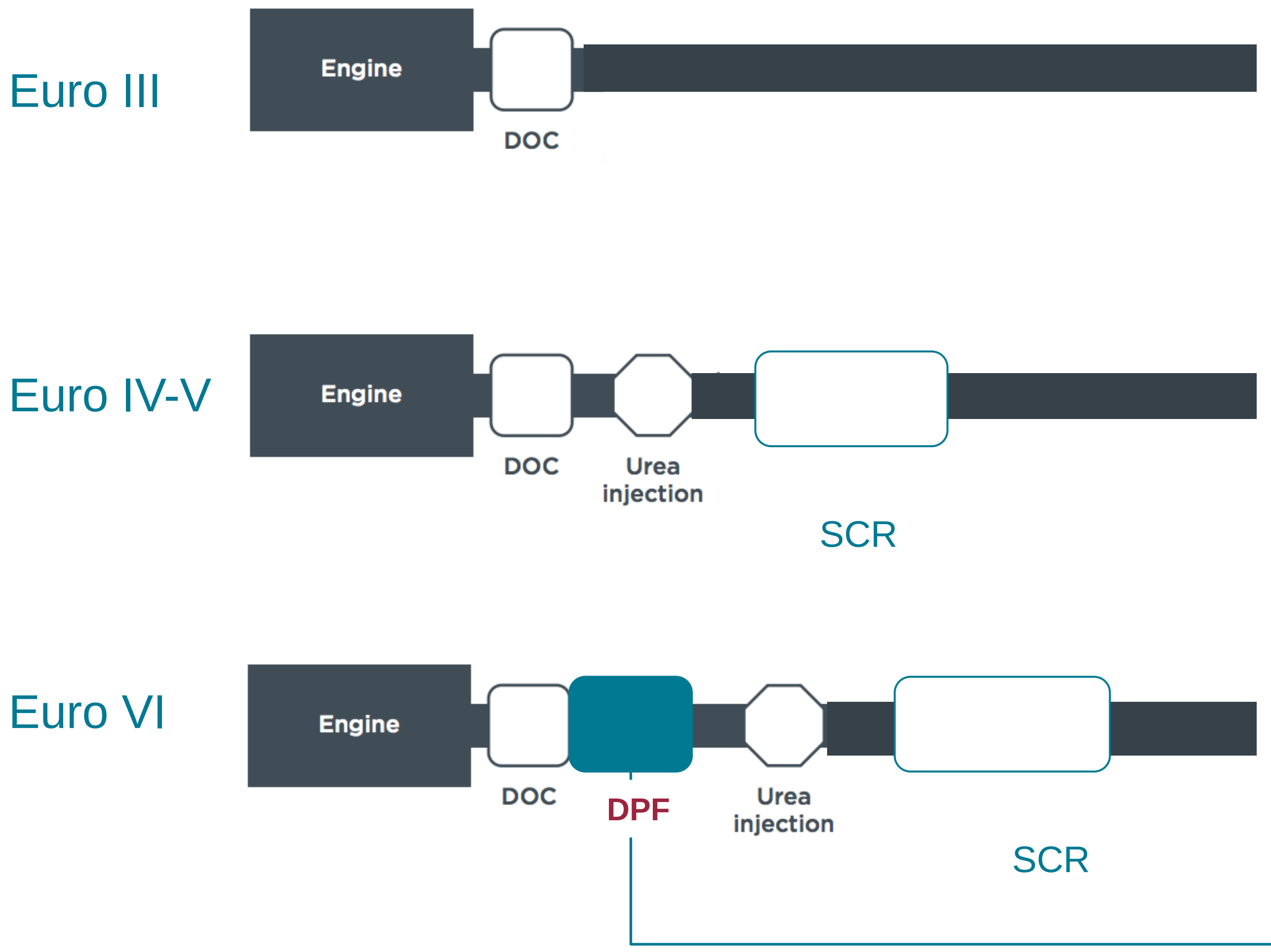
SCR requires **Urea** (automotive grade)
2-4% of diesel consumption

Aftertreatment

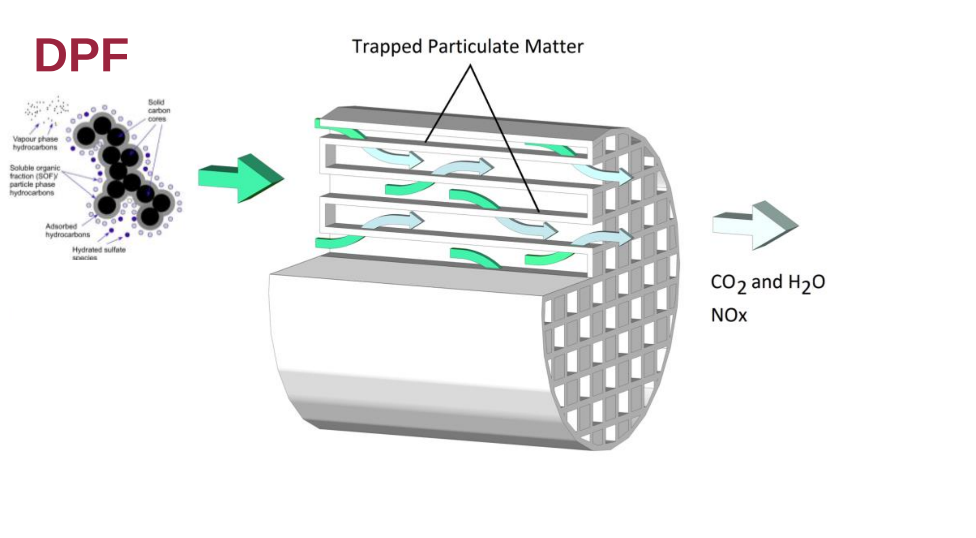
- Diesel Oxidation Catalyst (DOC)
  - CO (90%), HC (70%)
  - SOF fraction of PM (10-50%)
- Diesel Particulate Filter (DPF)
  - PM (95%)
  - PN
- Lean NOx Trap (LNT)
  - NOx (70-90%)
  - Require ULSD
- Selective Catalytic Reduction (SCR)
  - NOx (95%)

Diesel technology evolution according to emission standards

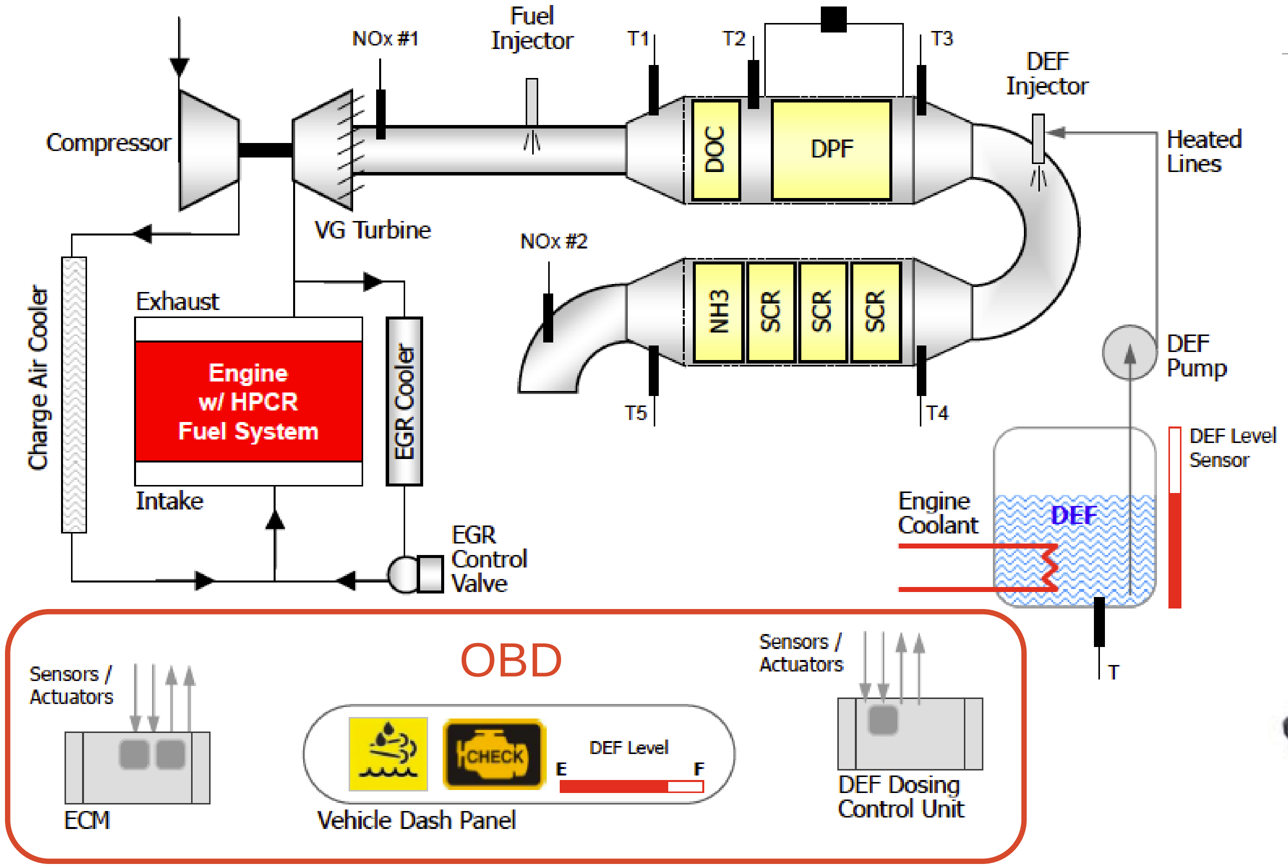


Aftertreatment emissions control

- Diesel oxidation catalyst (DOC)
  - CO (90%), HC (70%)
  - SOF, a component of PM (10-30%)
- Selective catalytic reduction (SCR)
  - NOx (85-95%)
- **Diesel particulate filter (DPF)**
  - PM (+98 %)
  - PN (+99 %)
  - CN (+99 %)



The sum of all the parts: Euro VI technology



DEC Asia - 2012

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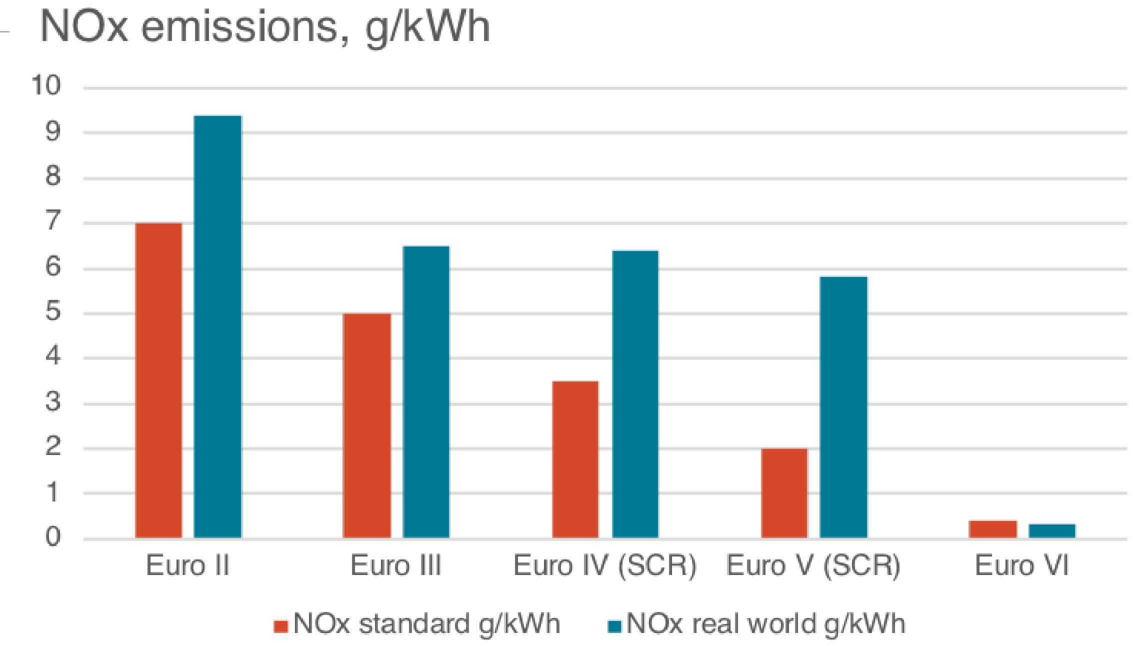
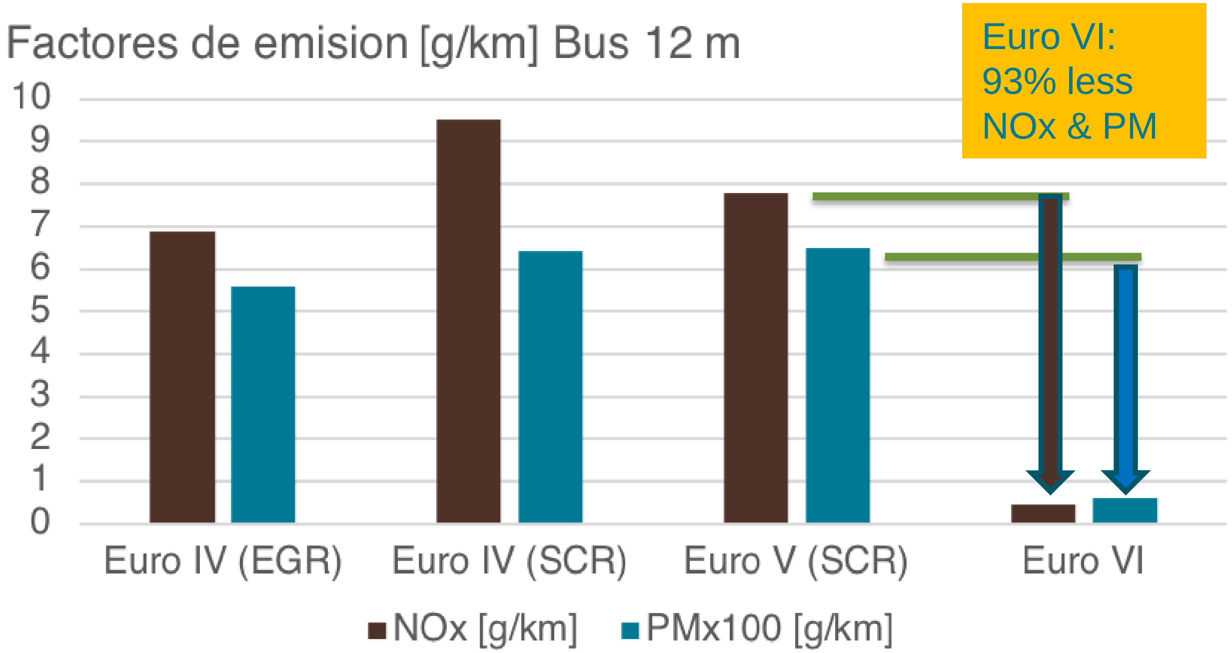
Component	Euro IV	Euro V	Euro VI
Regulation	Directive 2005/78/EC	Same as Euro IV	Global Technical Regulation R49-06 (9.2.2017) Amend 4
Testcycle	ESC / ETC High load cycle, not representative of real driving	Same as Euro IV	WHSC / WHTC Low load cycle, global tech regulation NTE test
NOx limit	3.5 g/kWh	2.0 g/kWh	0.46 g/kWh
PM / PN limit	PM: 0.02 g/kWh PN: ----	Same as Euro IV	PM: 0.01 g/kWh PN: 6.0x10^11 #/kWh
Off-cycle emissions test	---	---	NTE, OCE
Anti-tampering	Some Only torque reduction, weak	Same as Euro IV	Strong, Torque and speed reduction
ISC – PEMS	---	---	PEMS
Useful life	Up to 500’000 km	Same as Euro IV	Up to 700’000km
OBD	Simple. OBD comm protocols not standardized	Same as Euro IV	Wide coverage of malfunctions. Standardization of comms protocols – OBD for I&M is possible
Real world performance	Poor – NOx emissions higher than limit	Poor – NOx emissions higher than limits	Best

Can we just stay at Euro V ?
Only Euro VI provides real world emission benefits

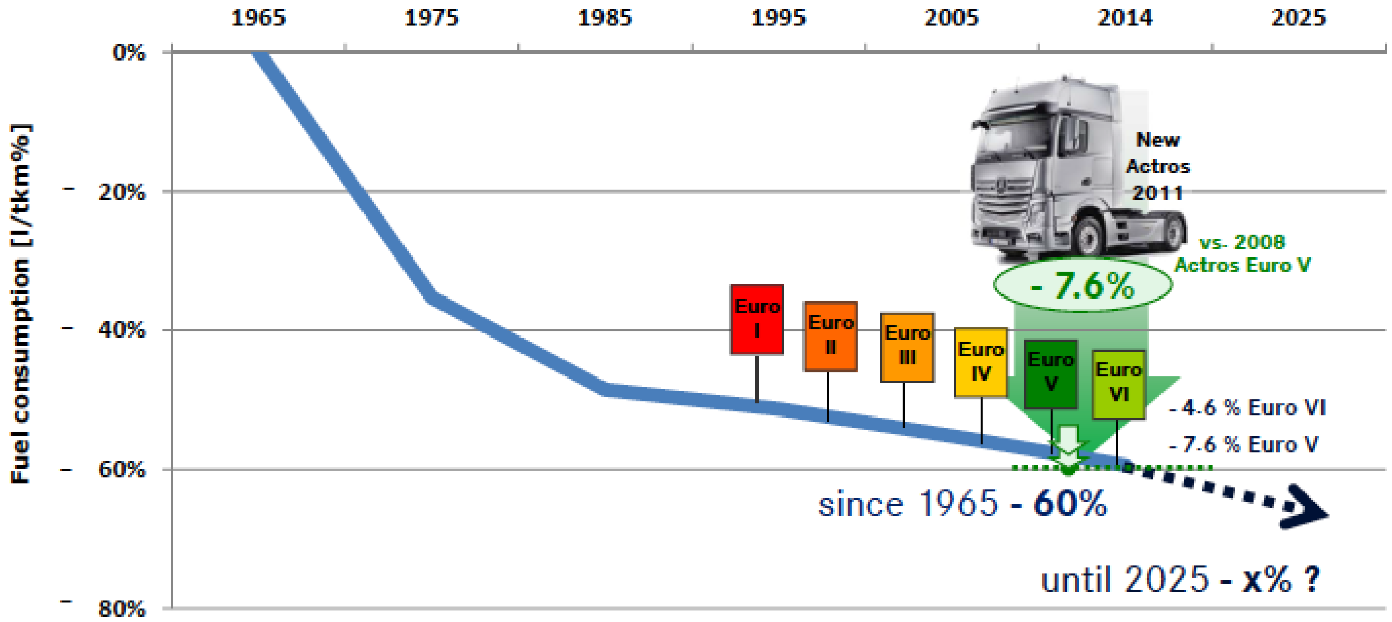




- NOx emissions for Euro IV and V technology is on par with Euro III, despite more than 60% expected reductions required by the standards.
- Only Euro VI technology achieved the required NOx reductions
- PM emissions have been reduced with Euro IV and V standards, but only Euro VI shows ultrafine particle control via DPF

The European truck industry has come a long way, despite demanding emissions requirements

Fuel consumption reduction of new HDVs per tkm in Europe



Introduction (appr.): Euro I (1992), Euro II (1996), Euro III (2000), Euro IV (2005), Euro V (2008), Euro VI (2013))
Source: Lastauto Omnibus (1967-2010), Daimler AG (2011, 2014)

The improvement in transport efficiency has been driven by market forces, not by regulation

Societal benefits and costs

Table 7. Benefit-cost analyses for light- and heavy-duty vehicle emissions regulations

Rule	Benefits	Costs	Benefit-Cost Ratio
US LDV Tier 3[1]	$6.7b–$19b annually (2030)	$1.5b annually (2030)	5:1 to 13:1
US LDV Tier 2[2]	$25.2b	$5.3b	5:1
US 2010 HDV emissions[3]	$70b annually (2030)	$4.2b annually (2030)	16:1
California Advanced Clean Cars Program (LEV-III)[4]	$10.6b cumulative vehicle operating cost savings	$3.4b cumulative annualized incremental cost	3:1
Mexico HDV NOM-044[5]	$135b (cumulative, 2018–2037)	$12b (cumulative, 2018–2037)	11:1
Euro 5/V and 6/VI[6]	$2,13b (2009 price)	$1,55b (2009 price)	1.4:1
China 6/VI[7]	4.4t RMB	1.8t RMB	2.5:1
India Bharat VI[8]	$43.8b in 2025; $107b in 2035	$14.5b in 2025; $14.2b in 2035	8:1 in 2035

https://www.theicct.org/sites/default/files/publications/ICCT_G20-briefing-paper_Jun2015_updated.pdf

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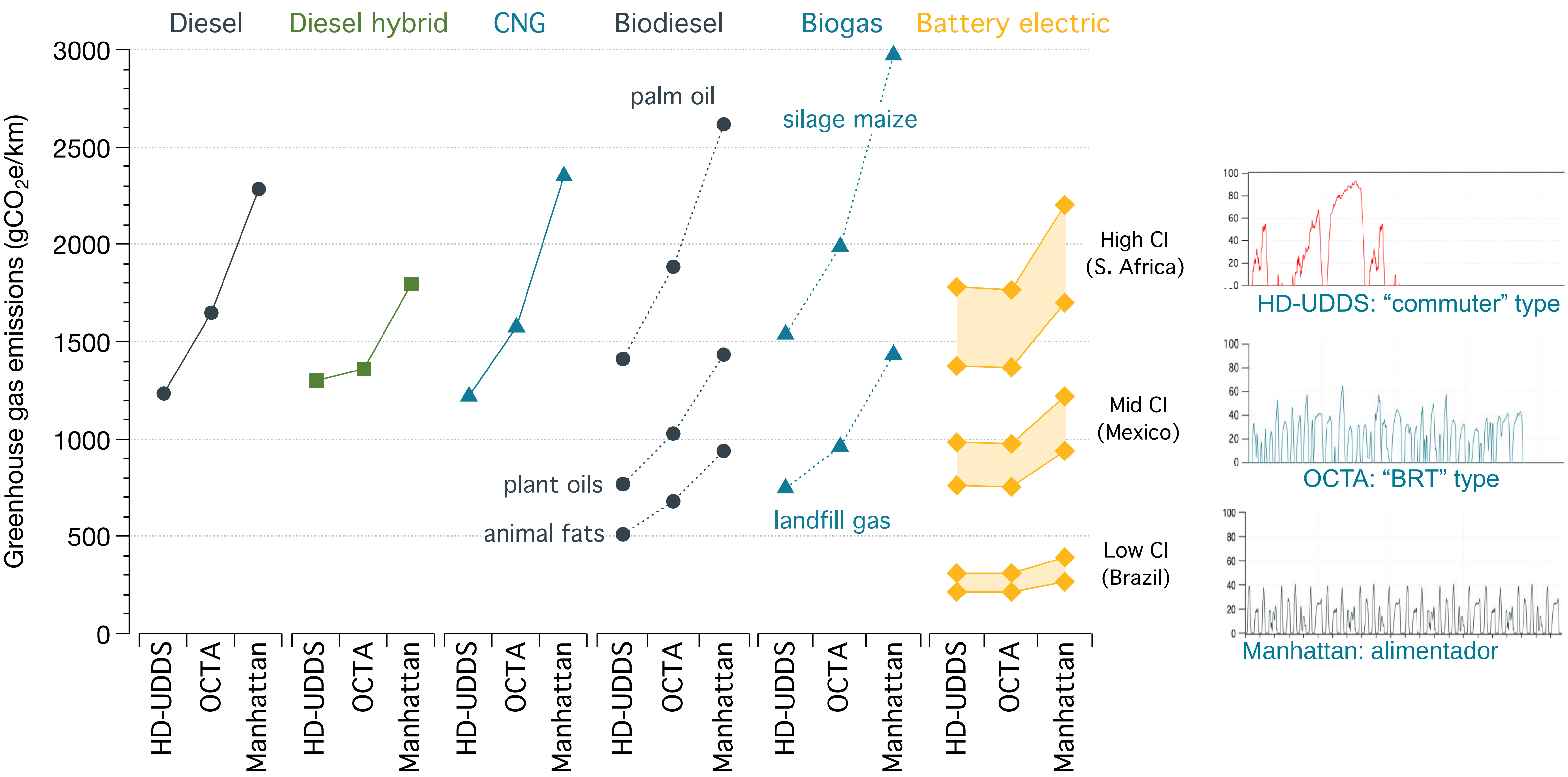
Zero emission HDV technology

The cities can lead this process: electric buses

Public transit city buses can become the entry point of electric technologies in ASEAN countries

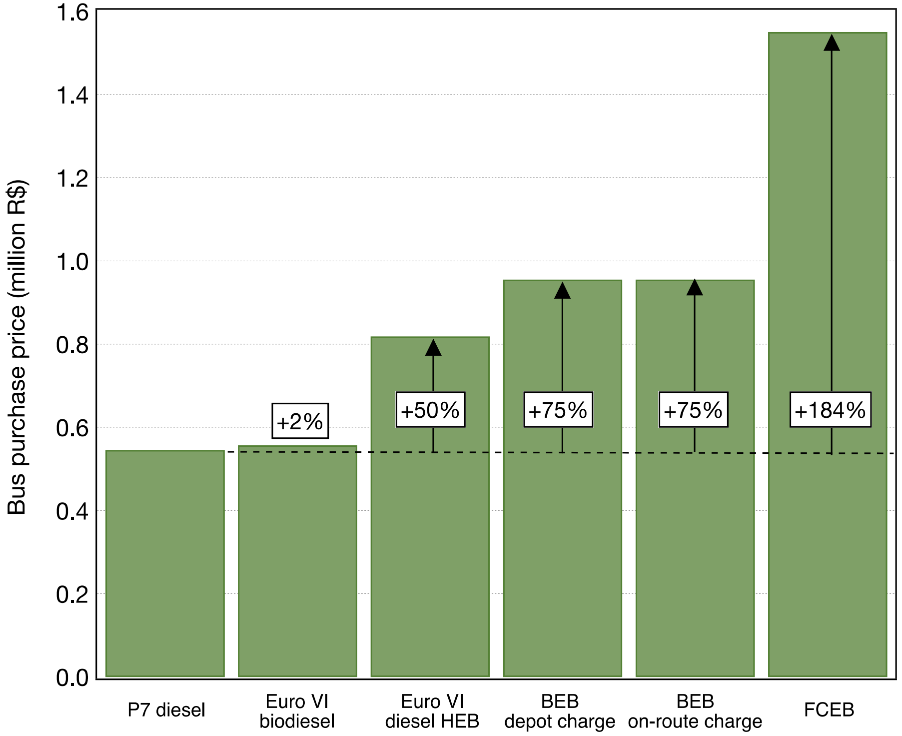
- Electric buses for public transit fleets present the greatest potential for addressing local pollution, climate goals, and new opportunities for green financing.
- Cities in ASEAN are piloting electric buses: Jakarta, Hanoi
- Latin American cities are reaching more than 2000 buses

GHG emission from soot-free buses depending on drive cycle and carbon intensity of grid

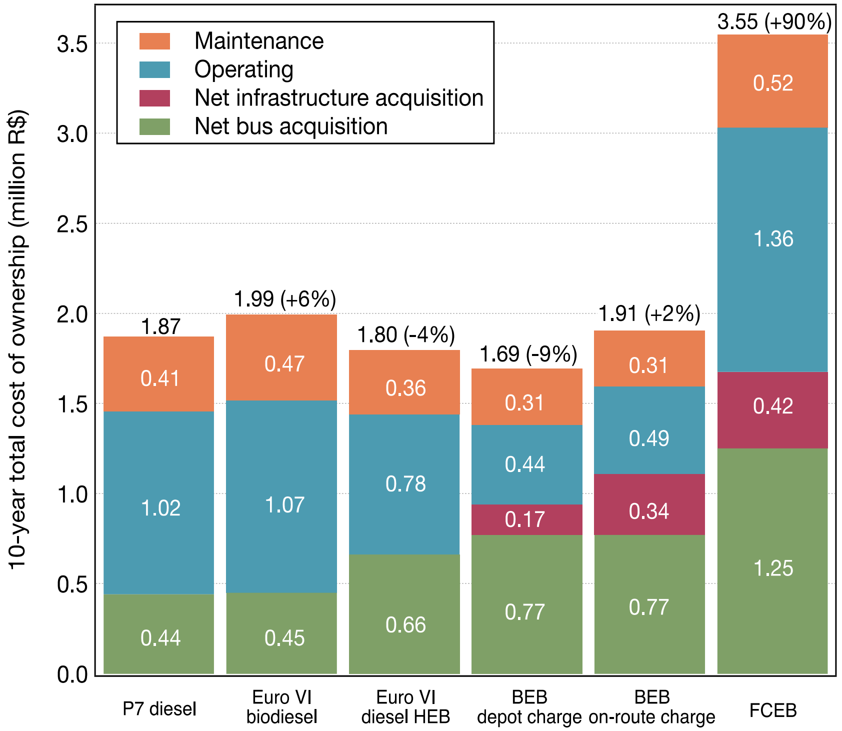


Electric buses present higher capital costs tan conventional technologies, but a total cost of ownership (TCO) evaluation can show savings

Purchase price for electric drive transit buses compared to a conventional diesel bus



TCO estimates over 10 years for conventional and alternative technology for Padron LE type buses in São Paulo



Source: *International Evaluation of Public Policies for Electromobility in Urban Fleets.* Prepared for Gesellschaft für International Zusammenarbeit (GIZ) as part of PN 2015.2127.7 – Efficient Propulsion Systems. Washington, DC: International Council on Clean Transportation.

Thank you!

Questions: francisco@theicct.org

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