Exhaust Emission Reduction Technologies of Diesel HDV in JAPAN

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Emissions & Fuel Efficiency Subcommittee
Japan Automobile Manufacturers Association
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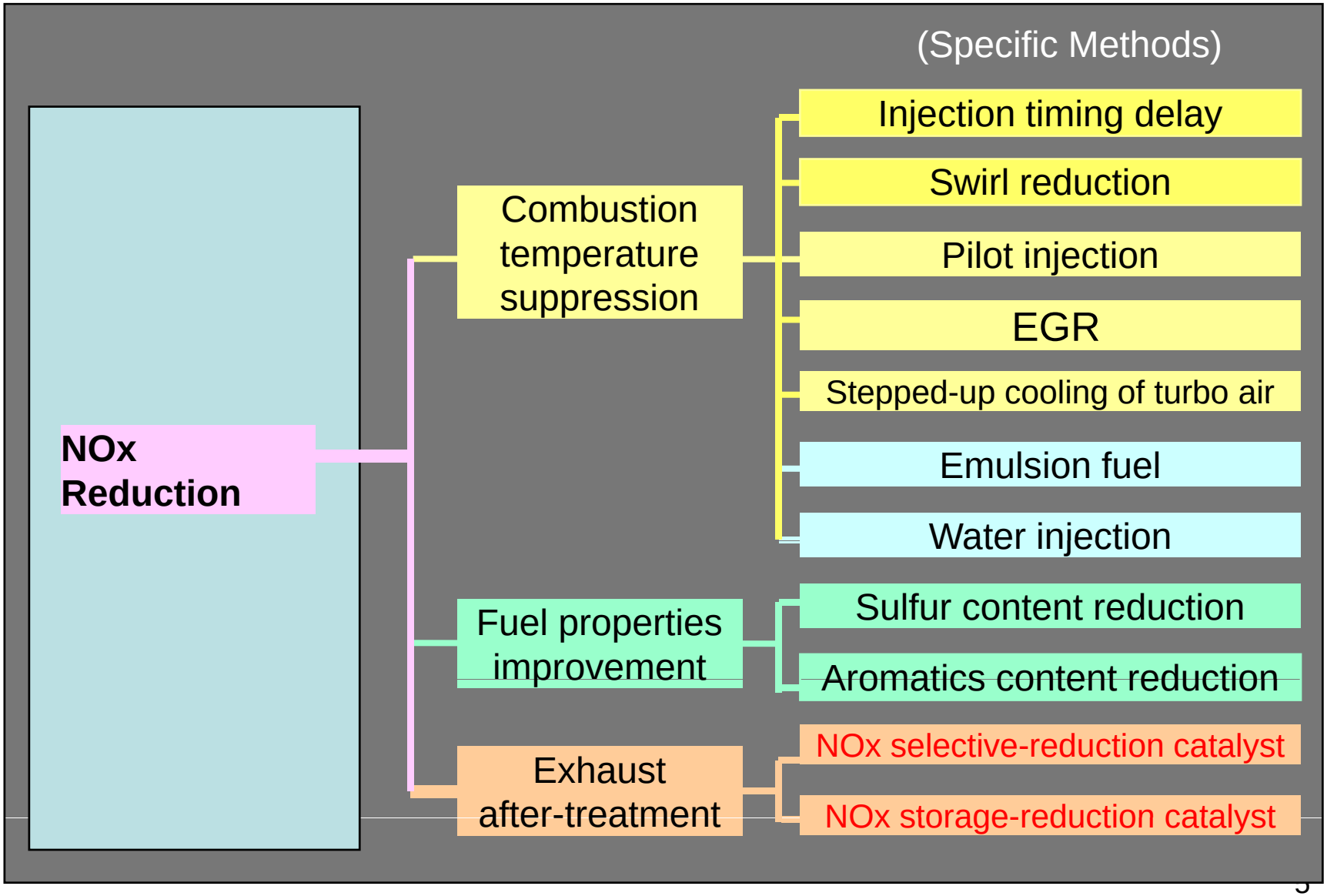
CONTENTS

1. History of Diesel Emission Reduction Measures

Characteristics of Diesel Emissions

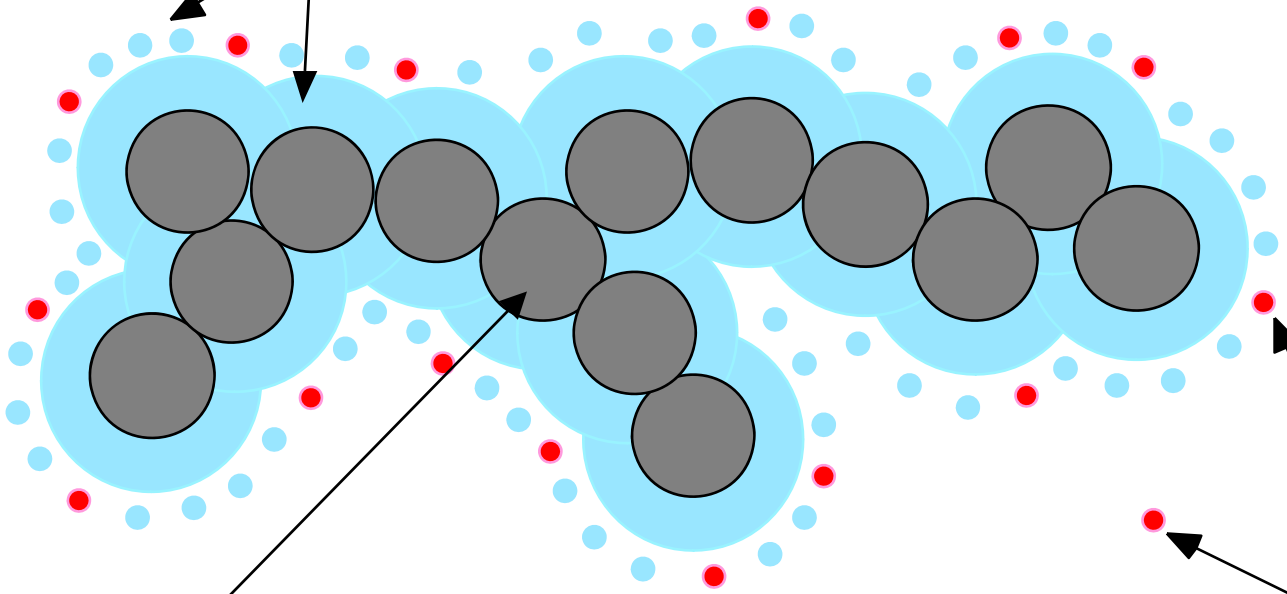
		Gasoline engines	Diesel engines
Exhaust gas constituents	CO	⊙ Substantially reduced by three-way catalysts & EGR (exhaust gas recirculation)	⊙ Extremely low emissions
	HC		⊙ Extremely low emissions
	NOx		× Disadvantaged by high combustion temperature
	PM	⊙ Below problem levels	× Trade-off relation with NOx: Due to air shortage during diffusive combustion
	CO_2	× Disadvantage: Larger fuel consumption due to low combustion efficiency	⊙ Advantage: Smaller fuel consumption due to high combustion efficiency

NOx Reduction Methods for Diesel Vehicles



Structure and Composition of Diesel Particulate

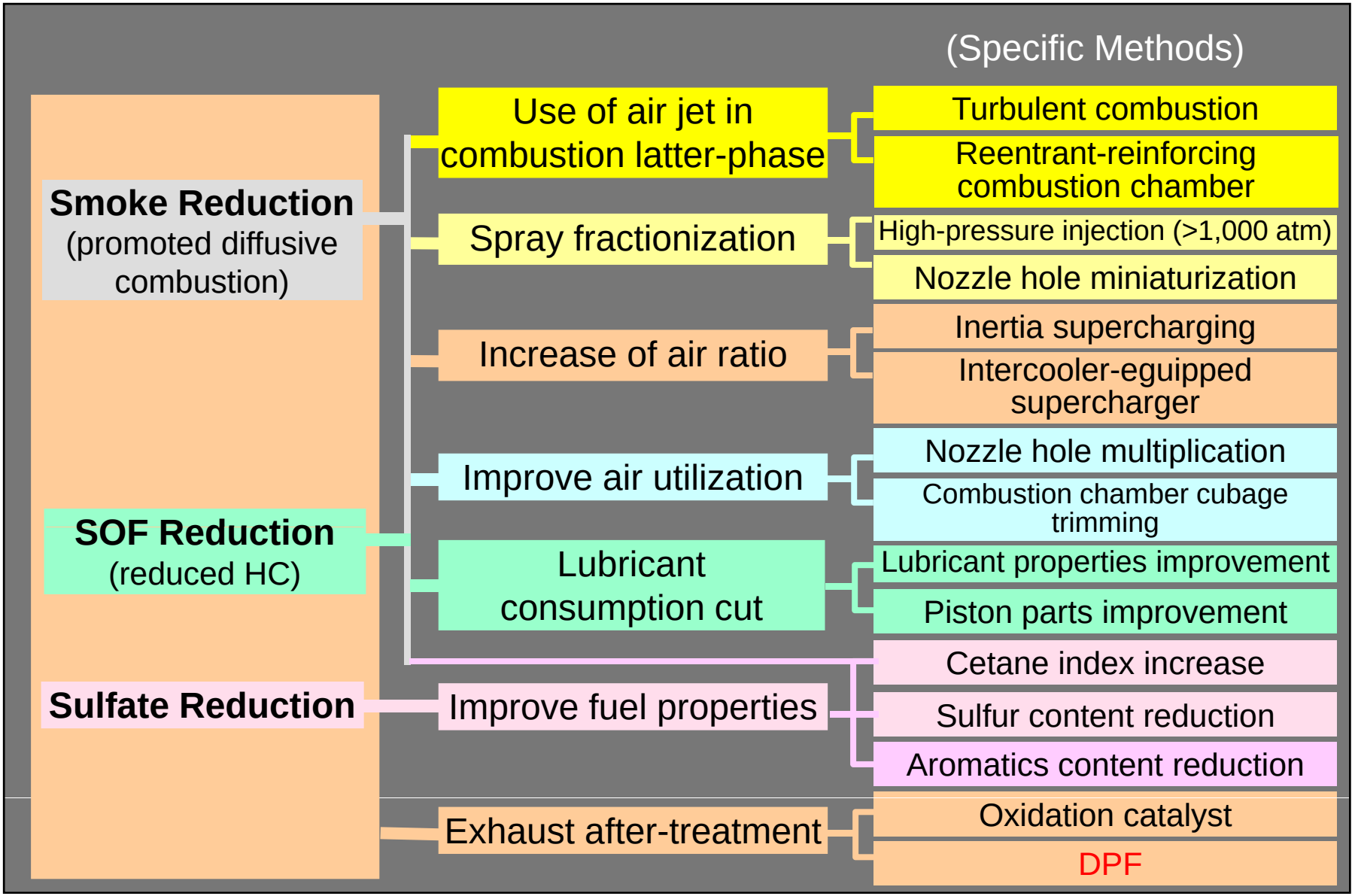
SOF (Soluble Organic Fractions) :
Remnants of half-burned fuel & lubricant



Soot: Product of incomplete combustion of fuel & lubricant

Sulfate: Generated by oxidation of fuel sulfur contents during combustion

PM Reduction Methods for Diesel Vehicles

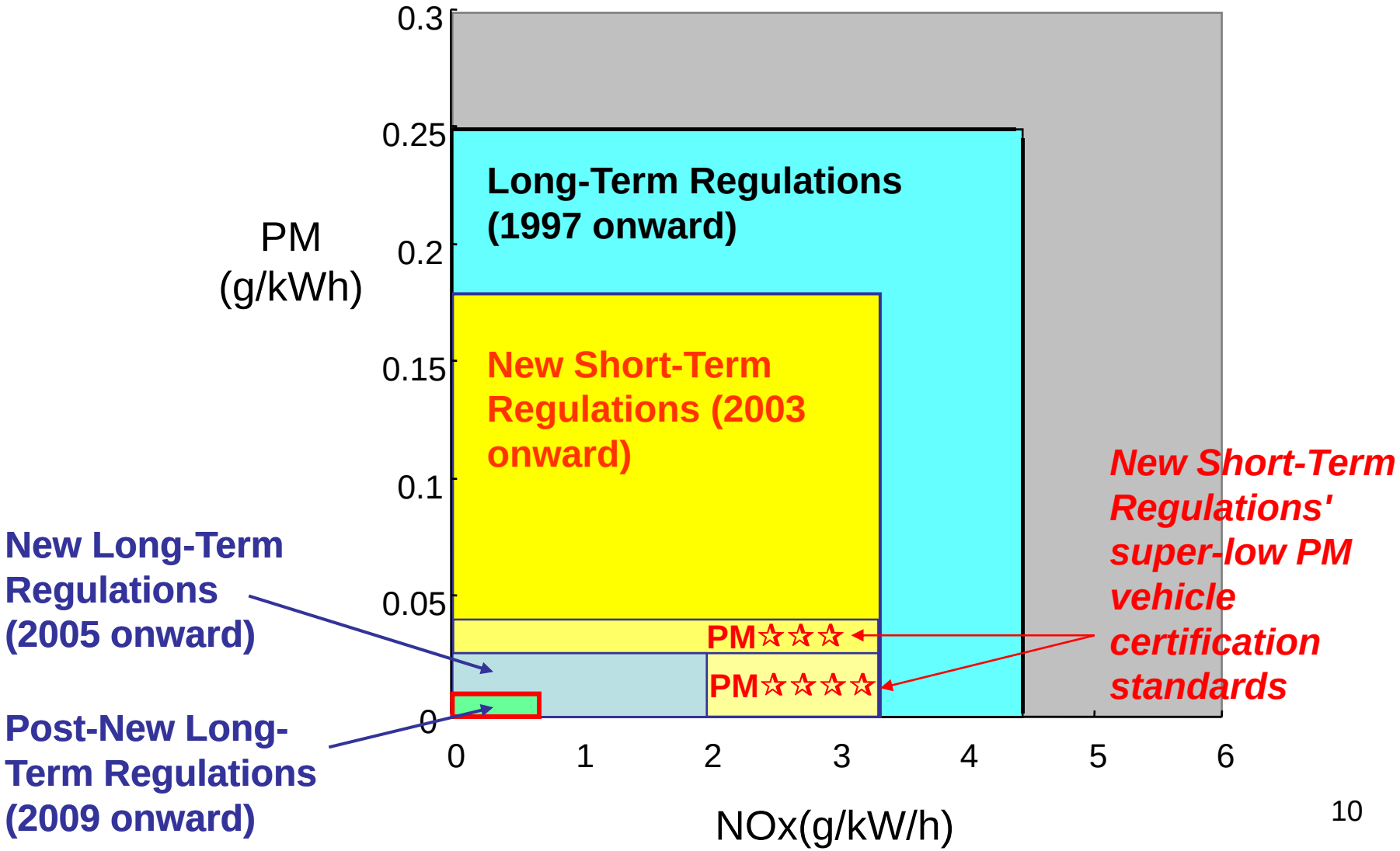


History of Diesel Exhaust Emission Control

Emission reducing technologies \ Emission regulations			Year	'74	'77	'79	'83	'89	'94	'97	'02
			Regulation	74Reg	77Reg	79Reg	83Reg	89Reg	Short-Term Reg	Long-Term Reg	New Short-Term Reg
Exhaust emission measures	Engine mainframe	Combustion chamber improvements (e.g., idle-cubage trimming)		●	●	●	●	●	●	●	●
		Displacement & compression ratio increase; improved cooling of combustion chamber				●	●	●	●	●	●
		EGR							●	●	●
		LOC reduction								●	●
	Fuel injection system	Injection timing delay; modified characteristics of governor and timer		●	●	●	●	●	●	●	●
		Injection nozzle and tube modification				●	●	●	●	●	●
		Higher-pressure injection pump									
		Variable pre-strokes					●	●	●	●	●
		Electronic control of governor and timer									
		Two-stage spring nozzle									CR
		Variable injection rate control (VE pump)						●	●	●	●
	Intake & exhaust systems	Intake & exhaust ports improvement		●	●	●	●	●	●	●	●
		Supercharging & supercharger improvement				●	●	●	●	●	●
		Intercooling & variable inertia supercharging					●	●	●	●	●
		Variable nozzle turbo						●	●	●	●
		Variable swirl mechanism (sub-port type)									
	Other	Minimized dispersions in emission-related parts & tuning accuracy				●	●	●	●	●	●
		Start assist device improvement					●	●	●	●	●
	After-treatment	Oxidation catalyst								●	●
		DPF									✹
		NOx reducing catalyst (NOx storage-reduction catalyst, urea SCR)									✹

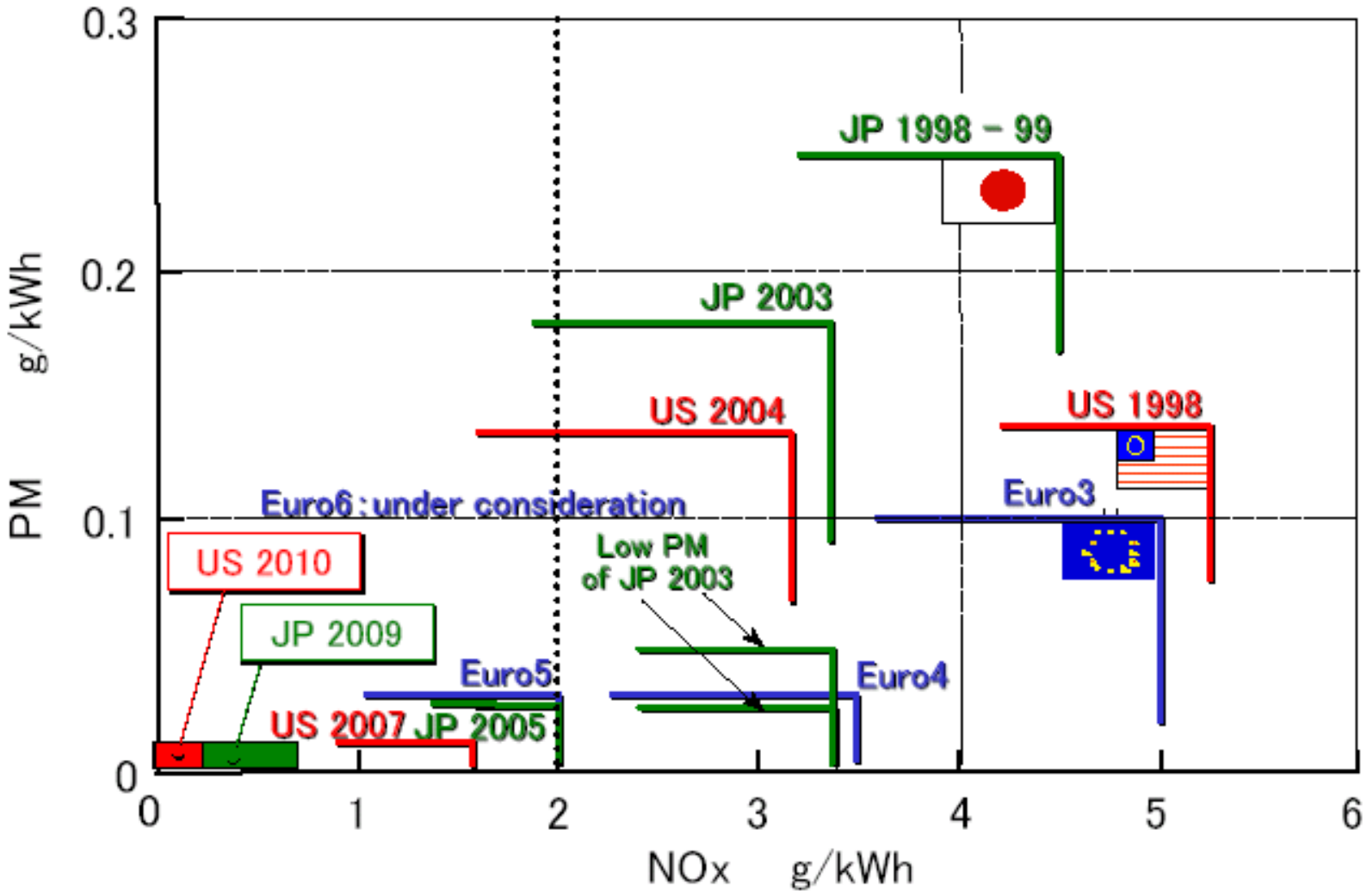
2. Technologies for Compliance to New Long-Term Regulations

History of HDV Emission Limit Values



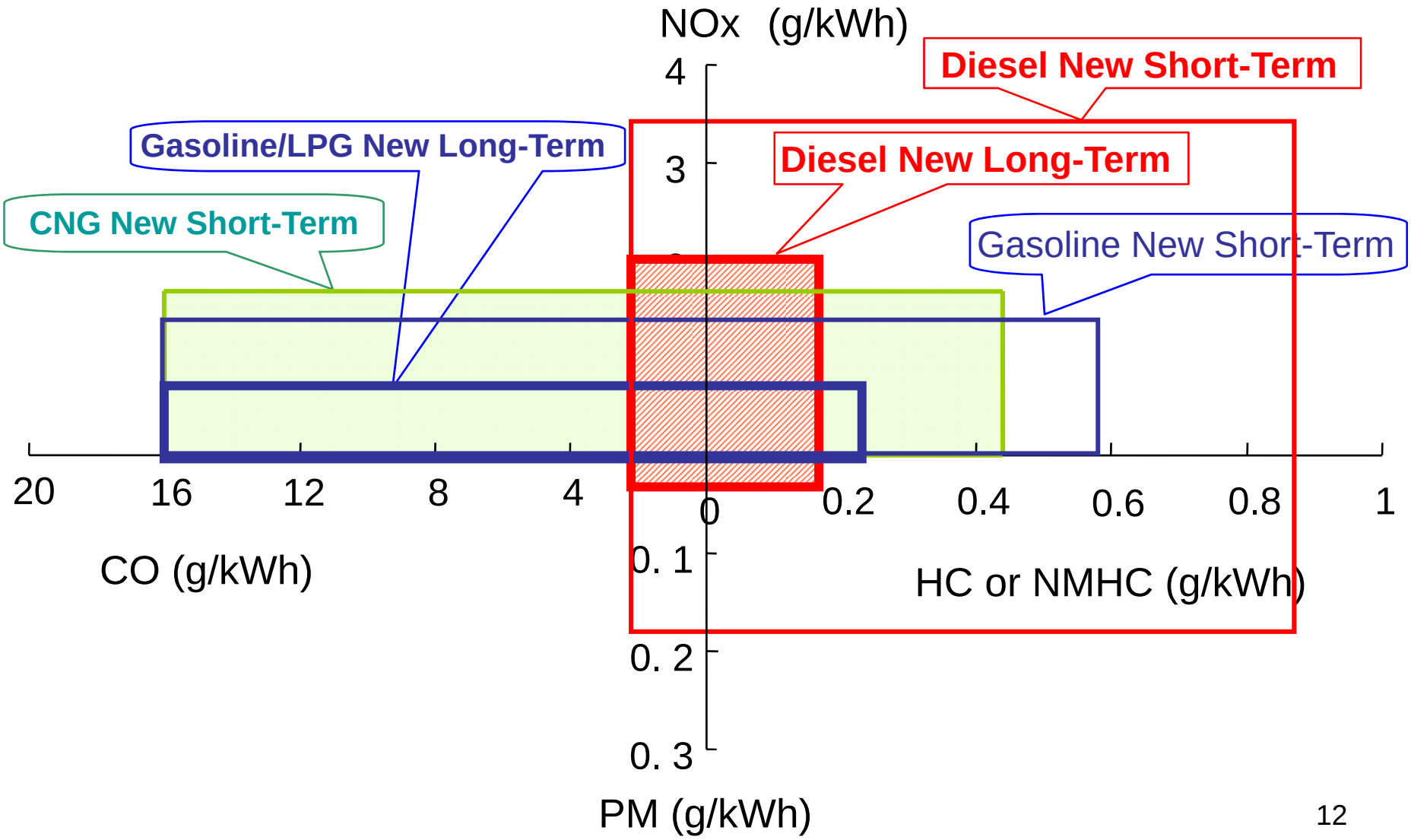
Emission Limits of Japan, U.S. and Europe

(JP2005 denoting Japan's New Long-Term Reg.)



Comparison of HDV Emission Limit Values

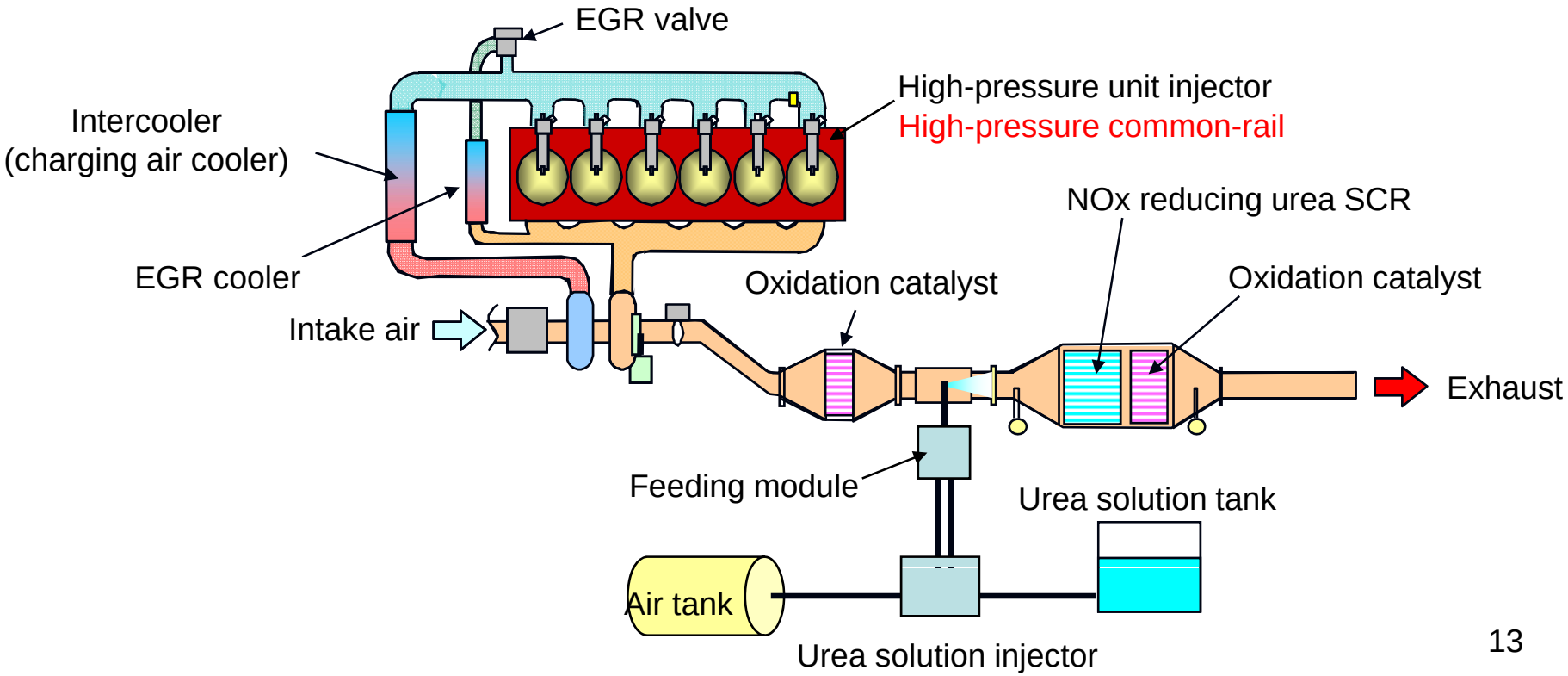
(Gasoline/LPG, Diesel, CNG)



New Long-Term Compliance Technologies - (1)

Urea selective catalytic reduction(SCR) + High-pressure fuel injector + Cooled EGR

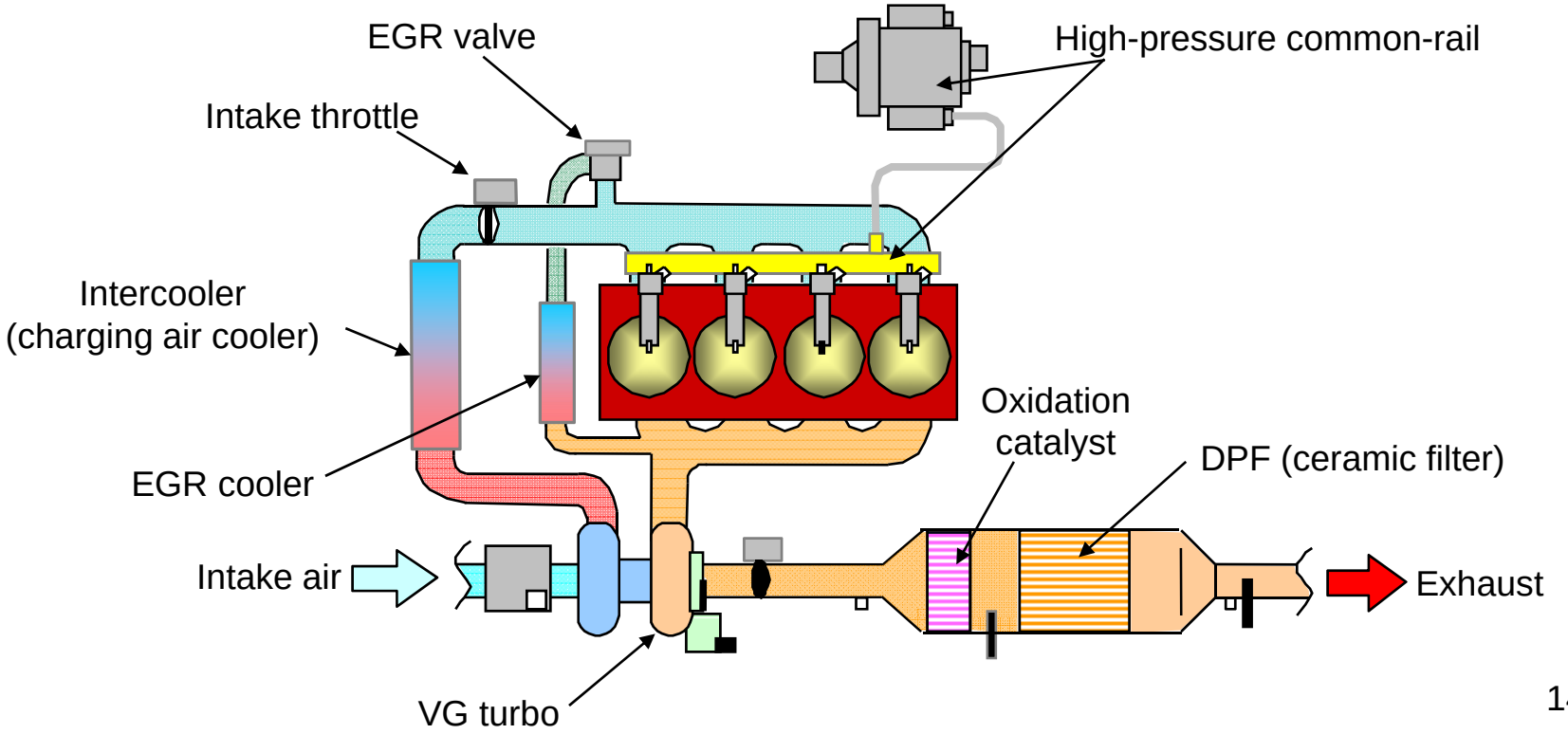
- PM is reduced by the high-pressure fuel injector which improves combustion.
- NOx is reduced by the cooled EGR (improving combustion) and by the urea SCR.
- SCR is a catalytic system that reduces NOx into harmless nitrogen, using ammonia generated from urea solution as reducing agent.



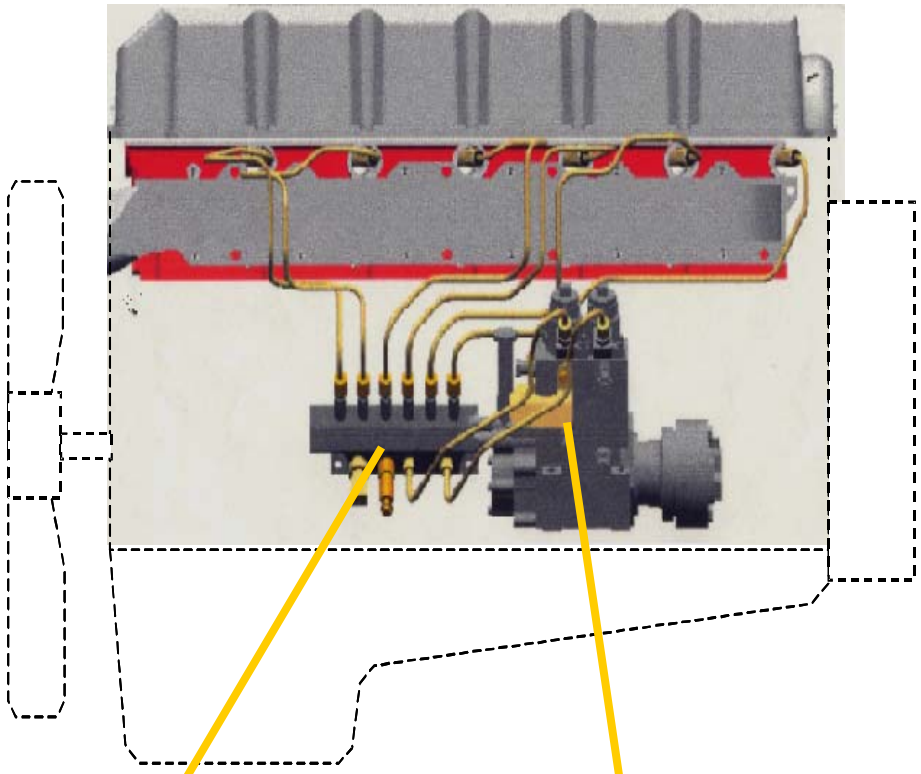
New Long-Term Compliance Technologies - (2)

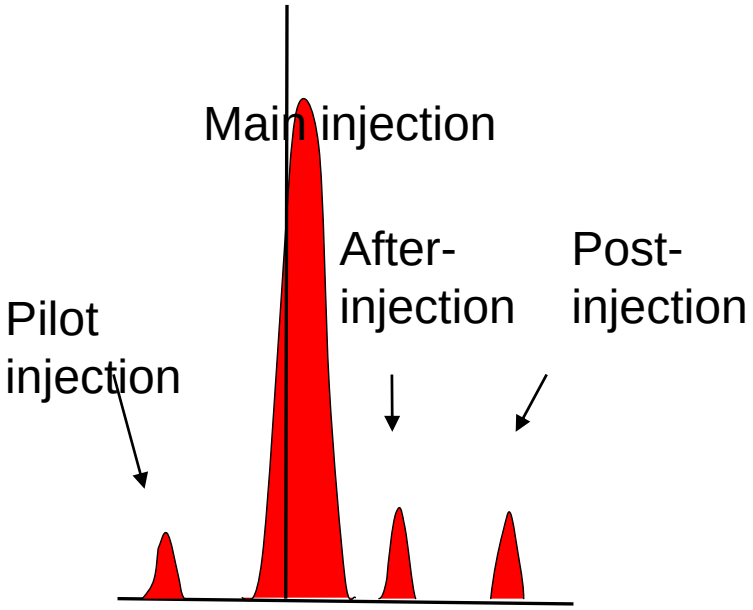
DPF + High-pressure fuel injector + Cooled EGR

- PM is reduced by the high-pressure fuel injector (improving combustion) and by the DPF.
- NOx is reduced by the high-pressure fuel injector and the cooled EGR, both improving combustion.
- The DPF is a ceramic filter for trapping PM from exhaust emissions.

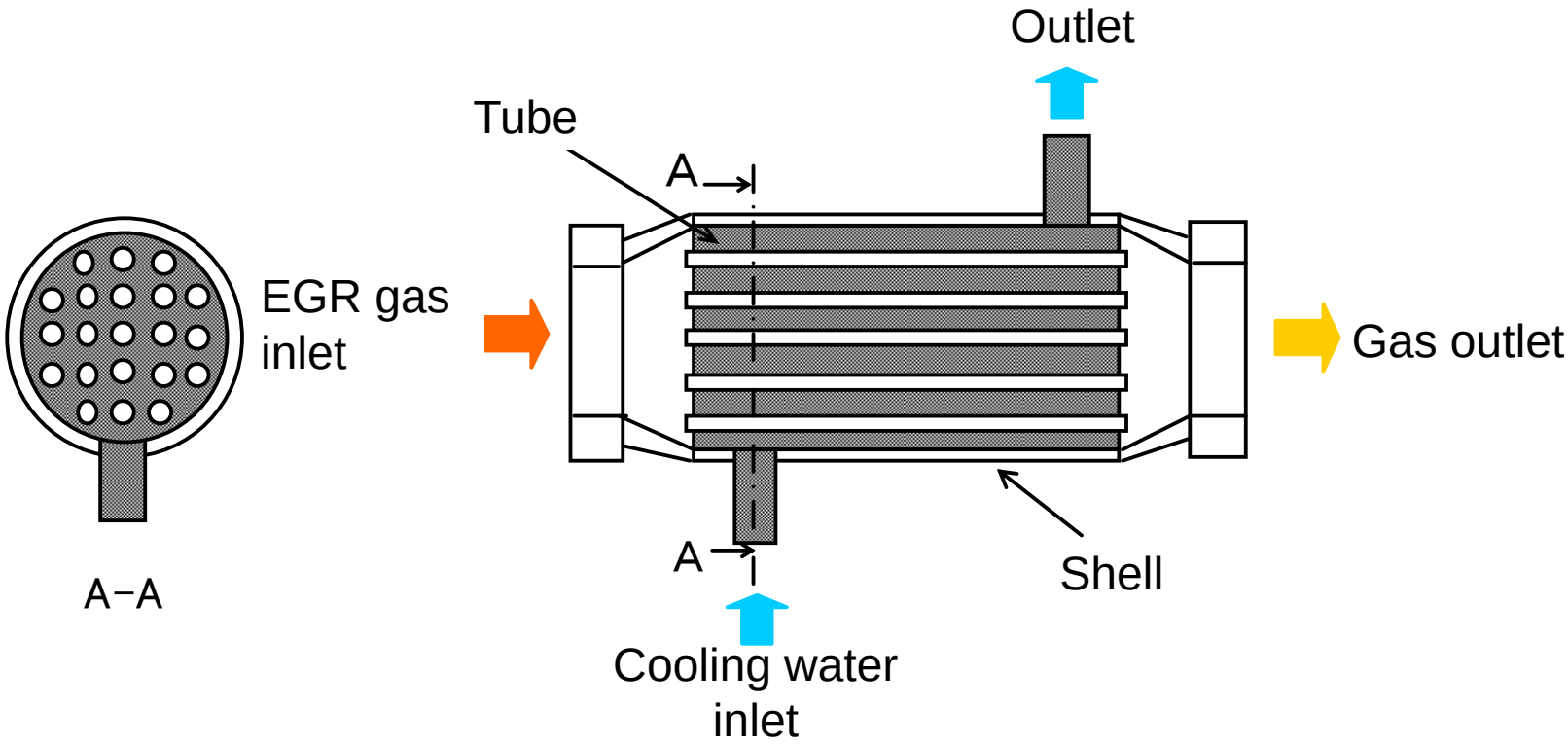


Injection Pattern of a High-pressure Common-rail Fuel Injector for a New Long-Term Regulation Complying Engine with DPF

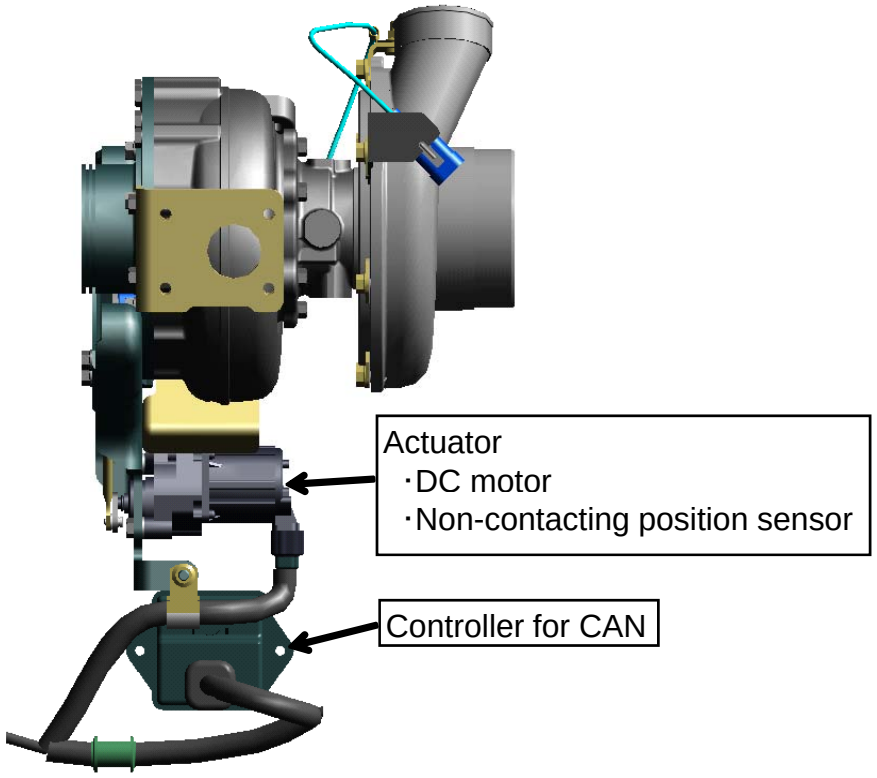


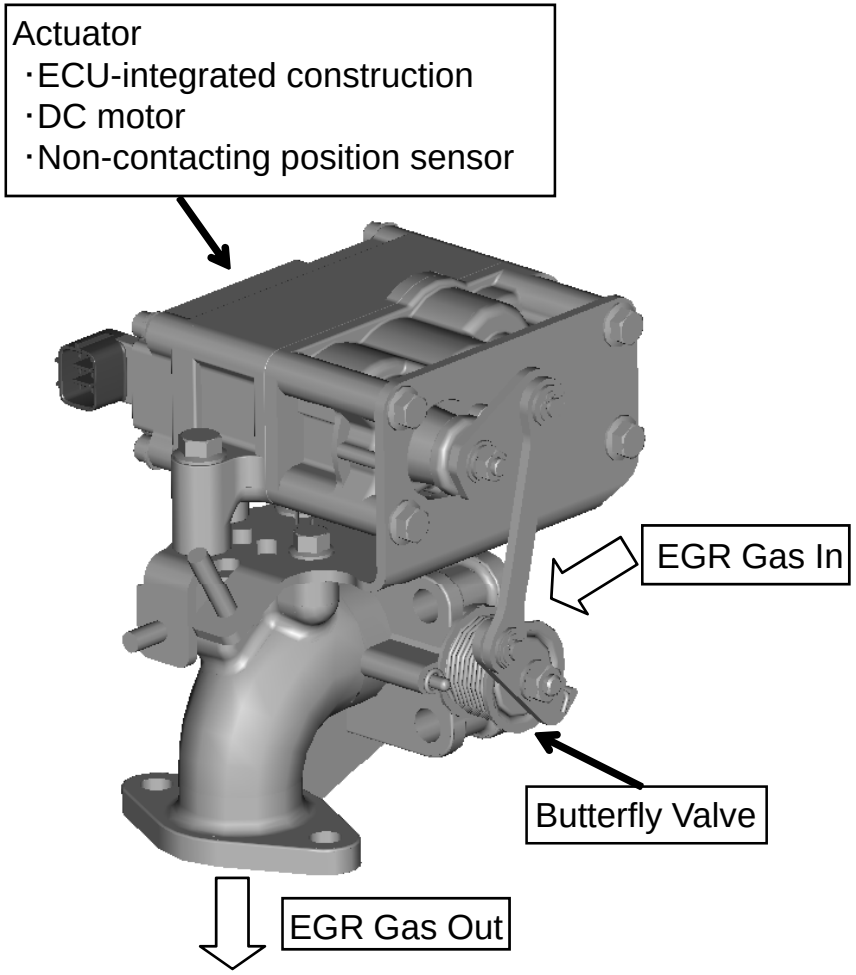


Structure of the EGR Cooler

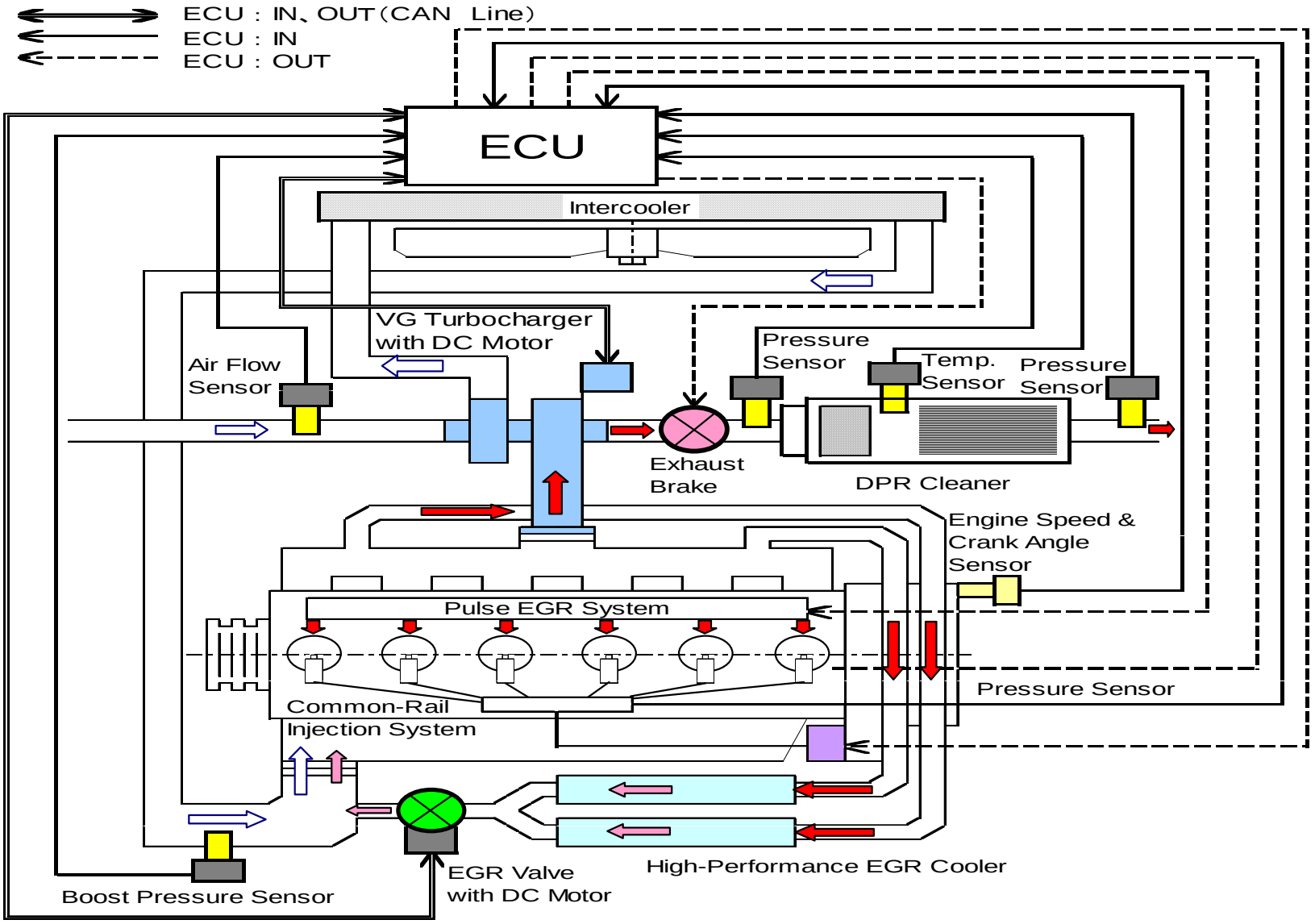


Continuous Control of the VG Turbo and EGR





A Precision Fuel Injection Control System



Technologies and Fuel Economy by Vehicle/Engine Type - (1)

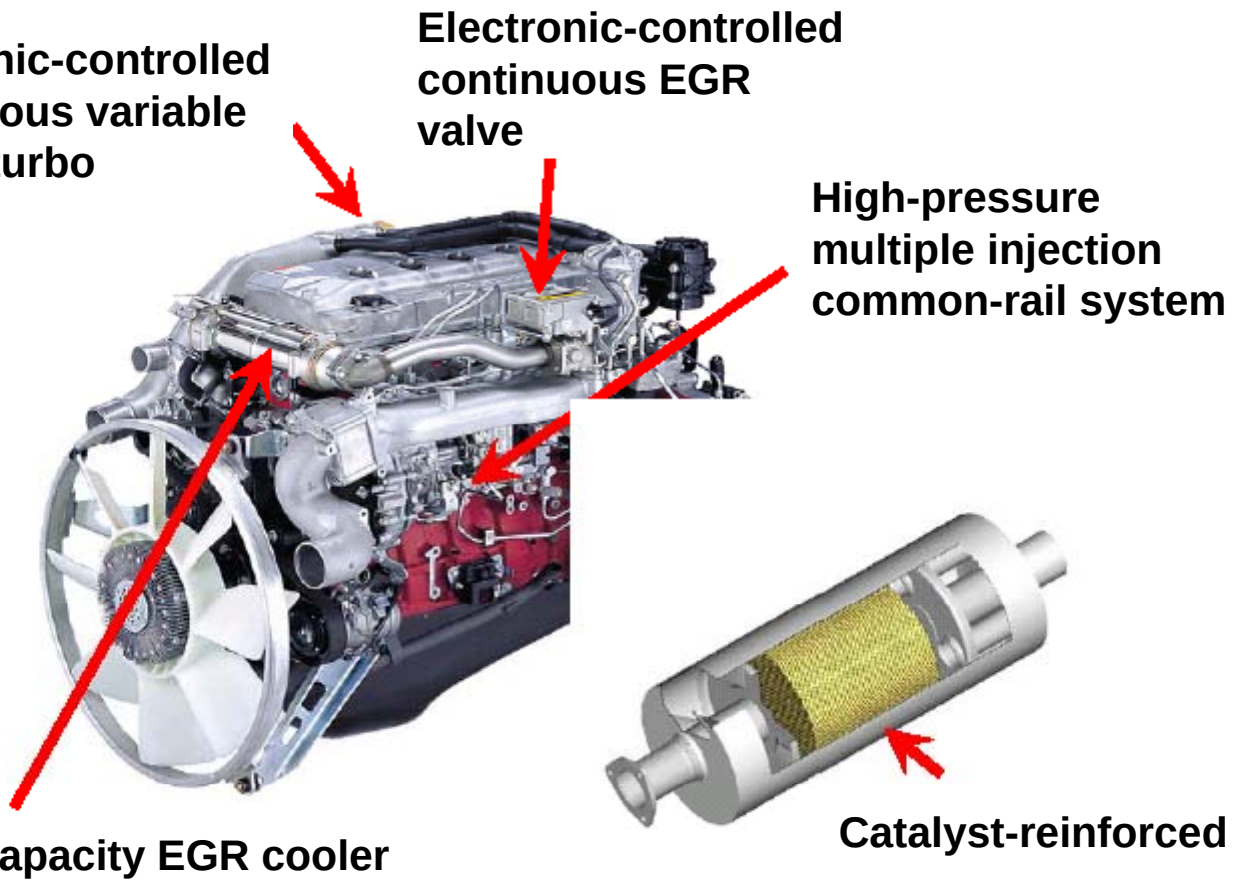
	Displace-ment	Combustion technology						After-treatment technology			Hybrid	No. of types complying to fuel economy standard	Total No. of types
	(L)	Injection sys.		VG turbo	Cool EGR	Continuous control		DPF	Urea SCR	NSR			
		CR	Other			VG	EGR						
GVW 3.5t or less	2.00	O	-	-	O	-	O	O	-	-	-	-	16
	2.98	O	-	O	O	O	O	O	-	-	-	-	12
Light trucks	2.95	O	-	-	O	-	O	O	-	-	-	0	28
	2.98	O	-	-	O	-	O	O	-	-	-	0	17
	2.98	O	-	-	O	-	O	O	-	-	O	4	4
	3.00	O	-	O	O	O	O	O	-	-	-	112	242
	3.00	O	-	O	O	O	O	O	-	-	O	14	14
	4.01	O	-	O	O	O	O	O	-	-	-	26	280
	4.01	O	-	O	O	O	O	O	-	-	O	25	26
	4.01	O	-	O	O	O	O	O	-	O	-	0	2
	4.73	O	-	O	O	O	O	O	-	-	-	0	43
	4.90	O	-	-	O	-	O	O	-	-	-	0	137
Medium trucks	5.19	O	-	O	O	O	O	O	-	-	-	11	19
	6.40	O	-	O	O	O	O	O	-	-	-	153	587
	7.55	O	-	-	O	-	O	O	-	-	-	0	32
	7.68	O	-	O	O	O	O	O	-	-	-	0	183
	7.79	O	-	O	O	O	O	O	-	-	-	4	16

Technologies and Fuel Economy by Vehicle/Engine Type - (2)

	Displace-ment	Combustion technology						After-treatment technology			Hybrid	No. of types complying to fuel economy standard	Total No. of types
	(L)	Injection sys.		VG turbo	Cool EGR	Continuous control		DPF	Urea SCR	NSR			
		CR	Other			VG	EGR						
Heavy trucks	9.20	O	-	O	O	O	O	-	O	-	-	0	14
	9.84	O	-	O	O	-	O	O	-	-	-	36	158
	12.74	-	O	O	O	-	-	O	-	-	-	12	12
	12.88	O	-	O	O	-	O	-	O	-	-	10	164
	12.91	O	-	O	O	O	O	O	-	-	-	44	255
	13.07	-	O	O	O	O	O	-	O	-	-	48	172
	15.68	O	-	O	O	-	O	O	-	-	-	35	74
Light buses	4.01	O	-	O	O	O	O	O	-	-	-	0	14
	4.73	O	-	O	O	O	O	O	-	-	-	0	8
	4.90	O	-	-	O	-	O	O	-	-	-	0	19
Medium buses	6.40	O	-	O	O	O	O	O	-	-	-	0	9
	7.68	O	-	O	O	O	O	O	-	-	-	0	4
	7.68	O	-	O	O	O	O	O	-	-	O	2	2
	7.79	O	-	O	O	O	O	O	-	-	-	37	108
Heavy buses	4.90	O	-	-	O	-	O	O	-	-	O	2	2
	9.20	O	-	O	O	O	O	-	O	-	-	21	31
	7.55	O	-	-	O	-	O	O	-	-	-	4	11
	12.88	O	-	O	O	-	O	-	O	-	-	4	4
	12.91	O	-	O	O	O	O	O	-	-	-	6	6

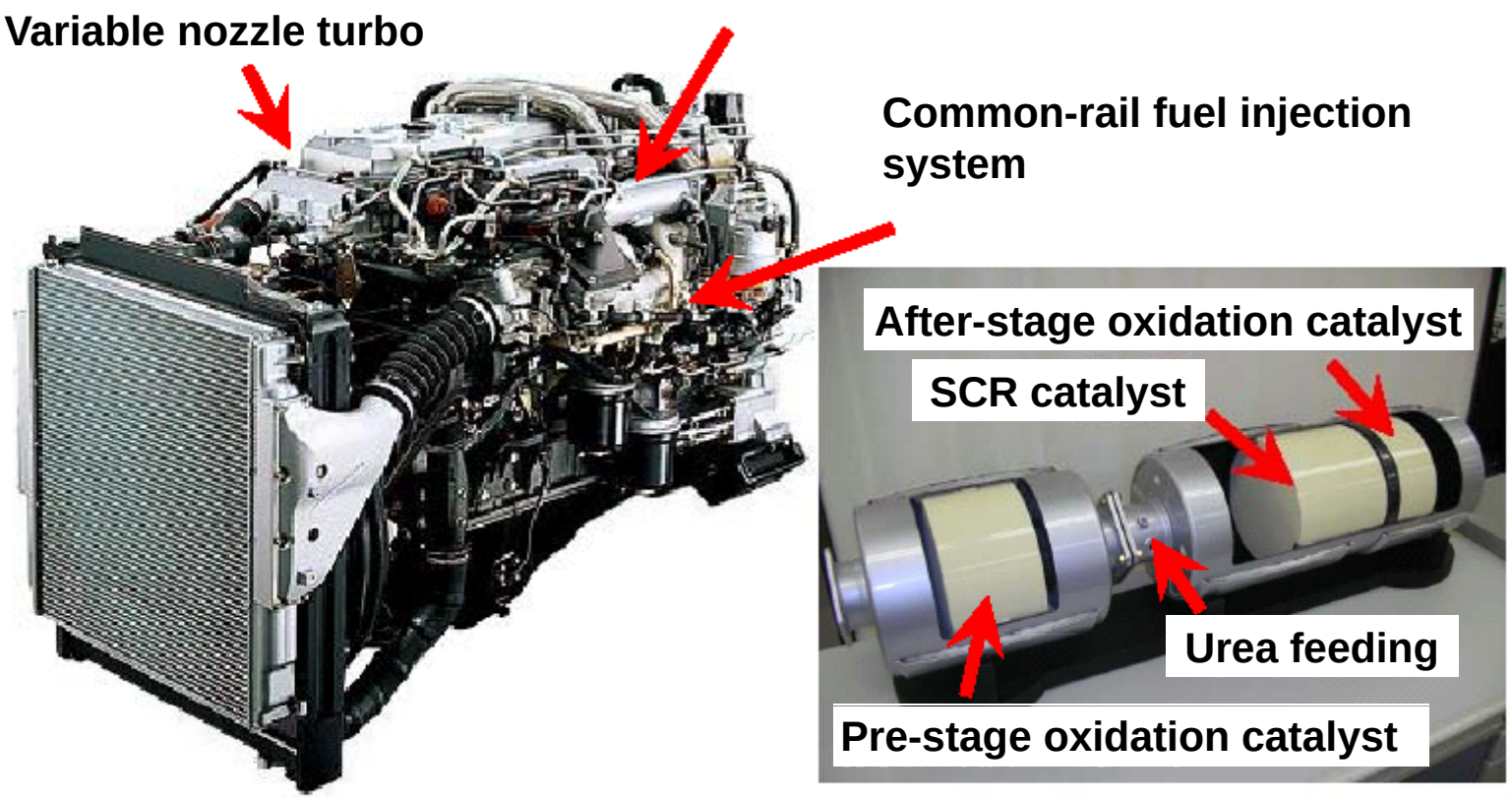
The New Long-Term Regulation Compliant Hino AO9C Engine

New heavy truck engine with L6 OHC structure
9L displacement (replacing conventional 11-13L engines)
No. of fuel economy standard compliant types / Total No. of types:
27 / 66



The New Long-Term Regulation Compliant Mitsubishi-Fuso 6M70 Engine

New heavy truck/bus engine with L6 OHC structure
12.9L displacement (with urea SCR system)
No. of fuel economy standard compliant types / Total No. of types:
14 / 168



Adopted Technologies and Fuel Economy Compliance: Summary

(1) A total of 25 diesel engine models for vehicles exceeding a GVW 3.5t have been certified as compliant to the New Long-Term Emission Regulations. (Engines with the same displacement but different emission reducing technologies and equipped with a hybrid system are counted as constituting different models. Engines for buses but used in trucks are counted as belonging to the same model as the engines for buses.)

(2) All diesel engines for HDV adopt NOx catalyzing or DPF as a full-scale after-treatment technology. Also, most of these engines are combined with common-rail fuel injection, VG turbocharging, cool EGR and continuous control technologies.

(3) Regarding after-treatment technologies, 3 large engine models have a urea SCR system, one small engine model an NOx storage catalyst, and 22 engine models a DPF.

3. Technologies for Compliance to Post-New Long-Term Regulations

Technological Approach to Post-New Long-Term Regulations

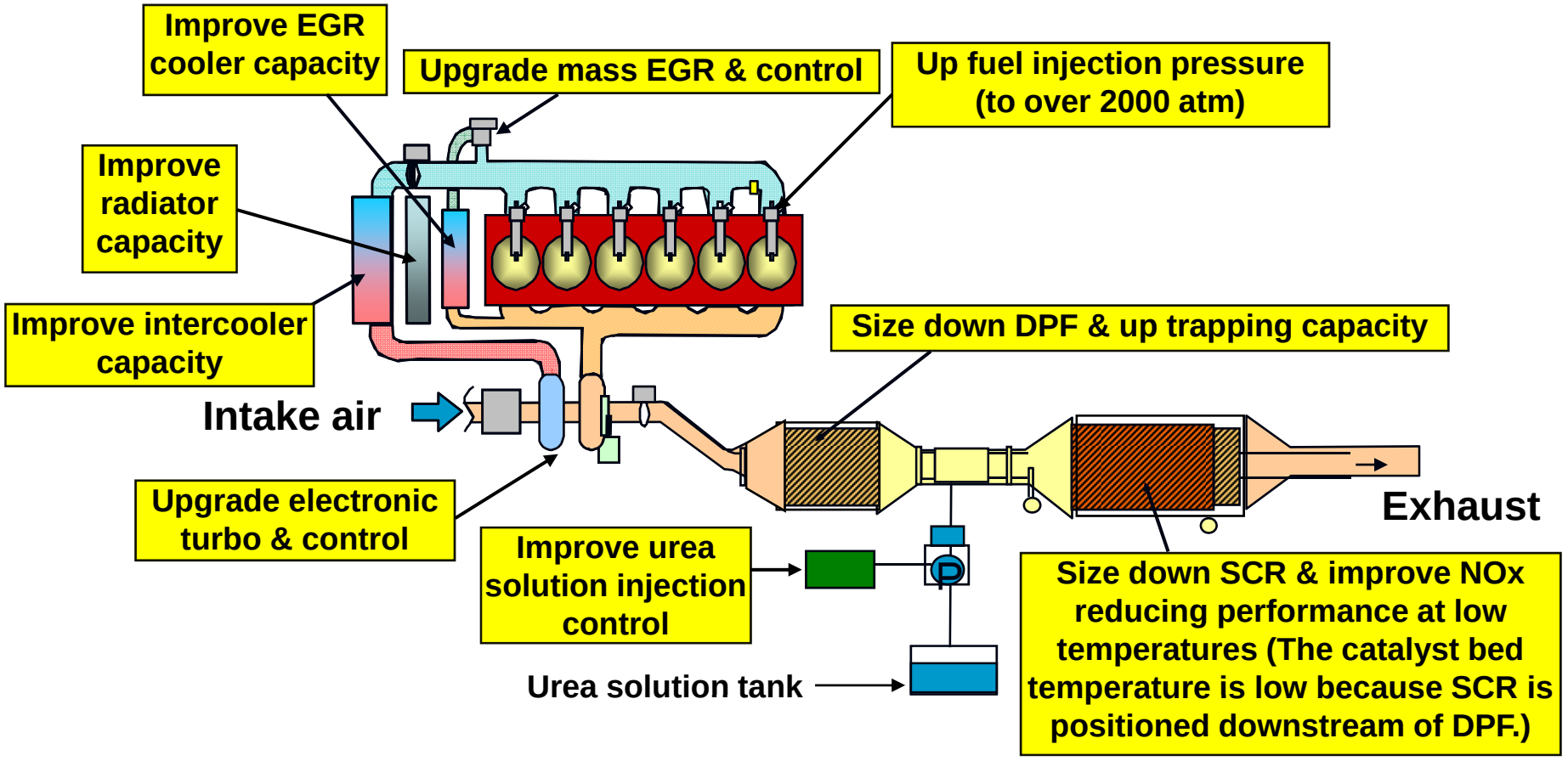
(1) Reduce PM and NOx at engine outlet levels by improving combustion with high-pressure injection, cool EGR, etc.; apply after-treatment (DPF, NOx catalysts) to further reduce below the limit values.

(2) Candidate NOx catalysts under consideration are SCR and storage-reduction catalysts.

(3) To upgrade the DPF and NOx catalyst and other after-treatment systems, not only advance the performances of catalysts but also optimize exhaust conditions such as exhaust temperature and oxygen concentration, which will require even more sophisticated engine control.

DPF + Urea Selective Catalytic Reduction System

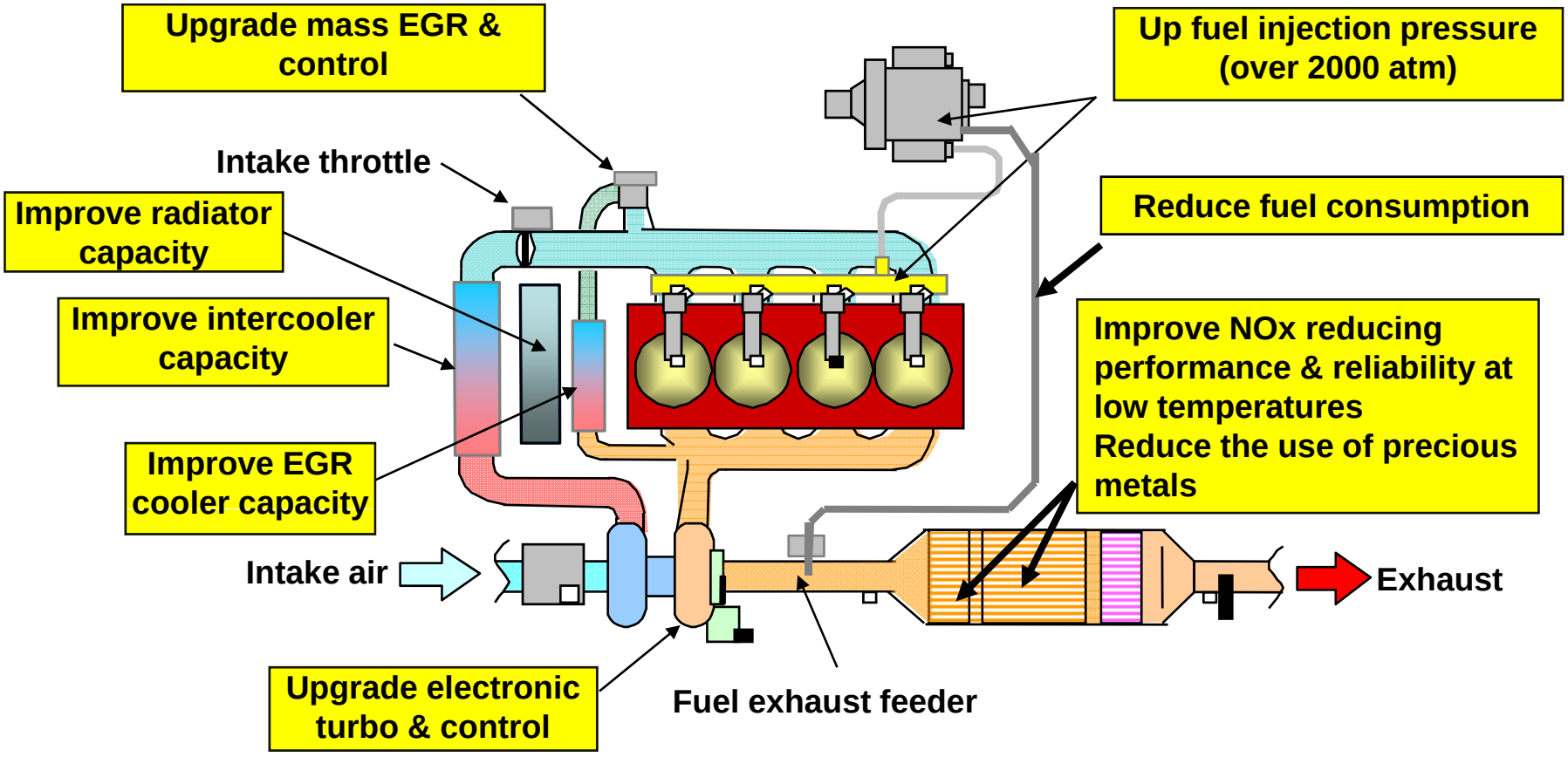
: Technological challenges for Post-New Long-Term Reg.



- **Urea solution servicing infrastructure is a must for spreading SCR to light/medium trucks.**

DPF + NOx Storage-Reduction Catalyst System

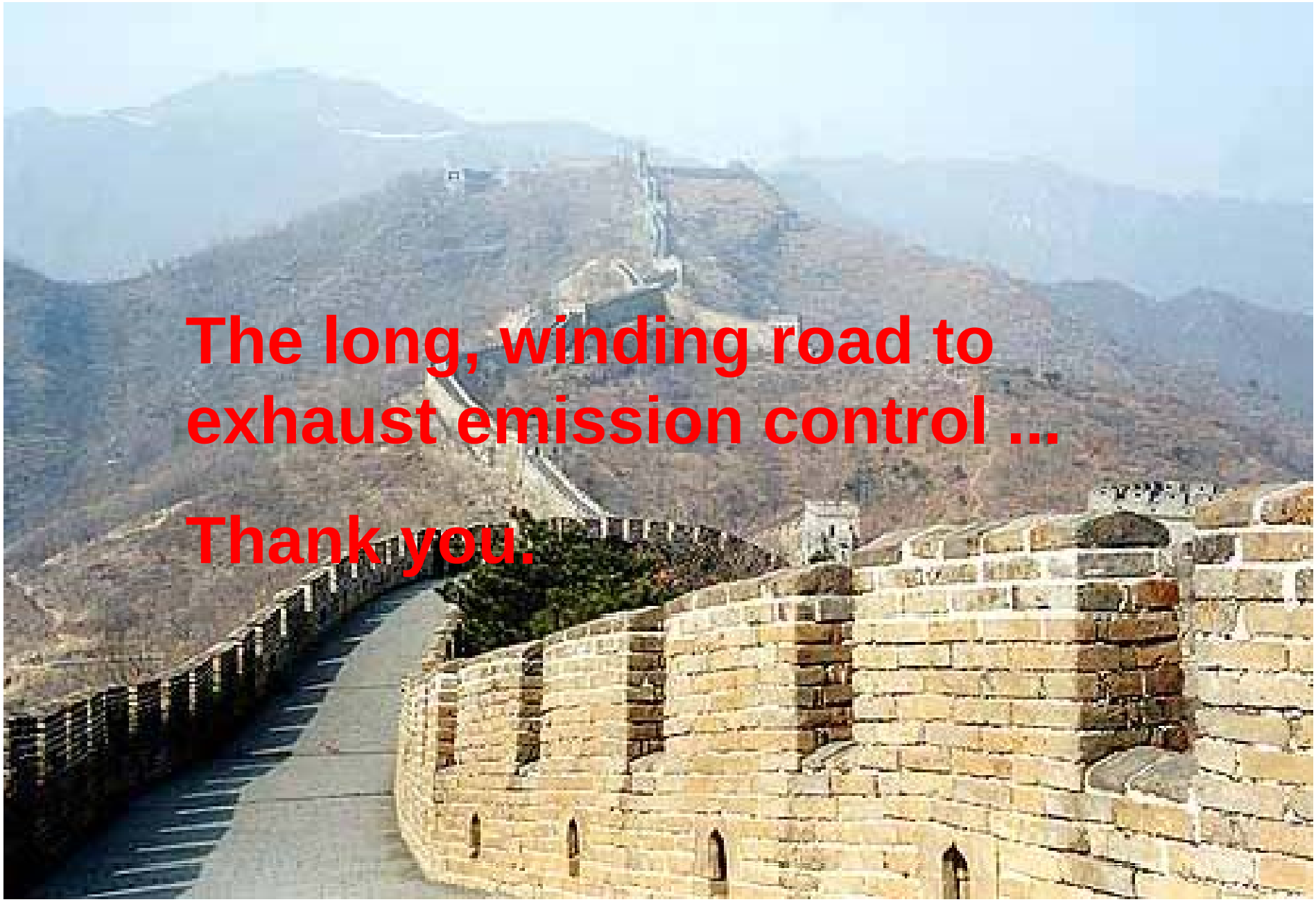
: Technological challenges for Post-New Long-Term Reg.



Prospective After-Treatment Systems for Post-New Long-Term Regulations

Pertinent items			DPF + Storage-reduction catalyst	DPF + Urea SCR
Major Components	PM reduction	PM filter	Ceramic filter	←
		Forced regeneration device	Common-rail, etc.	←
	NOx reduction	NOx catalyst	Storage-reduction catalyst	Urea SCR
		Reducing agent	Fuel (diesel)	Urea solution
		Reducing agent feeder	Fuel feeding valve	Urea solution feeder
		Reducing agent tank	Not necessary	Urea solution tank
Relevant Factors	Economic effects (on fuel economy, etc.)		Fuel economy decline due to exhaust pressure boost and fuel addition	Fuel economy decline due to exhaust pressure boost + Urea solution feeding expense
	Cost		Use of expensive precious metals for catalysts	Requirement of additional onboard components related to urea solution (tank, anti-freeze device, etc.)
	Mountability, Mass		Impaired mountability due to enlarged after-treatment system	Impaired mountability due to enlarged after-treatment system and additional components related to urea solution
	Infrastructure		Not necessary	Necessary*

* For light/medium diesel vehicles with urea SCR, urea solution should be made available at service stations.


The long, winding road to exhaust emission control ...
Thank you.