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Diesel Particulate Filters Market Introduction in Europe: Review and Status

Dr. Emmanuel Joubert and

Dr. Thierry SEGUELONG

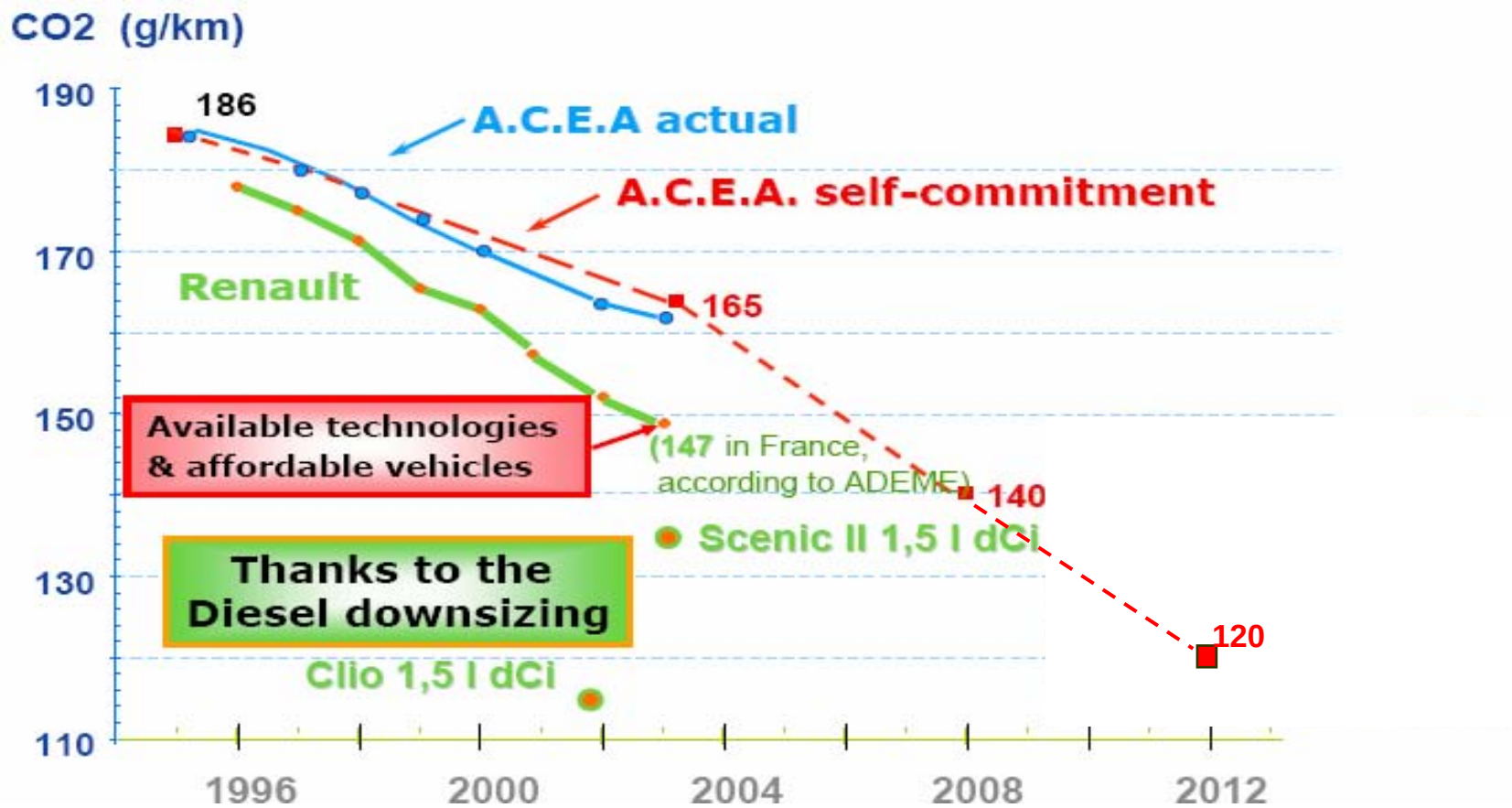
DEER CONFERENCE 2004

Presentation Outline

- The Strategic Situation of Diesel Engines
- The Year 2004 European Situation
- The Challenge of the DPF Regeneration
- The Cost Evaluations of the DPF Technologies
- The Future DPF Evolutions
- Conclusions

The Strategic Situation of Diesel Engines

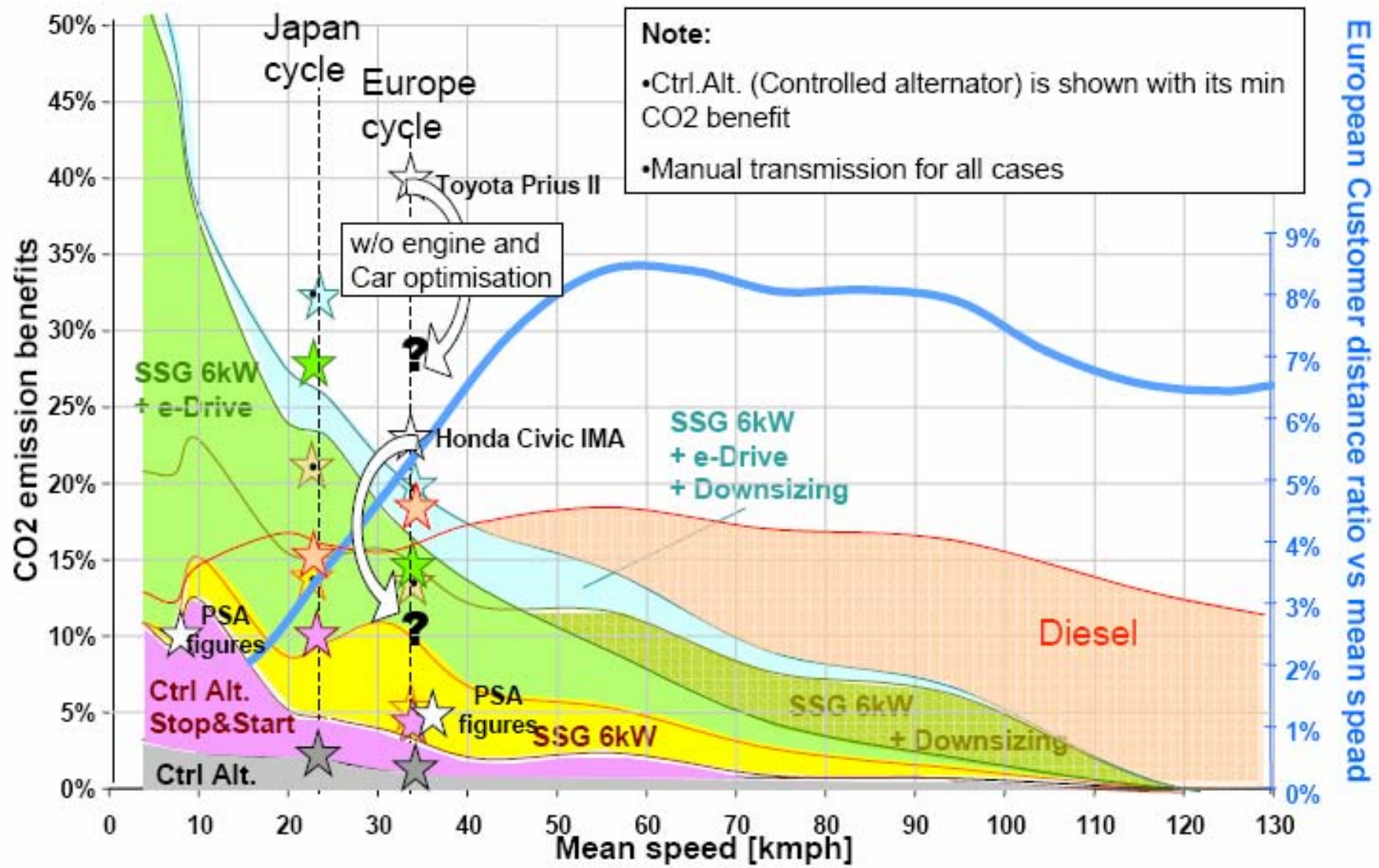
The Strategic Situation of Diesel Engines



- Reduction of Green House Effect (25% CO_2 reduction)
- Reduction of Energy Dependence (30% Fuel Economy)

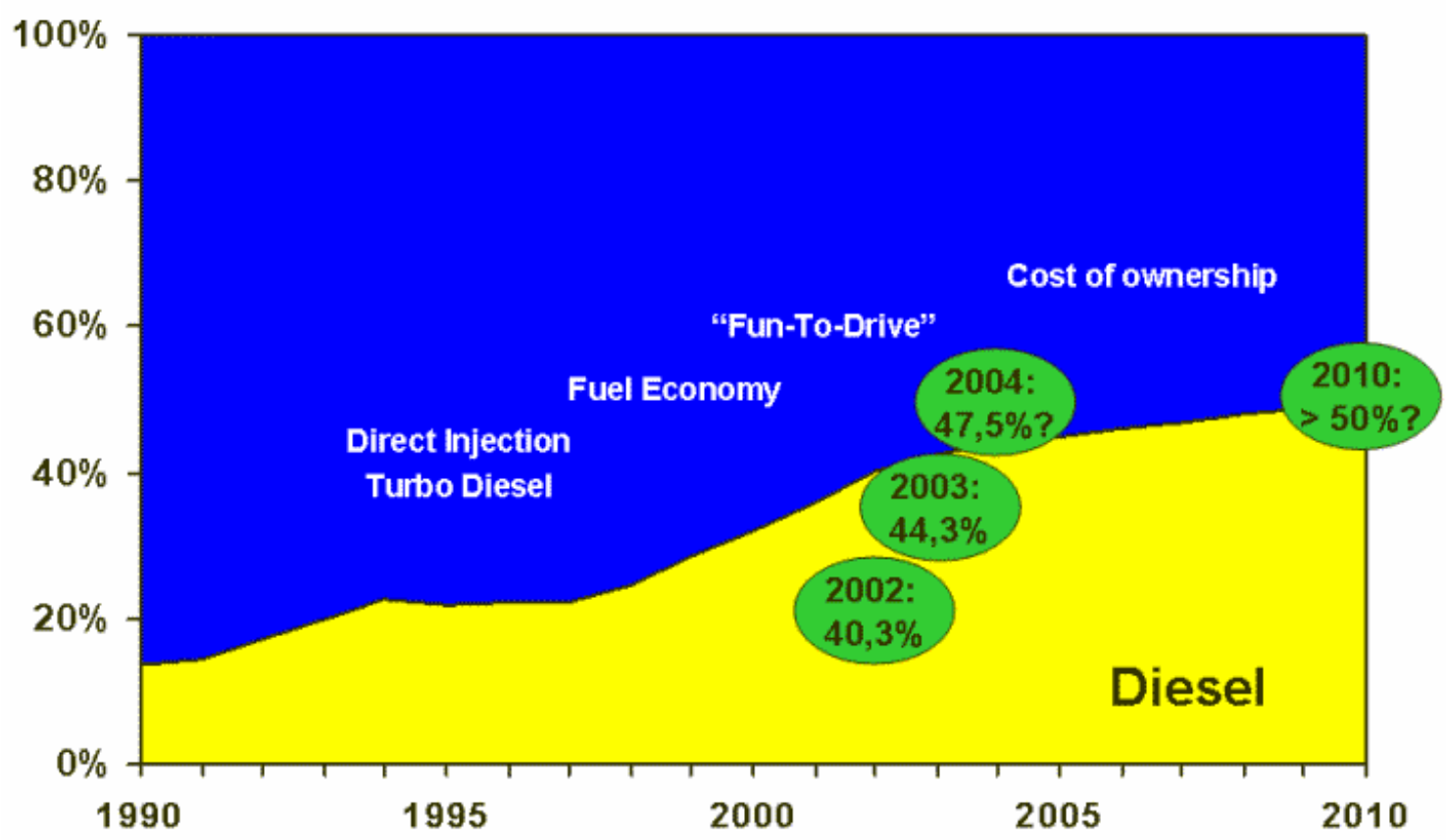
Source: SAE F&L K. Katoh, Renault, June 2004

… and Gasoline Hybrids can only fit niche market



Source: SAE F&L K. Katoh, Renault, June 2004

Constant Increase of Diesel Penetration in Europe



The Year 2004 European Situation

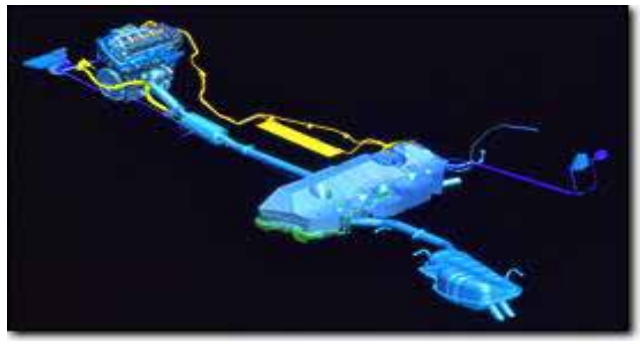
IAA Frankfurt Automotive Motor Show 2003

Announcements of DPF Implementation in Europe

	Fuel-Borne Catalyst DPF	Pt-Coated DPF	Pt-Impregnated Catalyzed DPF
DPF	Ibiden, NGK Europe		
Catalyst	Octel, Rhodia	Engelhard, Umicore	
Car manufacturers	Fiat / Lancia Ford Motor Co., PSA Peugeot Citroën, VW AG	Mercedes	Audi AG, BMW, GM / Opel, Renault, VW AG
Start of production	since 2000	end of 2003	scheduled in 2004

The two main DPF technologies (w/ FBC and w/ Pt)
can coexist within the same Car Manufacturer

PSA, FoMoCo & VW (Fuel-Borne Catalyst-Based DPF)

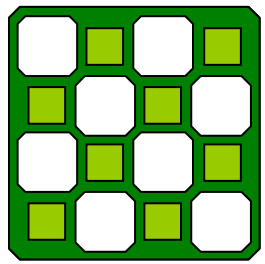


- on the market since May 2000

- as a standard equipment

- about 850,000 vehicles sold

- a proven technology with 4-years+ experience
- with flexibility (under-floor or close-coupled)



- constant Improvements since market introduction:
"zero" DPF maintenance is available in 2004, thanks to global improvements:
  - SiC-DPF design (ash storage),
  - FBC Catalytic enhancement
  - Engine Strategy

- with better Vehicle Integration and Global Cost Reduction

DaimlerChrysler (Platinum-Coated DPF)

Close-Coupled Position DPF System:

Diesel Oxidation Catalyst : 2,5 liters
DOC Platinum loading :>120g/ft^3

One-Can Box w/flange (filter maintenance)

SiC-DPF (Ibiden) : 2,5 liters - round shape
DPF Pt loading : 30 to 40g/ft^3

- available since October 2003 (4 cyl.; *E & C Class*)
- DPF is offered as an option: 580€
- 80% of the sales are with DPF (EURO 4 tax incentives)
- about 50,000 vehicles have been sold since Oct. 2003

- DPF maintenance @ 100,000 km (standard replacement)

BMW AG (Catalyzed DPF)

- available since February 2004
- 6 cyl.; 525d and 530d models
- standard equipment
- w/EURO 4 compliance

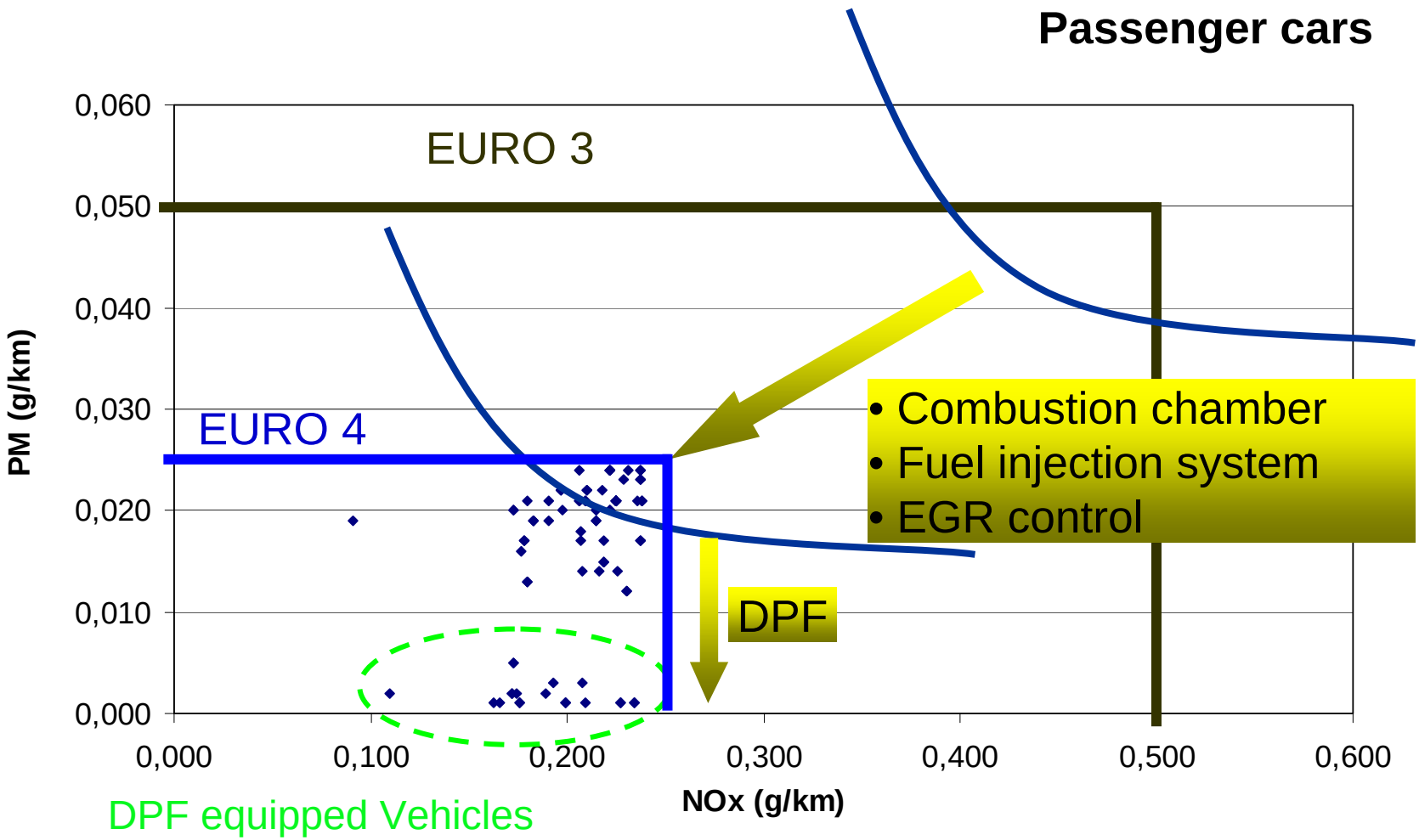
- SiC-DPF in under-floor position:
  - racetrack _ 4,7 liters
  - 530 w/200cpsi - 525 w/300cpsi
  - Ibiden and NGK Europe
  - DPF Platinum loading <90g/ft3

Diesel Oxidation Catalyst in Close-Coupled Position

Exhaust line thermal insulation

- announced “without DPF maintenance”

EURO 4 Vehicle NOx and PM Emissions



Future DPF Implementation in Europe

Manufacturer	Model	Power (hp)	DPF Equipped
Ford	C-Max TDCi	136	600 euros option
Mazda	5	136	600 euros option
Mercedes	E 320 CDI	204	696 euros option
Mercedes	S 320 CDI	204	696 euros option
Opel	Vectra 1.9 CDTI	120	Serie
Opel	Vectra 1.9 CDTI	150	Serie
Opel	Signum 1.9 CDTI	120	Serie
Opel	Signum 1.9 CDTI	150	Serie
Renault	Vel Satis 2.2 dCi	150	Serie
Volvo	S40/V50	136	600 euros option

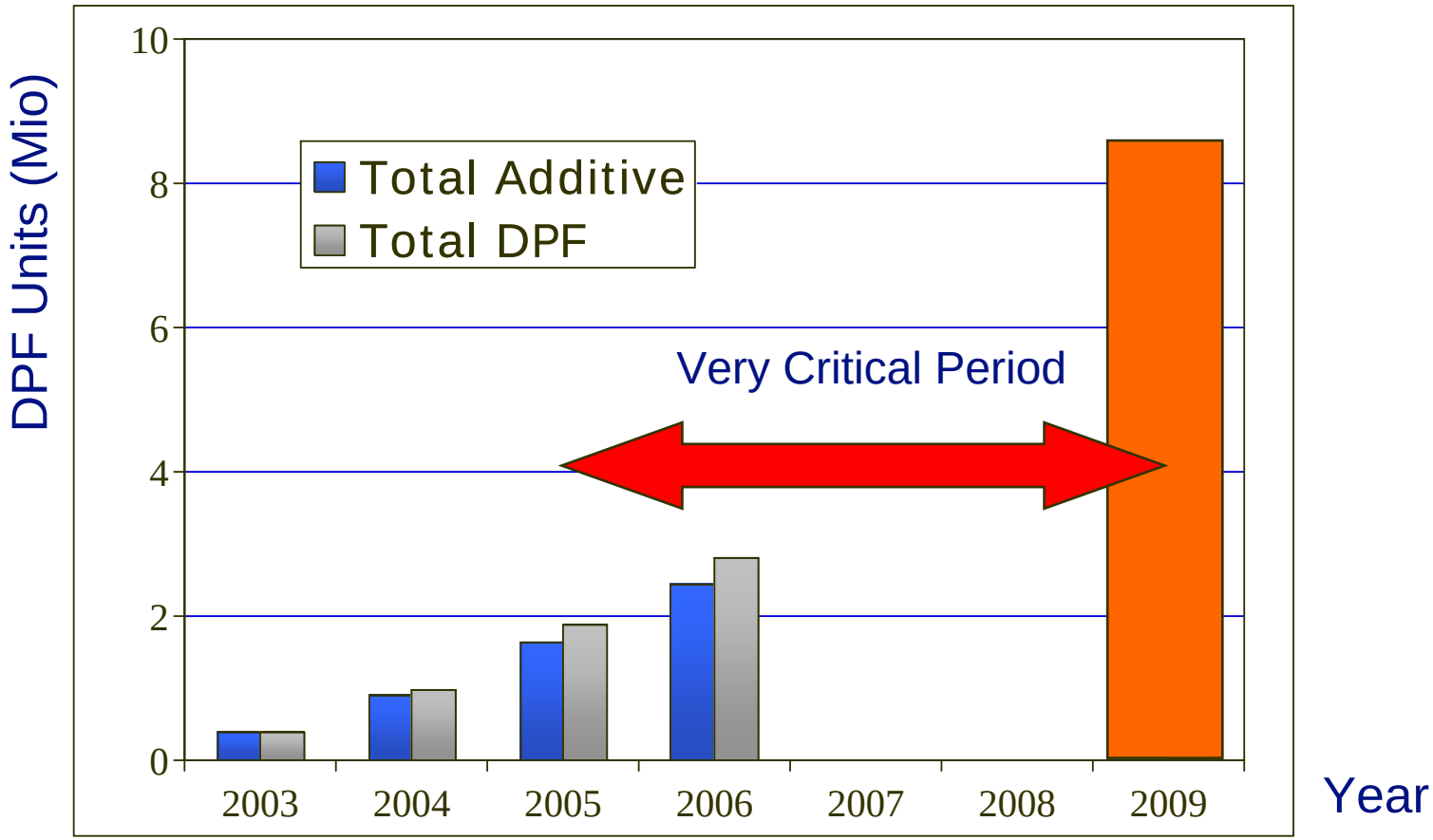
New Manufacturers and Models scheduled in 2004

Germany's car makers have agreed to equip diesel cars sold in Germany with filters:

- with a plan to provide tax incentives of € 600 from 2005
- the proportion of DPF should reach 75% by the end of 2007
- and 100% by 2009

Additional “Bonus/Malus” rules, based on CO_2 (g/km) emissions may be also available in 2005 (French initiative)

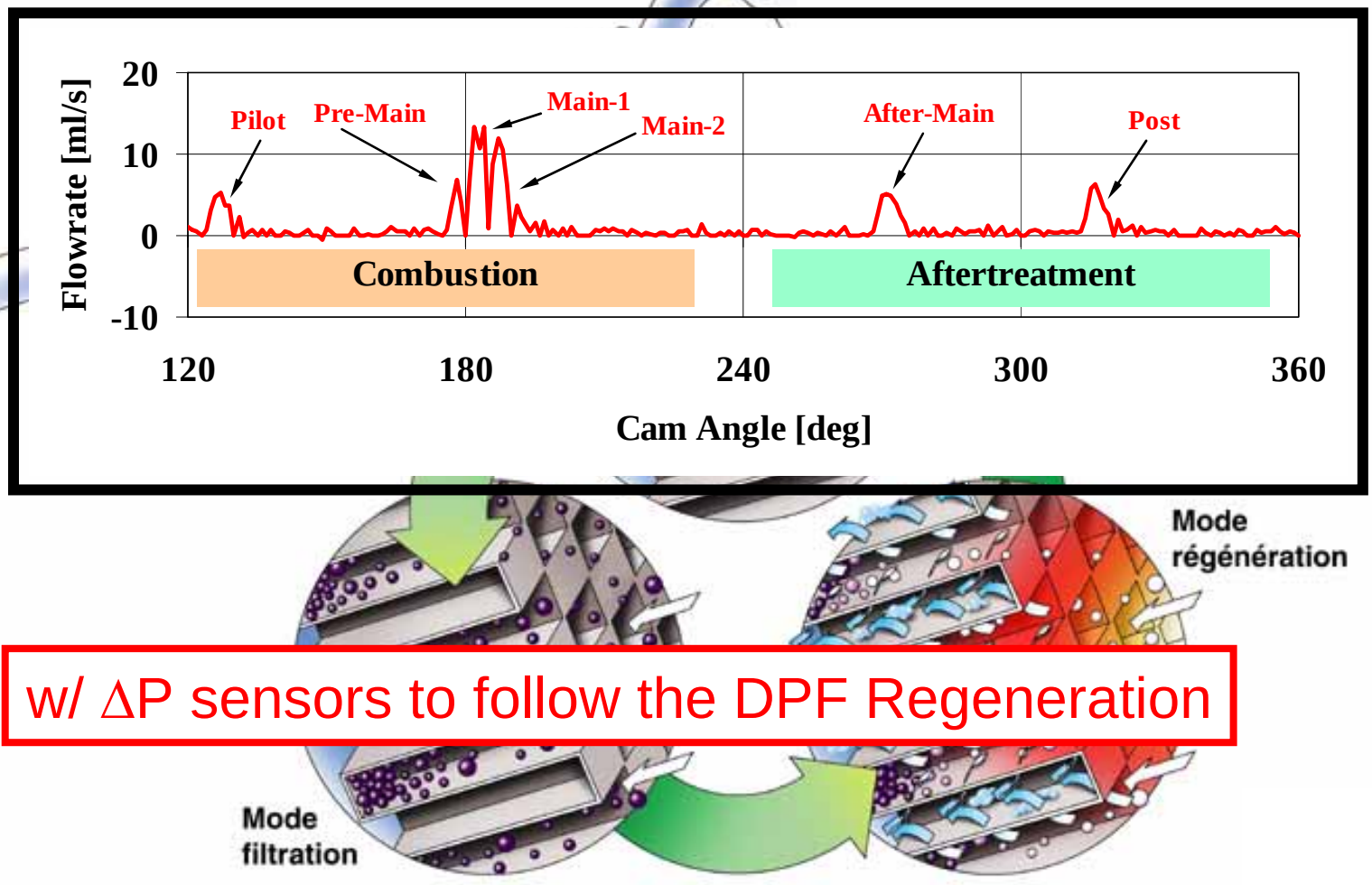
Forecast in DPF Implementations in Europe



Very difficult 2005/2007 and 2007/2009 steps !!!
…with only 2 or 3 DPF manufacturers as real players

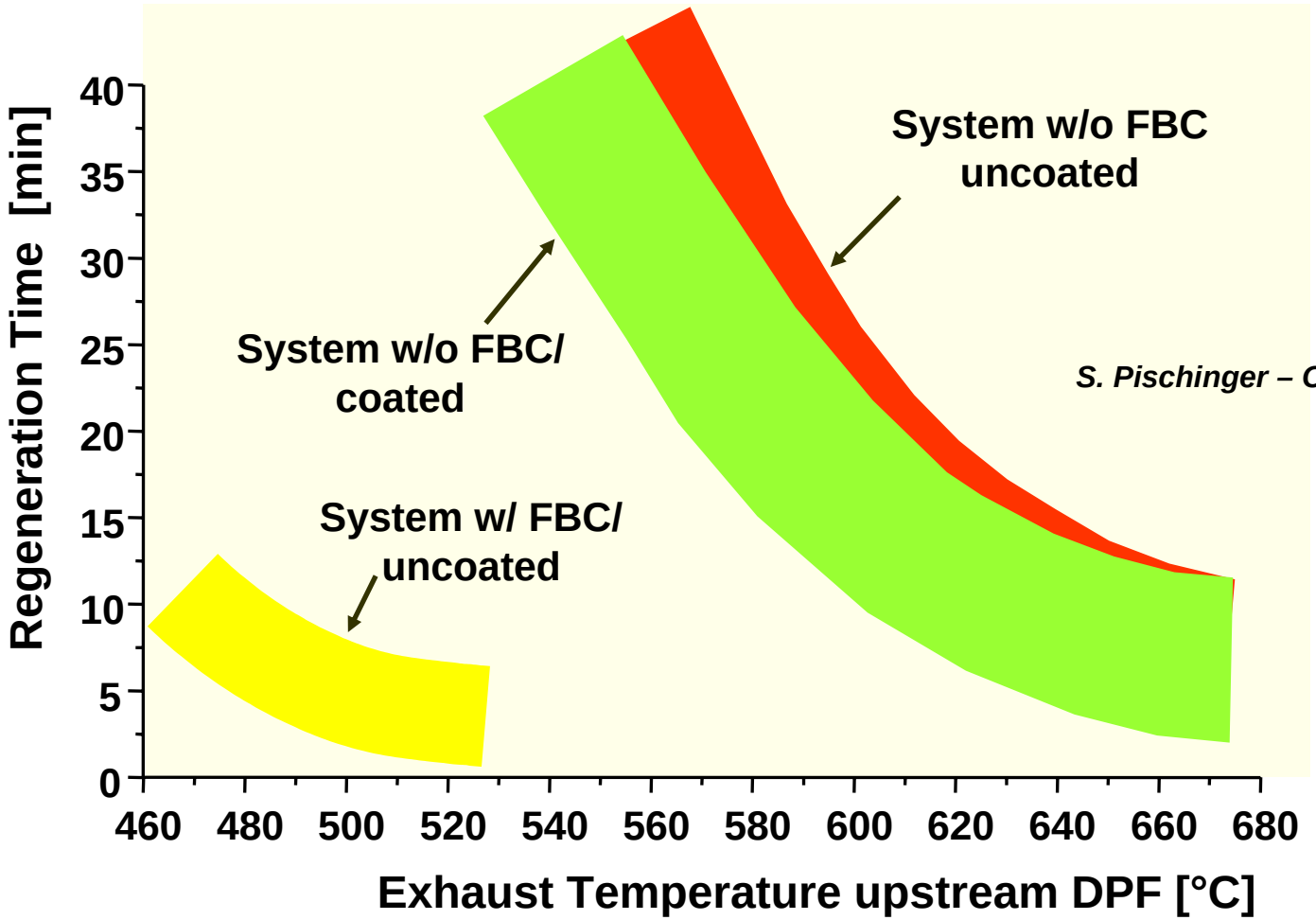
The Challenge of the DPF Regeneration

Sequential DPF Regeneration Cycle



w/ ΔP sensors to follow the DPF Regeneration

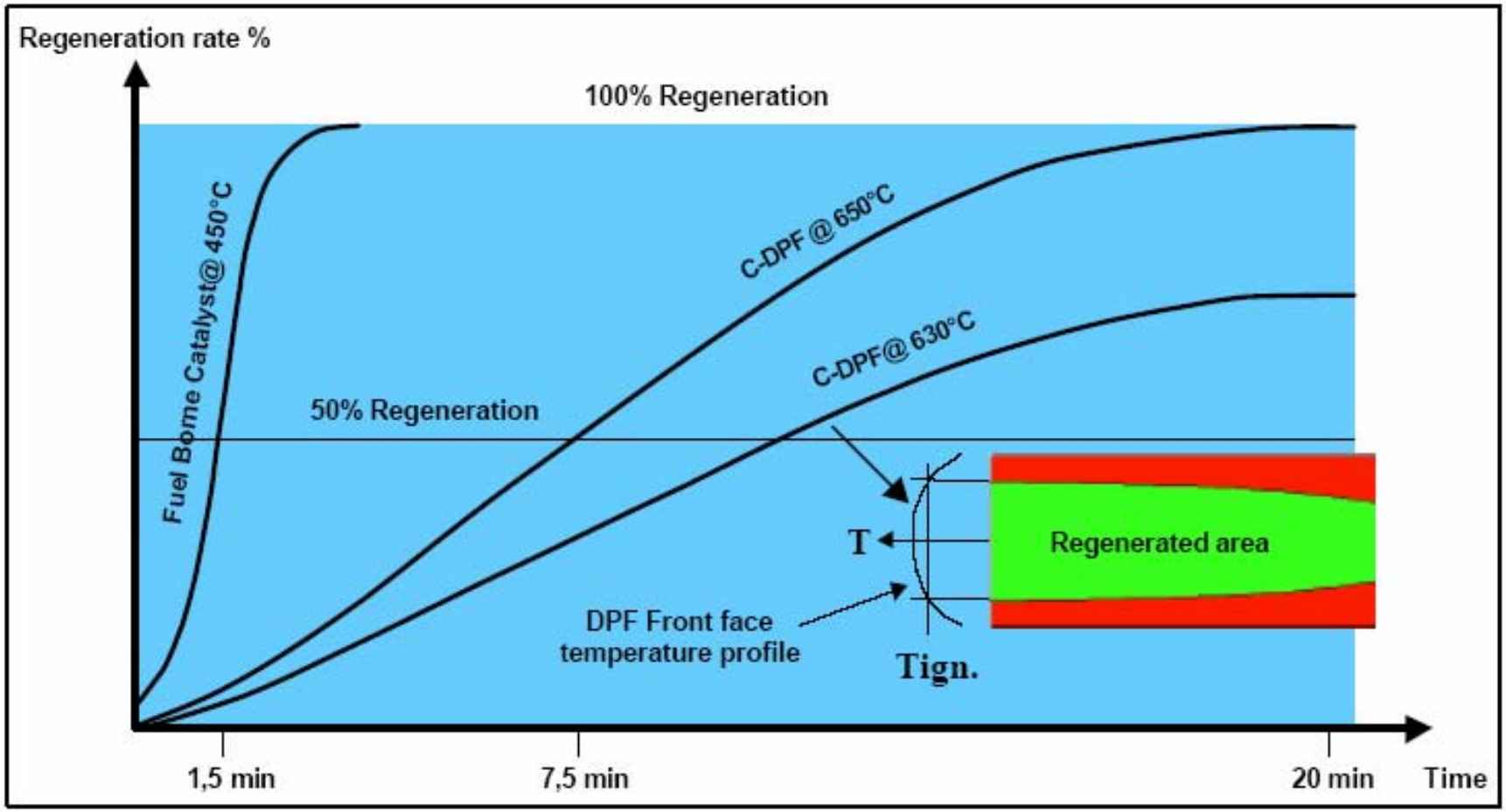
Sequential DPF Regeneration Cycle



Source :
S. Pischinger – CAPoC 6 2003

Catalyst does not help the Catalyzed-DPF regeneration:
no big difference between coated and uncoated filters;

Complete DPF Regeneration with FBC

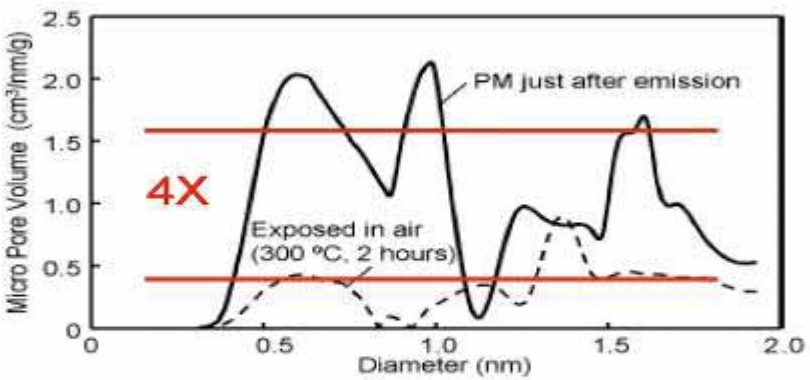


Nonhomogeneous DPF regeneration with Platinum-based Technologies

Source : J. Michelin – VDI Wolfsburg 12/2003

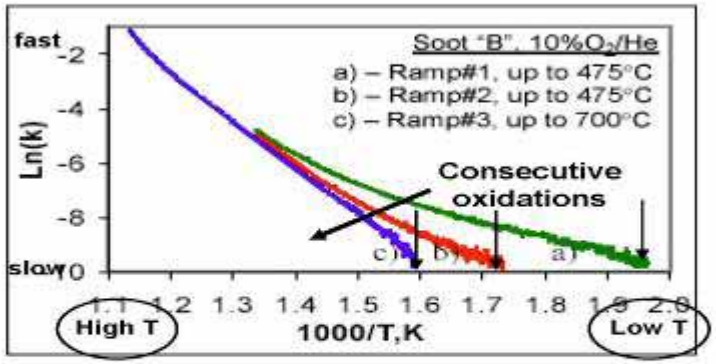
Incomplete Regeneration Changes Soot Reactivity

Perhaps filter regenerations should be done more frequently to take advantage of highly reactive, fresh soot



Fresh soot has more micropores than older soot

Toyota SAE 2002-01-0957



Fresh soot is more reactive than older soot

Cummins, SAE 2003-01-0833

Source : T. Johnson – Corning
DEER 2003

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Incomplete and partial DPF regeneration causes dramatic soot modifications in:

- physico-chemistry and composition
- structure, porosity and morphology

…with Direct Customer Effect

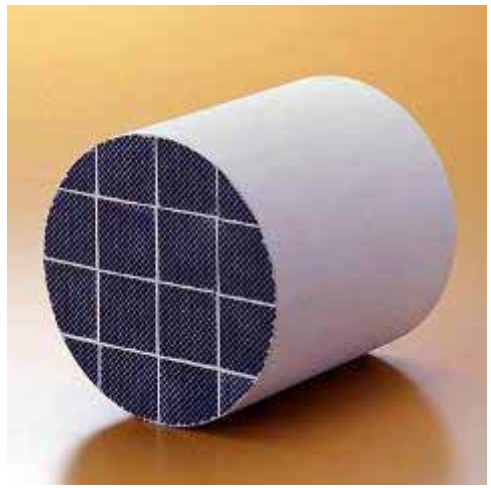
April 3, 2004

Mazda Motor Corporation said **it will recall a total of 2,656 diesel vehicles** in four models in the Japanese market to fix a defect in the diesel particulate filter (DPF) system.

Subject to the recall are the Bongo truck, the Bongo Brawny van, the Delica van and the Vanette van manufactured between last December and February. Mazda said that the level of PM emissions from the vehicles may exceed mandated standards due to the DPF system problem.

The vehicles are powered by a 2.0 liter common-rail diesel engine utilizing **catalyzed wall-flow particulate filter** and exhaust gas recirculation for NOx control. The filter is regenerated through the combined effect of the catalyst and increased combustion temperature, controlled by common-rail injection system. The problem was caused by computer software which did not properly control filter regeneration. All affected engines will be fitted with new Engine Control Units featuring updated software. The regeneration problems may have caused overheating and failure of the filter element and/or the temperature sensor positioned downstream of the filter. If damaged, these component will be also replaced at no charge.

The new Mazda Bongo was the first light commercial vehicle in Japan fitted with a diesel particulate filter.

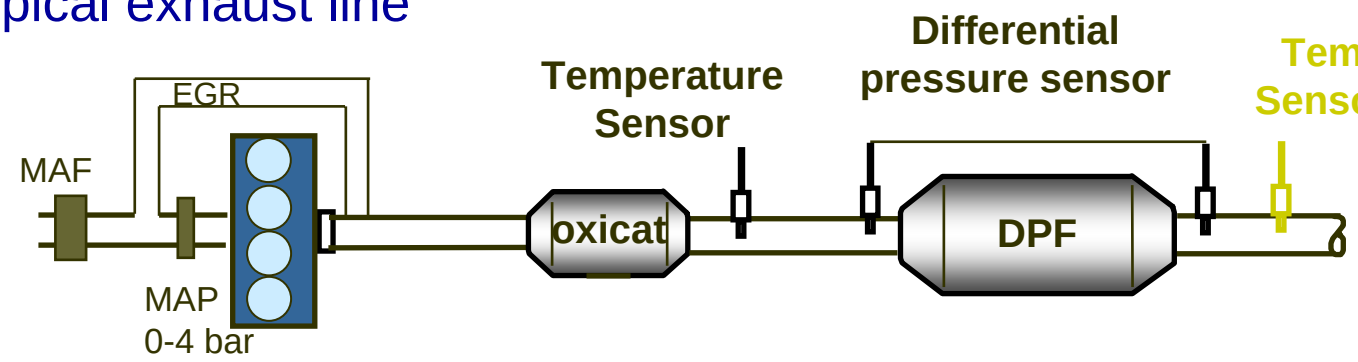


Source : www.Dieselnet.com

The Cost Evaluations of the DPF Technologies

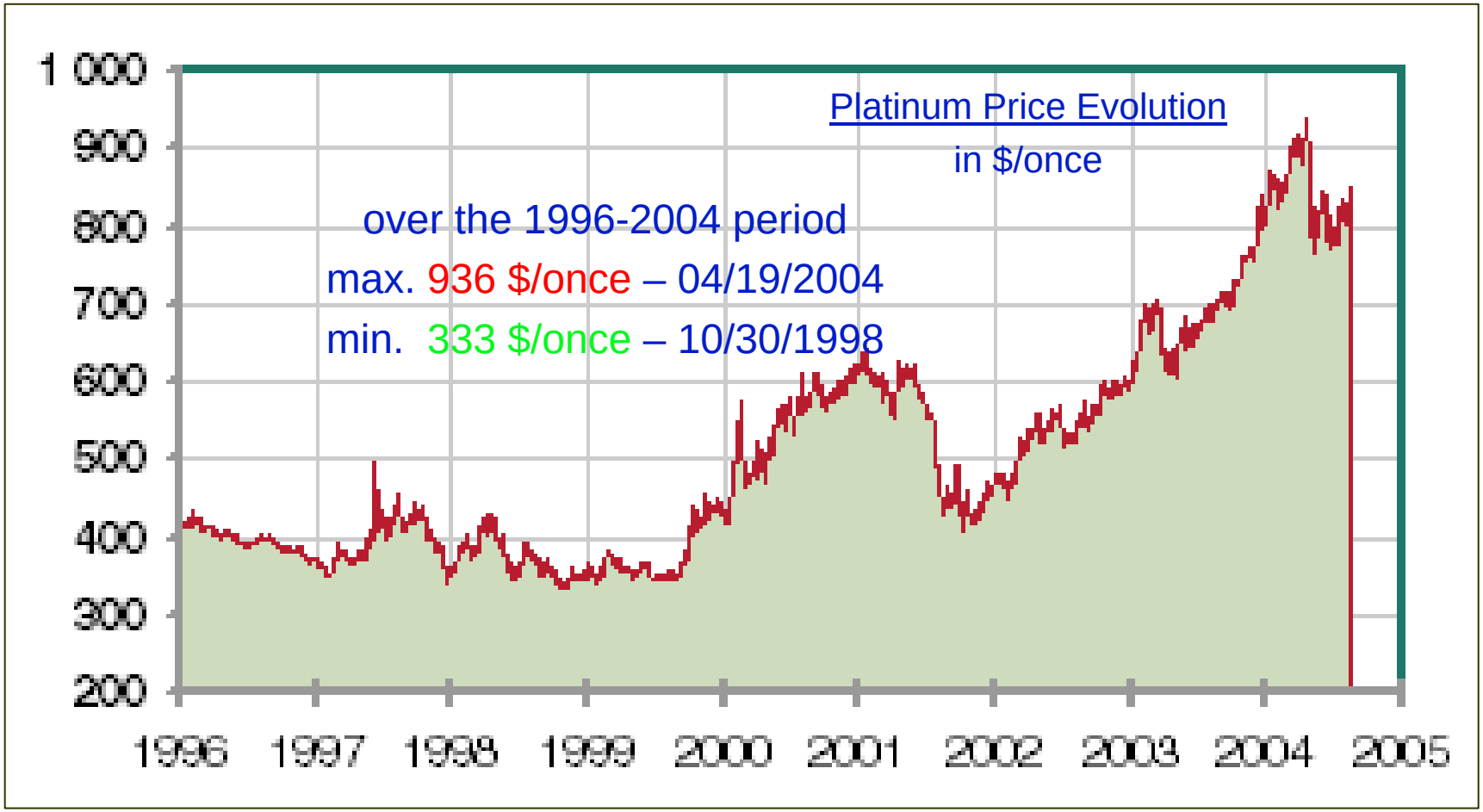
Similar Architectures vs. DPF Technologies

Typical exhaust line



- Diesel Oxidation Catalyst Platinum loading
  - targeting the EURO4 - 100,000km durability requirement
  - Pt from 90 to 140 g/ft^3 (CO/HCs, post-injection management)
- Can and sensors (w/o flange for one or two boxes)
- SiC-based DPF: no difference in design and in scale effect
- Fuel-Borne Catalyst (tank, dosing system, interface, wires, connections, additive fluid)
- Platinum DPF wash-coating
  - Platinum loading (30 to 90 g/ft^3)
  - specific wash-coat (Catalyzed-DPF with SiC)

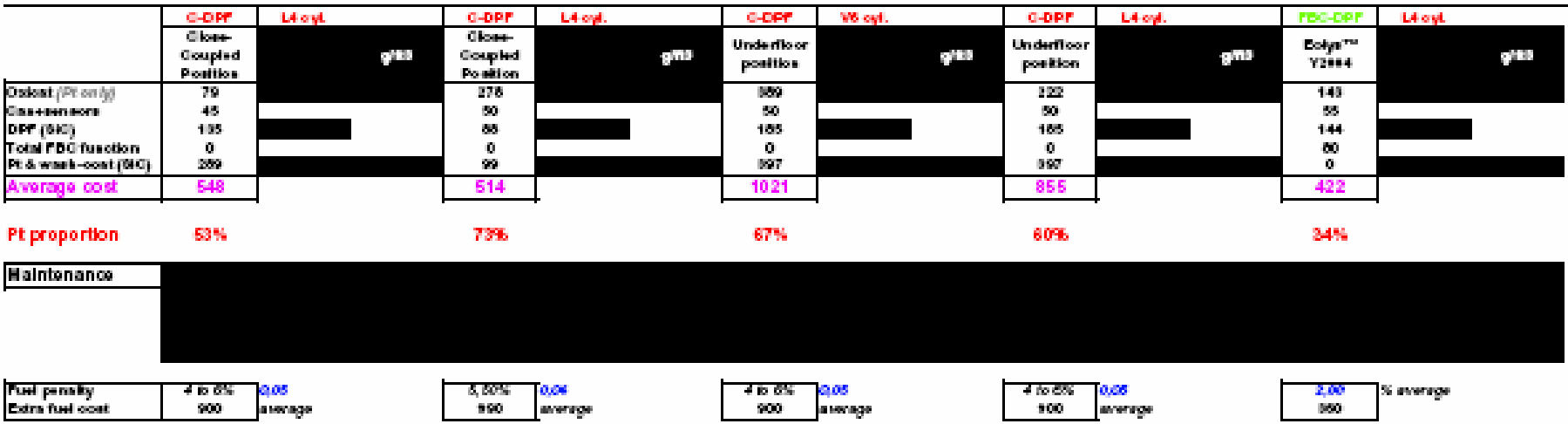
Platinum Price Evolution (London Fixing PMG)



max. 936 $/once – 04/19/2004

min. 767 $/once – 05/10/2004

Chart based on the Market Data



Specific MAT for C-DPF not included
Round / Oval shape difference not taken into account
Oxicat wash-coating not taken into account
Flange for two CAN not taken into account (approx. 10€)
Specific exhaust part insulation not taken into account

Market data

SIC DPF (high volume price)

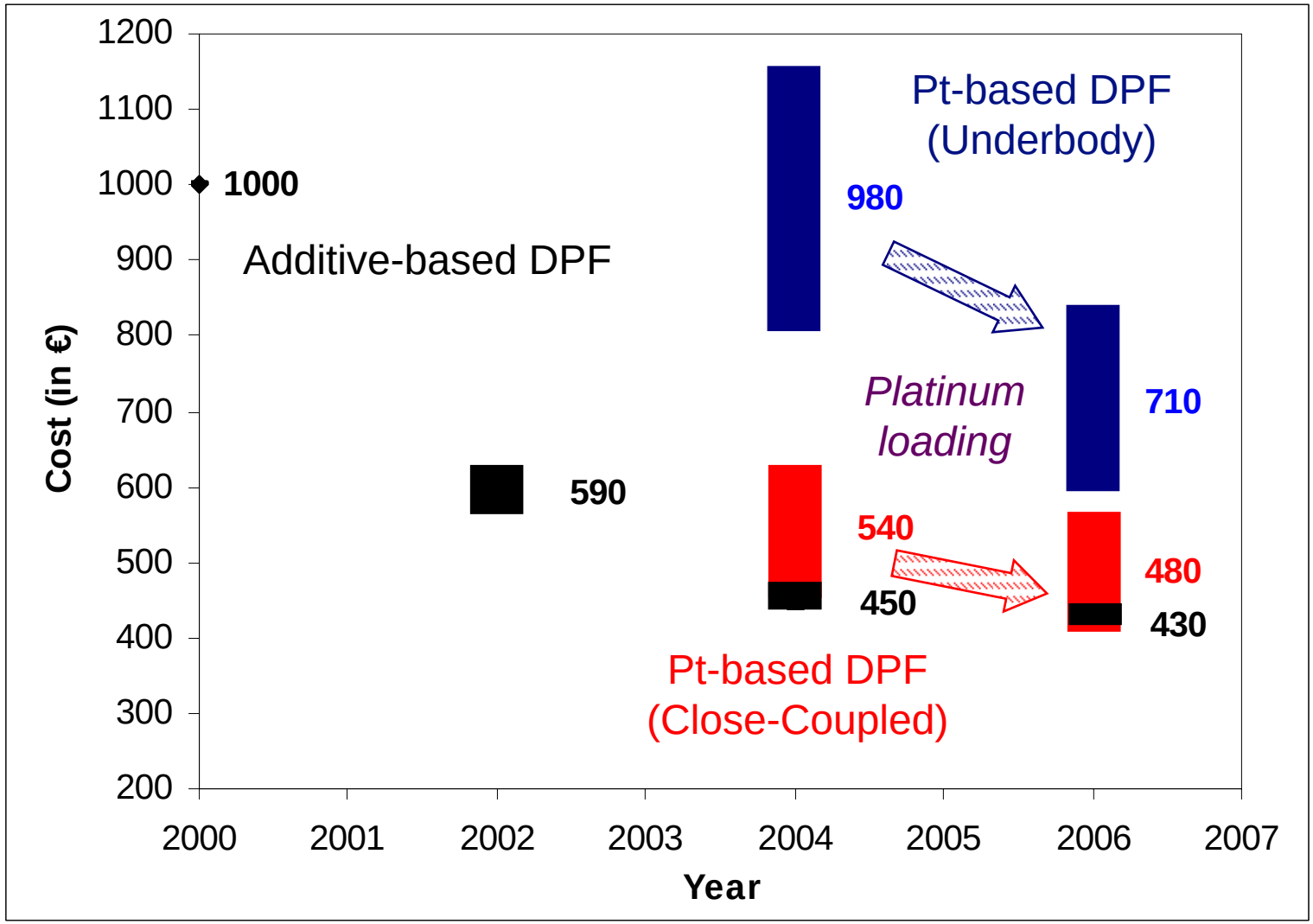
200cpsi SQ	[redacted]	€/litre
300cpsi SQ 8"		€/litre
200cpsi OS2 10"		€/litre
specific SIC wash-Coat	[redacted]	€/litre

Platinum price 636,61 €/oz
29-mars-04 22,46 €/g
767 $/oz

Volume 1 ft3
28,3 litres

round shape	6"	2,47 litres
	8"	3,29 litres
	10"	4,12 litres
	11"	4,53 litres
	12"	4,94 litres
ratio $/€	0,83	

Cost Evaluation of DPF Technologies



Situation of Platinum-Based DPF Technologies

at similar scale production (vs. additive-based reference):

- underbody Pt-based DPF is never competitive
- close-coupled Pt-based DPF may be competitive, but a DPF maintenance is required

still some points to be addressed:

- fuel penalty for DPF regeneration (time, temperature)
- lubricant dilution and engine parts damages
- DPF maintenance operation and Pt recycling
- partial and incomplete regeneration (maintenance, recall)

Platinum cost part represent (in 2006):

- 45-70% of Pt-based Close-Coupled Position
- 40-60% of Pt-based Underbody Position
- 35-40% of Additive-based DPF

Large market introduction of Pt-based DPF need dramatic changes and evolutions of the present Pt-based technologies

The Future DPF Evolutions

Future Evolutions to Fit the Market Requirements

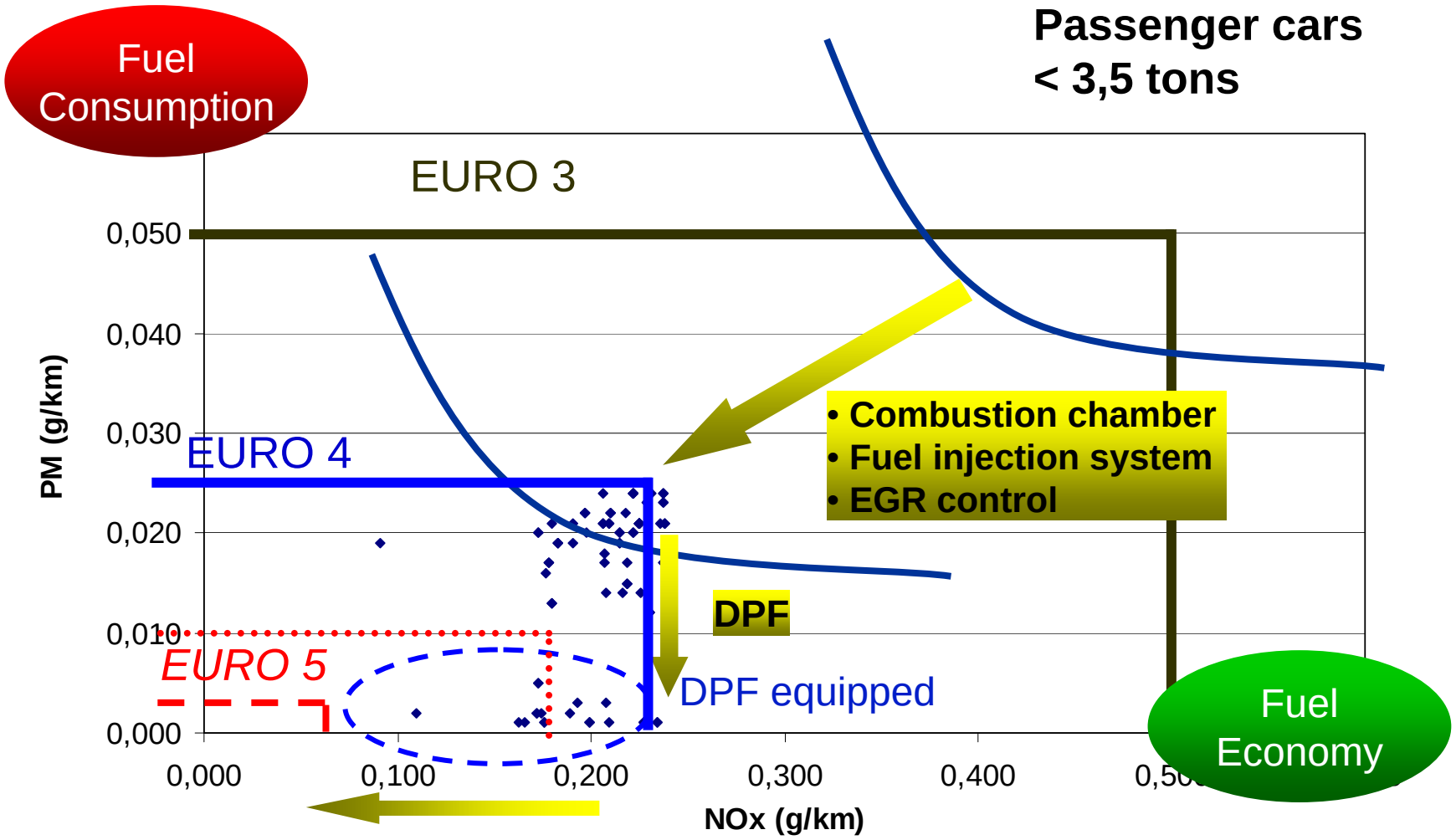
Pt-based DPF
Reduction of Pt loading
20 to 5g/ft^3

FBC-based DPF
Reduction of
FBC dosing rate

- additional exhaust heat injection
  - to reach Carbon Pyrolysis (>850°C)
  - to save engine parts (lubricant)
- new DPF design
  - for unburned soot management
- combination Pt-based w/ FBC
  - integration of DOC
  - volume saving (close-coupled)
- constant system improvement

to prepare the next EURO5/Tier2-Bin5 (NOx+PM)
(volume saving, thermal management, cost reduction, flexibility)
with New Injection Technology Systems

The Future Challenge for NOx, PM, and CO2



…and 120 to 160,000km
(74 to 94,000 miles) durability

Conclusions

Conclusions

- In 2004, the DPF is well accepted by the European car makers;
- At present, the additive-based DPF is the only proven technology;
- Some platinum-based DPF technologies have been proposed since Oct. ‘03, with important points to address, as the maintenance issue, the lubricant dilution, partial and uncontrolled DPF regenerations…;
- In addition, the platinum price evolution does not favour the market introduction of these technologies;
- The platinum-based DPF technologies need dramatic improvements and new approaches for significant market introduction;
- If the present EURO 4 was based on an emotional choice and marketing strategy, the next EURO 5 stage should be different, with integration of NOx and PM aftertreatments while targeting the CO2 and cost challenges.