Updated Statement to CITEPA on Cost of European Diesel Emissions Regulation

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RD 04/140701.1

James Devriendt, Barry Train, Nick Owen

Ricardo UK Ltd

Introduction

- Ricardo conducted a study for CITEPA between May and November 2003 detailing the impact of past, future and projected emissions legislation on the cost of European engines
- Outputs from the study included:
  - Documented historical or projected future emissions reductions
  - Effect of the regulations on the production cost of engines
- A report was prepared and issued to CITEPA who distributed to various organisations for comment (RD 03/162101.5)
- Comments returned from ACEA highlighted concern over elements of the report relating to **light-duty diesel engines** (passenger car / light commercial vehicle)
  - Cost increases viewed as smaller than expected
  - Market penetration of certain technologies questioned
- A Ricardo response to these concerns (RD04/113001.1) was circulated and discussed at a meeting on 7 April 2004 involving Ricardo, ACEA, CITEPA and other stakeholders
  - At this meeting, it was agreed that these issues arose from the assumptions surrounding the study, especially the **effect of rising Diesel sales on costs**
- Ricardo agreed to re-evaluate according to new assumptions agreed at the meeting
  - **This report explains the changed assumptions and replaces data presented in RD03/162101.5**

Assumptions – New Technology Introduction Costs

- Ricardo's original sources for this data included collated information from manufacturers and suppliers over many years
- **Growth in passenger-car Diesel engines has been one of the biggest market trends in recent years.** It is clear that as a diesel engine technology is introduced, it is more expensive than after several years of production. Reasons for this are:
  - First introduction of Diesel engines, and of subsequent technology improvements, tended to be on on low-volume "premium" or "niche" products, where margins are typically higher, high unit costs can be tolerated
  - **Rising Diesel sales**, improvements in component manufacturing capabilities, "supply and demand" economics and the recovery of original tooling investment after many years of production, have all led to **substantial benefits in terms of price per unit**
- **This effect arises to some extent for any new technology.** In the original study, these "volume" effects were generally **excluded**, with the "stabilised" cost of components in mainstream production being used. However, for Diesel engines the effect was so large that it was originally agreed to include it.
- Subsequent discussion led to the decision that these **volume effects should be removed from the analysis**. This updated analysis uses "stabilised" component prices at a level representing circa 1 year after volume technology introduction
- As before, prices are corrected for inflation to current levels

Assumptions - Expected Technology Penetration for Diesel Oxidation Catalyst and Exhaust Gas Recirculation; Diesel Car and LDT (Updated Statement – p. 30 of RD03/162101.5)

Euro Emissions Standard	0 (ECE R15/04)	1	2	3	4	5 (draft)
Year of Introduction:	< 1992	1992	1996	2000	2005	2010
Emissions Technology Requirement (Majority of Vehicles) - Incremental	Mechanical fuel pump / IDI combustion system / Low pressure injectors	Mechanical / part-electrical fuel-control / IDI combustion system / Low pressure injectors / EGR system with electric control	Electric fuel timing/metering / cooled EGR circuit / Turbocharged	DI combustion system (HP injectors) / turbocharged, intercooled, Diesel oxidation catalyst	4V cylinder head design	2nd generation common rail or unit injectors, variable nozzle turbocharger, (catalysed) Diesel particulate filter, modulated EGR and/or Lean NOx trap
AIR MANAGEMENT						
naturally aspirated	79	66	44	15	7	0
wastegated turbocharger	21	34	49	71	44	29
intercooler	9	17	38	52	71	89
variable nozzle turbo	0	0	7	14	49	69
two-stage turbocharging	0	0	0	0	0	2
intercooler by-pass (for start-up)	0	0	0	0	1	15
4V per cylinder	0	3	5	28	73	92
inlet port deactivation (variable swirl)	0	0	2	4	16	46
NOx REDUCTION						
EGR circuit	0	**5**	100	100	100	100
EGR cooler	0	**0**	56	78	92	98
modulated EGR cooling	0	0	0	0	5	27
AFTER TREATMENT						
Diesel oxidation catalyst	0	0	**99**	100	100	100
2nd Diesel oxidation catalyst	0	0	**0**	**5**	**10**	**15**
Diesel particulate filter	0	0	0	1	9	31
Catalysed Diesel particulate filter	0	0	0	0	8	69
Lean NOx trap	0	0	0	0	1	25
Selective Catalytic Reduction (Urea required)	0	0	0	0	0	5

- Updates to DOC and EGR market penetration according to ACEA-supplied data

Assumptions – Technology Requirements

- Ricardo had prepared the report according to the assumption that . . . **'the minimum technology required to satisfy the emissions legislation would be used'**
  - For example, an average 2.0-litre engine in an average application will not require a DPF in order to meet Euro 4 emissions legislation, but several vehicles are currently fitted with DPFs in this category
  - Possible reasons for adopting this strategy include obtaining warranty and field trial information **which will assist with later high-volume introduction to meet legislation**
- In this example, a DPF is a relatively expensive technology and so the interpretation of technology requirements is very influential
  - The same argument can be applied to many different Light Duty Diesel technologies in the study
- This updated statement for market penetration of emissions reduction technology, as suggested in the comments from ACEA, estimates **'what will actually happen in the market'**, whether purely for current emissions purposes, or for other reasons (e.g. DPF example above) which may assist **future emission control**

Assumptions - Technology Incorporation for Reasons other than Emissions Legislation

- Some technologies were originally implemented to improve engine performance as well as for reasons of emissions control. Examples of this include:
  - **Diesel DI combustion systems** were implemented to improve fuel consumption, not for reasons of legislated emissions reduction at that time
    - However, it is unlikely the older IDI combustion system would be capable of complying with the speculated “Euro 5 legislation (or possibly “Euro 4”)
    - Therefore it is necessary to account for the full cost of the switch to DI somewhere
  - **Turbochargers** were introduced as a means to increase power density, but are now an essential component for reasons of emissions compliance
    - Likewise, it is therefore necessary to include the full cost of the adoption of turbocharging
  - **The updated statement retains the historically correct market penetration figures** and future projections, as before, but now 100% of the cost is attributed to emissions legislation from introduction of the technology.

Revised Analysis Result
(Updated Statement – p. 62 of RD03/162101.5)
Expected Technology Penetration; Diesel Car and LDT

Item	Classification / Parameter	Symbol		Euro Emissions Legislation / Year of introduction						
				0 / 1990	1 / 1992	2 / 1996	3 / 2000	4 / 2005	5 / 2010	6 / 2015
1	**Technology Requirement**		R [1]	Mechanical fuel pump / IDI combustion system / Low pressure injectors	Electronic control DI fuel pump / DI combustion system / high pressure injectors	Turbocharger to reduce displacement	4 valve per cylinder	Common rail	Port deactivation Diesel Particulate Filter (DPF) + NOx Aftertreatment ? (2010)	Fully developed aftertreatment strategies allowing better engine optimization for fuel economy. Updated FIE and controls
	Assumptions			As stated previously in this update document						
2	Incremental Emissions Costs From 1990 [Euro]	*I*	R	**0**	**59**	**183**	**355**	**536**	**738**	**994**
3	Additional Operating and Maintenance costs [Euro]	*f*	R	**0**	**125**	**118**	**120**	**132**	**145**	**165**
5	Lifetime of control Equipment [years]	*lt*	R	**10**	**10**	**10**	**10**	**10**	**10**	**10**
9	Change in fuel consumption caused by implementation of the Euro (?) measures [%]	λ^e	R [3]	**100**	**92**	**87**	**82**	**84**	**86**	**87**
10	Average fuel consumption 2005-2010 relative to 1990 [fraction]	*fe*	R	**1.000**	**1.006**	**1.168**	**1.063**	**1.040**	**1.006**	**1.020**

- Maintenance costs estimated for 200,000km (emissions system only)
- Line 9 based on known effect of individual emissions reduction measures
- Line 10 based on averaged fuel economy results

Data Comparison & Discussion
Diesel costs now rise above Gasoline post TWC introduction

- Plot indicates how assumptions requested have changed the on-cost of emissions technologies for Diesel cars