EU vehicle technology study: Development of preliminary cost curves for the EU market

Peter Mock
April 27, 2012
Brussels
## Agenda

1. Methodology for developing the curves
2. Preliminary results
3. Conclusions and outlook
Methodology
The ICCT approach

- EU vehicle market statistics (ICCT, Ökopol)
- Vehicle technology cost analysis (FEV / University Aachen)
- Vehicle CO₂ reduction potential simulation (Ricardo)

**Phase I**

**Phase II**

**Calculating effects for society (macro level)** (ICCT, tbd)

Accompanying workshops, briefings and publications
Methodology

Data sources

- FEV cost analysis on behalf of ICCT
- Ricardo CO₂ reduction potential analysis on behalf of ICCT
- EPA / NHTSA 2017-25 proposed rulemaking

EU cost curves

only where no EU information available
## Methodology

### The baseline vehicles

<table>
<thead>
<tr>
<th></th>
<th>Gasoline</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ricardo</td>
<td>EU-27</td>
</tr>
<tr>
<td>Vehicle model</td>
<td>Ford Focus</td>
<td>n/a</td>
</tr>
<tr>
<td>Engine size</td>
<td>4 cyl., 1.6 l</td>
<td>4 cyl., 1.6 l</td>
</tr>
<tr>
<td>Engine power</td>
<td>88 kW</td>
<td>86 kW</td>
</tr>
<tr>
<td>Engine type</td>
<td>PFI</td>
<td>PFI (MS DI≈19%)</td>
</tr>
<tr>
<td>Vehicle weight</td>
<td>1,257 kg</td>
<td>1,270 kg</td>
</tr>
<tr>
<td>Transmission</td>
<td>6-MT</td>
<td>MT (MS≈91%)*</td>
</tr>
<tr>
<td>Acceleration 0-100 km/h</td>
<td>---</td>
<td>11.3 s</td>
</tr>
<tr>
<td>CO₂ in NEDC</td>
<td>139 g/km</td>
<td>156 g/km</td>
</tr>
<tr>
<td>Remarks</td>
<td>Start-Stop/Reg. Euro 5 eq.</td>
<td>no Start-Stop Euro 4 (MS≈60%)</td>
</tr>
</tbody>
</table>

Ricardo simulations baseline vehicle vs. EU-27 average new vehicle in 2010

Abbreviations: PFI (port fuel injection), DFI (direct fuel injection), MS (market share), AT (automatic transmission), MT (manual transmission), vehicle weight is given in mass in running order (includes 68 kg driver and 7 kg of luggage)

* MS 5-MT: 49%, 6-MT: 42%
Methodology
Arriving at the starting point

- **Ricardo baseline vehicles include start-stop and improved alternator**
  - Factoring out alternator efficiency improvement (55% vs. 70%) → ≈ -3% effect
  - Factoring out effect of start-stop system, taking into account idling times in European driving cycle → ≈ -10% effect

- **Ricardo baseline vehicles include automatic transmissions in some cases**
  - For all EU segments: manual transmission as starting point
  - E.g. going from A6 to M6 → ≈ 4% effect
Methodology

Plotting technology packages

- C-segment gasoline
Methodology

Plotting technology packages

- C-segment gasoline
Methodology

Plotting technology packages

- C-segment gasoline

<table>
<thead>
<tr>
<th>Technology Package</th>
<th>Additional Direct Manufacturing Costs [EUR]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray-guided DI</td>
<td>+106 EUR</td>
</tr>
<tr>
<td>Turbo (two stage series sequential)</td>
<td>+453 EUR</td>
</tr>
<tr>
<td>Downsizing</td>
<td>-150 EUR</td>
</tr>
<tr>
<td>Gasoline particulate filter</td>
<td>+50 EUR</td>
</tr>
<tr>
<td>8DDCT instead of M5</td>
<td>+329 EUR</td>
</tr>
<tr>
<td>TOTAL</td>
<td>+1540 EUR</td>
</tr>
</tbody>
</table>

**CO₂ reduction relative to 2010 baseline**

- SS, 1.6l, M5, 136 g/km, 5.6 l
- SS+CEGR, 0.8l, 8DCT, 93 g/km, 3.8 l
- P2 AtkCPS, 1.8l, 77 g/km, 3.1 l
- SS+SGTDi, 0.7l, 8DCT, 97 g/km, 4.0 l
- P2 AtkCPS, 1.2l, 8DCT, -27% mass, -20% RL, 58 g/km, 2.4 l
- P2 AtkCPS, 1.8l, 8DCT, -13% mass, -10% RL, 66 g/km, 2.7 l
- SS+SGTDi, 0.8l, 8DCT, -27% mass, -20% RL, 74 g/km, 3.0 l
- SS+SGTDi, 0.8l, 8DCT, 97 g/km, 4.0 l
- SS+CEGR, 0.8l, 8DCT, 93 g/km, 3.8 l
- SS, 1.6l, M5, 136 g/km, 5.6 l
- P2 AtkCPS, 1.2l, 8DCT, -27% mass, -20% RL, 58 g/km, 2.4 l
- P2 AtkCPS, 1.8l, 8DCT, -13% mass, -10% RL, 66 g/km, 2.7 l
- SS+SGTDi, 0.8l, 8DCT, -27% mass, -20% RL, 74 g/km, 3.0 l
- SS+CEGR, 0.8l, 8DCT, 93 g/km, 3.8 l
- SS, 1.6l, M5, 136 g/km, 5.6 l
Methodology

Fitting the cost curves

- C-segment gasoline
Methodology

2015 curve for illustrating purposes

- C-segment gasoline
Methodology

The final result

- **C-segment gasoline**

![Graph showing CO₂ reduction relative to 2010 baseline and additional direct manufacturing costs (EUR) relative to 2010 baseline. The graph includes data points for different vehicle specifications and their corresponding CO₂ emissions and fuel consumption.](image-url)
Agenda

1. Methodology for developing the curves
2. Preliminary results
3. Conclusions and outlook
Preliminary results

C-segment cost curve

- C-segment gasoline
Preliminary results
Comparison with vehicles on the market

- **C-segment gasoline**

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ford Focus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6L, 4 cyl., 74 kW</td>
<td>---</td>
<td>SS+SGTDI</td>
</tr>
<tr>
<td>1,175 kg</td>
<td>M5, 11.9 s</td>
<td>1,195 kg</td>
</tr>
<tr>
<td>159 g/km</td>
<td>-31%</td>
<td>109 g/km</td>
</tr>
<tr>
<td><strong>Ford Focus EcoBoost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0L, 3 cyl., 74 kW</td>
<td>SS+SGTDI</td>
<td>M5, 12.5 s</td>
</tr>
<tr>
<td>109 g/km</td>
<td></td>
<td>109 g/km</td>
</tr>
</tbody>
</table>

2010 vs 2012:
- Mass reduction: -31%
- Emission reduction: -15%

Data source for technical data: Automobil Revue
Preliminary results

Comparison with vehicles on the market

- C-segment gasoline

<table>
<thead>
<tr>
<th>Year</th>
<th>Car</th>
<th>Engine Size</th>
<th>Horsepower</th>
<th>Mass</th>
<th>Transmission</th>
<th>0-100km/s</th>
<th>CO₂</th>
<th>Fuel Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Audi A3</td>
<td>1.6L, 4 cyl., 75 kW</td>
<td>---</td>
<td>1,185 kg</td>
<td>M5, 11.8 s</td>
<td>162 g/km</td>
<td>-29%</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Audi A3</td>
<td>1.2L, 4 cyl., 77 kW</td>
<td>SS+SGTDI+7DCT</td>
<td>1,150 kg</td>
<td>7DCT, 10.4 s</td>
<td>116 g/km</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Data source for technical data: Automobil Revue*
Preliminary results

Comparison with vehicles on the market

- C-segment gasoline

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Engine Size</th>
<th>Engine Cylinders</th>
<th>Power (kW)</th>
<th>Weight (kg)</th>
<th>Transmission</th>
<th>Acceleration (s)</th>
<th>CO₂ Emissions (g/km)</th>
<th>Fuel Consumption (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2012</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toyota Prius</strong></td>
<td>1.8L, 4 cyl.</td>
<td>100 kW</td>
<td></td>
<td>1,370</td>
<td>CVT</td>
<td>10.4</td>
<td>89</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>HEV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P2 AtkCPS, 1.6L, 8DCT</strong></td>
<td>-27% mass, -10% RL</td>
<td></td>
<td>66</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P2 AtkCPS, 1.2L, 8DCT</strong></td>
<td>-27% mass, -20% RL</td>
<td></td>
<td>74</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P2 AtkCPS, 1.8L, 8DCT</strong></td>
<td>-27% mass, -20% RL</td>
<td></td>
<td>58</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data source for technical data: Automobil Revue
Preliminary results
Comparison with vehicles on the market

- C-segment gasoline

<table>
<thead>
<tr>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toyota Yaris</strong></td>
<td><strong>Toyota Yaris Hybrid</strong></td>
</tr>
<tr>
<td>1.8L, 4 cyl., 108 kW</td>
<td>1.5L, 4 cyl., 74 kW</td>
</tr>
<tr>
<td>---</td>
<td>HEV</td>
</tr>
<tr>
<td>1,140 kg</td>
<td>1,100 kg</td>
</tr>
<tr>
<td>164 g/km</td>
<td>79 g/km</td>
</tr>
</tbody>
</table>

**2012**

<table>
<thead>
<tr>
<th><strong>Toyota Prius</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8L, 4 cyl., 100 kW</td>
</tr>
<tr>
<td>HEV</td>
</tr>
<tr>
<td>1,370 kg</td>
</tr>
<tr>
<td>CVT, 10.4 s</td>
</tr>
<tr>
<td>89 g/km</td>
</tr>
</tbody>
</table>

P2 AtkCPS, 1.8l, 8DCT, -27% mass, -20% RL, 58 g/km, 2.4 l
P2 AtkCPS, 1.6l, 8DCT, -35% mass, -10% RL, 68 g/km, 2.7 l
P2 AtkCPS, 1.5l, 8DCT, 77 g/km, 3.1 l
P2 AtkCPS, 0.7l, 8DCT, 27% mass, -20% RL, 74 g/km, 3.0 l
SS+SGTdi, 0.8l, 8DCT, 93 g/km, 3.8 l
SS+SGTdi, 0.8l, 8DCT, 97 g/km, 4.0 l

B-segment hybrid example:

<table>
<thead>
<tr>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toyota Yaris</strong></td>
<td><strong>Toyota Yaris Hybrid</strong></td>
</tr>
<tr>
<td>1.8L, 4 cyl., 108 kW</td>
<td>1.5L, 4 cyl., 74 kW</td>
</tr>
<tr>
<td>---</td>
<td>HEV</td>
</tr>
<tr>
<td>1,140 kg</td>
<td>1,100 kg</td>
</tr>
<tr>
<td>164 g/km</td>
<td>79 g/km</td>
</tr>
</tbody>
</table>

Data source for technical data: Automobil Revue
Preliminary results

C-segment cost curve

- C-segment diesel

![Graph showing additional direct manufacturing costs and CO2 reduction relative to 2010 baseline.]

- Baseline: 1.7l, M5, 131 g/km, 4.9 l
- SS: 1.7l, M5, 111 g/km, 4.2 l
- SS+AdvDie: 1.3l, 8DCT, 90 g/km, 3.4 l
- SS+AdvDie P2: 1.4l, 8DCT, 74 g/km, 2.8 l
- SS+AdvDie: 1.2l, 8DCT, -13% mass, -10% RL, 78 g/km, 3.0 l
- SS+AdvDie P2: 1.2l, 8DCT, -13% mass, -10% RL, 64 g/km, 2.4 l
- SS+AdvDie: 1.0l, 8DCT, -27% mass, -20% RL, 68 g/km, 2.5 l
- SS+AdvDie P2: 1.0l, 8DCT, -27% mass, -20% RL, 55 g/km, 2.1 l
Preliminary results

Comparison with vehicles on the market

- C-segment diesel

### 2010 vs 2012

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Engine</th>
<th>Power</th>
<th>Mass</th>
<th>Acceleration</th>
<th>CO2</th>
<th>Fuel Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Audi A3</td>
<td>1.6L, 4 cyl., 66 kW</td>
<td>1,280 kg</td>
<td>M5, 12.9 s</td>
<td>114 g/km</td>
<td>95 g/km (3.9 l/100km)</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Audi A3</td>
<td>1.6L, 4 cyl., 77 kW</td>
<td>1,225 kg</td>
<td>M5, 11.4 s</td>
<td>99 g/km</td>
<td>80 g/km (3.3 l/100km)</td>
<td></td>
</tr>
</tbody>
</table>

**CO2 reduction relative to 2010 baseline:** -14%

Data source for technical data: Automobil Revue
Preliminary results
Comparison with vehicles on the market

- C-segment diesel

B-segment example:

<table>
<thead>
<tr>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ford Fiesta</strong></td>
<td><strong>Ford Fiesta Econetic</strong></td>
</tr>
<tr>
<td>1.6L, 4 cyl., 70 kW</td>
<td>1.6L, 4 cyl., 70 kW</td>
</tr>
<tr>
<td>---</td>
<td>SS+low RR tires+…</td>
</tr>
<tr>
<td>M5, 11.8 s</td>
<td>M5, 12.9 s</td>
</tr>
<tr>
<td>107 g/km</td>
<td>87 g/km</td>
</tr>
</tbody>
</table>

-19%

2010 data source: Automobil Revue

2012 data source: Ford Fiesta Econetic

- 1.6L, 4 cyl., 70 kW
- SS+low RR tires+
- M5, 11.8 s
- 107 g/km

Additional direct manufacturing costs [EUR] relative to 2010 baseline

Additional direct manufacturing costs [EUR] relative to 2010 baseline

CO₂ reduction relative to 2010 baseline

Data source for technical data: Automobil Revue
Preliminary results

Comparison with vehicles on the market

- C-segment diesel

<table>
<thead>
<tr>
<th>Year</th>
<th>Peugeot 3008</th>
<th>Peugeot 3008 Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>2.0L, 4 cyl., 120 kW</td>
<td>1.7L, 4 cyl., 120 kW</td>
</tr>
<tr>
<td></td>
<td>1,540 kg</td>
<td>1,735 kg</td>
</tr>
<tr>
<td></td>
<td>A6, 10.2 s</td>
<td>A6, 8.5 s</td>
</tr>
<tr>
<td></td>
<td>173 g/km</td>
<td>99 g/km</td>
</tr>
</tbody>
</table>

Data source for technical data: Automobil Revue
Preliminary results

**D-segment cost curve**

- **D-segment gasoline**
Preliminary results

D-segment cost curve

- D-segment diesel
Preliminary results

B-segment cost curve

- B-segment gasoline

Additional direct manufacturing costs [EUR] relative to 2010 baseline

CO₂ reduction relative to 2010 baseline

25
Preliminary results

B-segment cost curve

- B-segment diesel
Preliminary results
All vehicle segments

- From a 2020 perspective
Preliminary results
All vehicle segments

- From a 2025 perspective
Agenda

1. Methodology for developing the curves
2. Preliminary results
3. Conclusions and outlook
Conclusions and outlook

Main conclusions

- Based on preliminary EU cost curves
  - Technologies to meet 95 g/km target are already in the market
  - For average market, 95 g/km can be met by making use of improved combustion engines
  - Going beyond 70-80 g/km will require some lightweighting and / or hybrid electric technology
  - Additional manufacturing costs:
    - for meeting 95 g/km in 2020 ≈ 1,000 EUR
    - for meeting 70 g/km in 2025 ≈ 2,200 EUR
  - Technology requirements and costs may be different for individual manufacturers
  - Payback period from consumer perspective: ≈ 3 years for 95 g/km
Conclusions and outlook

Outlook

- **Additional results to come soon**
  - Cost curves for N1 (vans) vehicles
  - New lightweighting cost results from FEV

- **Next steps**
  - Summarizing report on methodology and results
  - Macro-economic modeling
Contact details

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