Cost Effectiveness of Technology Solutions for Future Vehicle Systems

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Reducing CO2 Footprint

- Two ways to reduce the CO2 footprint of vehicle systems
  - Efficiency Improvement
  - Alternative Fuels
- Hypothesis: Efficiency improvements always make sense and should receive the highest priority. Alternative fuels are limited by supply issues and may not always make sense.
Basic Question

What are the economic costs or benefits for CO2 control through vehicle efficiency improvements?

Can the customer save money while preserving the atmosphere?
Cost Benefit of CO2 Reduction

Scope

- Information derived from ARB funded NESCCAF study, June 2004 (California)
  - Retail price & cost increase
  - CO2 savings
  - Customer Net cost effect

- SwRI study, 2008
  - Cost differences, in-house cost model
  - European Scenario
  - Update of Net cost for 2008 fuel prices
Methodology

- **Individual Technology Identification**
- **Technology Grouping**
- **Vehicle Performance Checks**
- **Price & Costing**
- **Cost/Benefit**
- **Net Cost**
- **Net Cost per avoided CO2**
- **Payback Period**

**Correlation of US M-H combined & NEDC fuel consumptions**

**Drive Cycle CO2**

- 120g/km CO2 NEDC
  - 0.06g/km/kg (2000kg ITW)
- 120g/km CO2 NEDC
  - 0.086g/km/kg (1400kg ITW)

**Incremental Cost and RPI for Technology (Euro/US car vs 2004 baseline)**

- 3.35 Euro/L (8.33$/USG)

**INTERACTING TECHNOLOGIES**

- Multi Point Fuel Injection (Y)
- A/1 Aftertreatment (Y)
- Cam Phaser (In) (Y)
- Cam Phaser (Ex) (Y)
- Cam Phaser (Dual) (Y)
- Cam Phaser (Coupled) (Y)
- Variable Lift-Discrete (Y)
- Variable Lift-Continuous (Y)
- Camless-Electrohydraulic (Y)
- Turbocharging (Y)
- Elect. Assist turbo (EAT) (Y)
- Cylinder de-activation (Y)
- Variable Charge Motion (Y)
- GDI-A/1 (Y)
- GDI-Dilute (Y)
- SI HCCI (Y)
- CI HSDI (N)
- CI HCCI/multimode (N)
- HEDGE (N)

**Figure 4-1: Schematic of GM-DCC**

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**Incremental Cost and RPI for Technology (Euro/US car vs 2004 baseline)**

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Derived Information from ARB Study

**Key Aspects**

- ARB (NESCCAF) study used Martec to assess price variances for technologies; *updated by SwRI cost model*
- NESCCAF deduced manufacturing cost relationship to retail price; *updated with SwRI cost model*
- AVL performed US M-H drive cycle predictions for CO\(_2\) variances; *additional points added with correlated SwRI drive model, and transposition of M-H CO2 data to NEDC*
- Effects of individual and grouped technologies considered, but only “grouped” technologies pursued.
- Baseline is 2004MY
  - ~1600kg (curb weight) 3.2L V6, 4 speed auto with 345g/mile (215g/km) CO\(_2\)
  - ~1260kg (curb weight) 2.4L I4, 4 speed auto with 291g/mile (182g/km) CO\(_2\)
- Price & cost are projected for 2008 onwards
Predicted M-H CO2 Reduction vs $US Price & Cost Changes

Metro-Highway (M-H) CO2 reduction vs Cost & Retail Price Increase (RPI)
(derived from CARB Martec Study, June 2004; HSDI values 6% increased over Martec)

1259 kg Curb Weight
2.3L, Auto 4spd (2004) I4 base, 291 g/mile CO2 M-H

Engine Items only

Incremental Cost and RPI for Technology ($/US car vs 2004 baseline)
Predicted M-H CO2 Reduction vs Price & Cost Changes

Metro-Highway (M-H) CO2 reduction vs Cost & Retail Price Increase (RPI)
(derived from CARB Martec Study, June 2004)

- Manufactured oncost
- Retail Price Increase
- Ref. Oncost Threshold?
- Retail Price Threshold?

Non-Engine Items

- Manufactured oncost
- Retail Price Increase
- Ref. Oncost Threshold?
- Retail Price Threshold?

Non-Engine Items

- Variable A/C Comp.
- 6 spd auto manual
- CVT
- Elect. Accessories
- 6 spd auto
- 42V 10kW ISG + motor
- 42V 10kW ISG
- HSDI

1259 kg Curb Weight
2.3L, Auto 4spd (2004) I4 base,
182 g/km CO2 M-H 2002

Incremental Cost and RPI for Technology (Euro/US car vs 2002 baseline)
Predicted M-H CO2 Reduction vs Price & Cost Changes

Metro-Highway (M-H) CO2 reduction vs $US Cost & Retail Price Increase (RPI)
(derived from CARB Study, June 2004: HSDI values 14% higher than Martec)

1600 kg Curb Weight
3.2L V6, Auto 4 spd Base
345 g/mi CO2 M-H (2002)
Correlations

In order to transpose the previous data from the US Metro-Highway to NEDC, the following relationships are examined:

- US M-H vs NEDC fuel consumption correlation (as this is currently the most plentiful data for both markets)
- Fuel consumption vs CO2 correlation
Correlation of Metro-Highway & NEDC Fuel Consumptions

(Certification Data, ~30 vehicles with common USA & Europe specs.)
Cost of Ownership Assumptions

- 10 Years
- 240,000 km
- 5% inflation rate
Net Cost Savings for Customer

Comparison of NESCCAF and SwRI Net Cost to Customer over 10 years, including 5% inflation/year

- Negative "Cost" is net customer lifetime saving (240,000km)
- 130g/km European level (NEDC)
- 0.35 Euro/L (2$/USG)

CO2 Levels with technology improvements (g/km)
Net Cost Savings for Customer

Net costs calculated by NESCCAF method for Euro 0.35-1.05/L fuel costs, adjusted for inflation.

0.35 Euro/L (2$/USG)
0.45 Euro/L (2.58$/USG)
0.7 Euro/L (4$/USG)
1.05 Euro/L (6$/USG)

Negative "Cost" is net customer lifetime (240,000km) saving.

130g/km European level (NEDC)
Net Cost Savings for Customer

...and at current UK fuel prices...

Negative "Cost" is net customer lifetime (240,000km) saving

130g/km European level (NEDC)
Net Cost Savings for Customer

And the effect of only 160,000km use in 10 years

Assessed Net Lifetime Cost vs CO2 Levels from Grouped Technologies
(derived from NESCAFF GHG Study, Large Car data, M-H, baseline 215g/km CO2)

-12000.00
-10000.00
-8000.00
-6000.00
-4000.00
-2000.00
0.00
90 100 110 120 130 140 150 160 170 180 190 200
CO2 Levels with technology improvements (g/km)

-12000.00
-10000.00
-8000.00
-6000.00
-4000.00
-2000.00
0.00
90 100 110 120 130 140 150 160 170 180 190 200
Net Lifetime costs (Euro)

1.58 Euro/L (8.83$/USG)

130g/km European level (NEDC)

240,000km/ 10 years

160,000km/ 10 years

Negative “Cost” is net customer lifetime saving

...And the effect of only 160,000km use in 10 years
Net Cost/ton avoided CO2 vs vehicle CO2 levels

At current prices, European customers will personally save > Euro 500 per tonne of CO2 avoided, at least to ~160g/km, the benefit reducing to ~Euro 450 at 120 g/km CO2.

Lifetime Net Cost per avoided Tonne CO2 per Customer vs CO2 Levels
(LARGE car, 240,000km)

- Negative CO2 "Cost/benefit" is customer saving per avoided CO2 tonne

- Net Cost/Benefit avoided Tonne CO2 (Euro/tonne)

- Large car M-H CO₂/km

- 0.7 Euro/L (4$/USG)

- 1.05 Euro/L (6$/USG)

- 1.58 Euro/L ($8.83/USG)

- 0.45 Euro/L (2.58$/USG)
Conclusions

- The net lifetime cost of CO2 reductions by added engine technology is *negative* for current and likely future fuel pricing, *i.e.* the customer benefits, *as well as the climate.*

- For current fuel prices in Europe, the cost savings for the customer is 7000EU at 130 g/km CO2
Thank you

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