

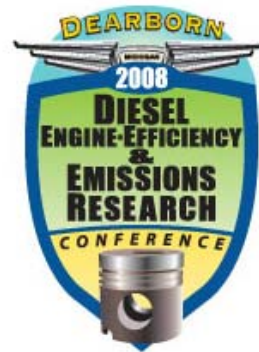
# Cost Effectiveness of Technology Solutions for Future Vehicle Systems

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**SAE** *International*

# Reducing CO2 Footprint

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- 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

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- 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

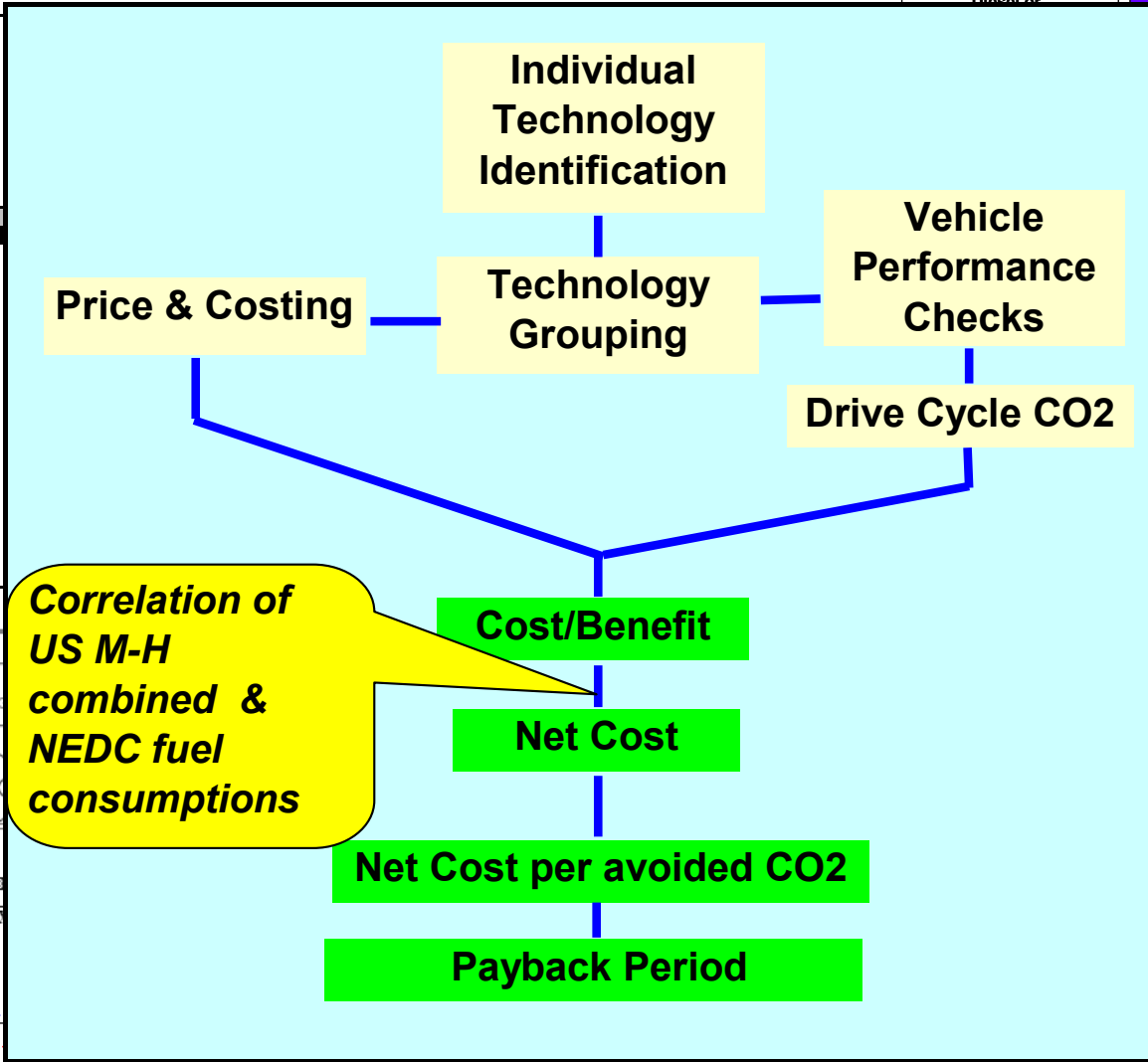
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## Scope

- 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

INTERACTING TECHNOLOGIES	Multi Point Fuel Injection
Multi Point Fuel Injection	Y
$\lambda=1$ 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- $\lambda=1$	Y
GDI-Dilute	Y
SI HCCI	Y
CI HSDI	N
CI HCCI/multimode	N
HEDGE	Y



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

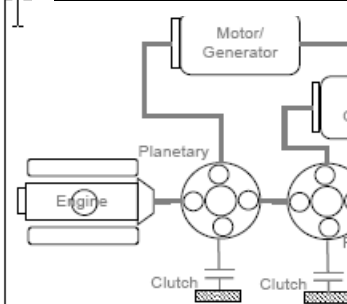
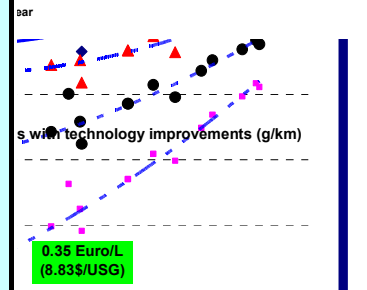
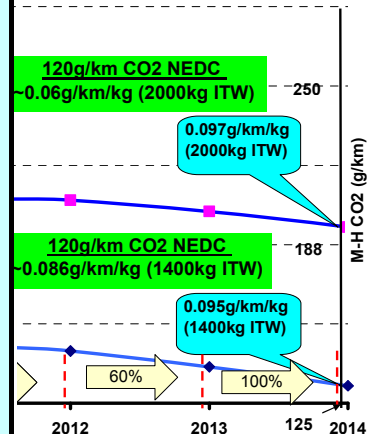
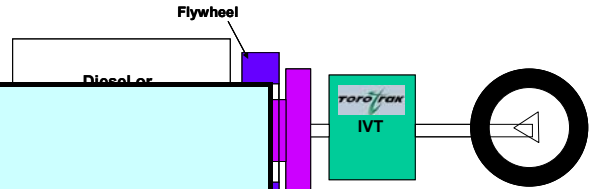
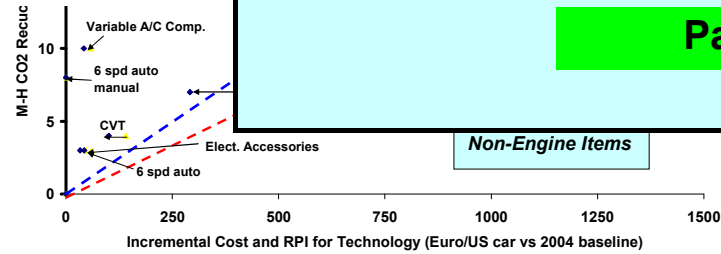


Figure 4-4: Schematic of GM-DCI



CO2 EMISSIONS (g/km) (NEDC)

CO2 EMISSIONS (g/km) (NEDC) are calculated based on the following assumptions: 1. A vehicle with a 1.8L engine and a manual transmission. 2. A vehicle with a 1.8L engine and a manual transmission. 3. A vehicle with a 1.8L engine and a manual transmission. 4. A vehicle with a 1.8L engine and a manual transmission. 5. A vehicle with a 1.8L engine and a manual transmission. 6. A vehicle with a 1.8L engine and a manual transmission. 7. A vehicle with a 1.8L engine and a manual transmission. 8. A vehicle with a 1.8L engine and a manual transmission. 9. A vehicle with a 1.8L engine and a manual transmission. 10. A vehicle with a 1.8L engine and a manual transmission. 11. A vehicle with a 1.8L engine and a manual transmission. 12. A vehicle with a 1.8L engine and a manual transmission. 13. A vehicle with a 1.8L engine and a manual transmission. 14. A vehicle with a 1.8L engine and a manual transmission. 15. A vehicle with a 1.8L engine and a manual transmission. 16. 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# Derived Information from ARB Study

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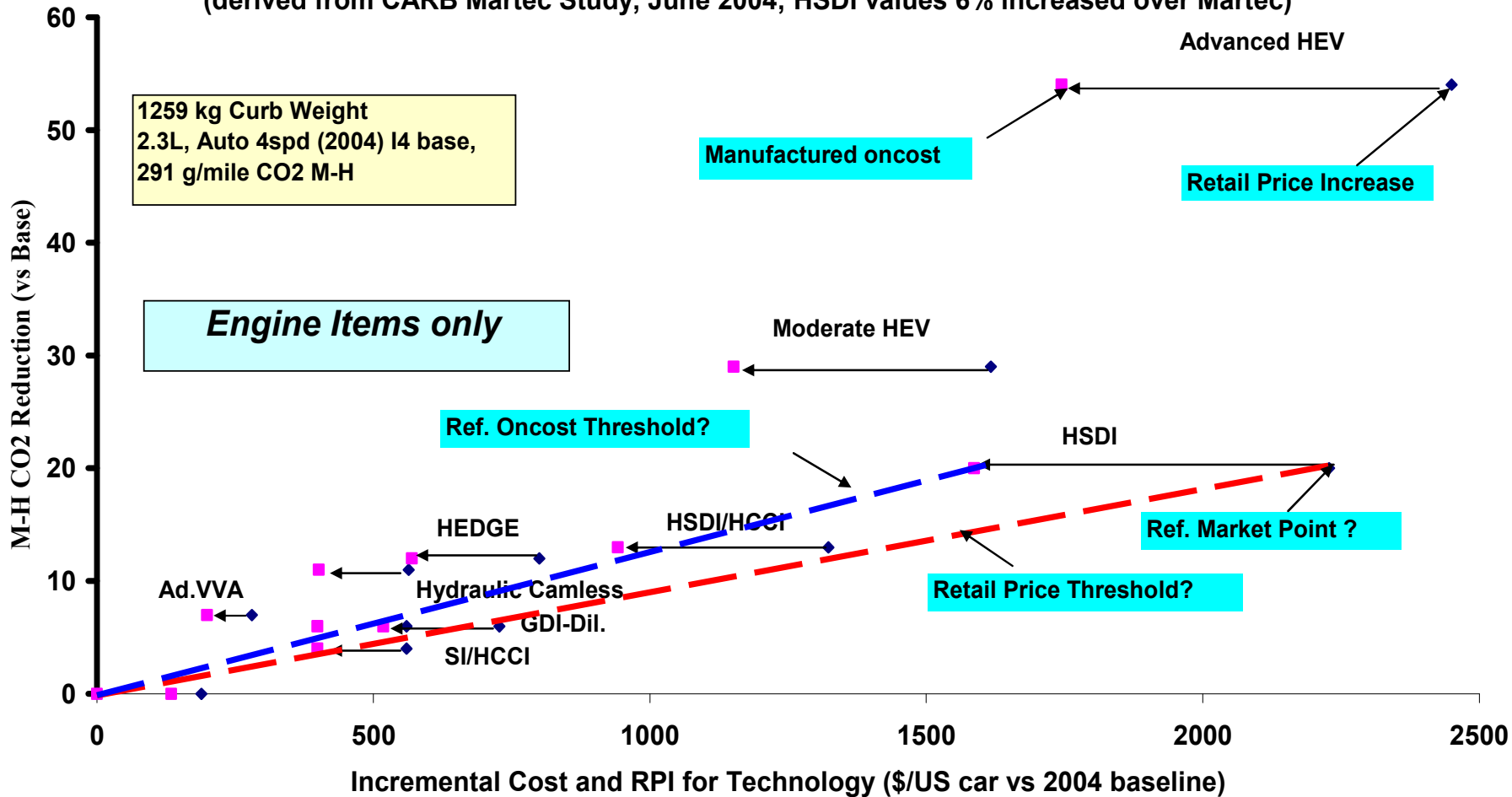
## Key Aspects

- 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<sub>2</sub> variances; *additional points added with correlated SwRI drive model, and transposition of M-H CO<sub>2</sub> 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<sub>2</sub>
  - ~1260kg (curb weight) 2.4L I4, 4 speed auto with 291g/mile (182g/km) CO<sub>2</sub>
- Price & cost are projected for 2008 onwards

# Predicted M-H CO2 Reduction vs \$US Price & Cost Changes

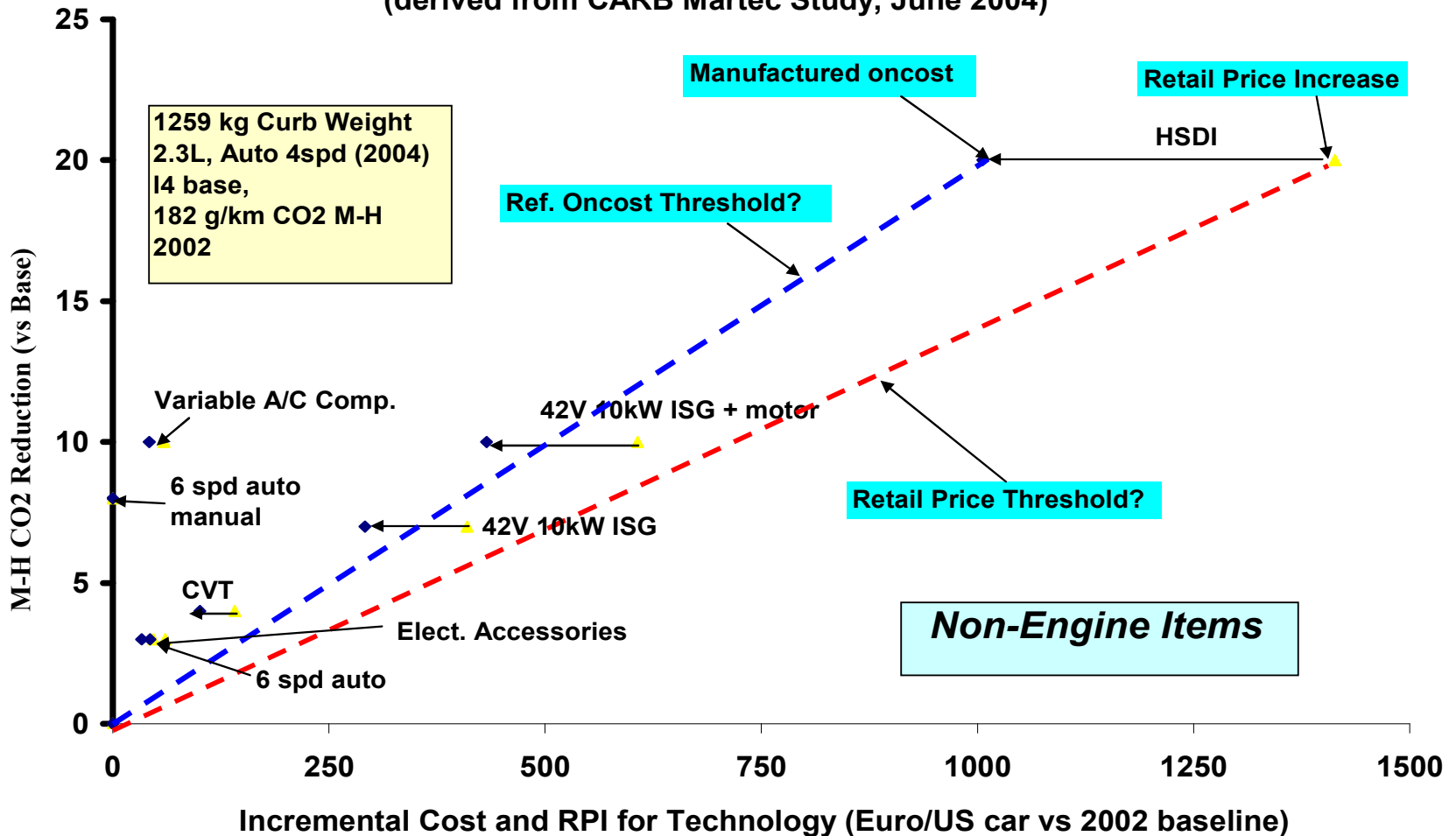
## Metro-Highway (M-H) CO2 reduction vs Cost & Retail Price Increase (RPI)

(derived from CARB Martec Study, June 2004; HSDI values 6% increased over Martec)



# Predicted M-H CO2 Reduction vs Price & Cost Changes

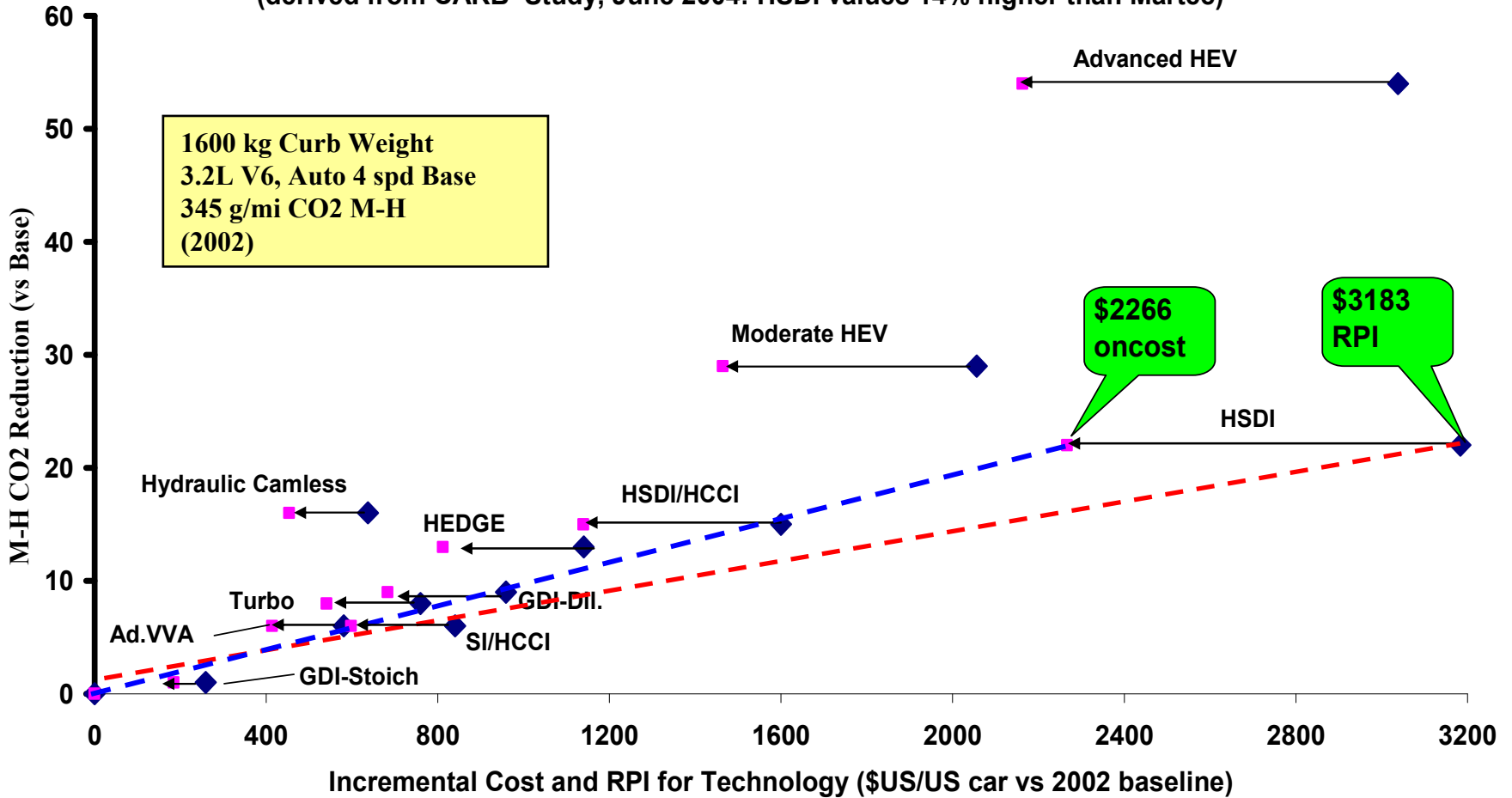
**Metro-Highway (M-H) CO2 reduction vs Cost & Retail Price Increase (RPI)**  
 (derived from CARB Martec Study, June 2004)





# 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)



# Correlations

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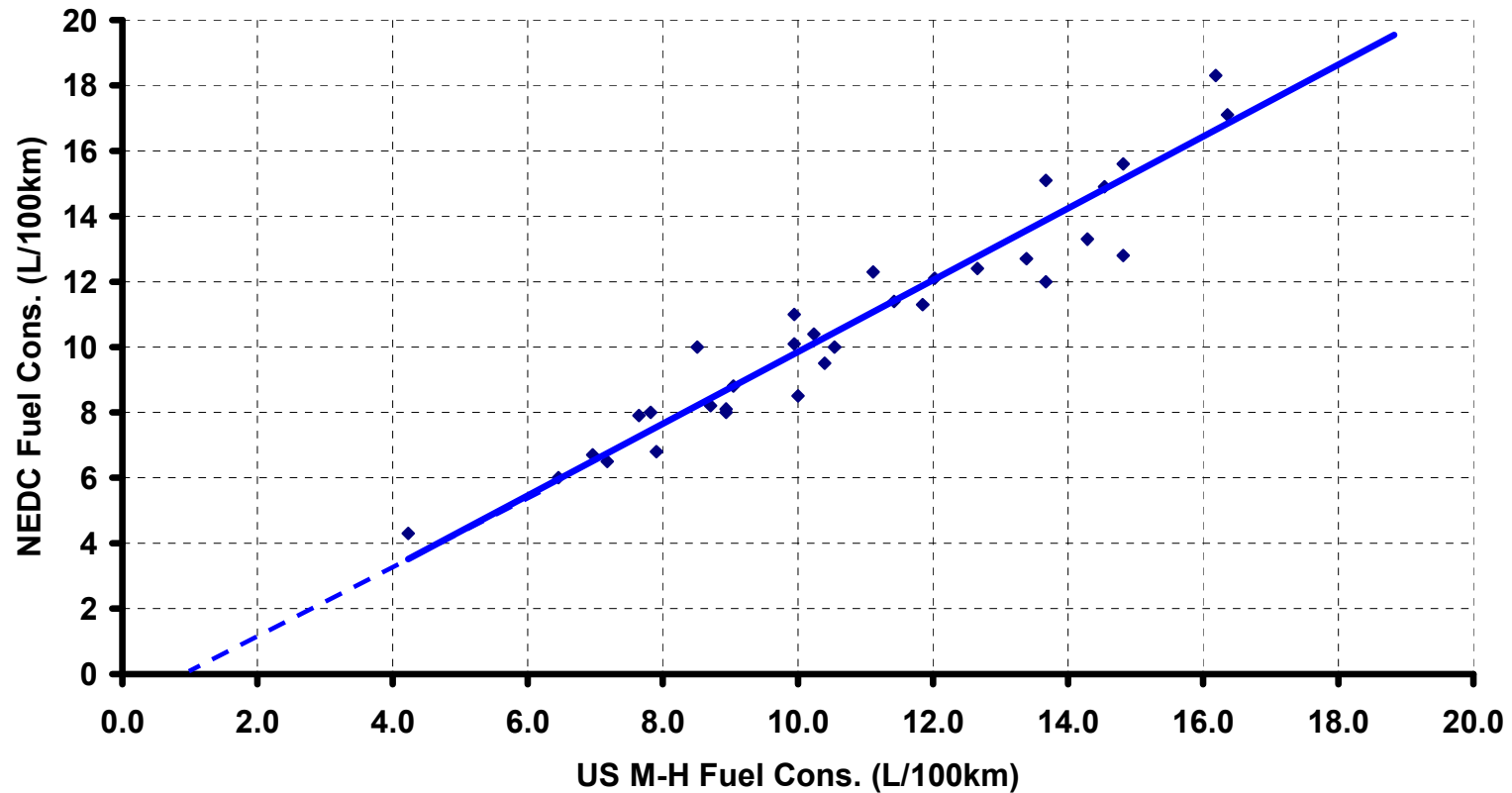
In order to transpose the previous data from the US Metro-Highway to NEDC, the following relationships are examined:

- US M-H vs NEDC fuel consumption correlation (as this is currently the most plentiful data for both markets)
- Fuel consumption vs CO<sub>2</sub> correlation

# Correlation of Metro-Highway & NEDC Fuel Consumptions

## 2007 US Metro-Highway & 2007 NEDC Fuel Consumption Comparisons

*(Certification Data, ~30 vehicles with common USA & Europe specs.)*



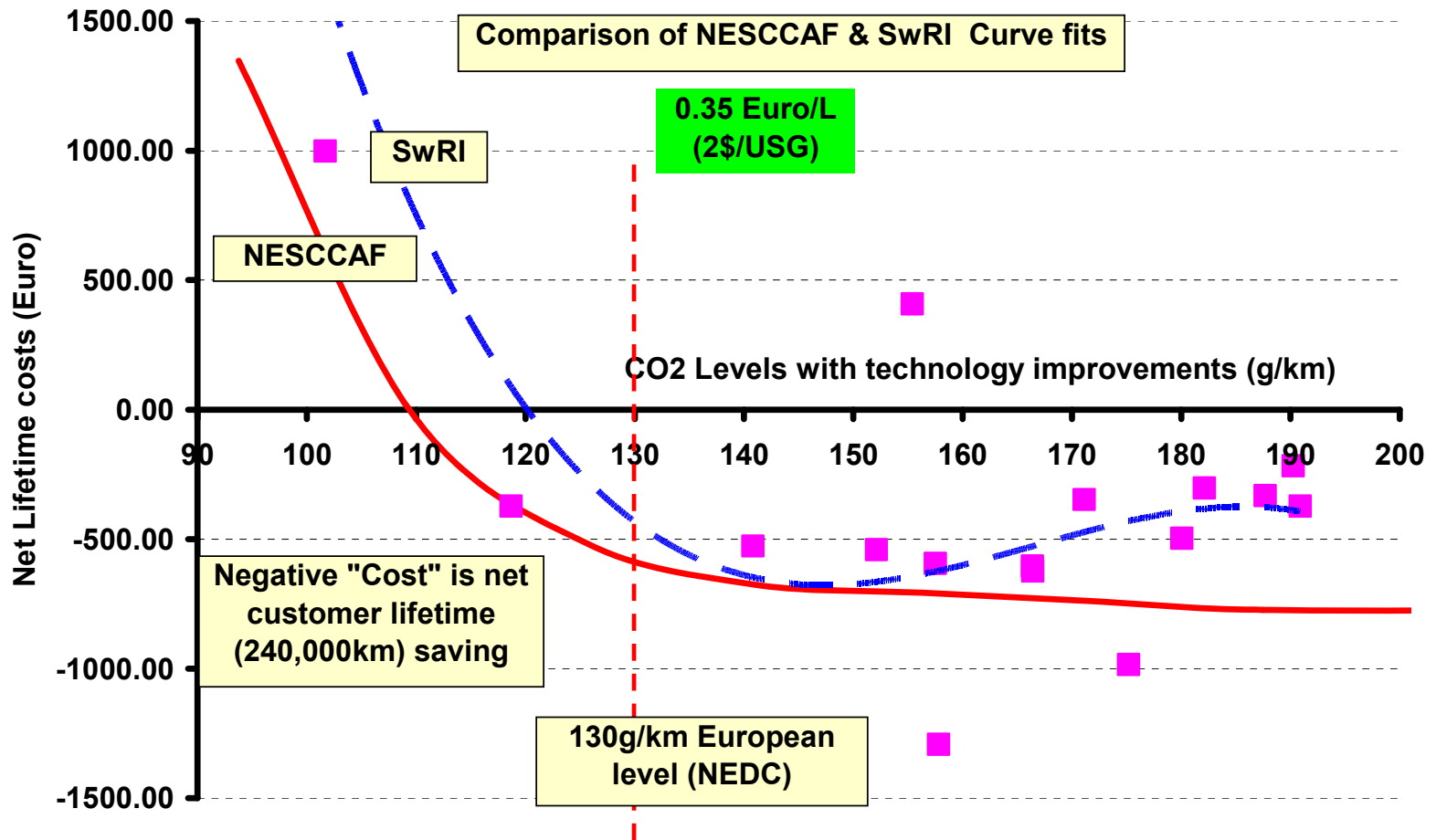
# Cost of Ownership Assumptions

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- 10 Years
- 240,000 km
- 5% inflation rate

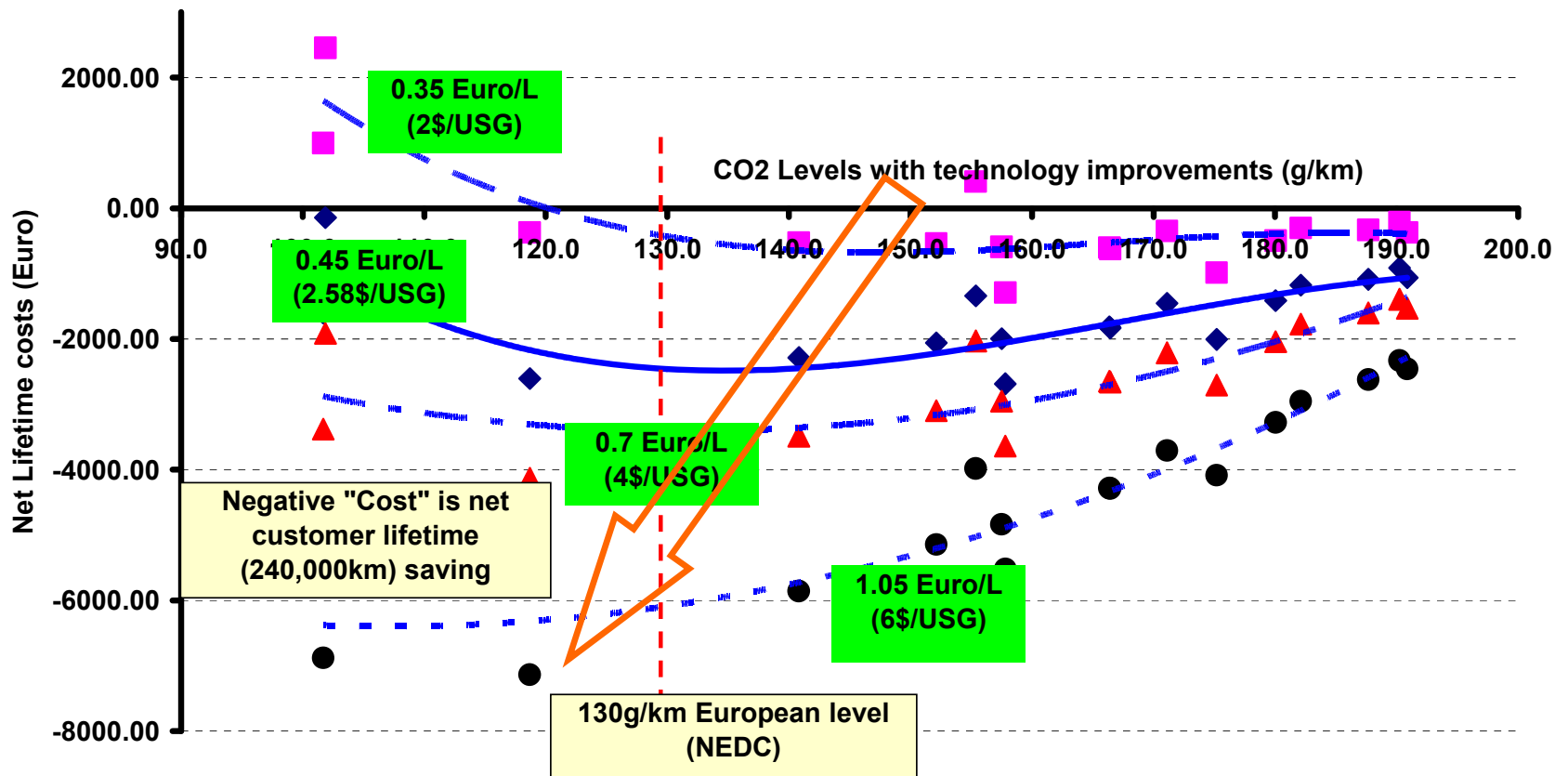
# Net Cost Savings for Customer

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

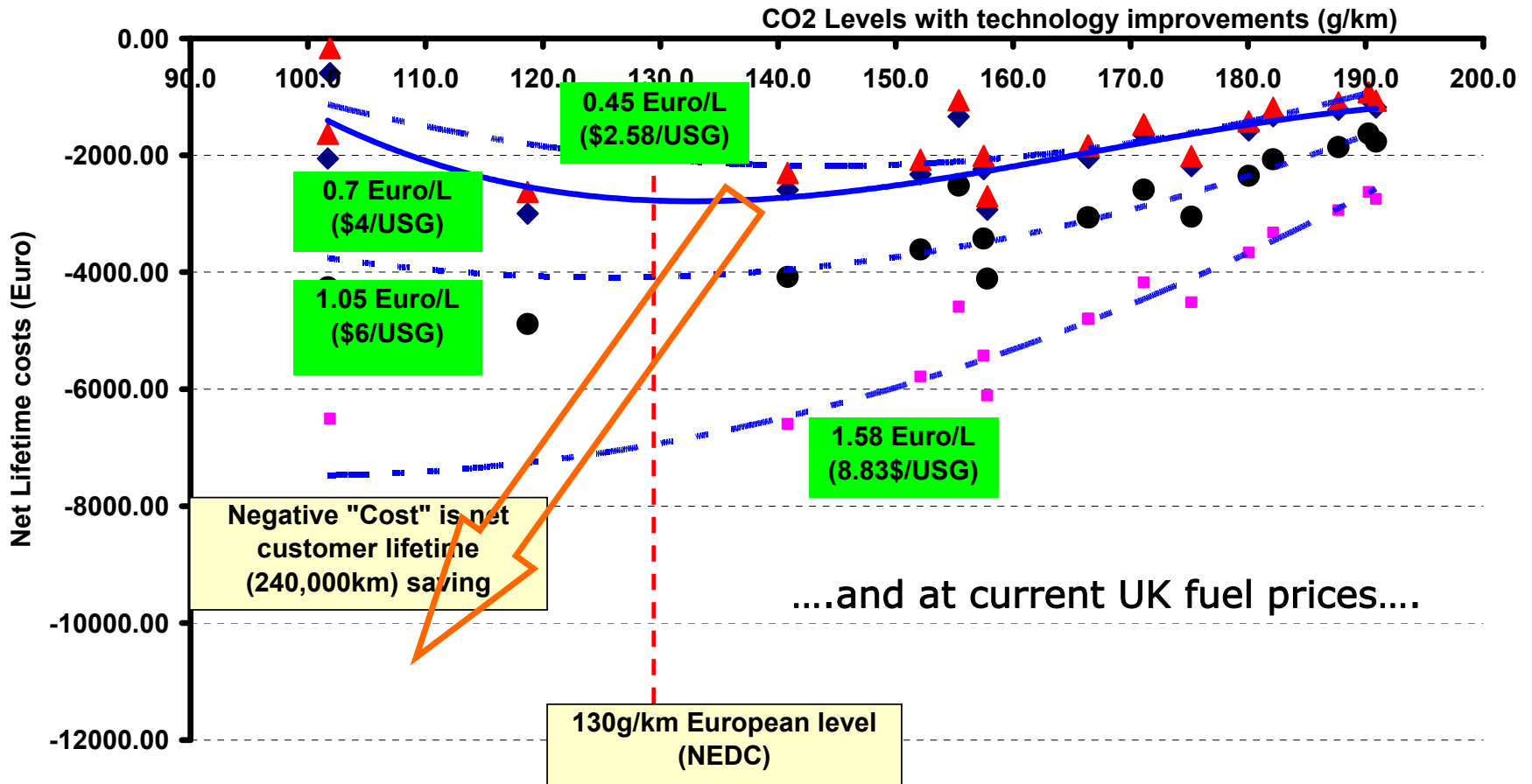


# Net Cost Savings for Customer

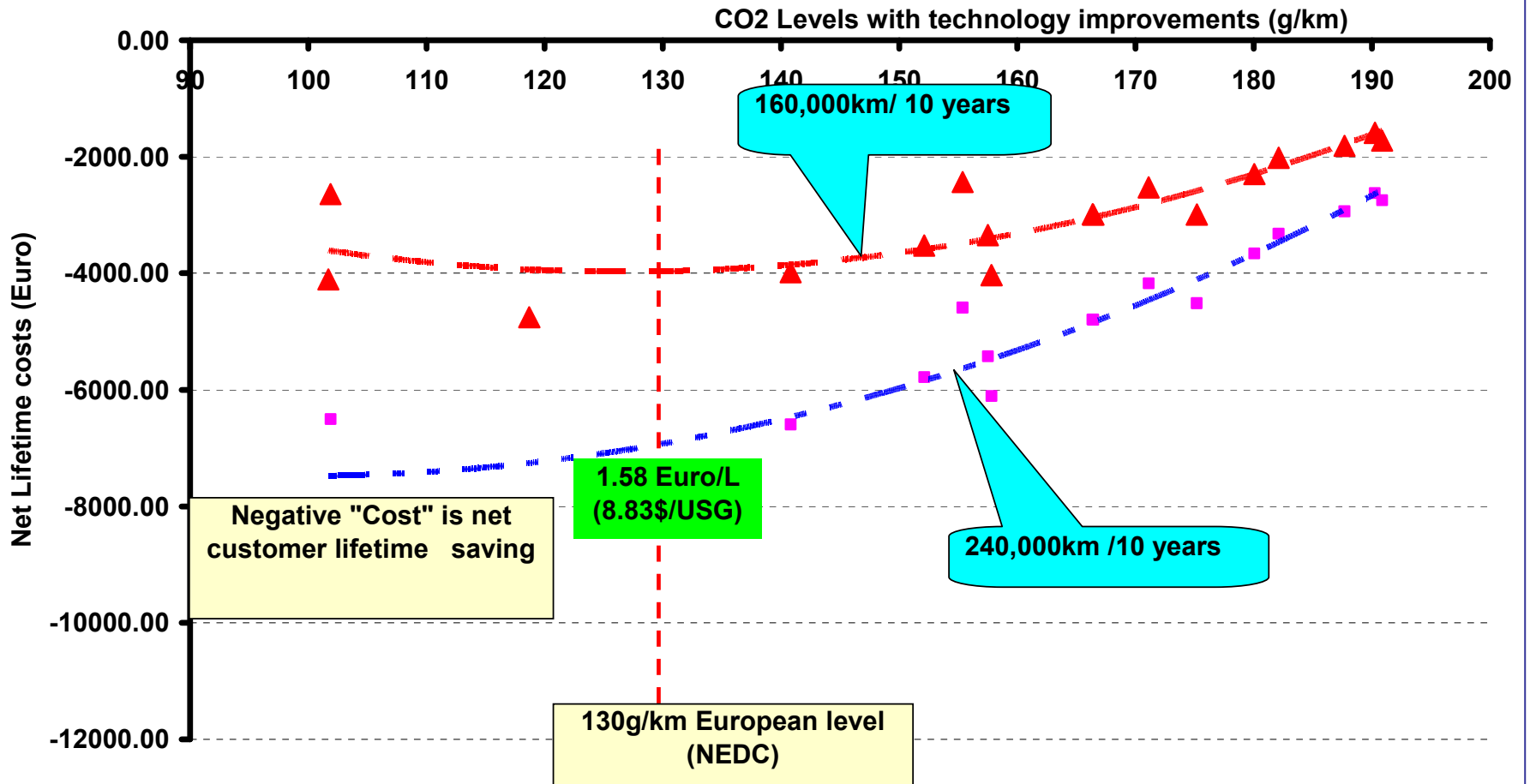
Net costs calculated by NESCCAF method for Euro 0.35-1.05/L fuel costs, adjusted for inflation



# Net Cost Savings for Customer



# Net Cost Savings for Customer

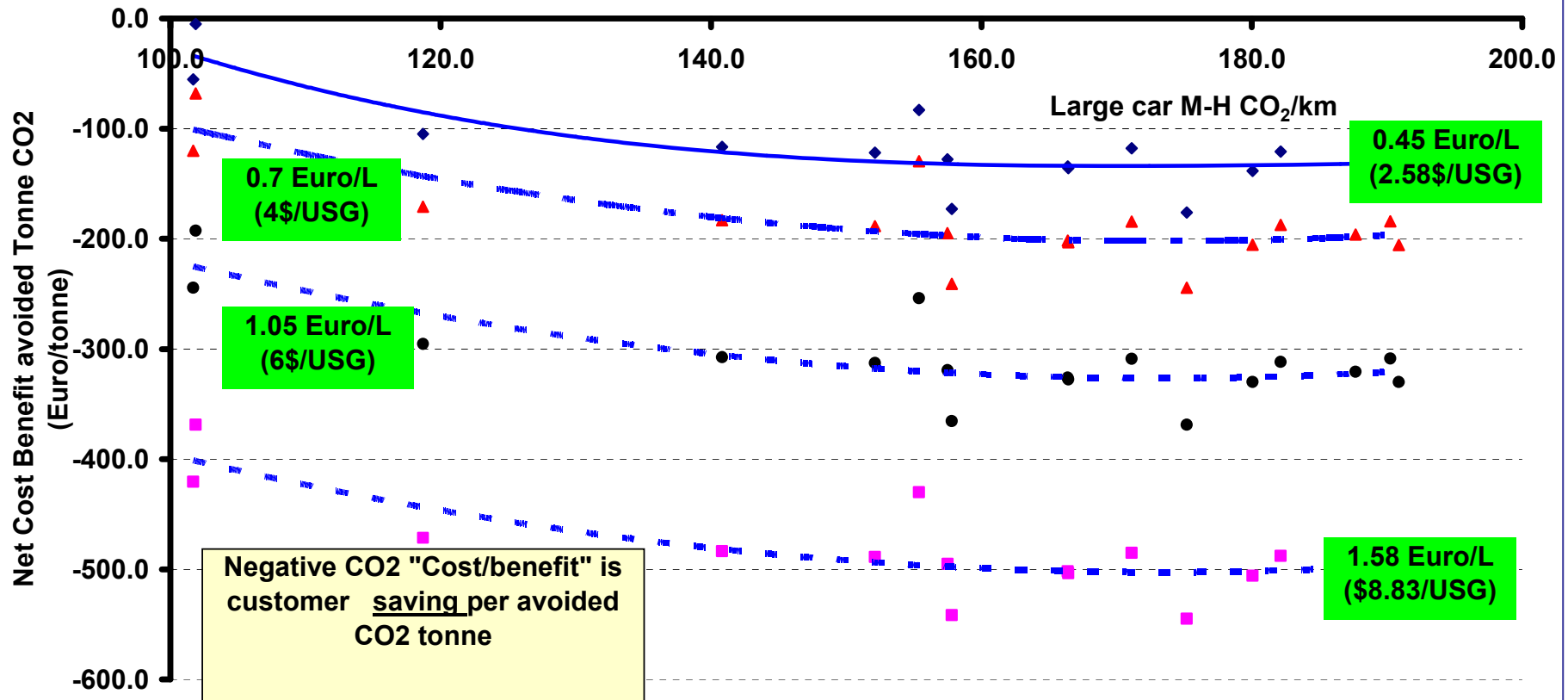


...And the effect of only 160,000km use in 10 years



# Net Cost/ton avoided CO2 vs vehicle CO2 levels

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



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

# Conclusions

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- The net lifetime cost of CO<sub>2</sub> 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 CO<sub>2</sub>

# Thank you

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