Powertrain Trends and Future Potential

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Sr. Vice President, Robert Bosch

Panel “New Directions in Engine and Fuels”
DEER Conference,
Dearborn, August 4, 2009

Automotive Technology

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Agenda

- **Global Trends – Fighting Global Warming**
- Future of Powertrain Systems –
  Efficient CO2 reduction @ reasonable costs
- Clean Diesel – Neglected in the U.S. for Too Long

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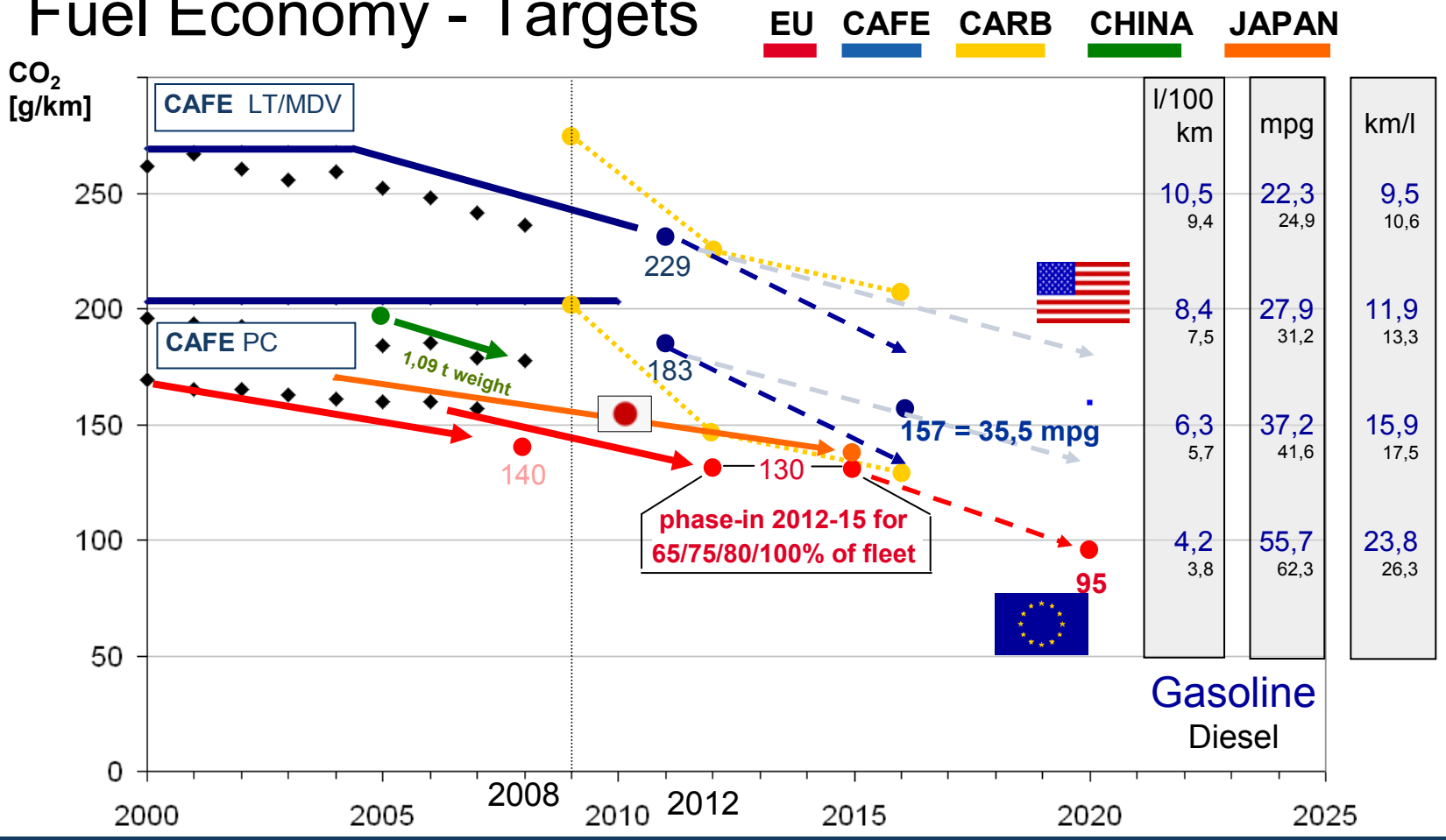
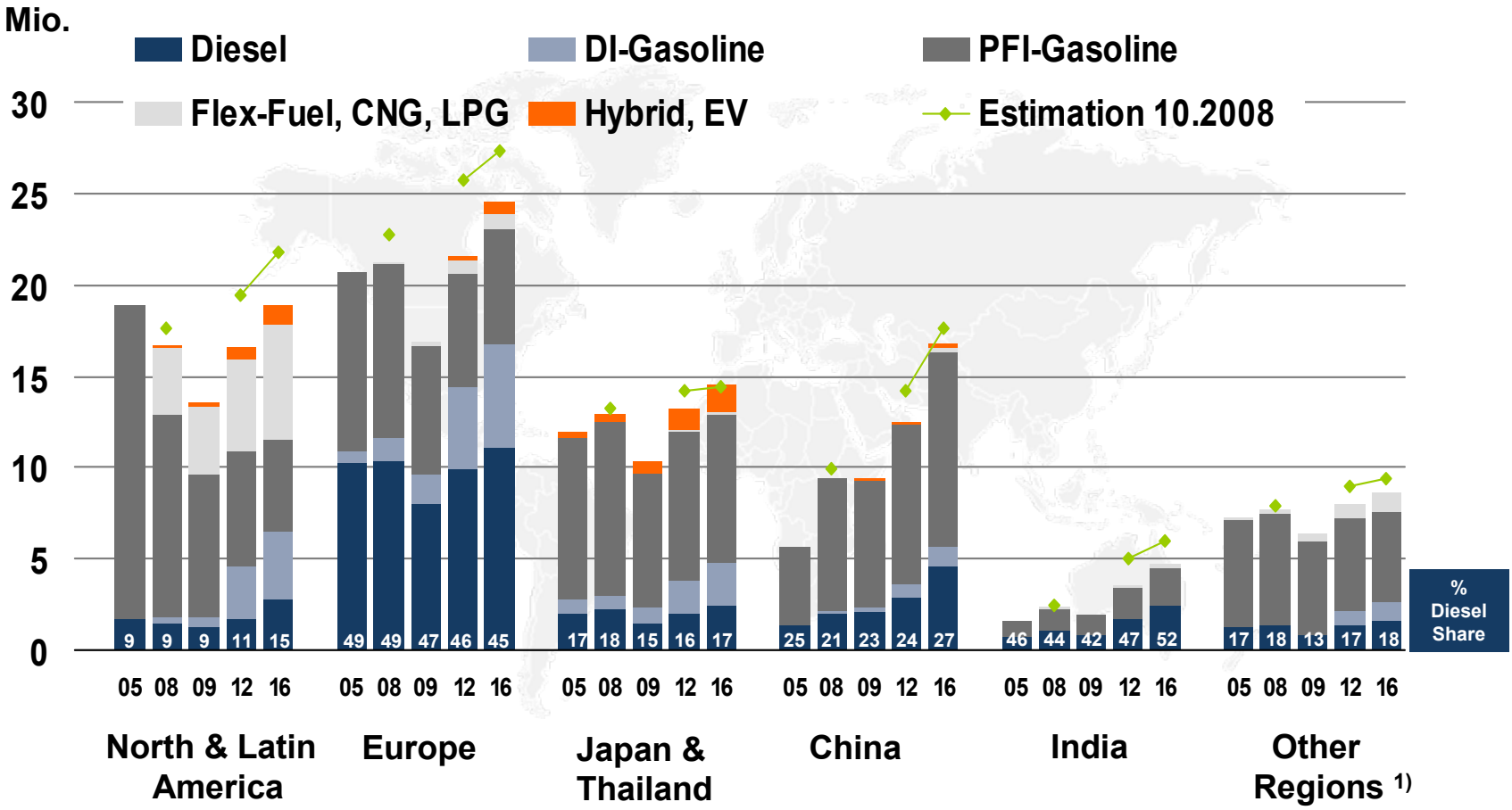
Fuel Economy - Targets



CO_2 emission reduction is a world-wide topic!

Production: Vehicles World by Region



Source: C/AS LTFC Cycle I 2009 Group View

* Other Regions = Australia, Africa and Asia w/o Japan, Thailand and China

Source: DS/MKS 9840144

DI-Gasoline = Direct Injection Gasoline; EV = Electric Vehicle;
CNG = Compressed Natural Gas; LPG = Liquified Petroleum Gas

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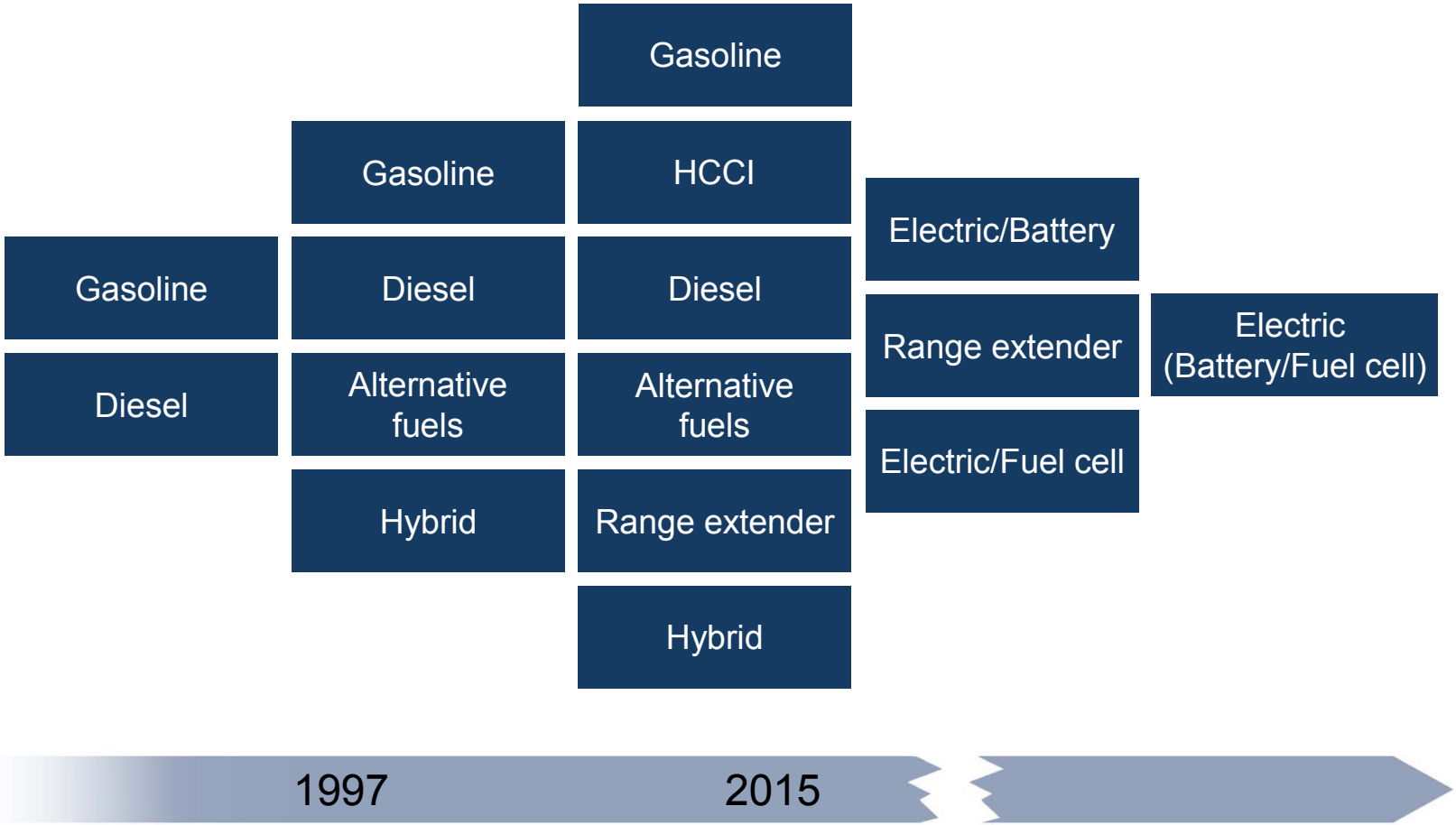
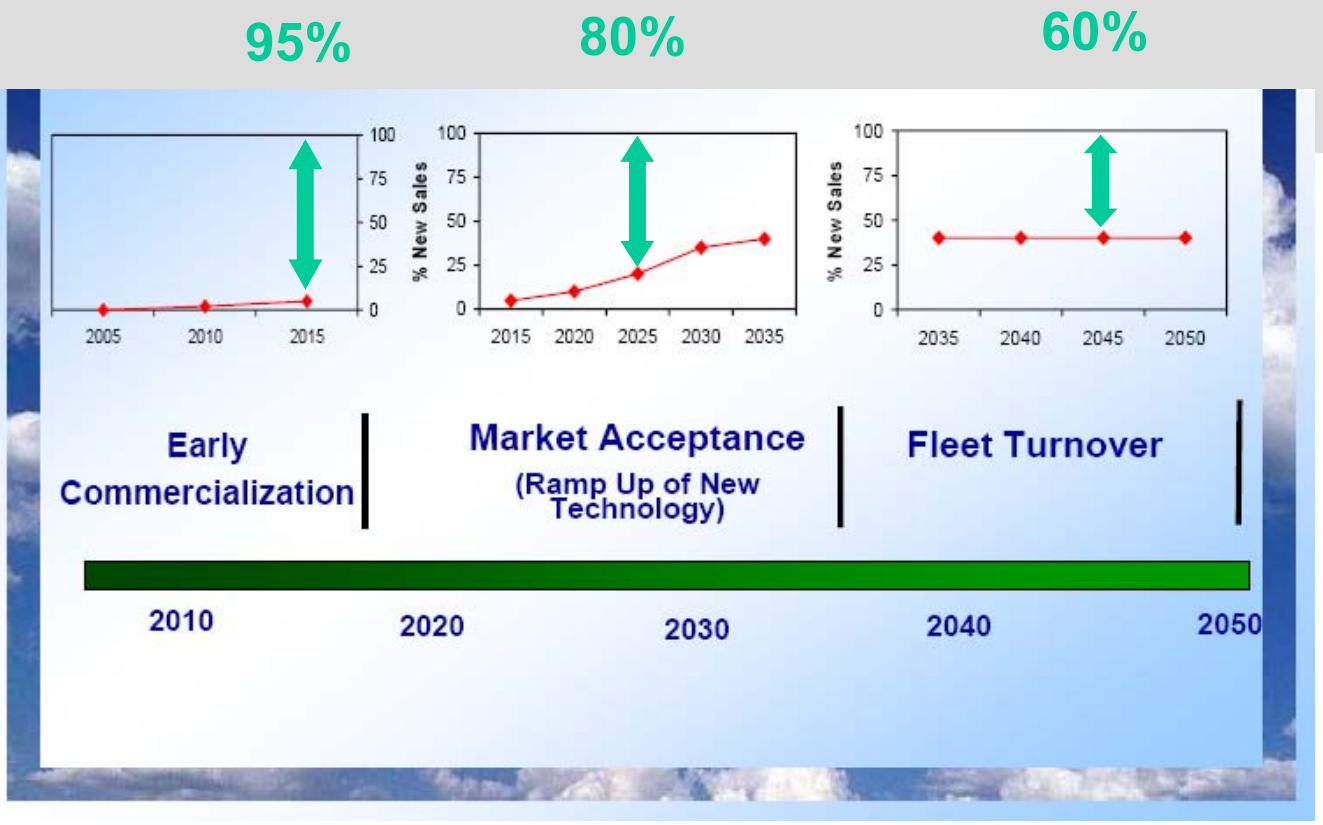
Powertrains for Passenger Cars – Timeline



CARB Scenario for the Introduction of Electric Cars

share of "conventional" technology



from: Cackette, California Air Resources Board, January 2009

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Efficient Emission Reduction

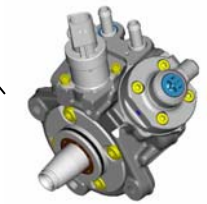
Reduction of Vehicle CO_2-Emissions

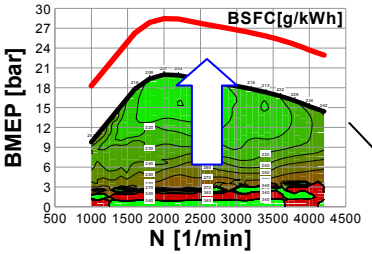
Direct: oCCS[1)]

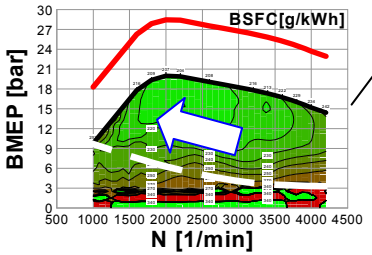
Low NO_x-Combustion as enabler

Indirect:

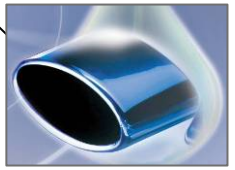
- **Hydraulic Efficiency**
- **Mechanic Efficiency**
- **Thermodynamic Efficiency**







- **Conventional Powertrain**
  - **Downsizing**
  - **Downspeeding**
  - **Optimized DeNOx**
- **Electrified Powertrain**



1) Optimized Conventional Combustion System

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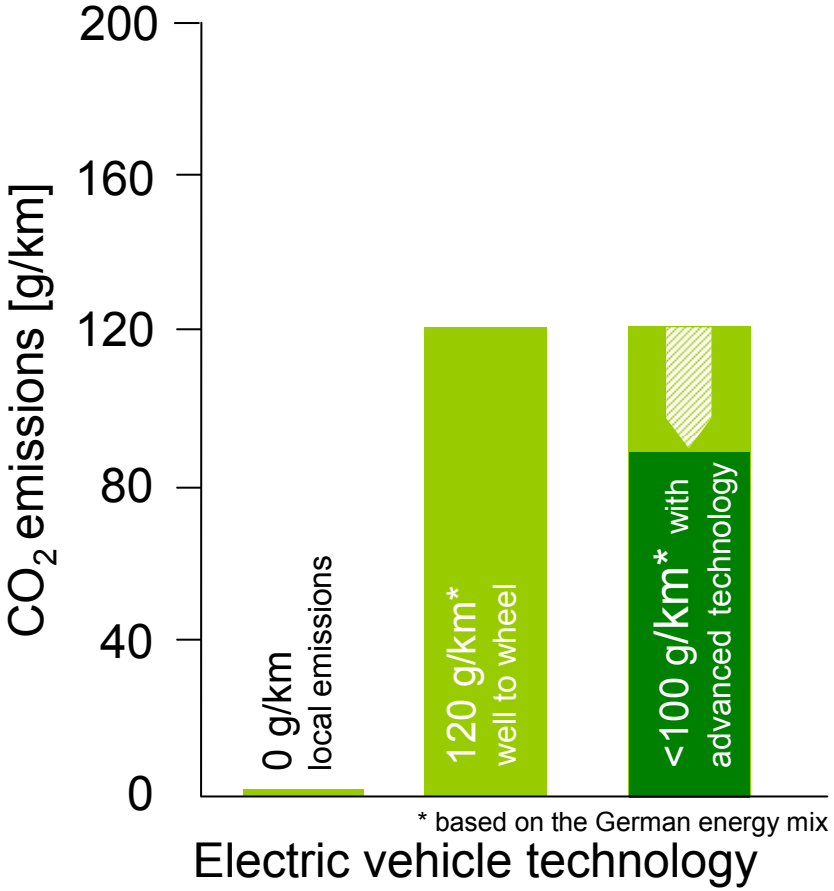
Electric vehicle – CO_2 emissions



Vehicle weight 1000 kg, Range 200 km, Battery 35 kWh

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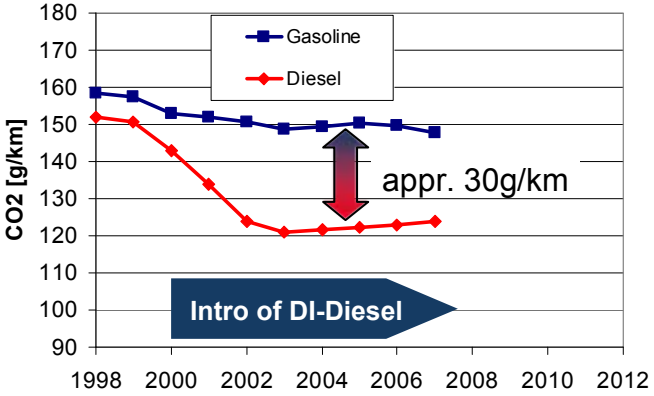
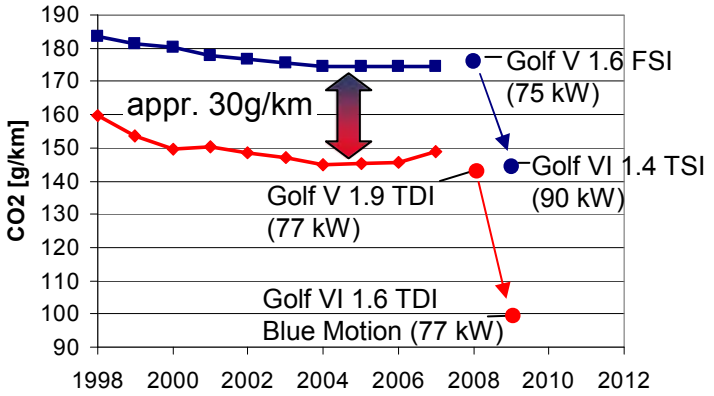
CO_2 Emissions (New PCs, EU15)

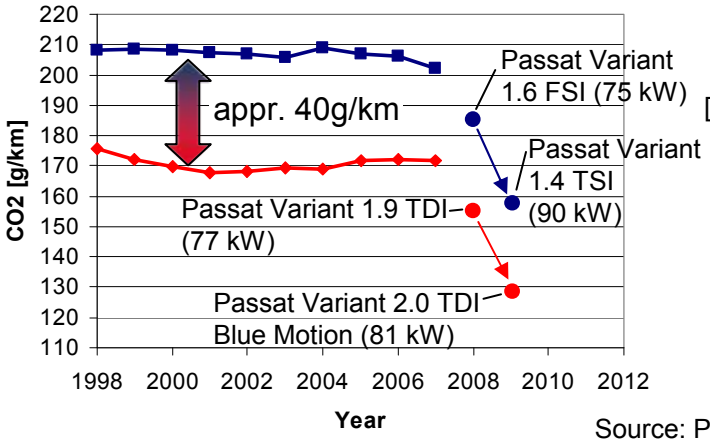
Small
[1250-1470 kg]



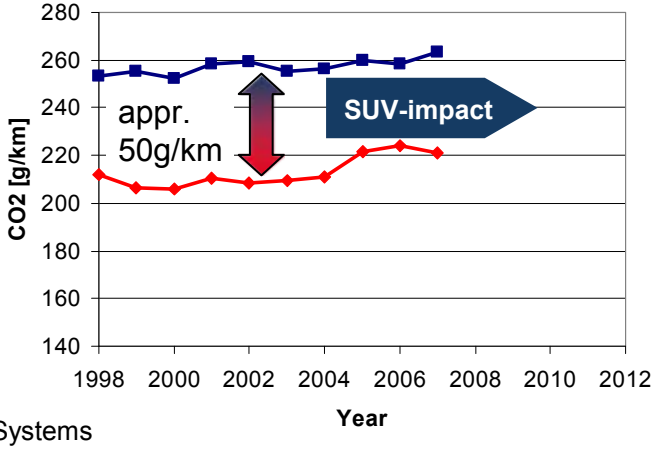
Compact
[1470-1700 kg]



Medium
[1700-1810 kg]



Upper Medium
[1810-1930 kg]

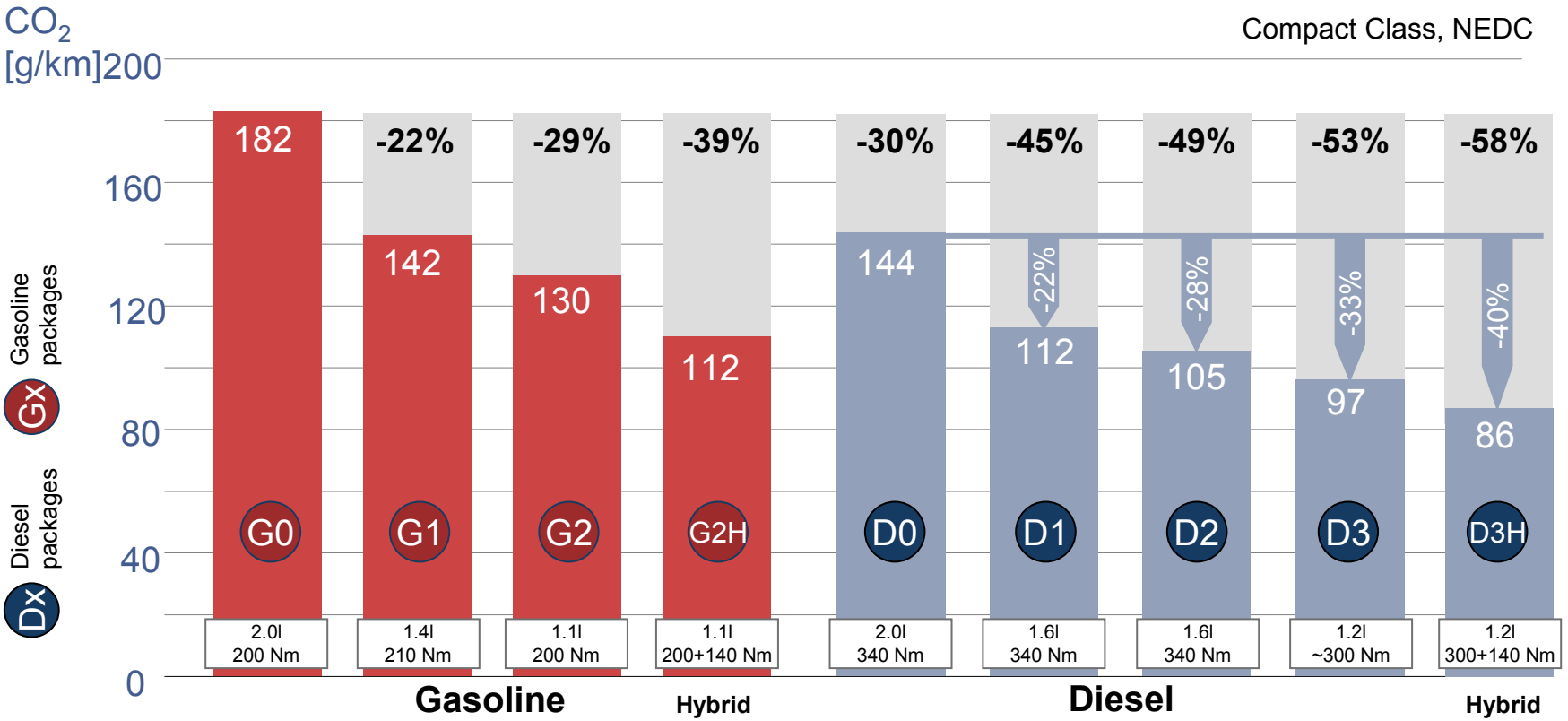


[Inertia Weight]

Source: Polk Marketing Systems

Drastic gains achievable for both, Gasoline and Diesel technology

CO_2 Emissions for Diesel & Gasoline Technologies



Gasolines AND Clean Diesels provide potentials for further CO_2 reduction

Evolution in Clean Diesel & Gasoline Technology

Gasoline			Clean Diesel		
Pkg.	Description	Displ. & Torq.	Pkg.*	Description	Displ. & Torq.
G0	Port fuel injection (PFI)	2.0 l 200 Nm	D0	Common rail system, turbo	2.0 l 340 Nm
G1	Direct injection (DI)[1], turbo, downsizing, start/stop[3], thermal management	1.4 l 210 Nm	D1	+ oCCS (opt. Combustion) + start/stop [4] + thermal management [7] + downsizing ,+ close PI	1.6 l 340 Nm
			D2	+ NO_x-EGT	1.6 l 340 Nm
G2	+ downsizing + var. valve lifting (VVL)[8]	1.1 l 200 Nm	D3	+ downsizing	1.2 l 300 Nm
G2H	+ hybrid [2,5]	1.1 l 200+140 Nm	D3H	+ hybrid [2,5]	1.2 l 300 + 140 Nm

Medium class car (1 400 kg), 100 kW, MT5 (manual transmission), MVEG-cycle, EU6

1) turbo-charged with downsizing and var. valve timing (VVT); 2) max. potential w/ downsizing, transmission optimization; 3) Start/Stop w/ recup., thermo management (ThM), Decos; 4) Start/Stop w/ recup., combustion optimization; 5) Battery 1.0 kWh; 6) ThM, down speeding, downsizing, T/C optimization; 7) CO_2 optimization; 8) VVL in 2-step, down speeding, downsizing; / costs 2014 / * Further Clean Diesel evolution steps D1 & D3 are not shown

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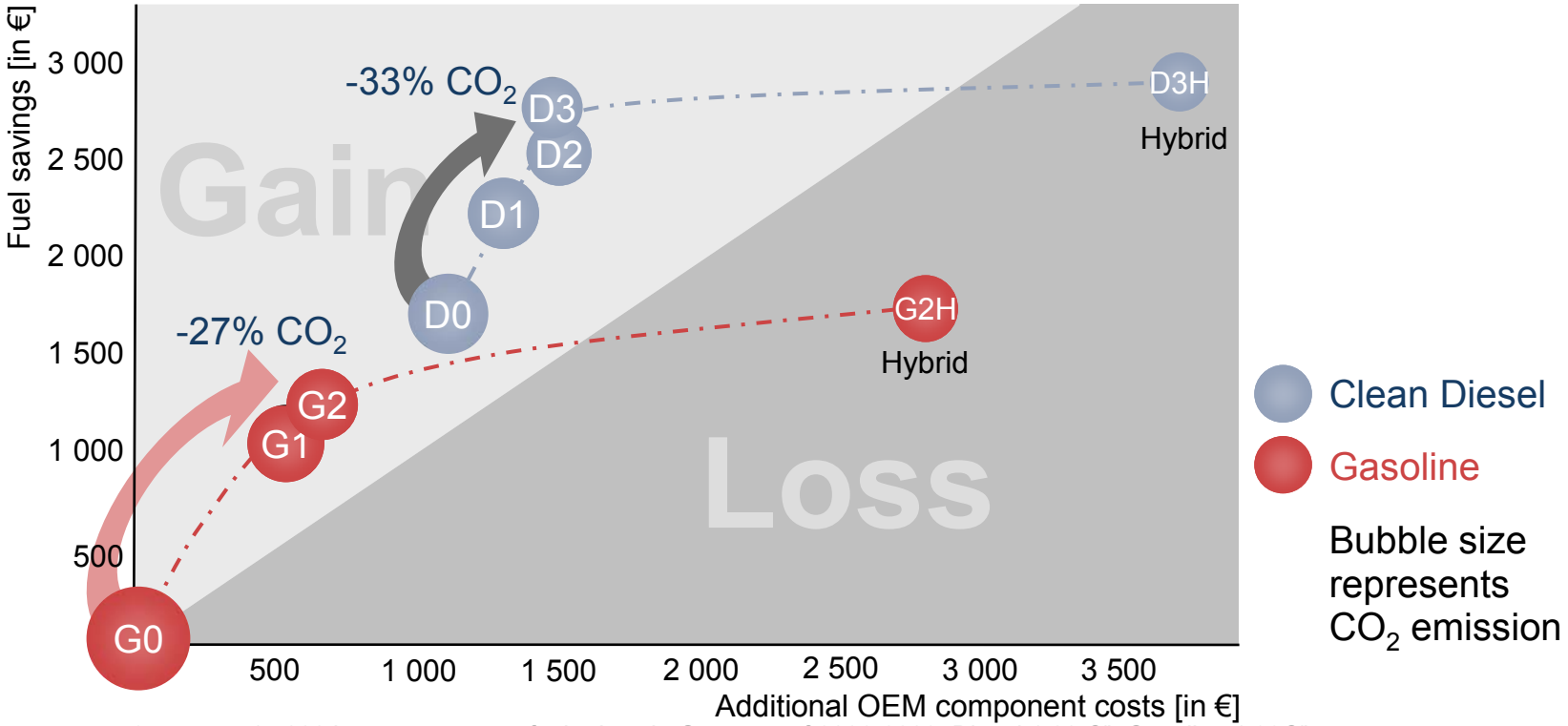
Fuel Savings vs. Additional Component Costs



Premise: costs over 3 years at 15 000 km p.a., average fuel prices in Germany of 2006-2008: Diesel 1.20 €/l, Gasoline 1.33€/l

FE enhancement for Clean Diesels & Gasolines follows similar gradient

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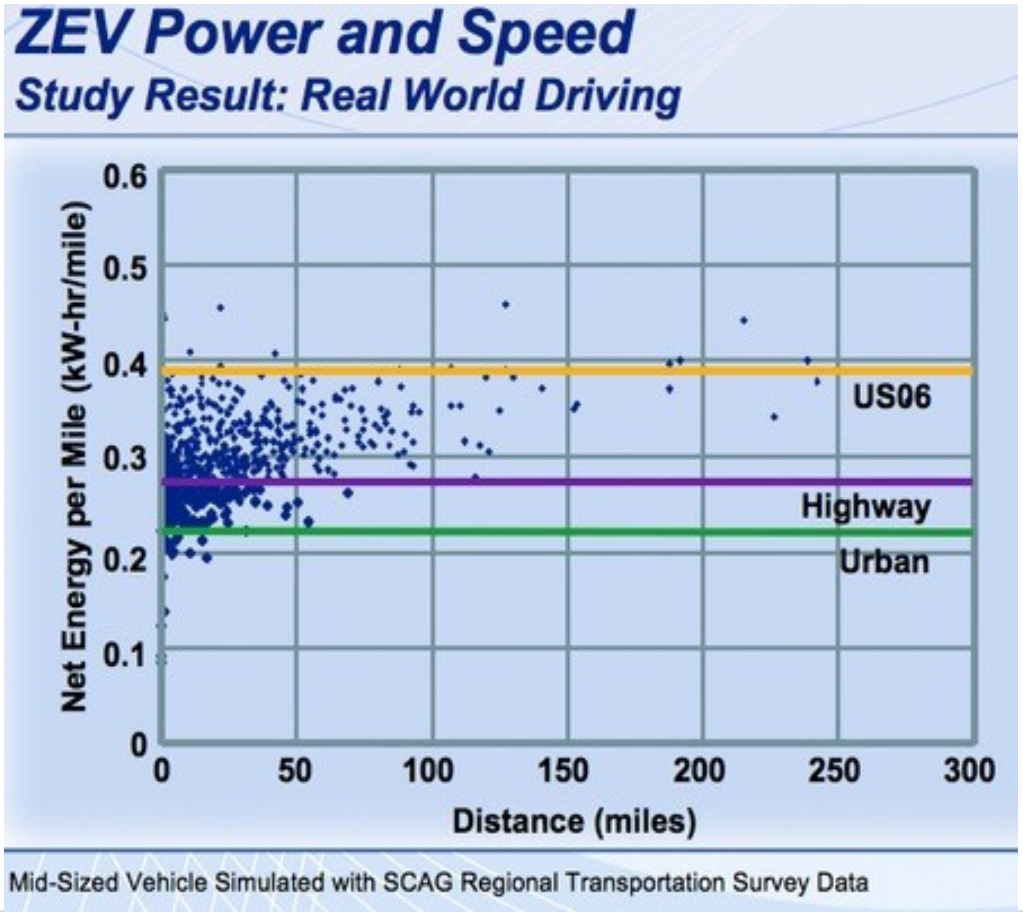
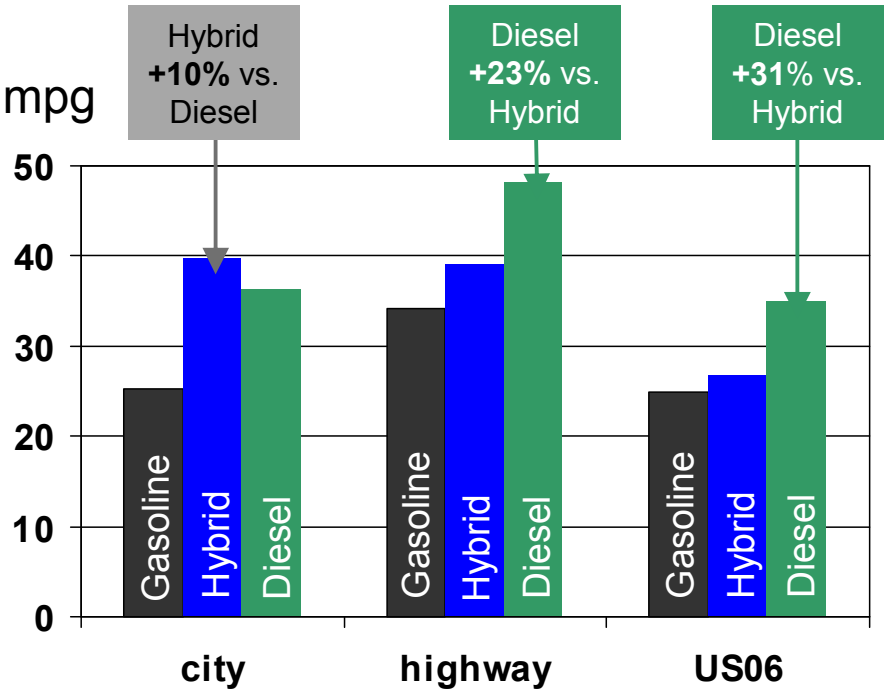
Real American Driving Profile



- Study based on GPS-monitored Californian mid-size sedan owners:
  - Median Californian driving intensity is between highway and US06 cycles

Emissions follow real-world driving, not test cycles

cycle based calculation



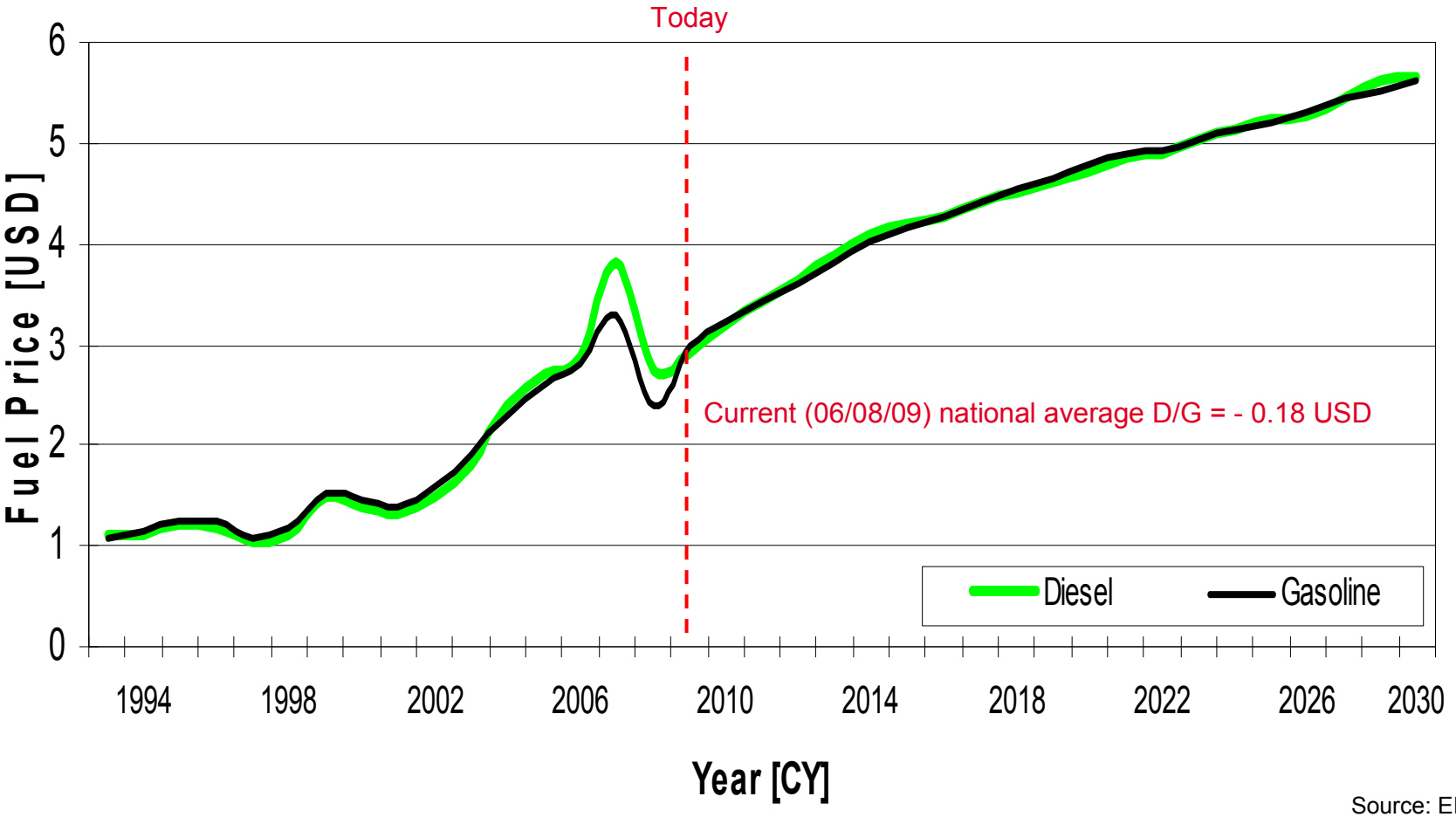
real-world driving

source: auto motor sport, 2008

Further potential of Clean Diesel with e.g. Start-Stop not even considered

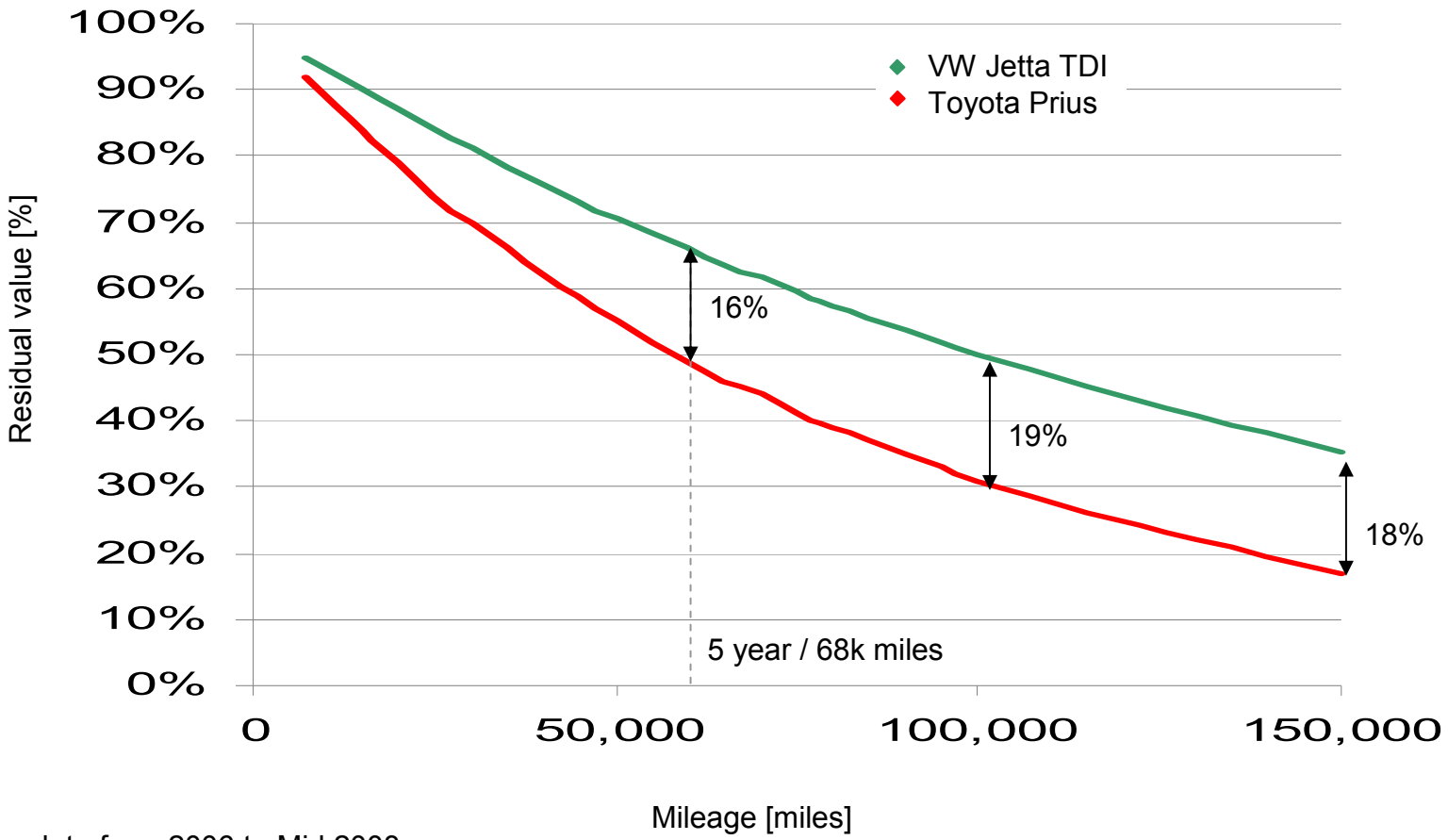
Source: simulation based on Mercedes E-class, 1700kg, combustion 110kW, electrical 31kW, Li-Ion battery, 6-speed AT

EIA Diesel/Gasoline Price History and Forecast



Source: EIA

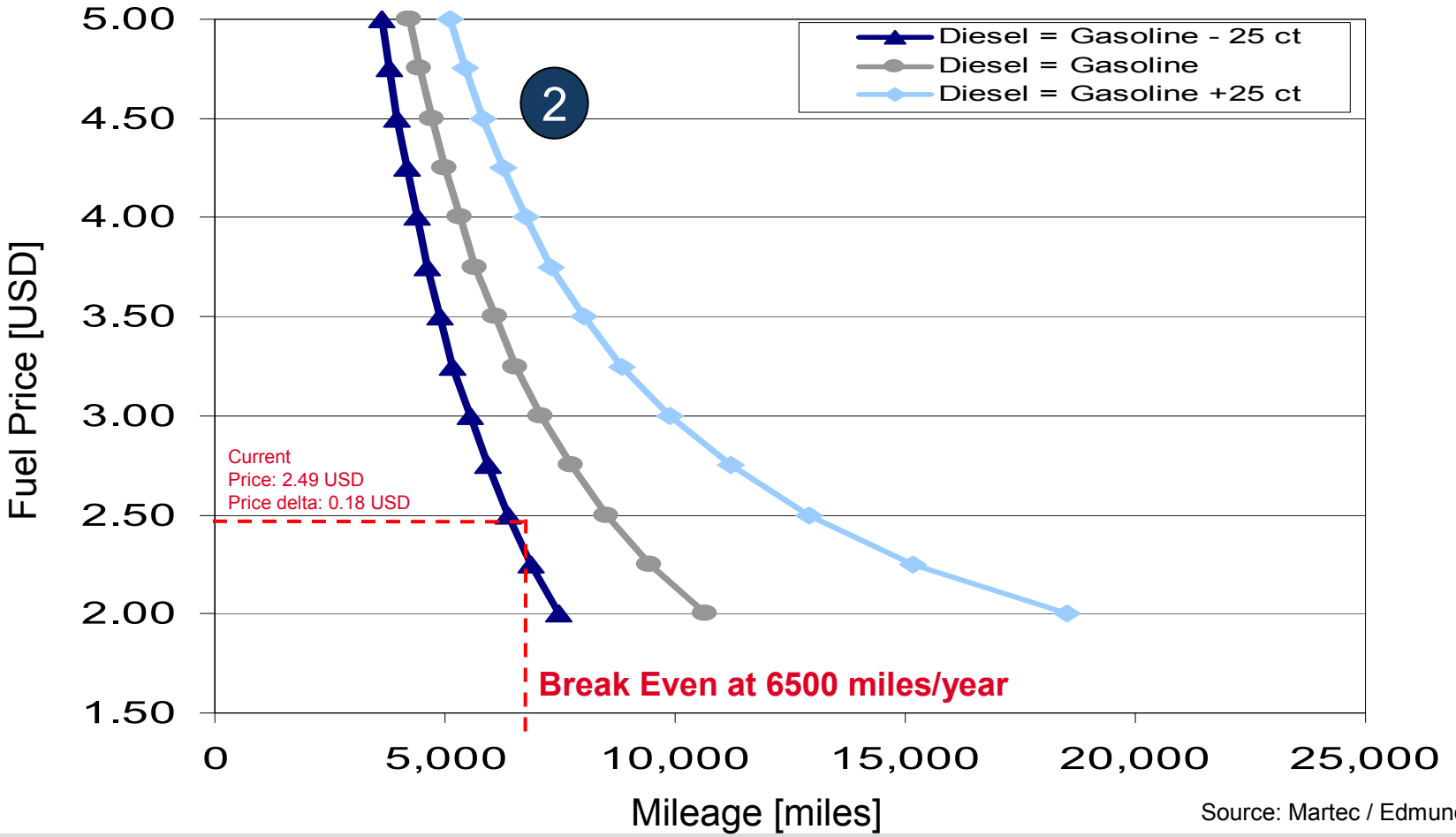
Auction Results (Example Jetta TDI / Prius)



* auction data from 2006 to Mid 2008

Source: Martec / Mannheim Auto Auction

TCO example VW Jetta TDI



Source: Martec / Edmunds

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