



DEER 2002 Conference



European Diesel Engine Technology: An Overview

Steve Brueckner

AVL Powertrain Engineering, Inc.



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- ◆ **Market Factors**
 - ◆ **Legislation**
 - ◆ **Customer Requirements**
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- ◆ **Current Trends**
- ◆ **Future Technologies**
- ◆ **Summary**



- ◆ Emissions

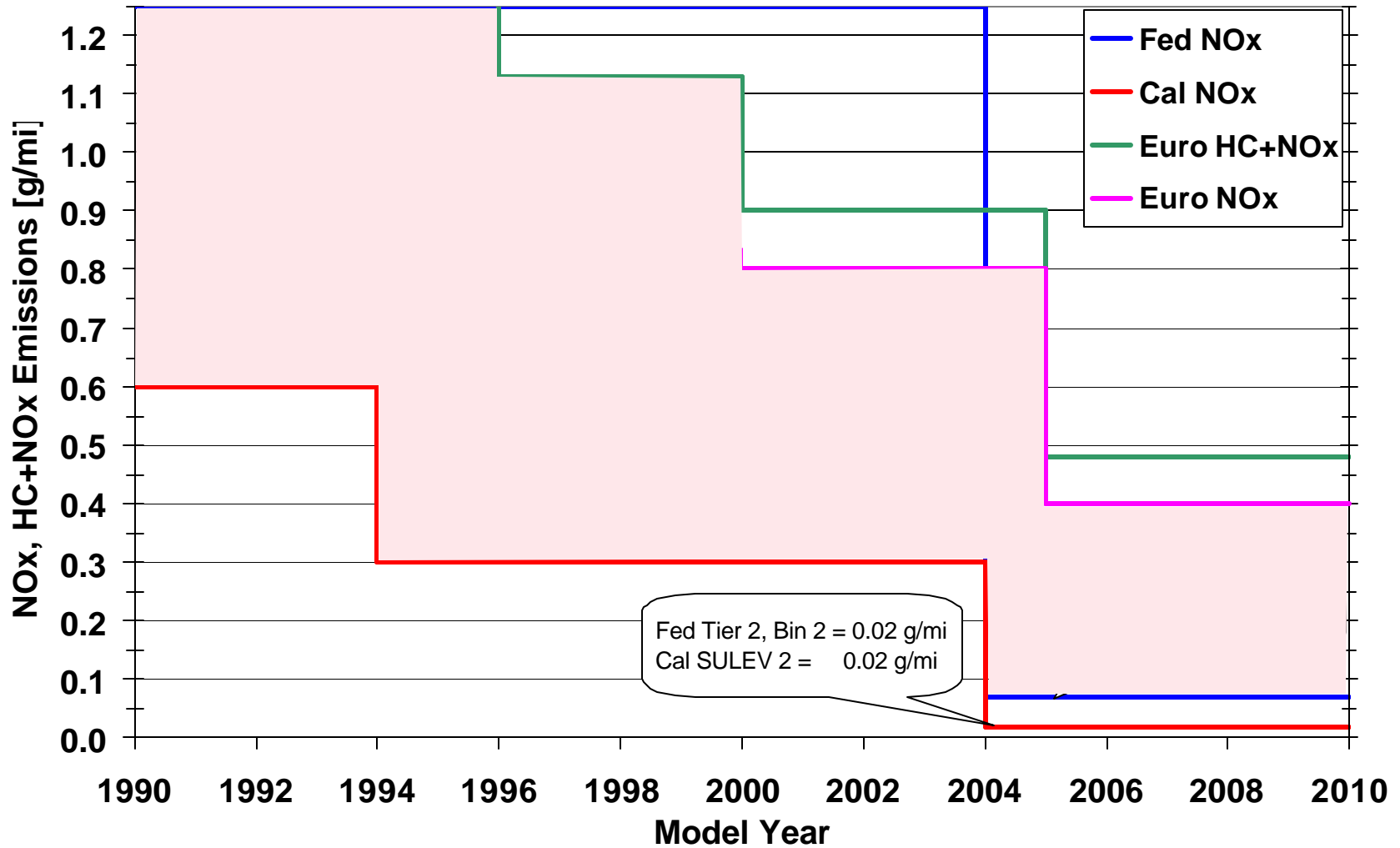
- ◆ CO₂



Emissions - NO_x



Comparison of NO_x Emission Standards (Diesel)

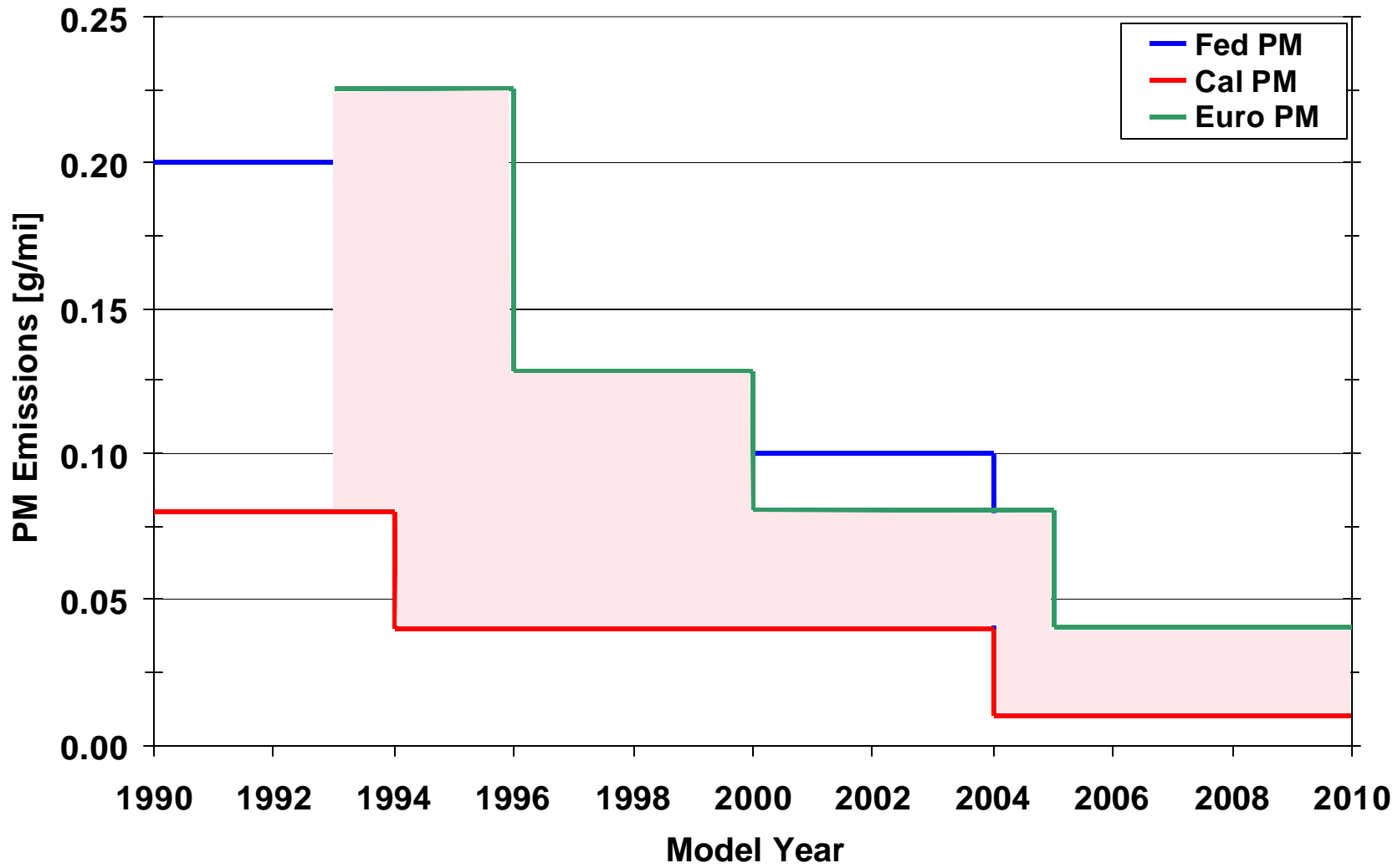




Emissions - Particulates

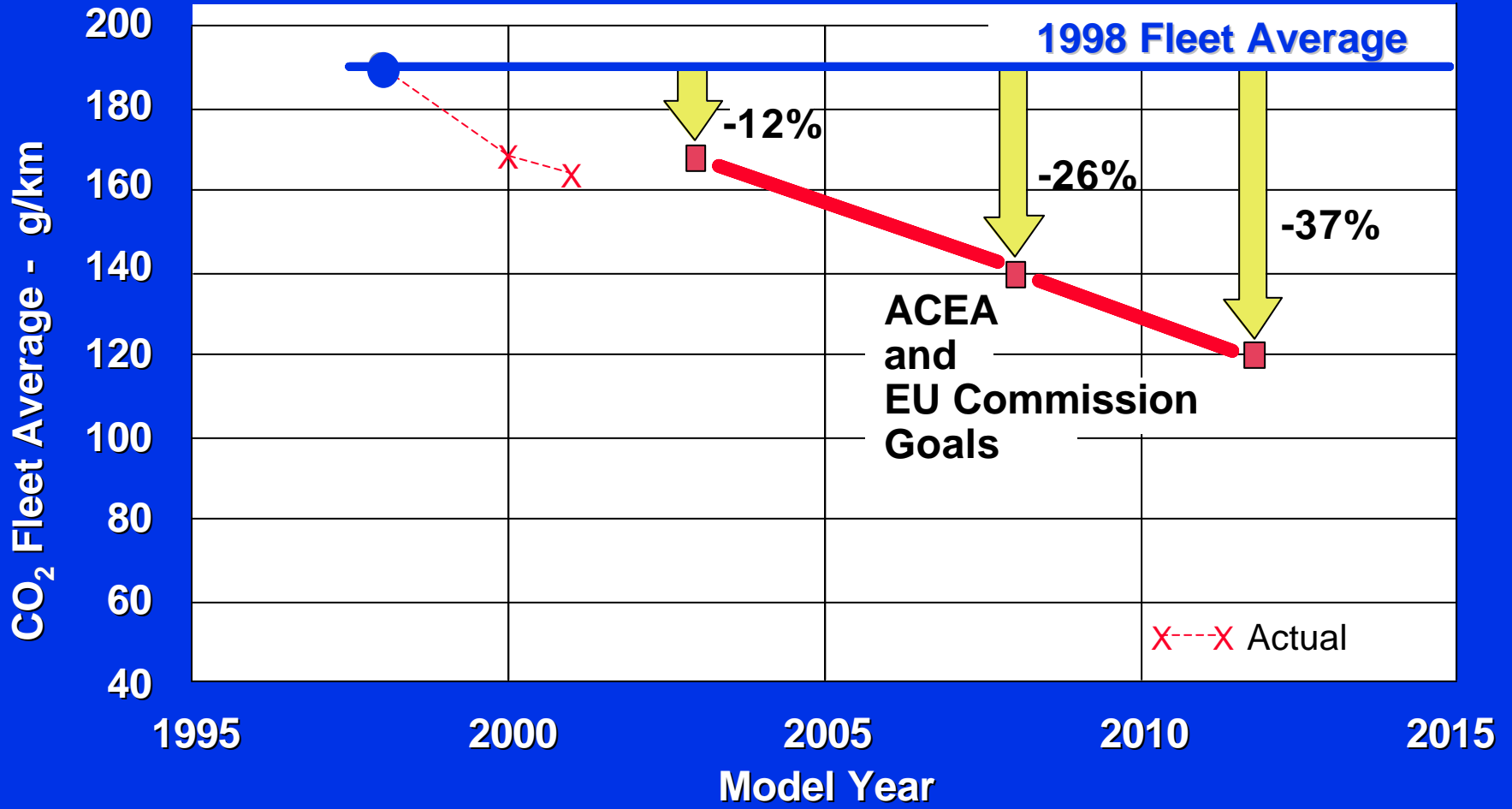


Comparison of PM Emissions Standards



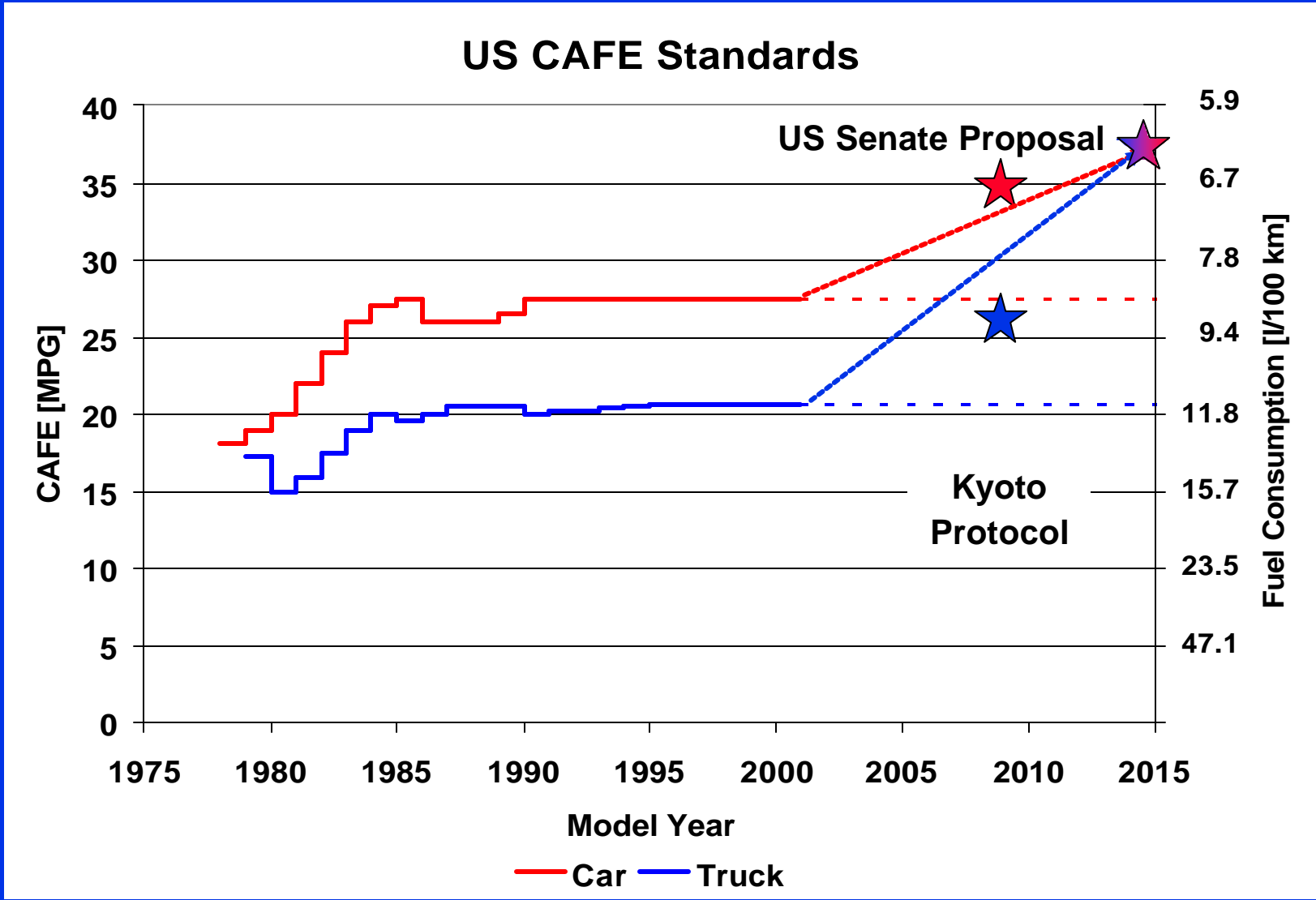


CO₂ Emissions - European Fleet Average and Required Reductions



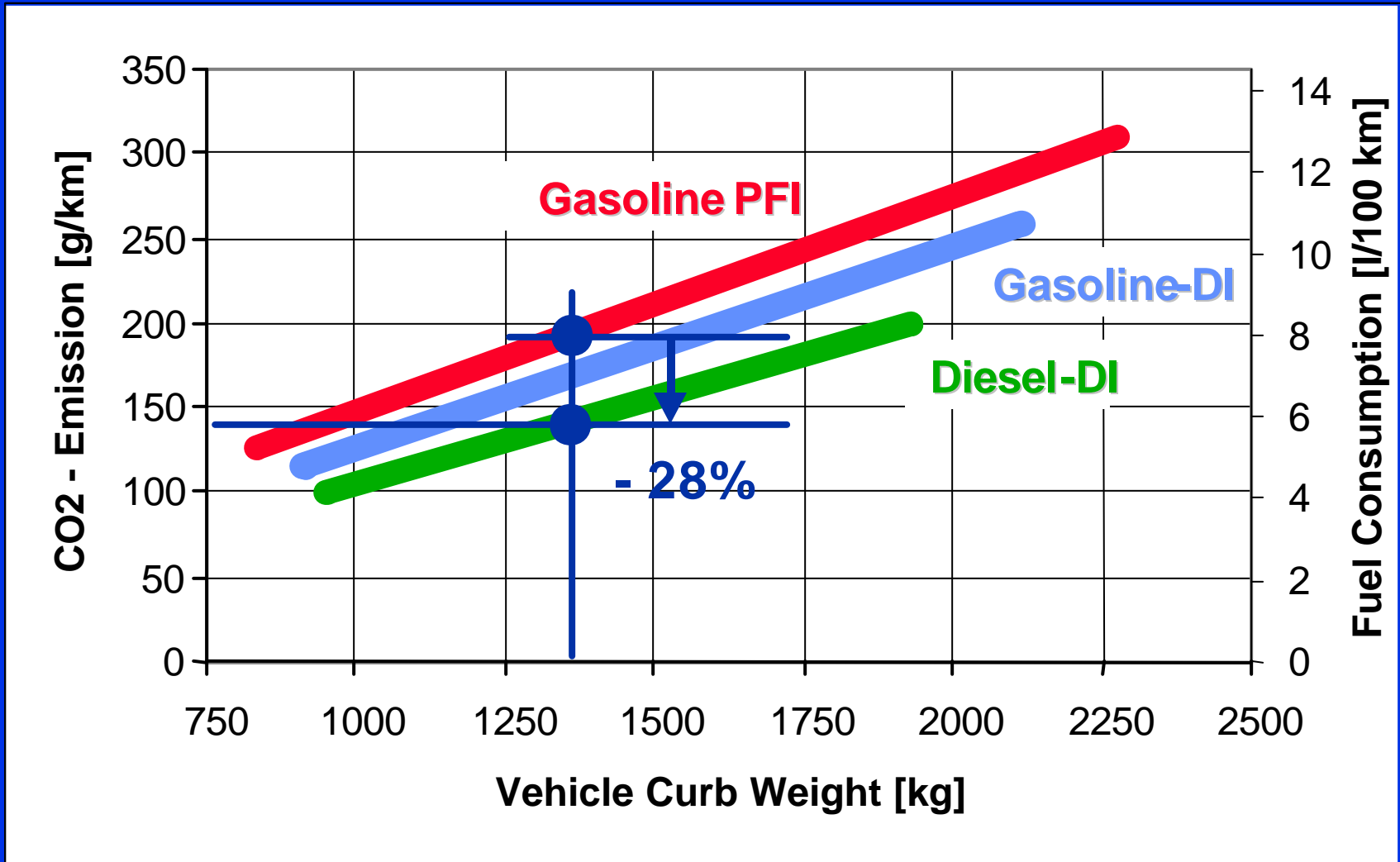


US Fleet Fuel Economy





CO₂ Emissions Potential - Diesel vs. Gasoline Engines



Source: Kraftfahr-Bundesamt (KBA), 7/1999



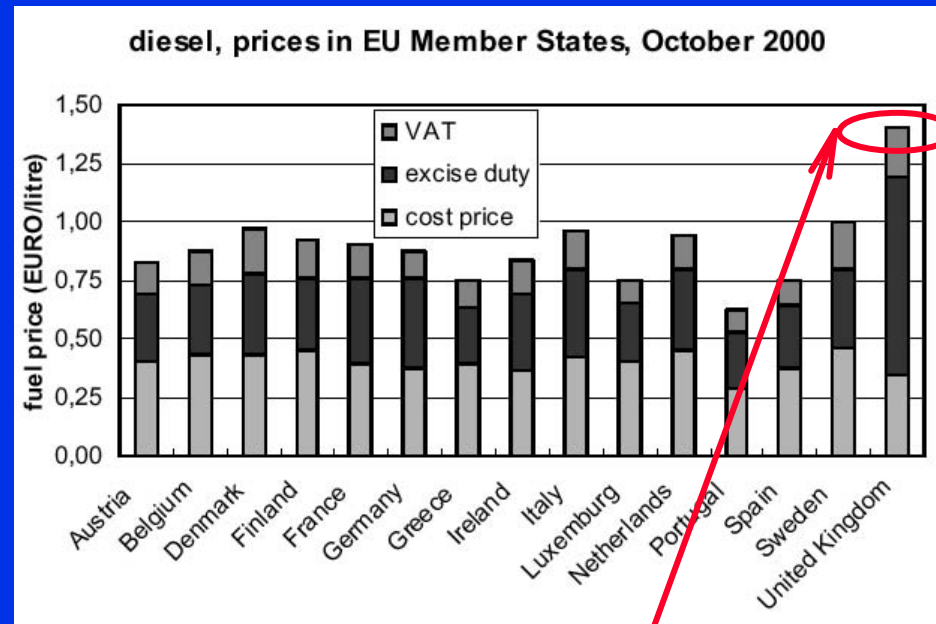
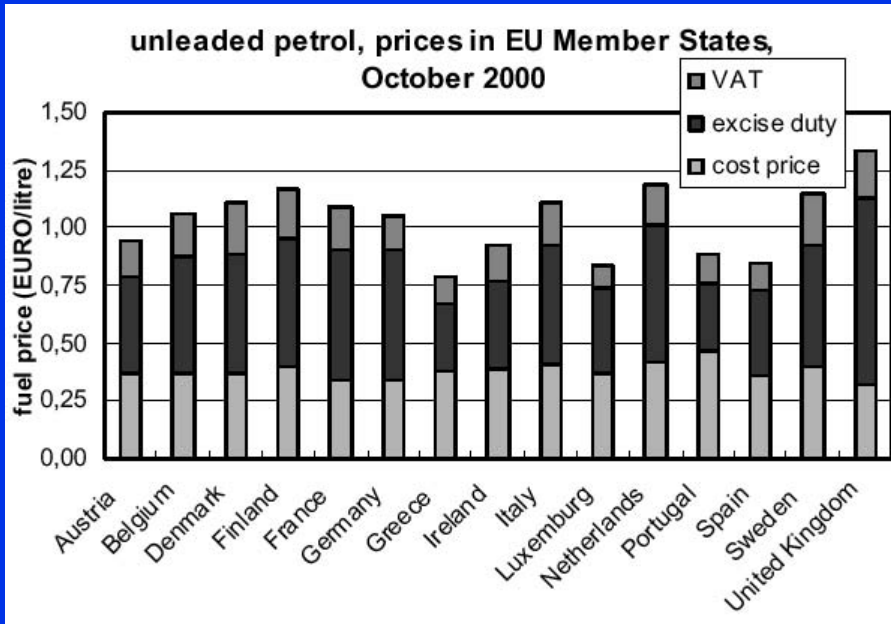
Customer Requirements



- ◆ **Costs**
 - ◆ **Fuel Costs**
 - ◆ **Initial Purchase vs. Operating Costs**
- ◆ **Performance**



European Fuel Prices

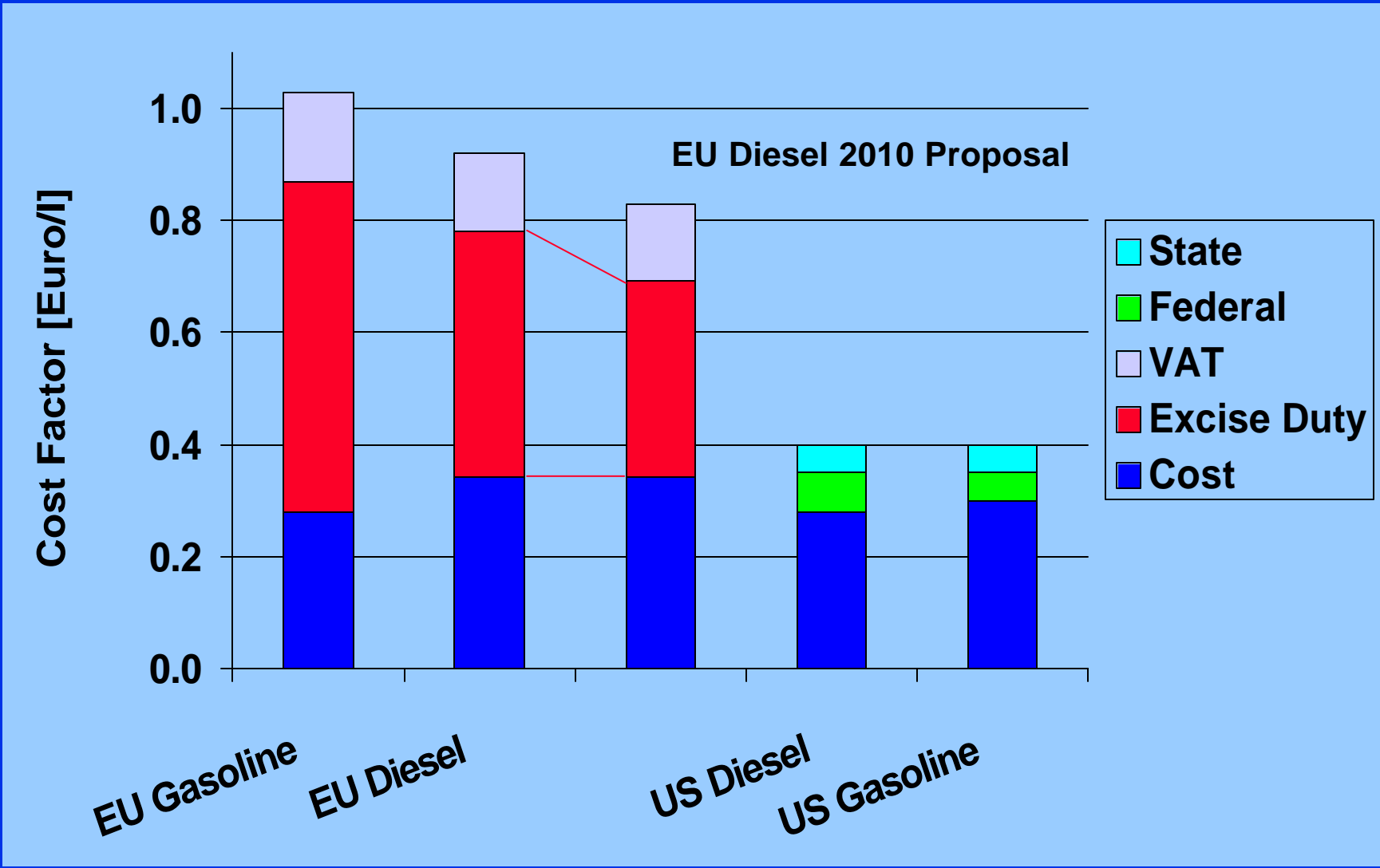


Source: Eurostat, 2001

Only Country With Lower Gasoline Price



Fuel Price Comparison



Source: Eurostat, 2001; EIA 2002



Cost Comparison



◆ VW Golf 1.9l TDI vs. 1.8l T

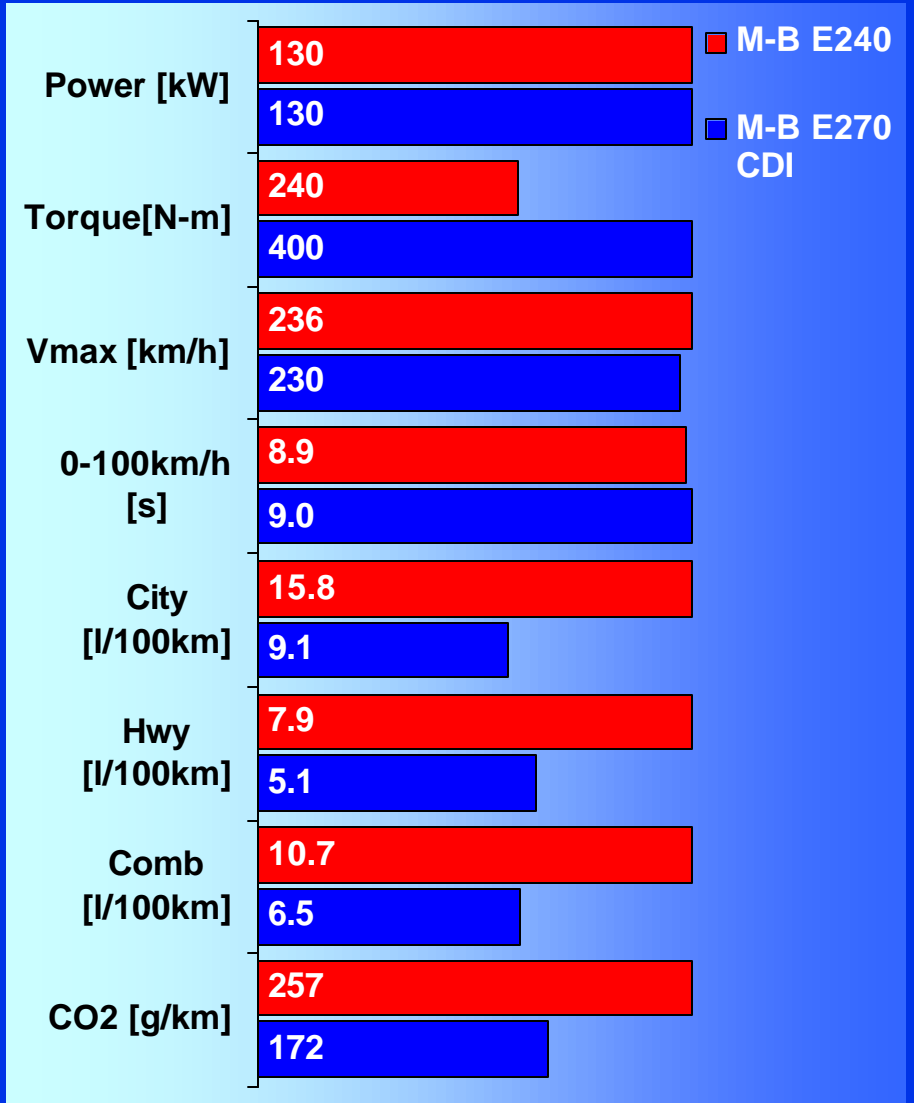
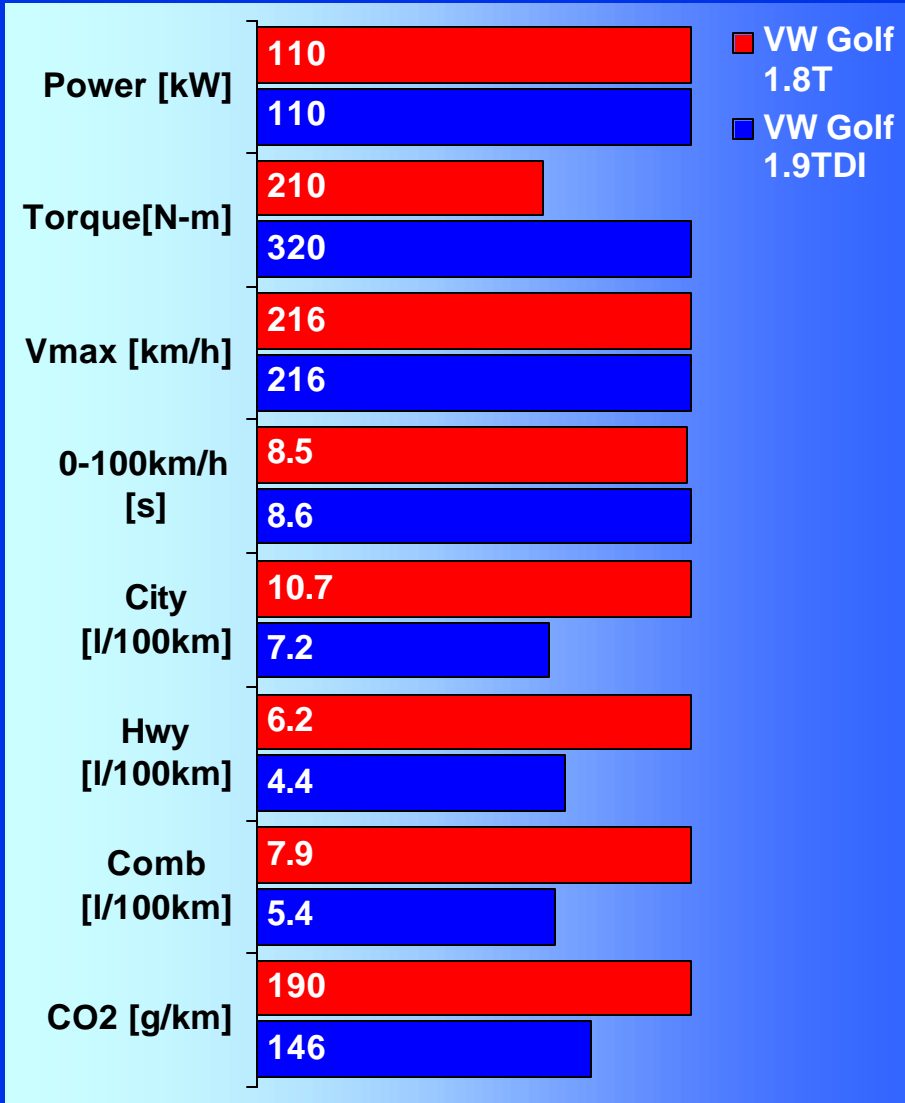
- ◆ » 1500 Euro Difference in Purchase Cost
- ◆ 5.4 vs. 7.9 l/100 km
- ◆ 15000 km /year
- ◆ 0.89 vs 1.03 Euro/l
- ◆ 720 vs. 1220 Euro Annual Operating Costs
- ◆ 3 Year Payback Period

◆ M-B E 270 CDI vs. E 240

- ◆ » 700 Euro Difference in Purchase Cost
- ◆ 6.5 vs. 10.7 l/100 km
- ◆ 15000 km /year
- ◆ 0.89 vs 1.03 Euro/l
- ◆ 870 vs. 1650 Euro Annual Operating Costs
- ◆ 1 Year Payback Period

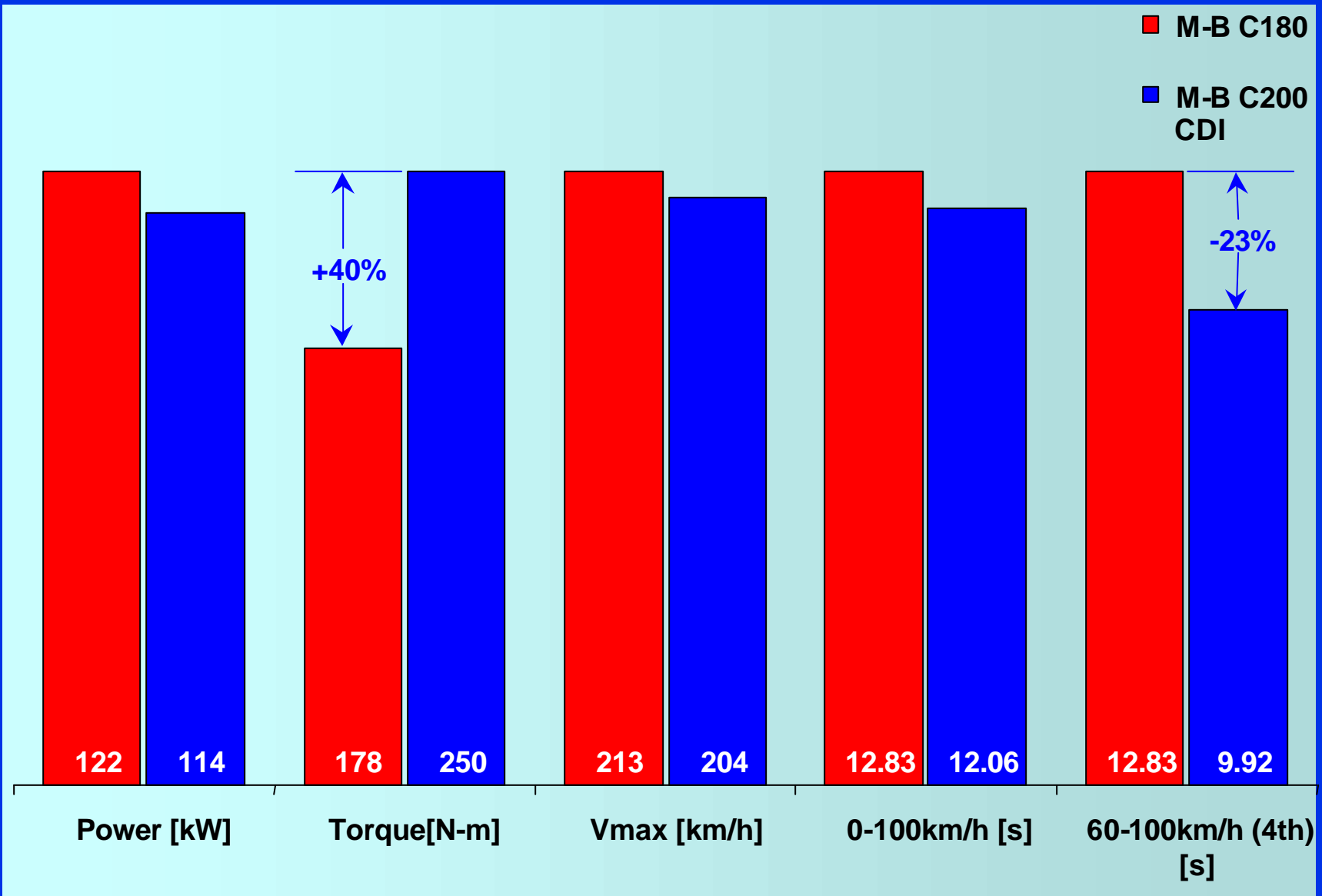


Performance: Diesel vs. Gasoline



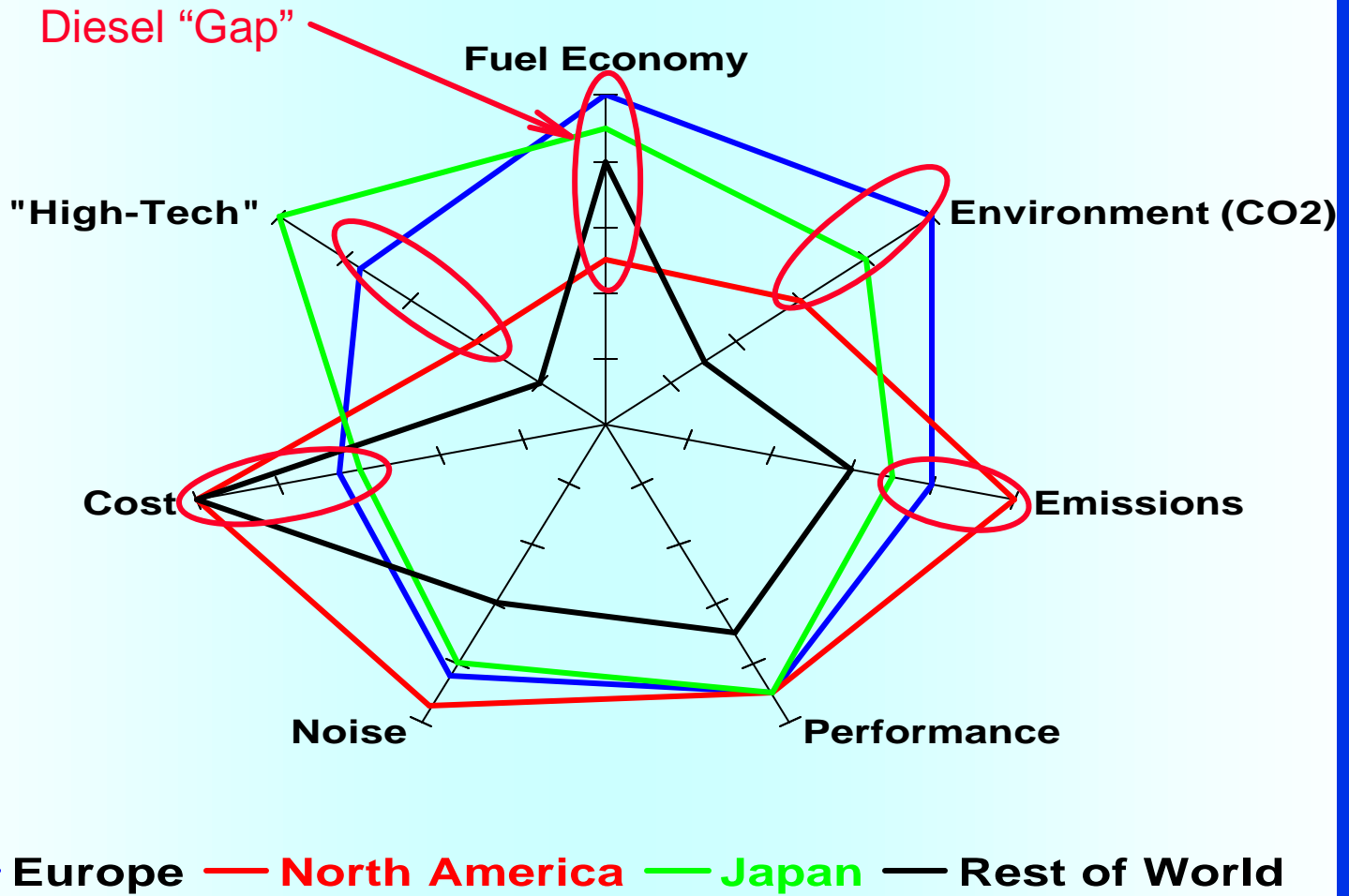


Elasticity: Diesel vs. Gasoline





Europe vs. US





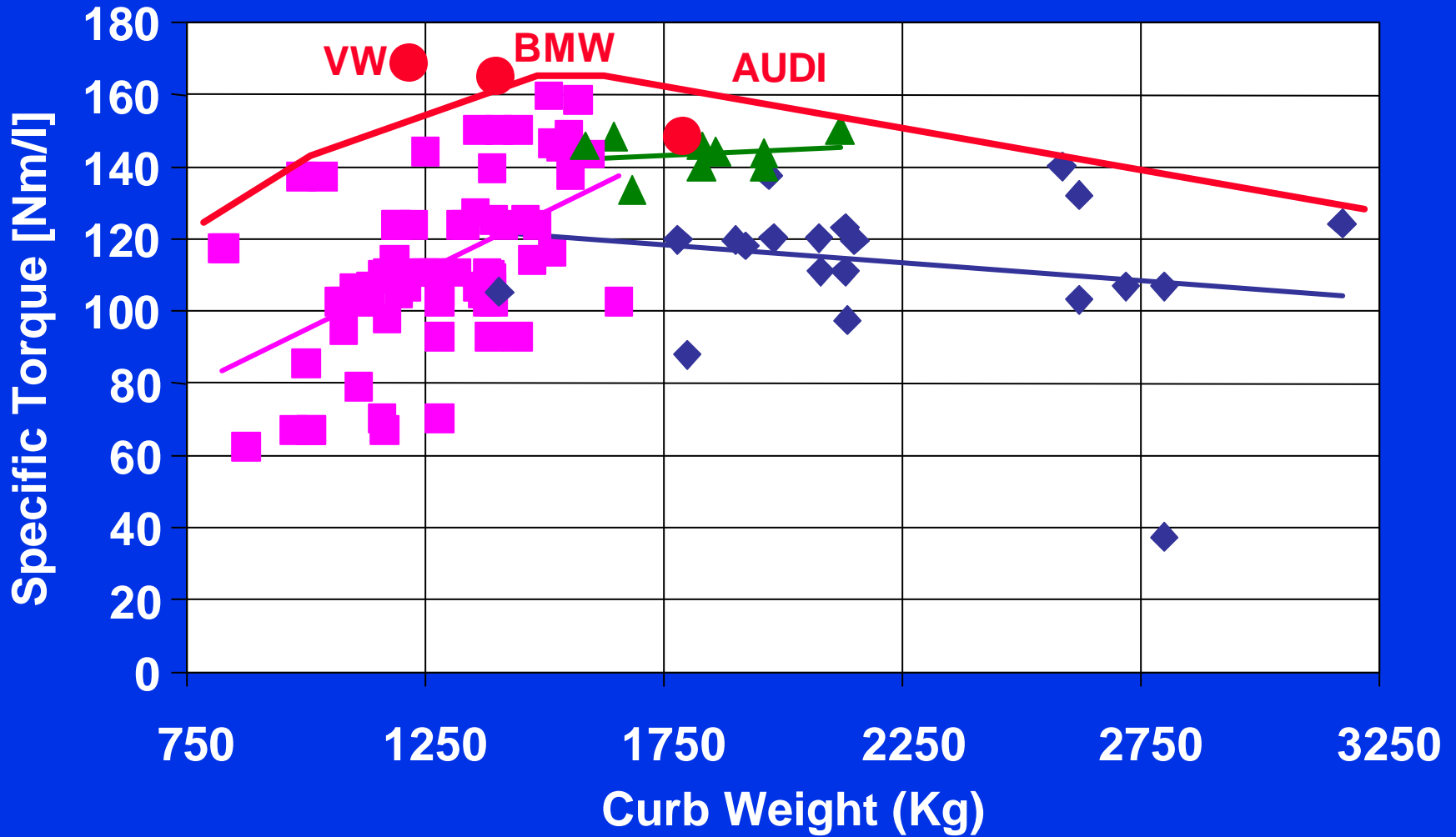
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Specific Torque of HSDI Diesels

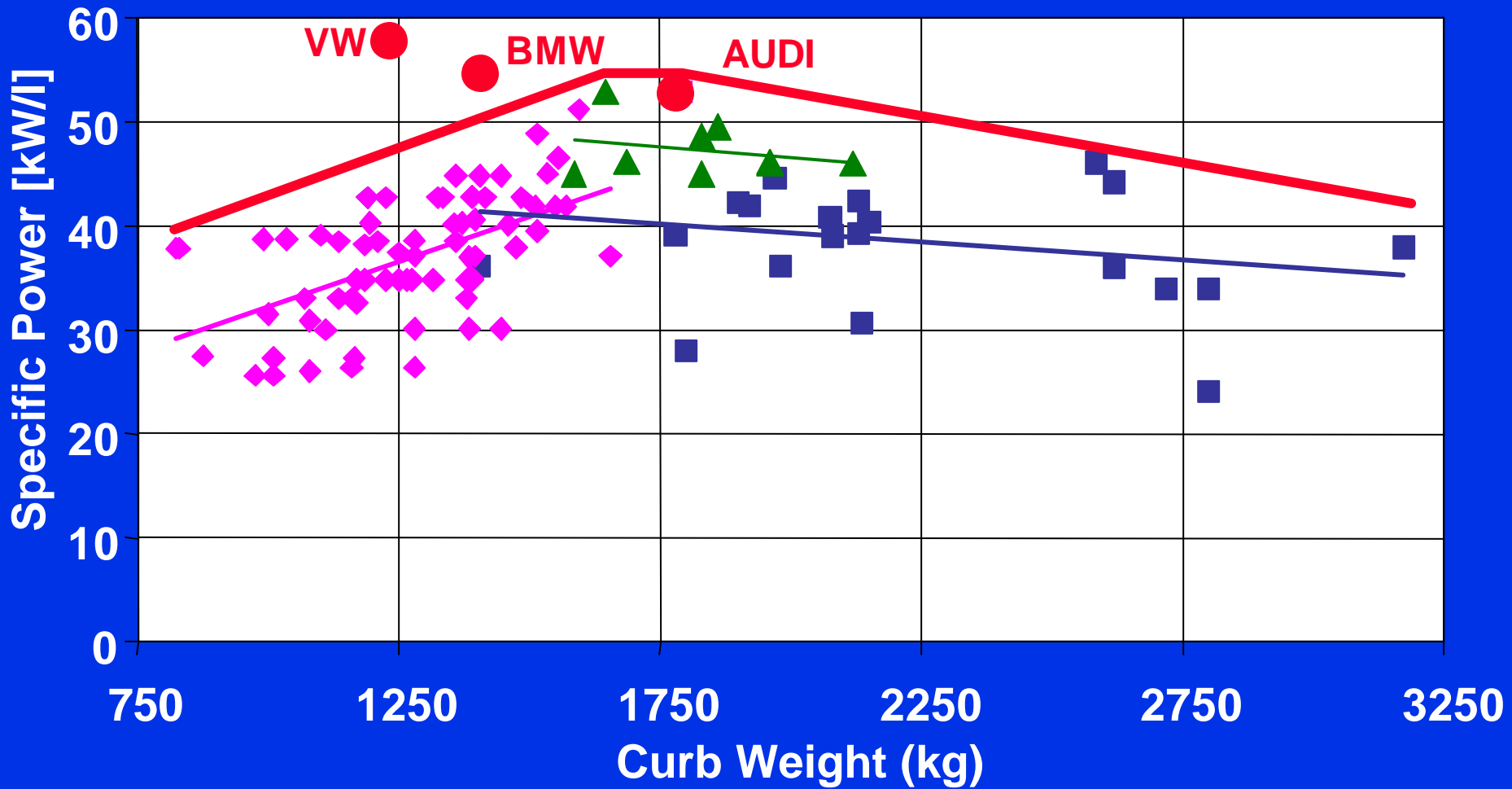


■ 3, 4 and 5 cyl. PC engines ▲ 6, 8 and 10 cyl. PC engines ◆ All SUVs

All SUVs = USA, Japan and Europe



Specific Power of HSDI Diesels



◆ 3, 4 and 5 cyl. PC engines ▲ 6, 8 and 10 cyl. PC engines ■ All SUVs

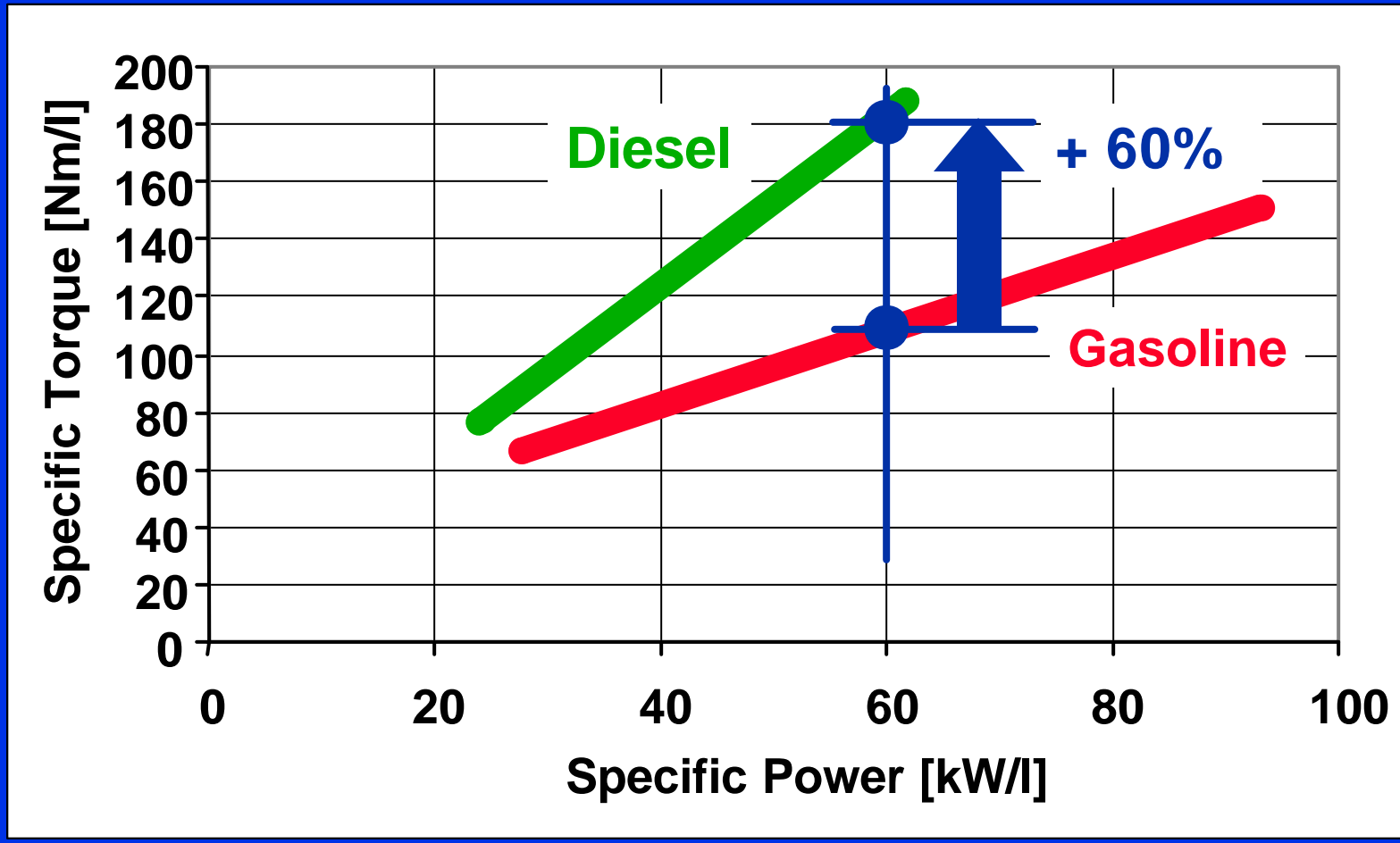
All SUVs = USA, Japan and Europe



Specific Torque vs. Specific Power



Passenger Car Engines Certified to EURO III or Better

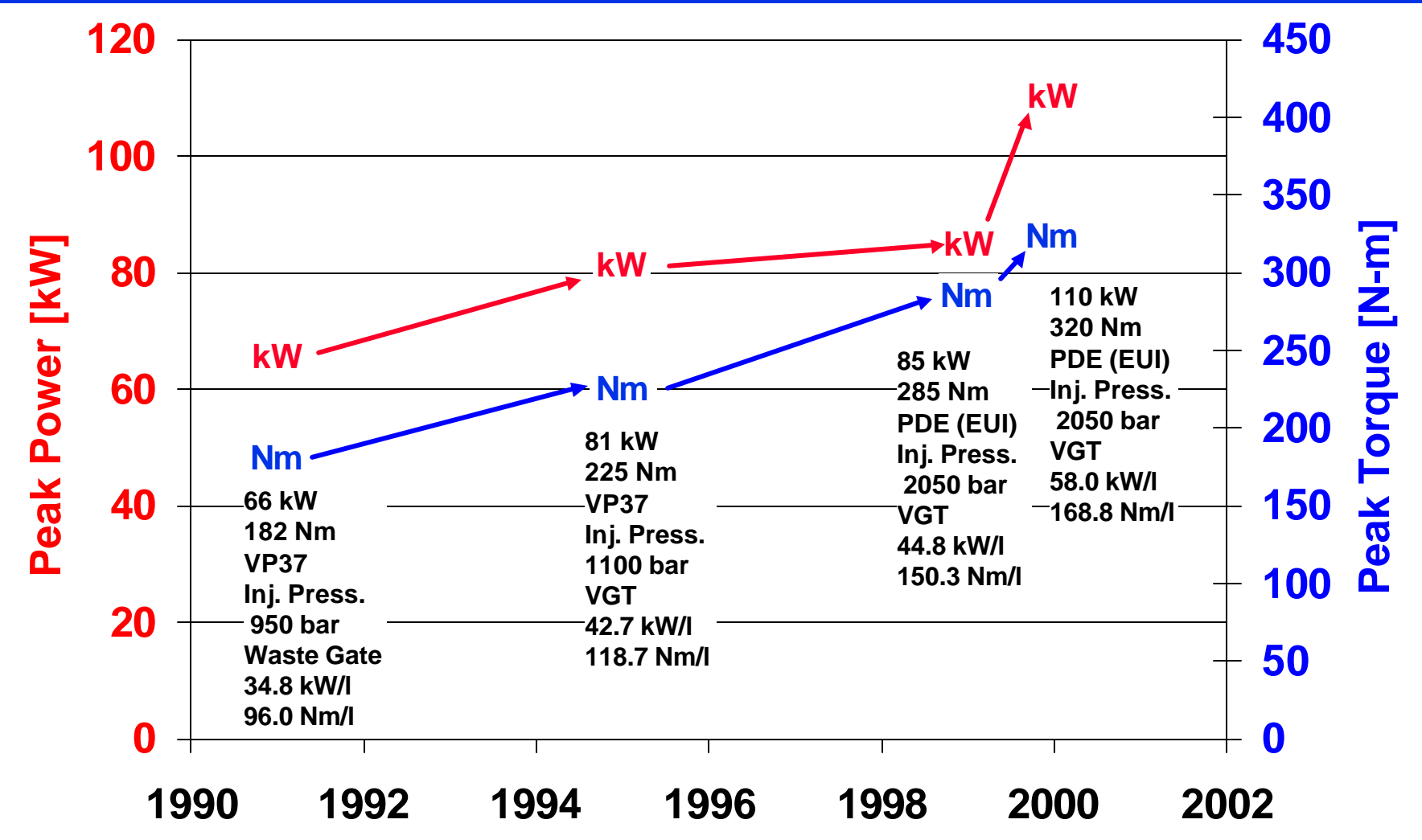


Source: Krafftahr-Bundesamt (KBA), 03/2000; mot 11/2000; Automobil Revue 2000



Evolution in Specific Output **AVL**

VW 1.9l TDI 2 Valve/Cyl

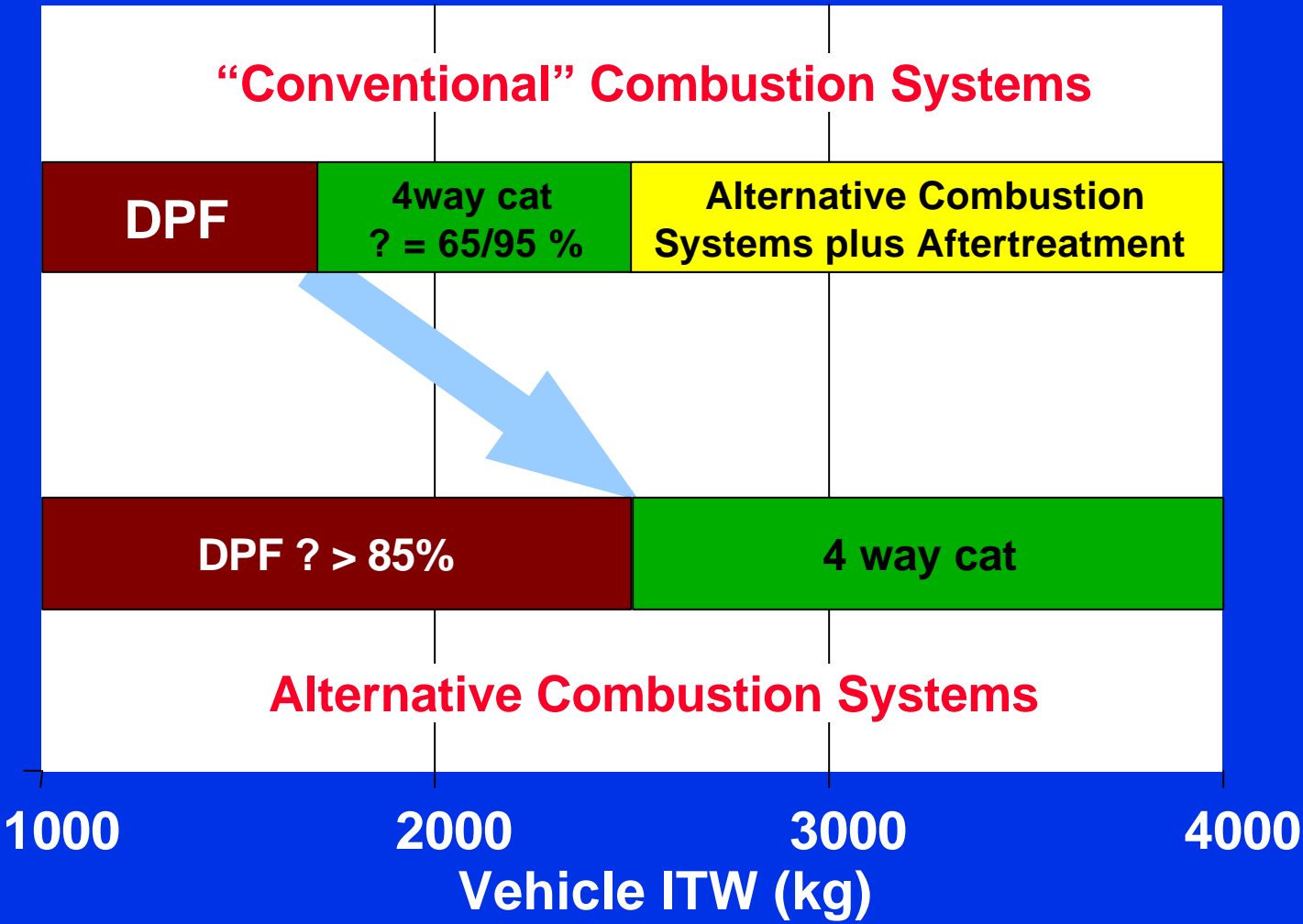




Assessment of Technologies to Meet Future Emissions Standards



EURO V, US Tier 2, CARB LEV II Standards





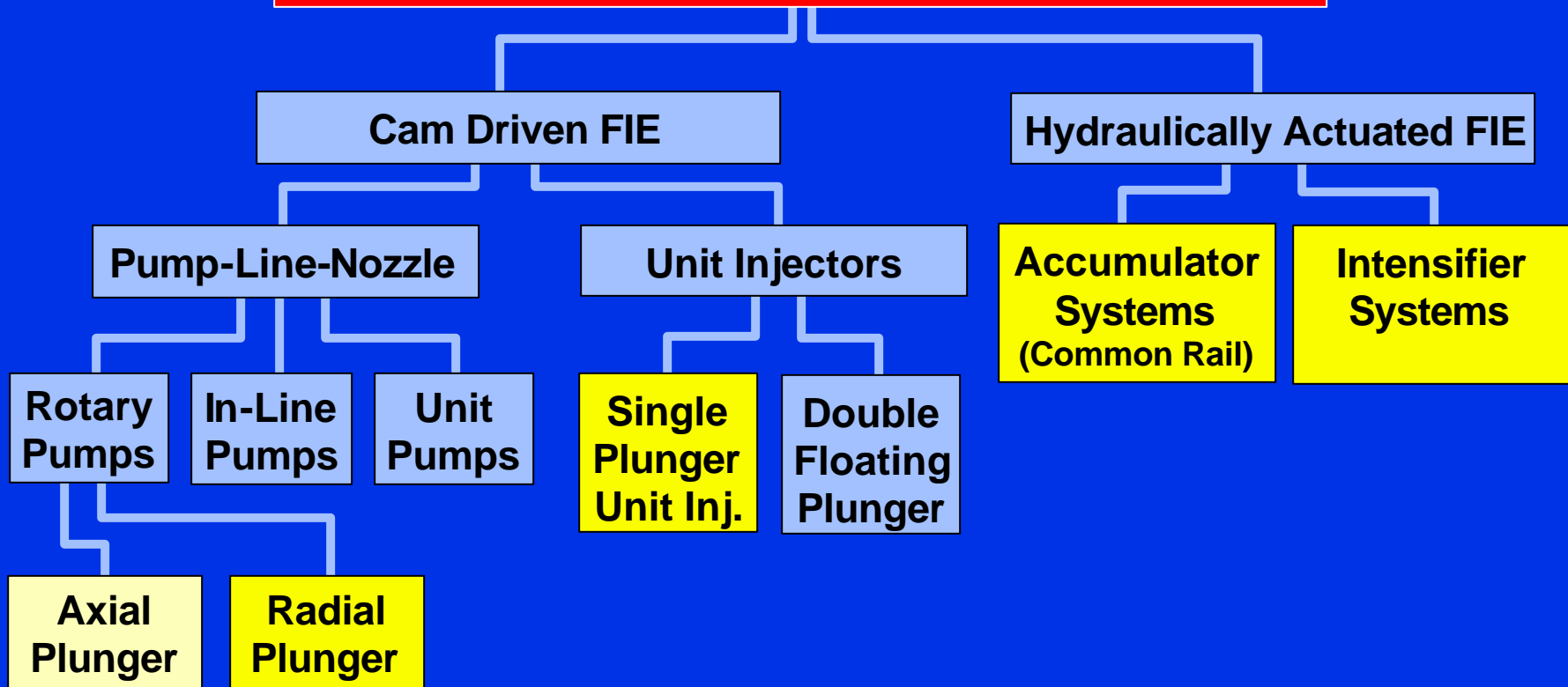
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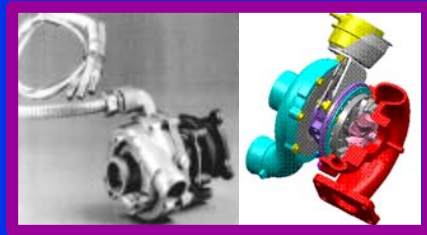


DI Diesel Fuel Injection System



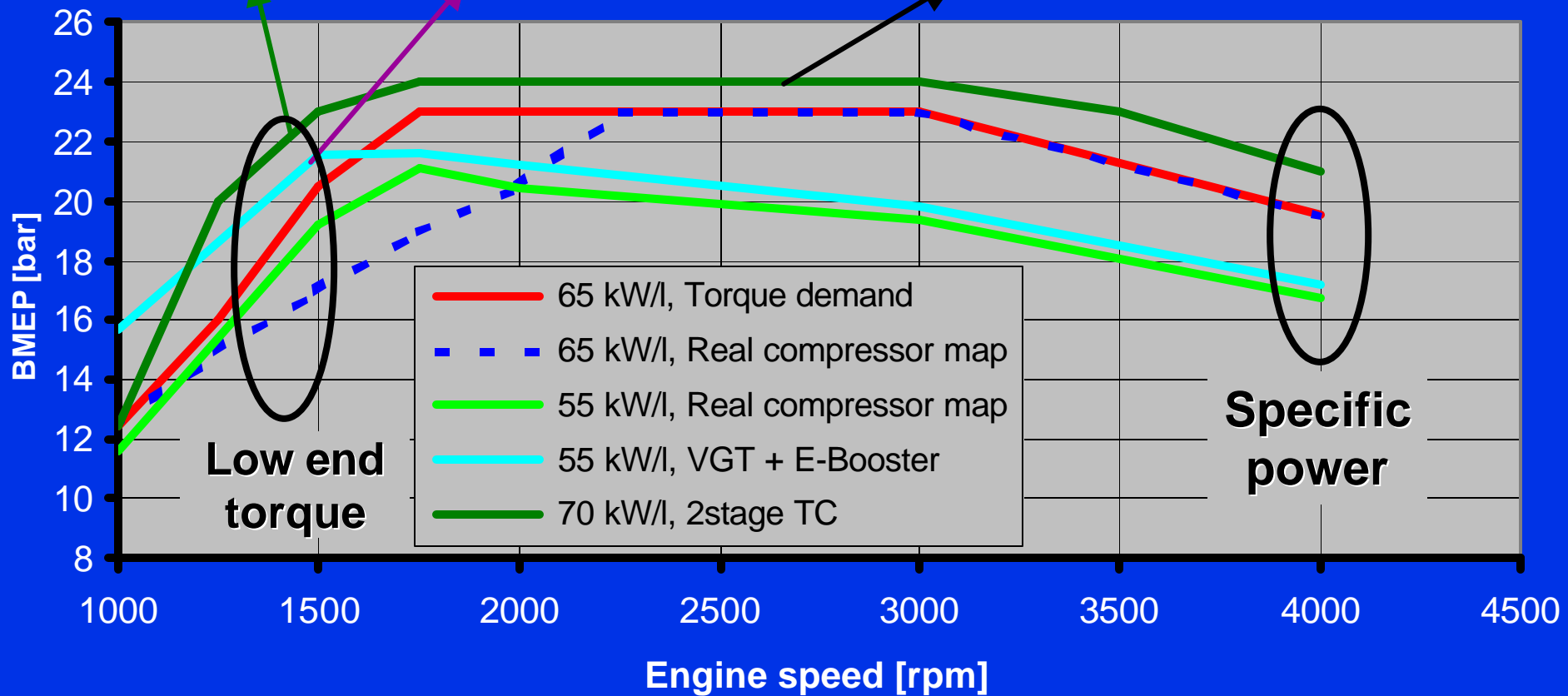
Most Promising Options for SUV / LDT

Effect of Charging Systems on Full Load Characteristics



6 Cylinder HSDI, 0.5 l/cylinder Class

Transmission Torque Limitation

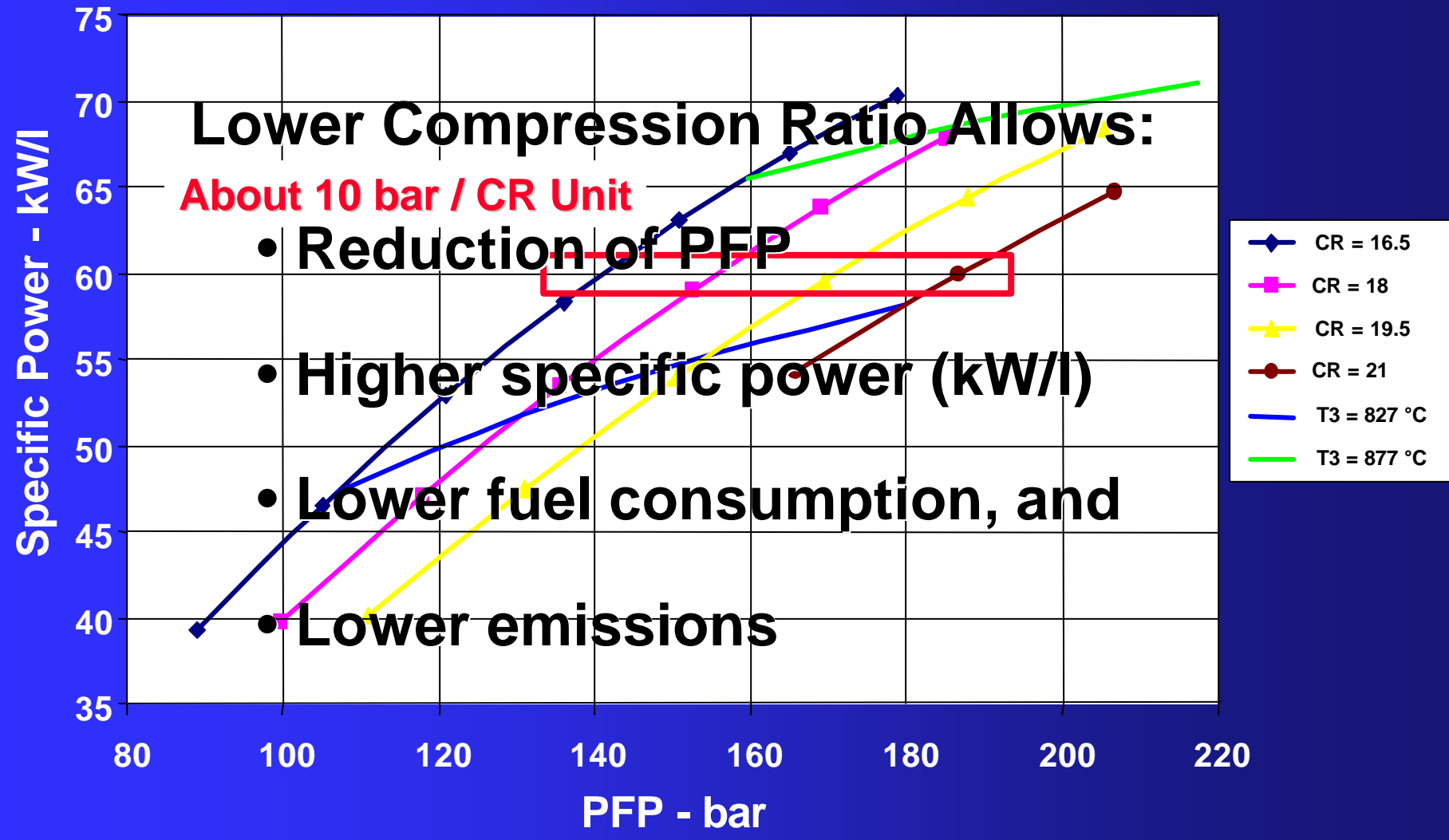




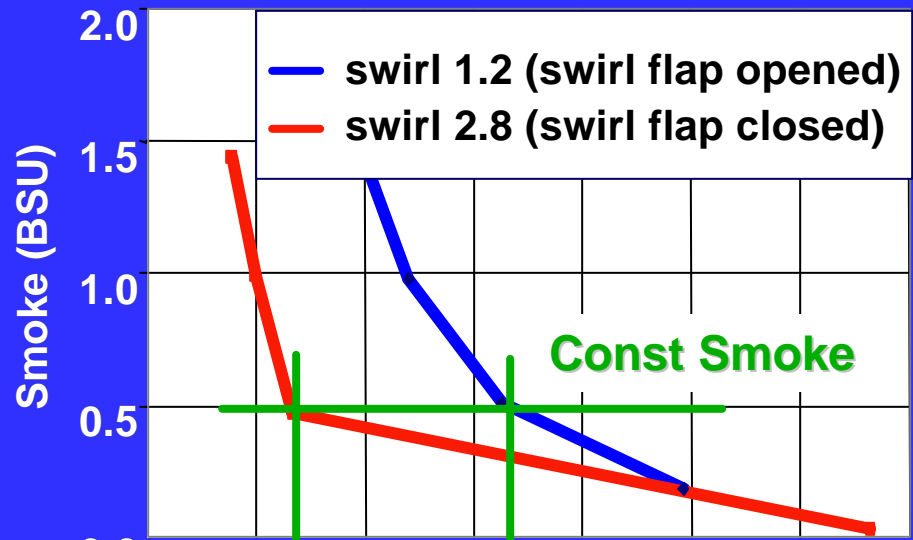
Specific Power vs. Peak Firing Pressure and Compression Ratio



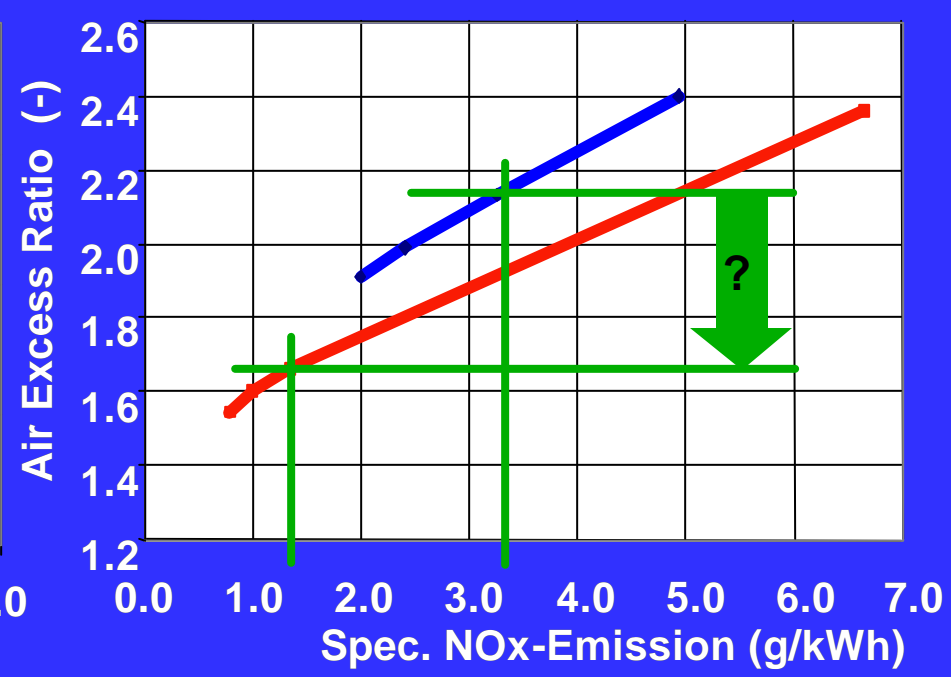
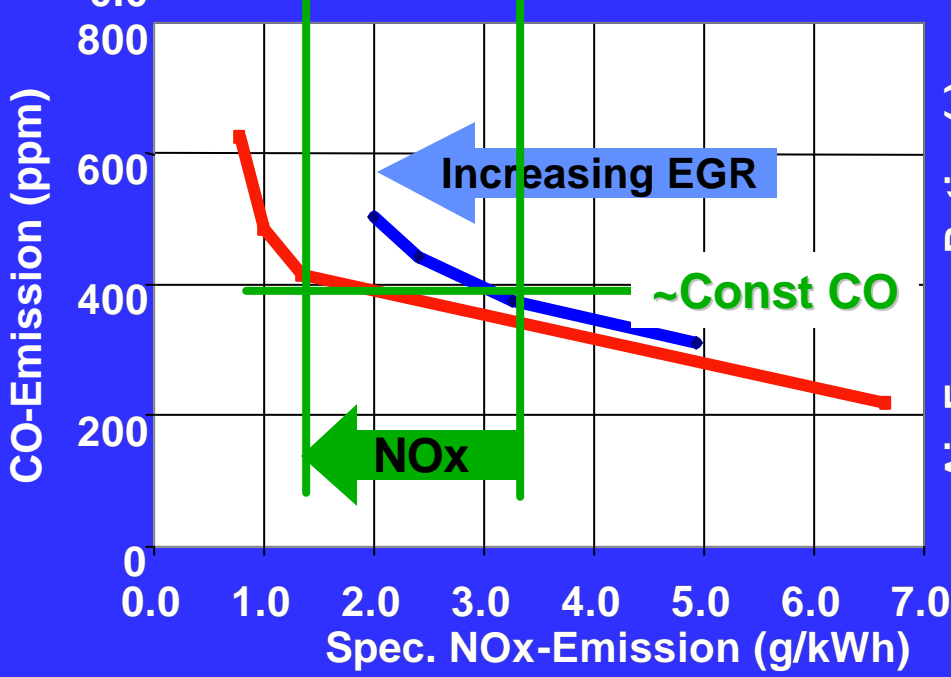
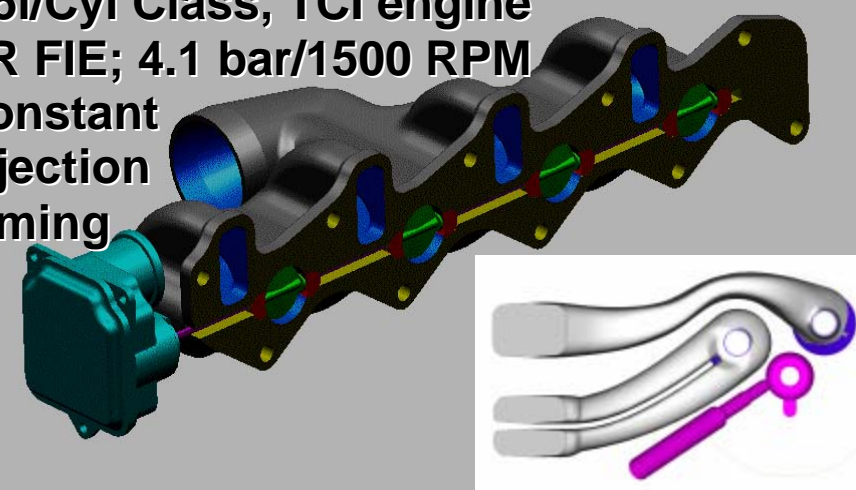
3l V6 at Constant Compression Ratio



Variable Swirl: Effect on Exhaust Emissions



0.5l/Cyl Class, TCI engine
CR FIE; 4.1 bar/1500 RPM
Constant Injection Timing

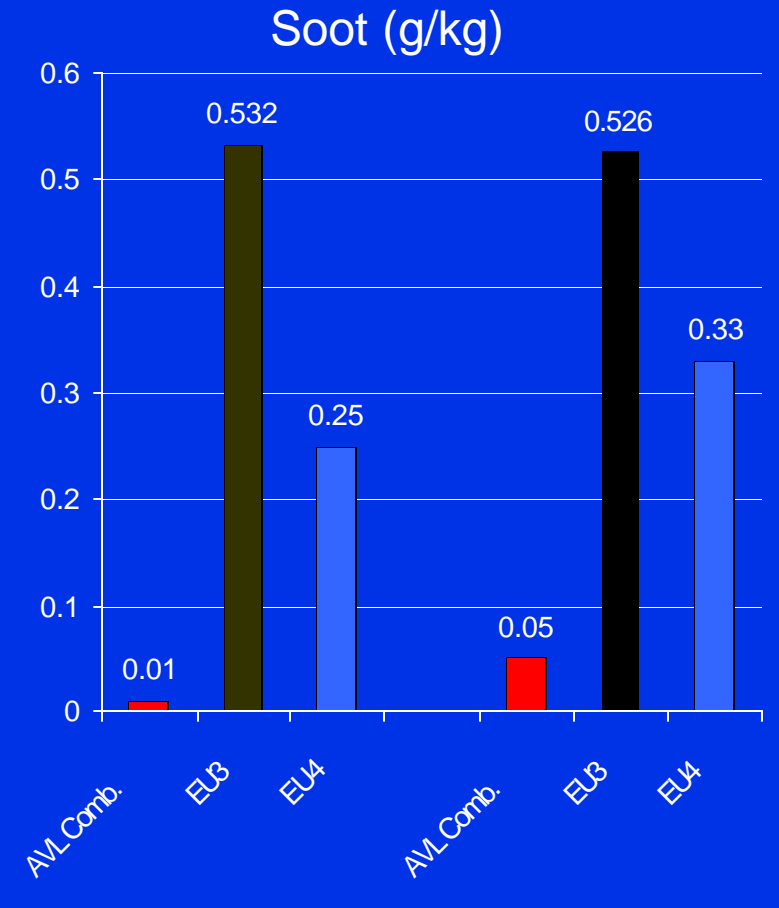
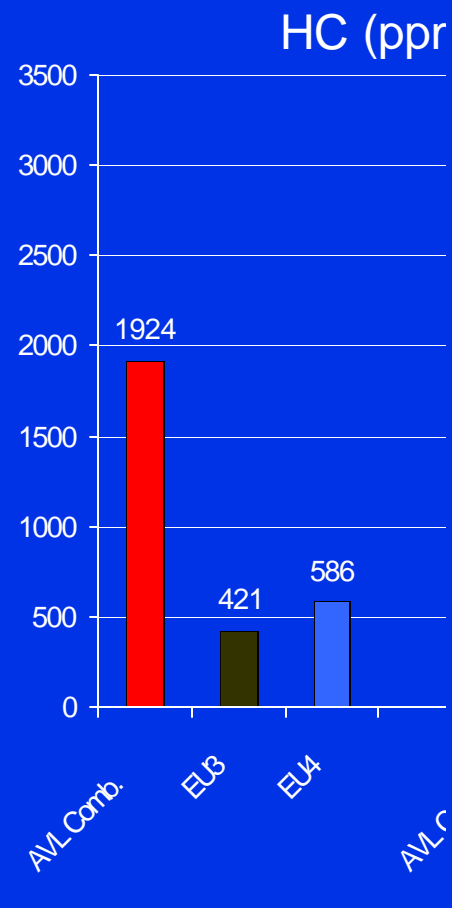
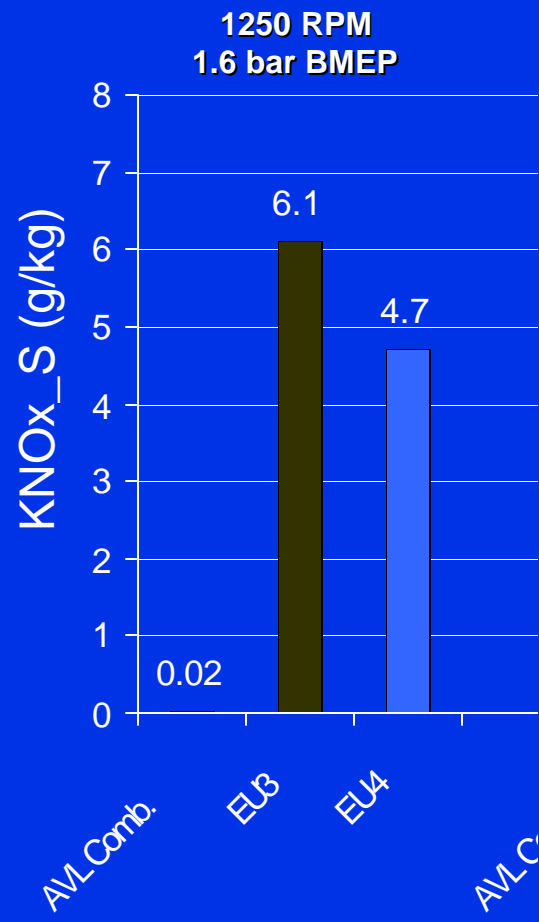




Alternative Combustion Systems



AVL Combustion: Single Cylinder Engine - 0.5 l/cyl.
EU III & EU IV Data: Multicylinder Engine - 0.40 l/cyl.





Summary and Conclusion



- **Specific Performance Will Reach**
 - **60-65 kW/l**
 - **180 Nm/l**

- **Engine Fuel Consumption Will be Reduced by:**
 - **Friction Reduction**
 - **Faster Engine Warm Up**
 - **Reduced Compression Ratio**
 - **Cylinder Deactivation, and**
 - **Start-Stop Operation**



- **Emissions Reductions to Very Low Levels by:**
 - **Increased Sophistication**
 - **Exhaust Aftertreatment**
 - **Improved Fuels**
 - **Alternative Combustion Systems**

- **Most Solutions Too Expensive or Not Ready for Mass Production**



- **“Mainstream” HSDI Diesel Technology Will be Cost Competitive With Gasoline Engines**
- **High-Tech Diesels Most Appropriate for Markets With Strong Emphasis on Fuel Consumption, i.e.**
 - **Europe**
 - **North America (Pick-Ups, SUVs, etc.)**