The Auto Oil Programs
Petrol and Diesel

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Outline

- Auto Oil Programs in
  - United States
  - European Union
  - Japan
- Objectives
- Processes
- Outcomes
- Legislation
- Summary

Auto Oil Programs

Part of Legislative Process:

- **Defining Air Quality Deficiencies**
- **Fuel Technology / Vehicle Emissions Relationships**
- **Air Quality Modelling**
- **Costs and Benefits**
- **Other Measures**
  - **Stationary Sources**
  - **Traffic Management**
  - **Inspection and Maintenance**

Approach to Develop Data

- Assessing Existing Information
  - Published
  - Proprietary In-house
- Research Programs Using Existing Technologies
- New Technologies
  - Development
  - Proof-of-performance Demonstration
- Cost / Effectiveness
- Security of Supply

Legislation

Affecting Vehicles and Fuel Qualities:

- **Fixed Limits**
- **Averaging and Pooling**
- **Predictive Models**

US Auto Oil Program

- Air Quality Improvement Research Program (AQIRP)
- Solving Local Air Quality Problems
  - Summer Ozone and Smog
  - Winter CO Emissions
- Alternative Fuels
  - Methanol
  - LPG
  - CNG
- No Diesel Vehicles / Diesel Fuels

US Auto Oil Program

- New and Older Cars
- Regulated Emissions
  - HC, CO, NOx
- Air Toxics
  - Benzene, 1,3-Butadiene, Aldehydes, POM
- Air Quality Studies
- Economics

US Auto Oil Program

- **Most Impotant Results for Petrol Vehicles**
  - **New Models Have Much Lower Emissions Than Older Cars**
  - **Lower RVP Reduces Evaporative Emisions and Ozone**
  - **Lower Sulfur Decreases Regulated Emissions, Air Toxics and Ozone**
  - **Lower Olefine Content Reduces Ozone**
  - **Lower T90% of Distillation Reduces Ozone and Exhaust HC Emissions**
  - **Lower Aromatics Content Lowers Air Toxics (Benzene)**
  - **Adding Oxygenates Reduces CO Emissions**

US Clean Air Legislation

- **US Federal Reformulated Gasoline: Clean Air Act Requirements**

Recipe

Benzene	Max. 1%
Oxygen	2.0 - 2.7%

+

Performance Standards
Against 1990 Avg. Gasoline

	1995	2000
VOC	-15%	-25%
Toxics	-15%	-25%
NOx	Cap	-5%

US Reformulated Gasoline

- **Simple and Complex Models Will Be Used to Estimate Federal RFG Performance**
- **1995 - 97: Simple Model**
  Fuel Variables to Control
  - **VOC: RVP, Oxygen Content**
  - **Air Toxics: RVP, Oxygen, Benzene, Aromatics**
  - **NOx Satisfied as Long as Oxygen < 2.7 % m/m**
- **1998+: Complex Model**
  - **Fuel Variables to Control: RVP, Oxygen, Benzene, Aromatics, Olefins, Sulfur, Distillation Parameters**

European Auto Oil Program

- European Program on Emissions, Fuels and Engine Technologies (EPEFE)
- New Legislation for the Year 2000
  - Air Quality Standards
  - Vehicle Exhaust Emission Legislation
  - Fuel Quality Requirements
- To Be Based on
  - Sound Technical Information
  - Air Quality Data for European Metropolitan Areas
  - Cost Effectiveness

Survey of Existing Data: Olefins in Petrol

- **10% Reduction Will Change Emissions by**

Vehicle	with Catalyst	w/o Catalyst
CO	0 %	0 %
HC (Exhaust)	+ 4 %	+ 12 %
HC (Evaporation)	– 2 %	– 2 %
NOx	– 4 %	– 12 %
Benzene	0 %	0 %

Survey of Existing Data: Sulfur in Diesel

- **Sulfur is Partially Oxidized to H_2SO_4 / Sulfates: Adds with Bound Water to Weight of Particulate Matter**
- **Percent Change in PM Emissions When Reducing Sulfur Content by 100 ppm:**
  - **Light Duty Cars – 0.16 %**
  - **Heavy Duty Engines – 0.87 %**
- **No Effect on HC, CO and NOx Emissions**

EPEFE Test Program

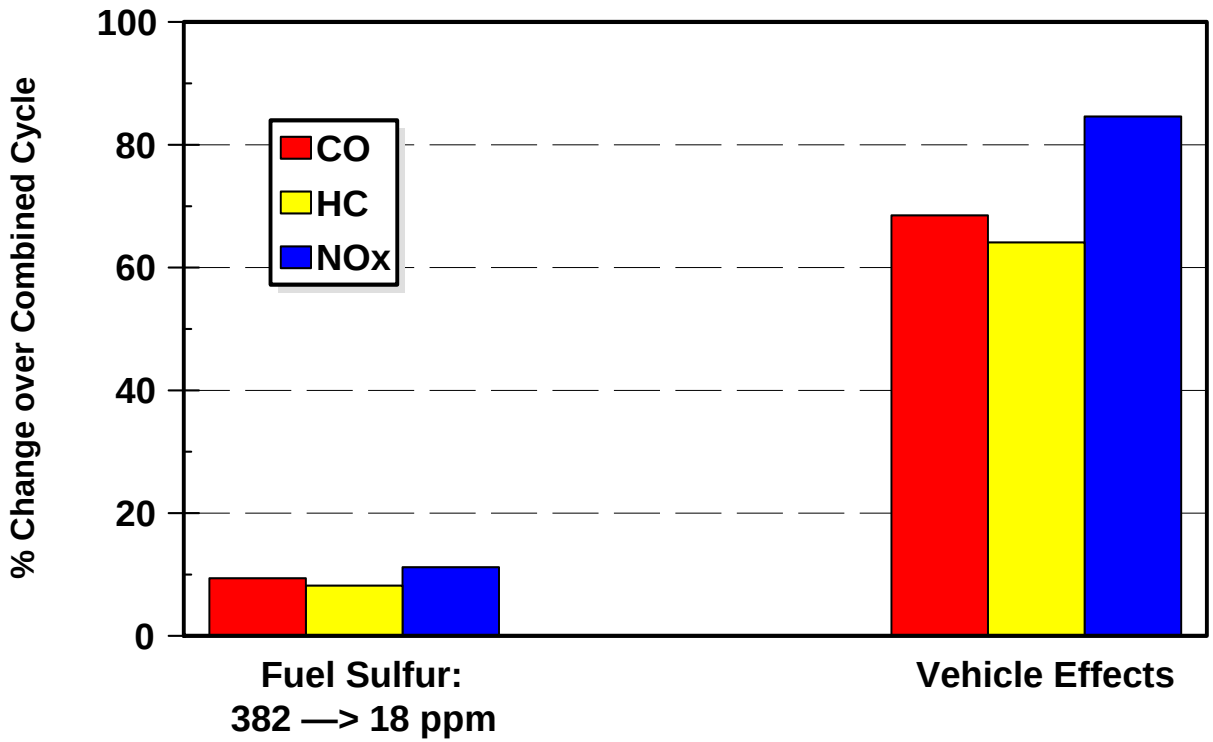
- **Concentrating on Those Areas Where Information Was Missing**
  - **Petrol**
    - **Sulfur**
    - **Petrol Aromatics and Mid-range Volatility**
  - **Diesel**
    - **Cetane Number**
    - **Distillation End Point (T95%)**
    - **Density**
    - **Poly Aromatics (2-Ring and Higher)**

European Auto Oil Program

- **Areas Not Investigated**
  - **Durability of Exhaust Emission Control Equipment**
  - **New Emerging Technologies**
  - **Effect of Ambient Conditions**
  - **Driving Cycles**
  - **Bio-fuels**
  - **Synthetic Fuels**
  - **Gaseous Fuels**
  - **After-market Conversions**
  - **Inspection and Maintenance**
  - **Stationary Sources**

EPEFE: Sulphur in Petrol

- **Effect of Sulfur Change Relatively Small Compared to Differences Between Vehicles**

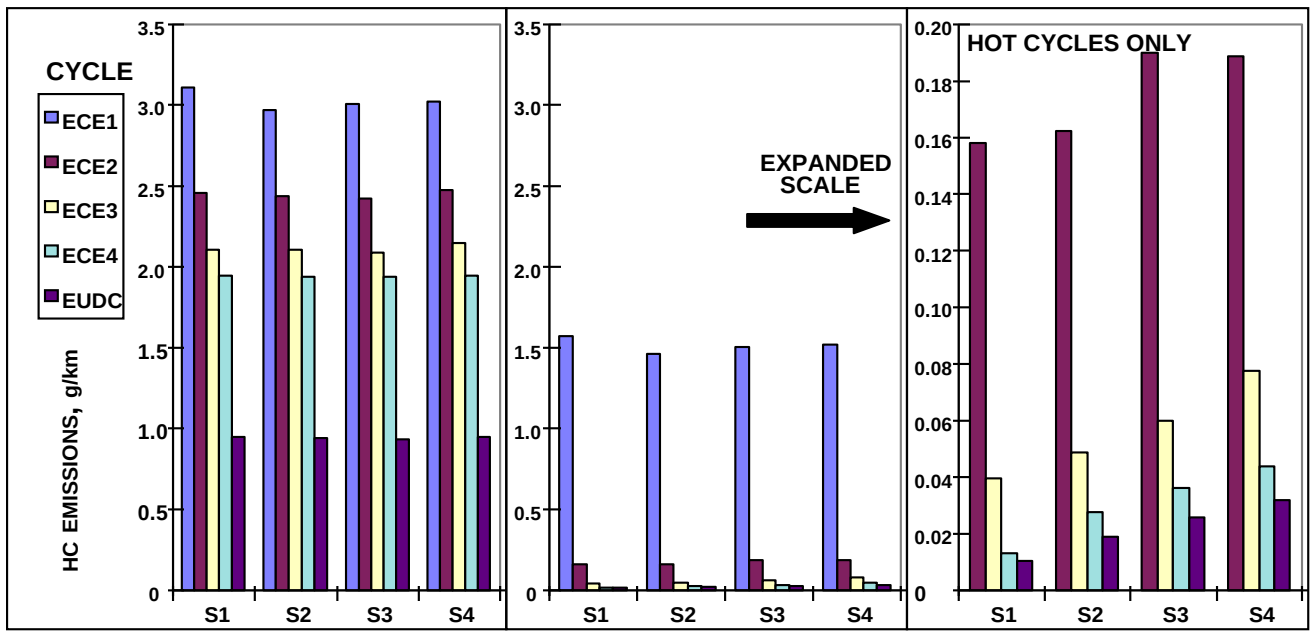


EPEFE: Cold Engine Emissions

- **Main Exhaust Emissions Immediately After an Engine Start**

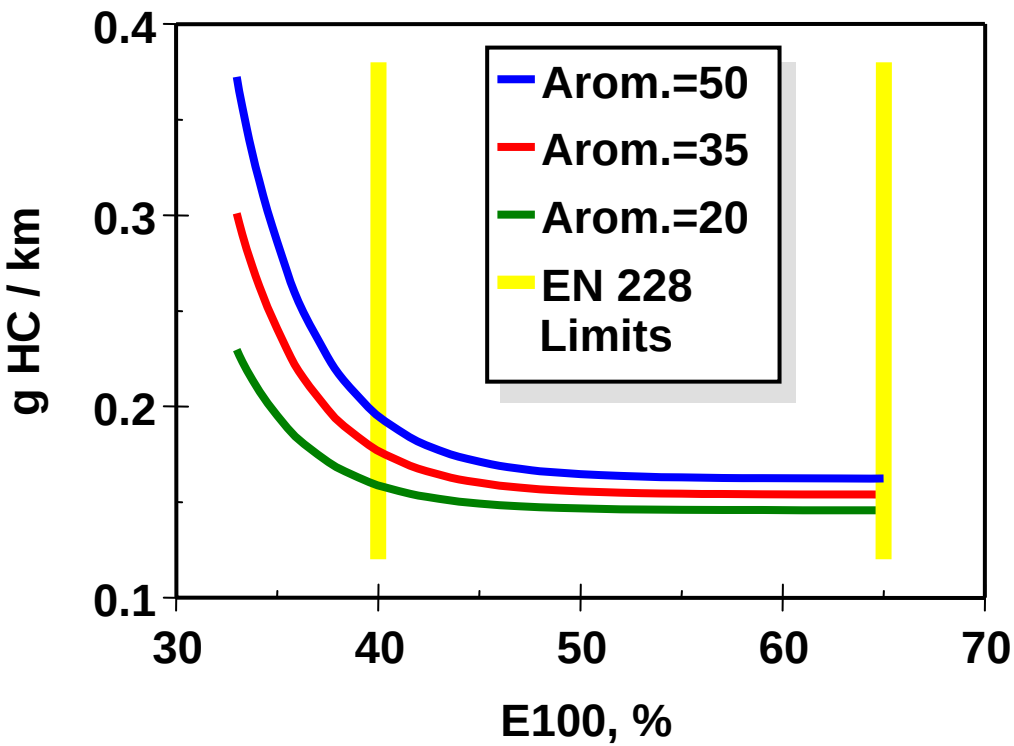
COMPARISON OF HC EMISSIONS BEFORE AND AFTER CATALYST

Engine-Out Emissions **Catalyst-Out Emissions**



EPEFE: Petrol Aromatics and E100ºC

- **Largest Effects When Properties Are Outside the Range Found in Marketed Qualities**

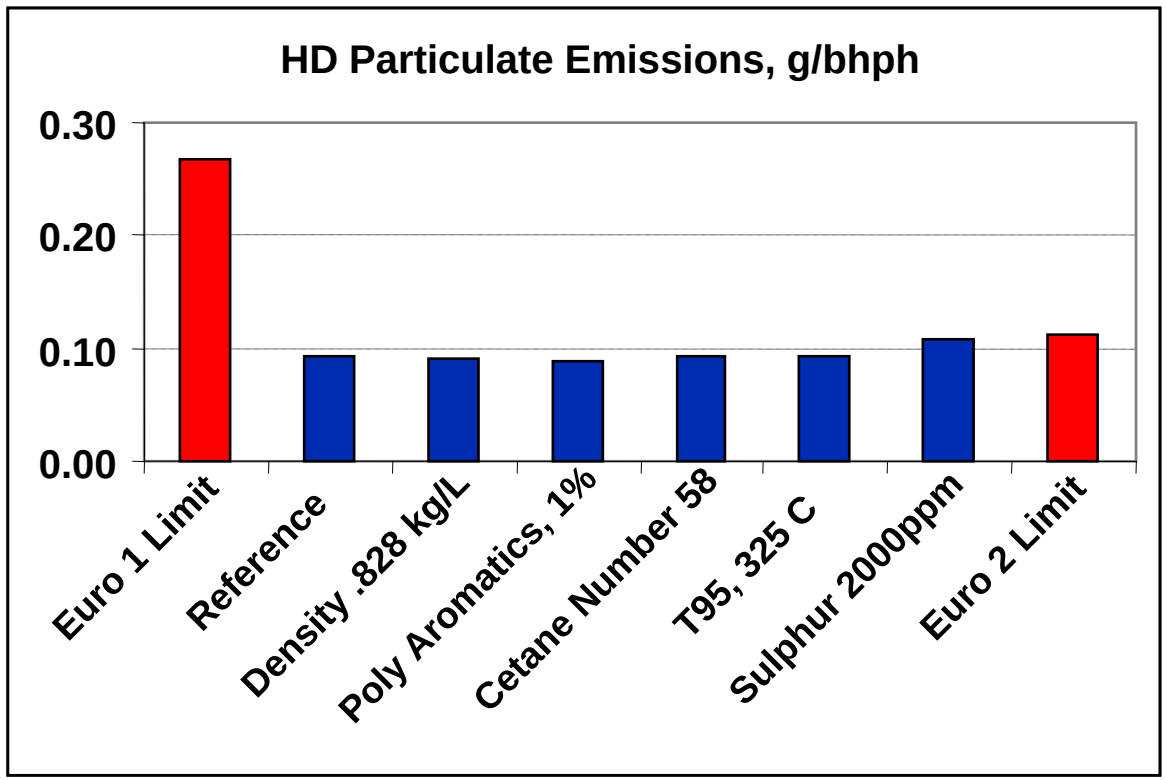


EPEFE: Diesel Effects

- **Vehicle Effects Larger Than Fuel Effects**
  - **Systematic Evaluation of Hardware Beneficial**
- **Fuel Effects Can Move in Opposite Directions for Cars and Trucks**
  - **Vehicle Mix / Test Procedures Must be Representative**
- **Individual Vehicles Respond in Different Ways**
  - **Fuel / Hardware Interaction Critical to Understanding**
  - **Large Number of Representative Vehicles / Engines Needed to Draw Robust Conclusions**
- **Fuel Interacts with Fuel injection Equipment**

EPEFE: Fuel Effects on PM Emissions

- European EPEFE study: 11 Fuels, 5 HD Engines, 1996 Level Engines
- Fuel Effects Calculated from Reference Baseline
  - Density 0.855kg/L, Poly Arom 8%, CN 50, T95 370C, Sulphur 400ppm



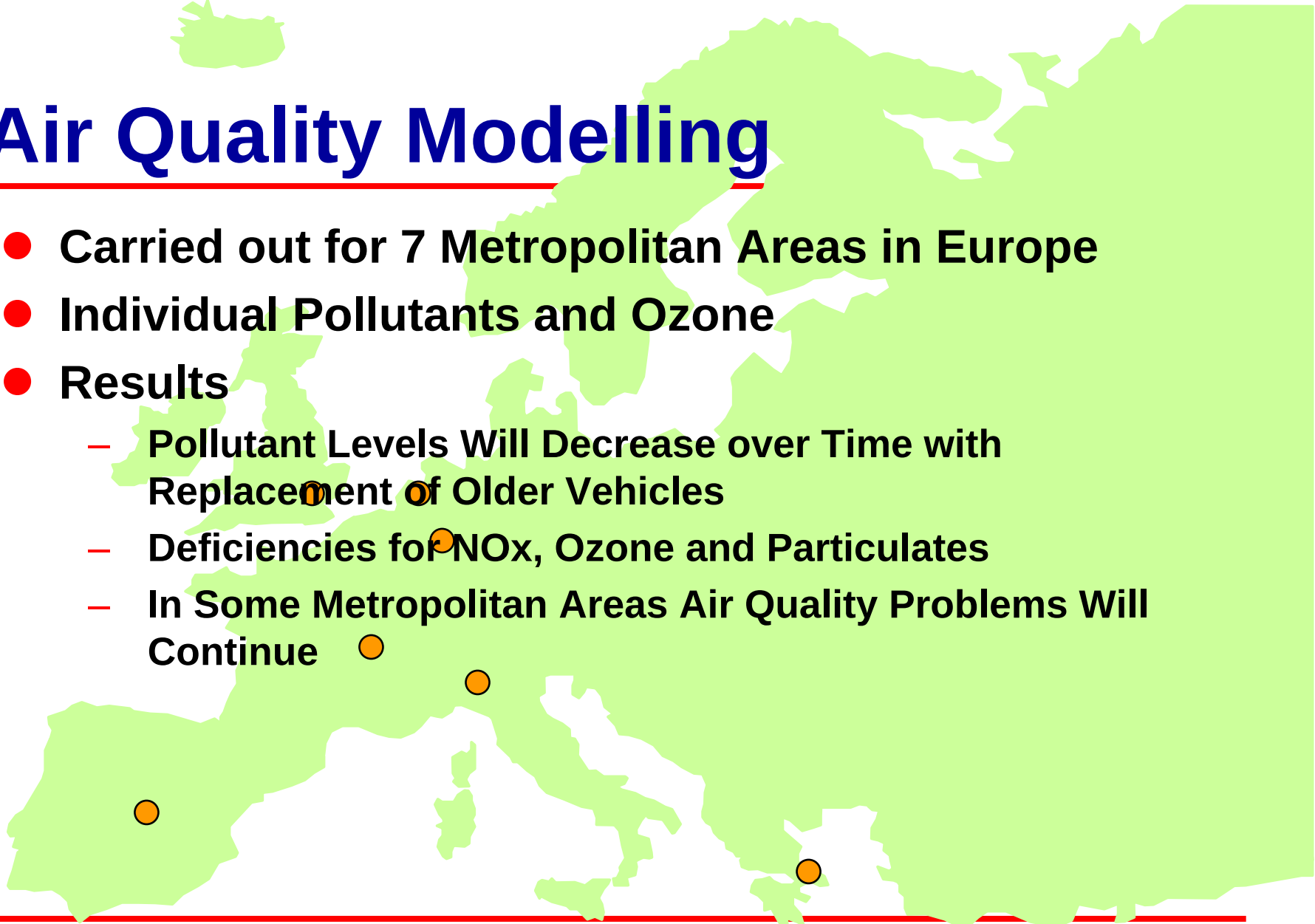
EPEFE: Diesel Effects

- **Effect of Fuel Variables Described in Regression Equations**

HC, CO, NOx, PM = f (Density, Polyaromatics, Cetane Number, T95%)

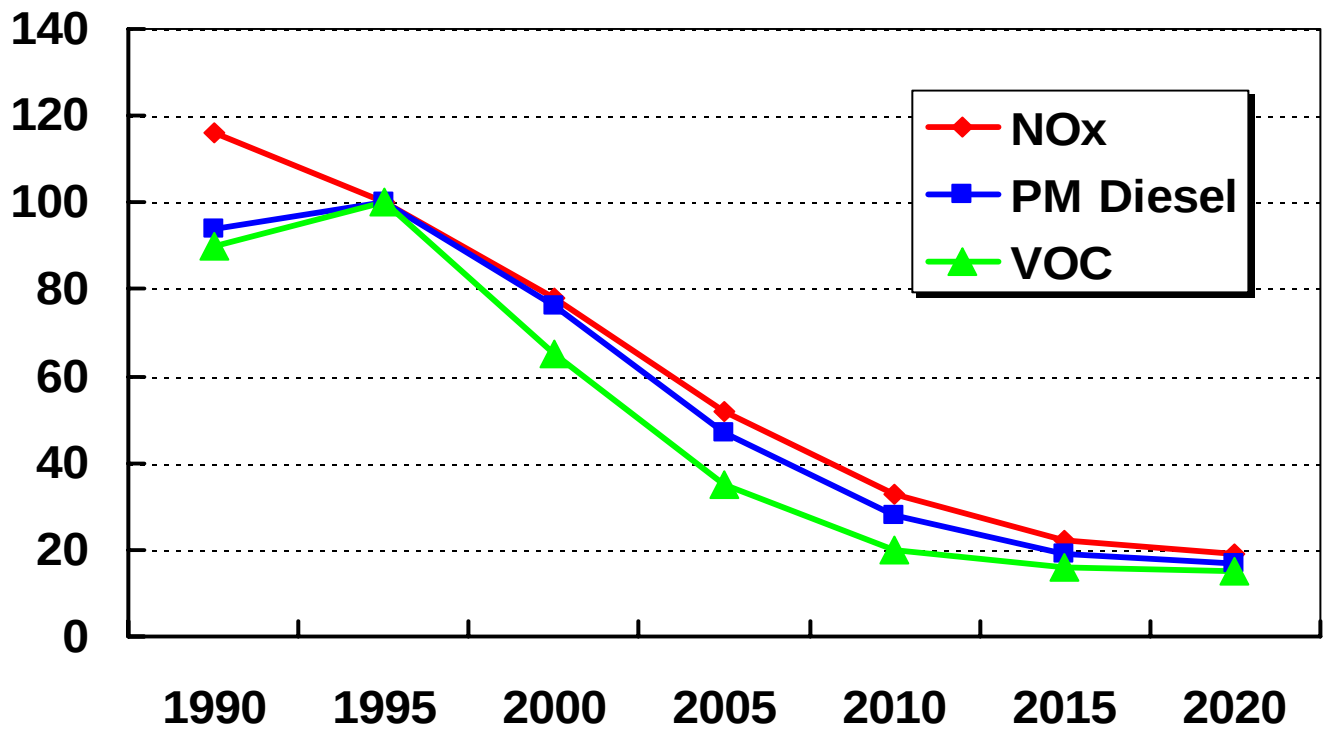
Air Quality Modelling

- Carried out for 7 Metropolitan Areas in Europe
- Individual Pollutants and Ozone
- Results
  - Pollutant Levels Will Decrease over Time with Replacement of Older Vehicles
  - Deficiencies for NOx, Ozone and Particulates
  - In Some Metropolitan Areas Air Quality Problems Will Continue



Air Quality Modelling

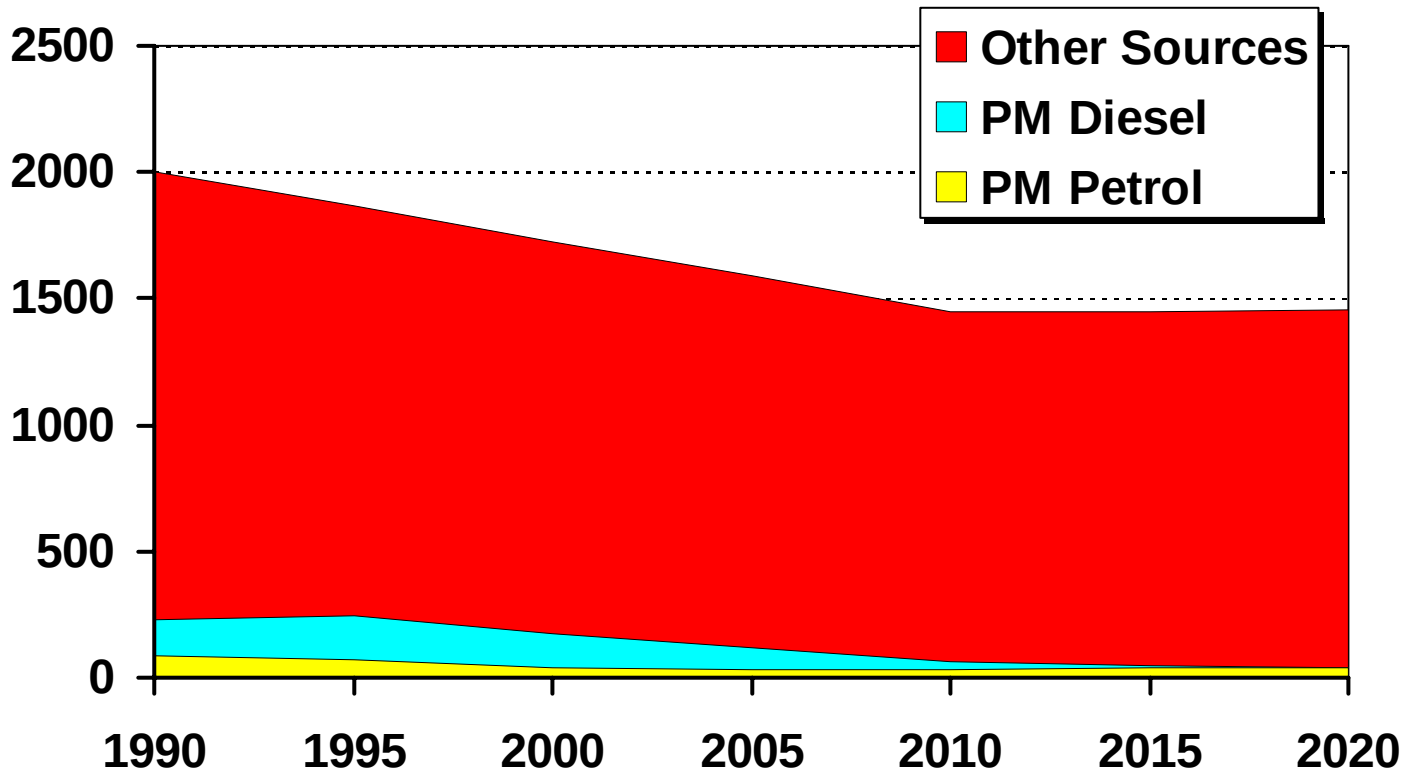
- **Road Transport Emissions in Europe (1995 = 100)**



European Commission, Auto Oil II Report, Sept 2000

Air Quality Modelling

- **EU Sources of PM10 in kto**



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Europe: Current and Future Specificatios

Petrol		Euro 2 Pre-2000	Euro 3 2000	Euro 4 2005
RON, MON	min	95 , 85	95, 85	95, 85
Sulfur, ppm	max	500	150	50
Benzene, %	max	5	1	
Aromatics, %	max	—	42	35
Olefins, %	max	—	18	
RVP (Su), kPa	max	70	60	
E100ºC, %	min	40	46	
E150ºC, %	min	—	75	
Oxygen, %	max	2.5 ... 3.5	2.7	

Europe: Current and Future Specificatios

Diesel		**Euro 2** **Pre-2000**	**Euro 3** **2000**	**Euro 4** **2005**
Cetane Number	**min**	**49**	**51**	
Sulfur, ppm	**max**	**500**	**350**	**50**
Density, kg/m^3		**820 - 860**	**820 - 845**	
Polyaromatics, %	**max**	**—**	**11**	
T95%, ºC	**max**	**370**	**360**	

Europe: Review for 2005 and Beyond

- Review with Stakeholder Input, No Test Program
- Special Review re Future Sulfur Levels
- Draft European Union Directive
  - Sulfur-free Petrol and Diesel (max 10 ppm) to be Introduced from 2005, Complete Market Coverage by 2011
  - No Further Changes in Petrol and Diesel Specs Above Those Already Agreed
  - Sulfur-free Fuels Required to Meet Euro 4 / 5 Exhaust Emission Limits and Fuel Consumption Targets
  - No Plan to Limit MTBE
  - Fuels Quality Monitoring to be Established

Japanese Clean Air Program

Objectives:

- **Identify Future Automotive and Fuel Technologies to Improve the Environment**
- **Predict the Air Quality Improvements by th Introduction of New Emission Reduction Technologies**
- **Evaluate the Costs and Effects of the Air Quality Improvements and Provide Technical Information for a Balanced Environmental Legislation**

JCAP Preliminary Results

- **Evaporative Emissions from Petrol Vehicles**
  - **Carbon Canister Size and Petrol Vapour Pressure Effects**
- **Sulfur in Petrol**
  - **Effect on Tail Pipe NOx Emissions, Especially With Lean Combustion**
- **Diesel Vehicles**
  - **High Performance Oxidation Catalyst Very Effective in Controlling HC, CO, Air Toxics, But Requires for PM Control Sulfur-free Diesel and Particulate Filter**
  - **For NOx Control Adsorption-De-NOx Catalysts and Selective Catalytic Reduction with Urea Investigated**

Lessons Learnt From Auto Oil Programs

- **Succesful Cooperation Between Auto and Oil Industries with Regulatory Bodies**
- **Different Vehicles and Exhaust After-treatment Systems React Differently to Fuel Quality Changes**
  - **Representative Vehicles**
  - **Representative Driving Cycle and Test Conditions**
- **Replacement of Older Vehicles by Low Emission Cars Most Effective for Air Quality Improvement**
- **Emissions from Transport Sector to be Assessed in Comparison to Stationary Sources**

The Road to Cleaner Air

- Representative Test Cycles
- Representative Vehicles and Test Fuels
- Technologies Covering the Market
- Representative Test Conditions
- Significant Correlations
- Reliable Air Quality Data
- Only Concerted Introduction of Low Emissions Vehicles and Fuels Has Large Impact on Exhaust Emissions and Ambient Air Quality

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