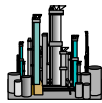


# The Need For and Benefits of Eliminating Lead From Gasoline

Montevideo, Uruguay  
June 2002

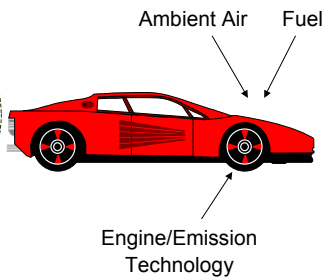


## Outline

- The Problem of Motor Vehicle Pollution
- Lead in Gasoline
  - Why Lead Was Added
  - Why A Consensus To Eliminate It
  - International Experience
- Beyond Lead

## Combustion Emissions

- Lead
- Hydrocarbons
- Carbon Monoxide
- Oxides of Nitrogen
- Carbon Dioxide
- Particulates
- Other toxic pollutants
- Water Vapor



## Other Emissions

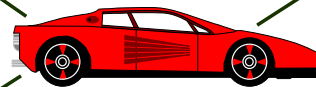
Refueling Losses  
displaced vapors

Evaporative Emissions  
diurnal, running losses, hot soak

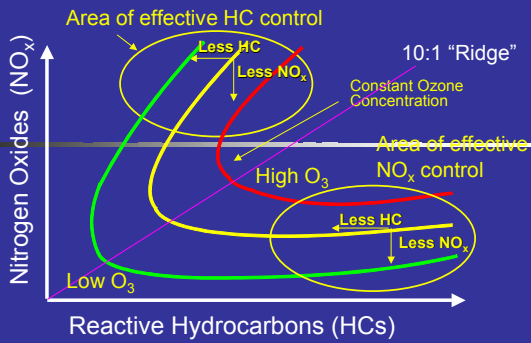
■ Other Emissions

- brake linings, tire wear, fluid leaks

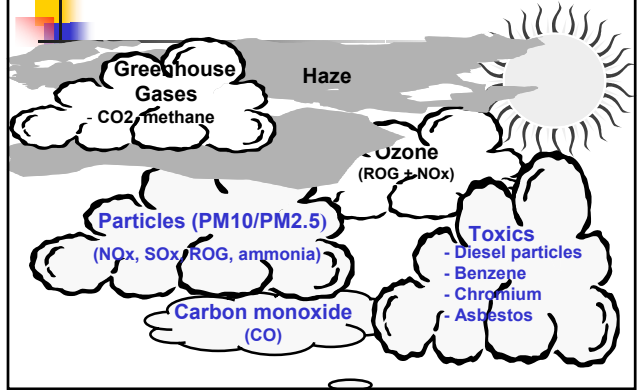
Crankcase Losses  
due to "blow-by"



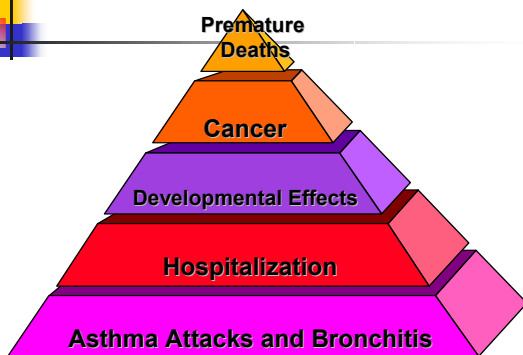
## Ozone Isopleth Plot (EKMA Diagram)



## What pollutants are of concern?



## Health Impacts of Air Pollution



## Health Effects

- Different Pollutants have Different Effects
  - Carbon Monoxide - circulatory system, heart
  - Ozone - respiratory system, lung
  - PM - lung, potential effects on heart
  - Diesel, Air Toxics - cancer, respiratory effects
- There are potential effects of the Mixture
- Some Populations more sensitive than others
  - elderly
  - people with heart and lung disease

## Special Population Exposures

- Average Annual Levels Can Be Misleading
- In Urban Areas, there are *Hot Spots*.
  - Street canyons, roadsides, urban centers
  - Exposure levels for PM, diesel, CO, air toxics can be 2 to 10 times higher than average
  - Exposure levels for Ozone will be somewhat lower (NOx "scavenges" the ozone)
- In these settings, vehicle contribution will be higher

## Carbon Monoxide Effects

- Known to cause death at high levels of exposure
  - raises levels of carboxyhemoglobin in the blood, blocking transport of oxygen to heart and brain
- In humans, effects have been shown even at low levels of exposure:
  - accelerates angina (chest pain) in people with coronary artery disease

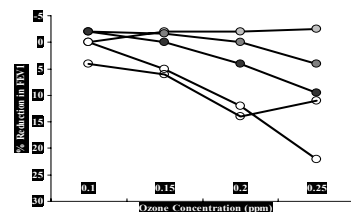
## Ozone Health Effects

- Known to cause inflammation in respiratory tract
- reduces ability to breathe (lung function) for some people
- Increases hospitalization for asthma, other lung diseases
- Effects have been demonstrated for short term, long term effects are less certain but evidence emerging

## Ozone Health Effects

Some humans have been shown to have reduced lung function (measured as FEV1) after exposure to ozone

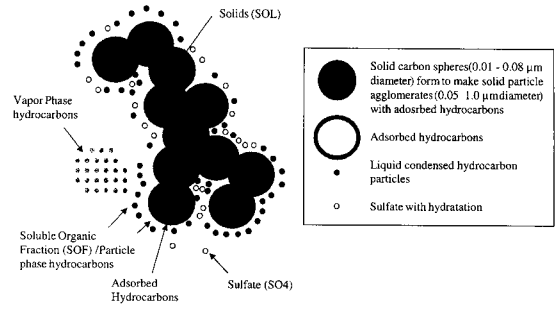
Figure 1. Individual Response to Ozone Exposure (after Kulle, et al, Am. Rev.)



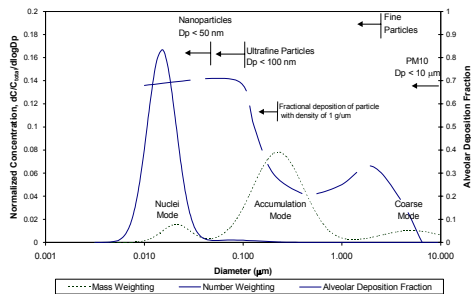
## PM Health Effects

- High levels of PM (e.g.  $500 \mu\text{m}^3$ ) known to cause premature death
  - e.g. London 1952
- Recent studies in US, Europe, Asia, South America have found association of PM with death at much lower levels
  - no evidence of a "threshold" (safe level)
- To date, a plausible biological mechanism for these effects has not been definitively determined

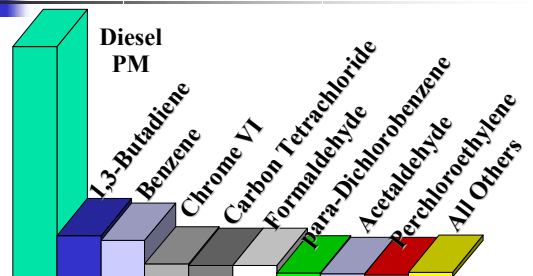
## Diesel Particulate Matter



## Typical engine exhaust mass and number weighted size distributions shown with alveolar deposition



## Relative Cancer Risks



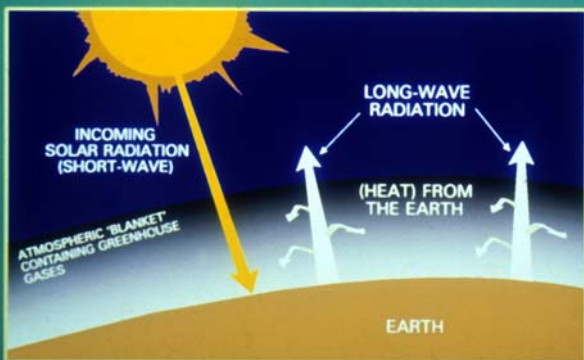
Based on ARB monitoring data 1995 - 1997

## Air Toxics Health Effects

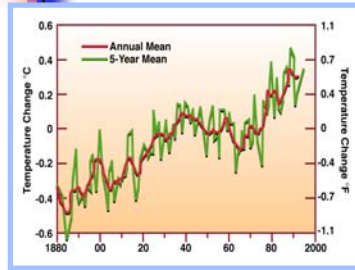
- Benzene
  - a "known human carcinogen"
  - studies in U.S., and Chinese workers have shown link between exposure and increased leukemia
  - levels of exposure a function of how much benzene in the fuel
- 1,3 Butadiene
  - a "probable human carcinogen"
  - studies in laboratory animals and US and Czech workers have shown effects
  - a product of combustion
  - vehicles the major environmental source



## THE GREENHOUSE EFFECT

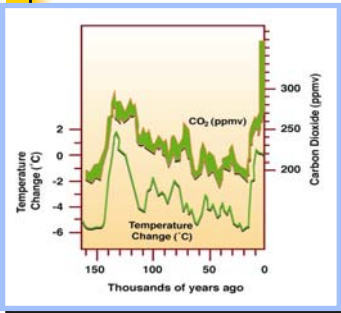


## Observed Global Surface Air Temperatures



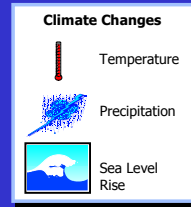
- 1990s warmest decade
- +1 °F last century
- Melting of glaciers
- Sea level rose 4-10"
- +2 to 6 °F by 2100

## Indicator of Climate Change



- **Temperature tracks carbon dioxide**

## Potential Climate Change Impacts

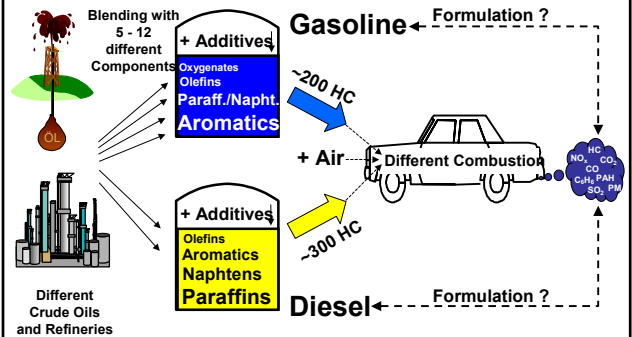


Source: Alamo Graphics (1998)



With All Of These Problems, Why Are We Worried About Lead in Gasoline?

## Different Automotive Fuels = Different Exhaust Emissions





## Why Are Fuels Important?

- Fuel Constituents **Directly** Affect Emissions/Air Quality/Health
- Fuel Changes Can **Immediately** Impact on Emissions From All Existing Vehicles
- Fuel Composition Can **Enable/Disable** Pollution Control Technology



## Why Was Lead Added To Gasoline

- Low Cost Octane Enhancer
- Higher Octane Allowed Better Engines
  - More Efficient
  - Higher Power Output



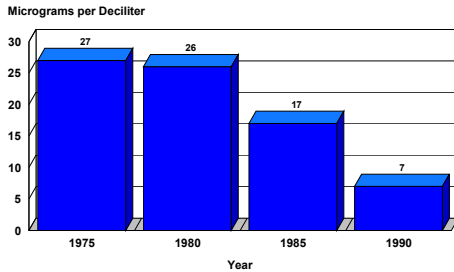
## We Have Learned However Lead In Gasoline Has Negative Side Effects

- High Ambient Lead Levels
- Serious Health Risks
- Precludes The Use of Catalytic Converters To Reduce Other Hazardous Vehicle Pollutants (CO, HC, NOx & Toxics)
- Higher Vehicle Maintenance Costs

## Why Do We Care About Leaded Gasoline?

- Concerns About Lead
  - Impairs development of brain function in children & lowers IQ
  - Causes cardiovascular diseases in adults
  - No safe level of exposure
- Concerns About Leaded Gasoline
  - Largest source of exposure in most urban areas
  - Effective dispersion to all environmental media
  - Long-term exposure by accumulation
  - Increasing problem due to high traffic growth

## Blood Lead Levels Considered Elevated

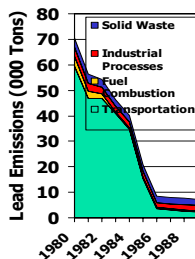


Is Any Lead Acceptable From A Health Standpoint?

## Children Are Especially Susceptible To Adverse Health Effects

- increased likelihood of exposure,
- increased absorption, and
- increased susceptibility of the brain.

## Trend in Lead Emissions and Air Quality in the US



- 87% Decrease in Average Ambient Lead Levels in 189 Urban Sites Over This Same Period
- Median Blood Lead Level Declined From 9.2 to 2.8 micrograms/dL

## The Experience Of Egypt - Health Effects Study

- Heart Attacks - 6,500 to 11,600
- Strokes - 800 to 1,400
- Premature Deaths (Adults) - 6,300 to 11,100
- Infant Deaths - ~820
- Average IQ Loss in Children - 4.25 Points

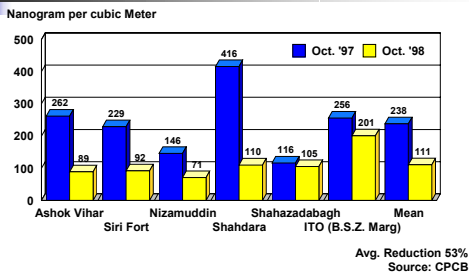
## The Experience of Egypt The Role of Gasoline

- Peak Ambient Levels ~ 10 micrograms/m<sup>3</sup>
- ~ 2/3rds from Gasoline; 1/3 Smelters

## The Experience of Egypt Results of Action

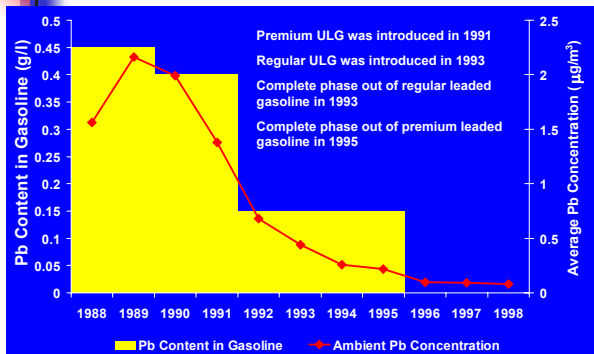
- Refinery Modifications
  - Process Changes
  - 15% Oxygenates
- Within 6 Months
  - 85% Unleaded Nationally
  - 100% Unleaded in Cairo

## Ambient Particulate Lead in Delhi Pre and Post Unleaded Petrol

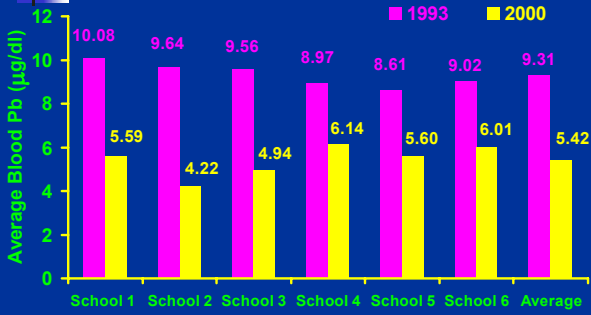


Lead Phase Out Started in September 1998

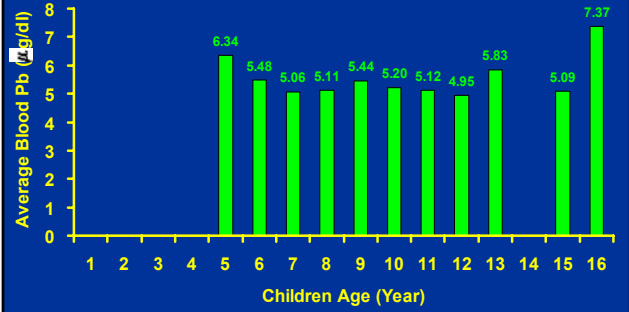
## Ambient Pb Concentrations in Bangkok and Pb in Gasoline from 1988 - 1998



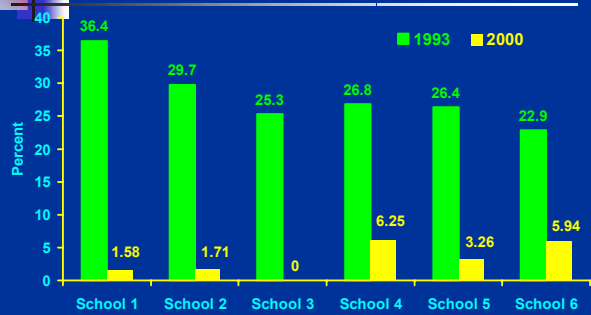
**Comparison of Average Blood Pb Levels in Children at 6 Schools in Bangkok between 1993 and 2000**



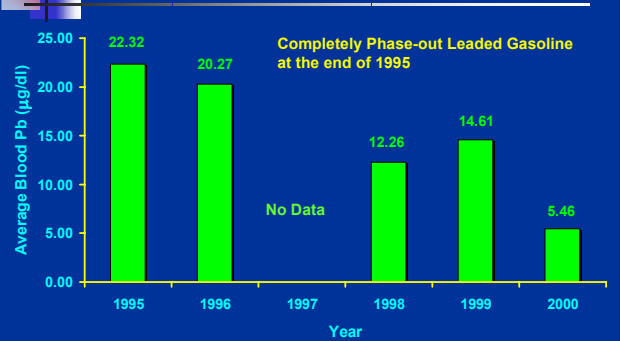
**Average Blood Pb Levels in School Children by Age in 2000**



**Percentage of School Children with Blood Pb Levels  $\geq 10$  µg/dl**



**Average Blood Pb Levels in Traffic Policemen in Bangkok from 1995 - 2000**



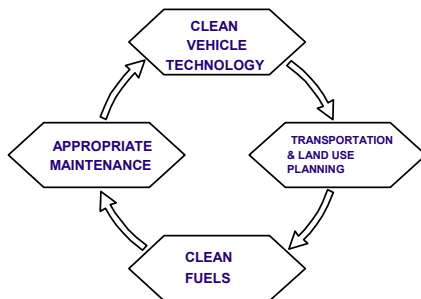
## The Magnitude of Health Impacts

- Losses of 4 or more IQ points in 30,000-70,000 Children in Bangkok
- More than 800 Infants and 10,000 Adult Deaths Annually in Cairo
- More than 150 Premature Deaths Annually in Jakarta

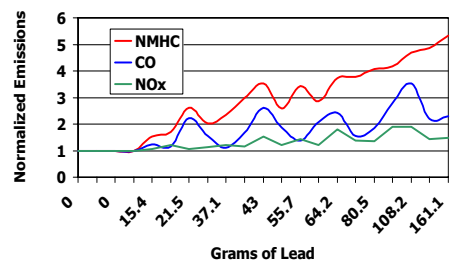
## The Cost of Health Impacts

- Reduced Productivity and Lifetime earnings
  - Increased Medical Costs
  - Compensatory Education Costs
  - Premature Deaths of Infants and Adults
- An Estimated \$17 Billion for each 1 ug/m<sup>3</sup> Increase in Ambient Airborne Lead in the US*

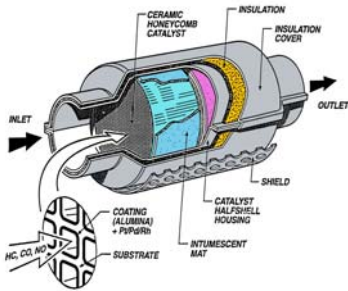
### ELEMENTS OF A COMPREHENSIVE VEHICLE POLLUTION CONTROL STRATEGY



## Impact of Lead on Catalyst Performance



### The Three-way Catalytic Converter: A Familiar Technology Re-Engineered for High Performance in Close-coupled and Underfloor Applications



- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management

### Unleaded Gasoline: Gateway To The Future

- Direct Health Benefits
- Technology Enabling
- Modern Vehicle Technology
  - Low "Conventional" Emissions
  - Low Greenhouse Gas Emissions
  - Retrofit Technologies
- Modern Gasoline Technology
  - Low Benzene
  - Low Sulfur
  - Low Volatility

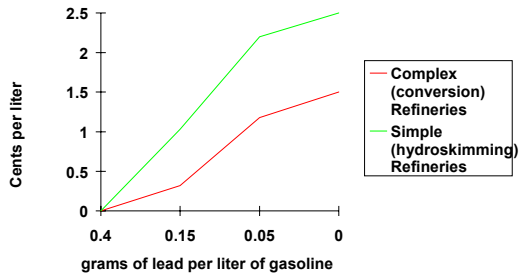
### Lead Free Fuel Can Be Used in Older Vehicles

- Valve Recession Problem Has Not Materialized
- Need Sustained High Speed, High Load Operation
- Lead Substitutes Exist if Needed
- No Other Impediments Identified

### Refinery Modifications Available To Replace Lead In Gasoline

- Increase Reformer Severity to Raise Reformate Octane
- Increase Production/Use of High Octane Blend stocks
  - Reformate
  - FCC Gasoline
  - Alkylate
  - Isomerate
  - Oxygenates

## Refining Costs of Lead Reduction (from 0.40 g/l)



## Quality Tradeoffs For Key Gasoline Blendstocks

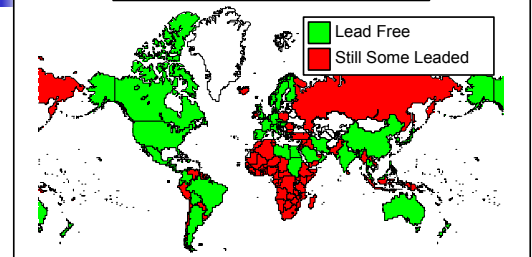
	High Octane	Low RVP	Low Olefins	Low Benzene	Low Aromatics
Butanes	Yes	No	Yes	Yes	Yes
Alkylate	Yes	Yes	Yes	Yes	Yes
Isopentane	Yes	No	Yes	Yes	Yes
C6 Isomerate	No	Yes	Yes	Yes	Yes
Lt FCC Naptha	Yes	No	No	No	Yes
HV FCC Naptha	No	Yes	Varies	Yes	No
Reformate	Yes	Yes	Yes	No	No
MTBE	Yes	No	Yes	Yes	Yes

## Worldwide Consensus

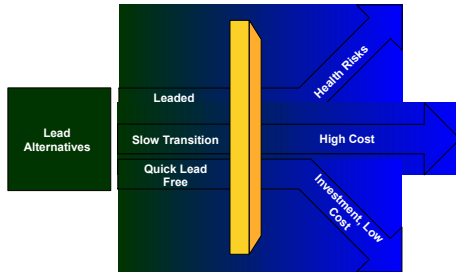
### Leaded Gasoline Should Be Eliminated

- Alternatives Are Widely Available
- Health Concerns No Longer Debatable
- Catalysts Are Best Solution To CO, HC, NOx Problems and Only Work With Lead Free Gasoline
- Modern Engines Designed For Lead Free Fuel

## Sales of Lead Free Gasoline By End of 2002



## Issue: Fast Track or Slow Track



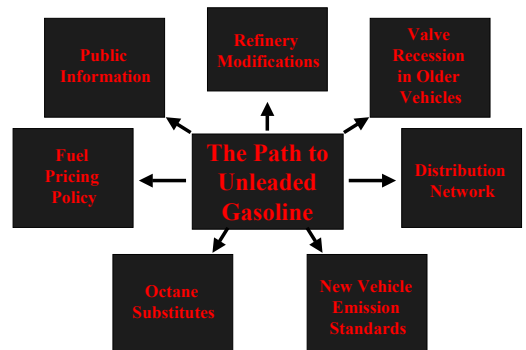
## Problems With A Slow Transition

- Risks of Contamination
  - Deliberate
  - Accidental
- Expense of Dual Distribution System
  - Delivery
  - Pumps & Storage
  - Vehicles
- Administrative

## Cost Effectiveness and Policy Implications

- Phasing out Lead from Gasoline is Highly Cost-effective (In the US, the Benefits Outweighed Costs more than 10 Times)
- Benefits Justify Rapid Phase-out - Faster than Car Fleet Replacement

## Issues to be Addressed in Phasing-Out Leaded Gasoline





## Policy Options For Lead Free

- Command and Control
- Vehicle Market Driven
- Fuel Pricing
- Combination



## Eliminating Lead Is Only The Beginning Toward Clean Fuels

- |            |          |
|------------|----------|
| ■ Gasoline | ■ Diesel |
| ■ Lead     | ■ Sulfur |
| ■ Sulfur   | ■ Sulfur |
| ■ RVP      | ■ Sulfur |
| ■ Benzene  | ■ Other  |



## Fuel Sulfur Negatively Affects Catalyst-Based Emission Control Technology

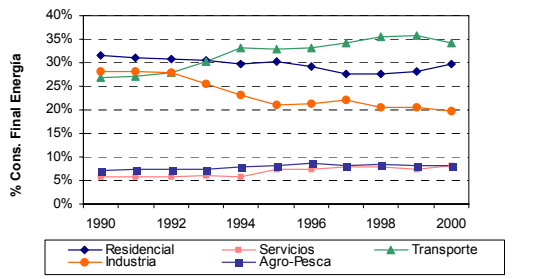
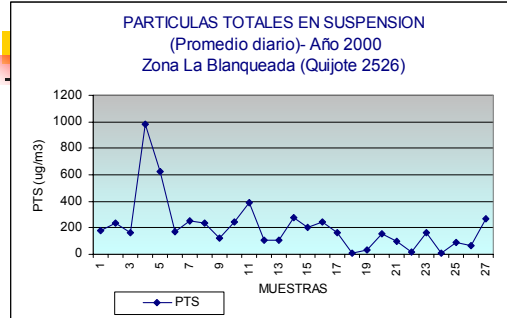
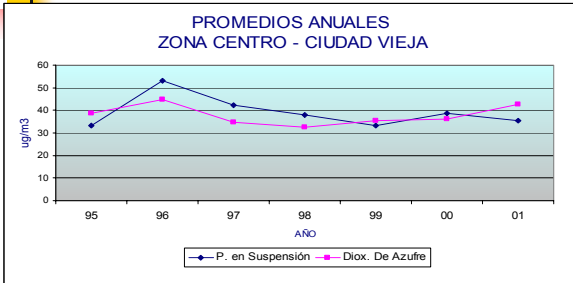
- Sulfur Inhibits Emission Control Performance and in Some Cases Is a Barrier to the Use of Certain Technologies
- Catalyst-Based Technologies Adversely Affected by Sulfur Includes
  - Automotive Catalysts
  - Oxidation Catalysts for Diesel Engines
  - Lean NOx Catalyst-Based Technologies for Automotive and Diesel Applications
  - Catalyst-Based Diesel Particulate Filters

*All Catalyst Technologies Adversely Affected*



## Low Sulfur Diesel Fuel

- Lower Sulfur Lowers Direct PM Emissions and SO<sub>2</sub>
- Lower Sulfur Allows the Use of Some Advanced Diesel NO<sub>x</sub>/PM Control Technologies
- Lower Sulfur Improves Performance of Other Advanced Technologies
- Enhances Retrofit Opportunities



## Policy Fundamentals From Bellagio Memorandum

- Vehicles and Fuels Are A Package
  - Clean Fuels Reduce Emissions Directly
  - Clean Fuels Enable Advanced Technologies
- Consider Air Quality and Energy Needs in Parallel
  - Case A - Diesel Cars - Conflict
  - Case B - Fuel Cells - Harmony
- Vehicles Doing Same Job Should Meet Same Standards
  - Diesel = Gasoline
  - Sport Utility Vehicles = Cars

