Financing Refinery Upgrades To Reduce Sulfur in Gasoline and Diesel Fuel

International Conference
On Fiscal Policies
For Promoting Cleaner
and
More Efficient Technologies
March 21-22, 2005

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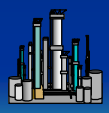


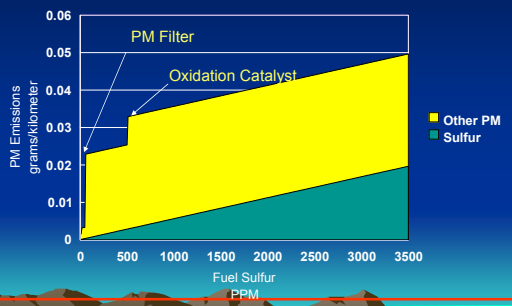
Overview

- Why Low Sulfur Fuels
- How Sulfur Levels Can Be Reduced
- What Does It Cost
- What Benefits Result

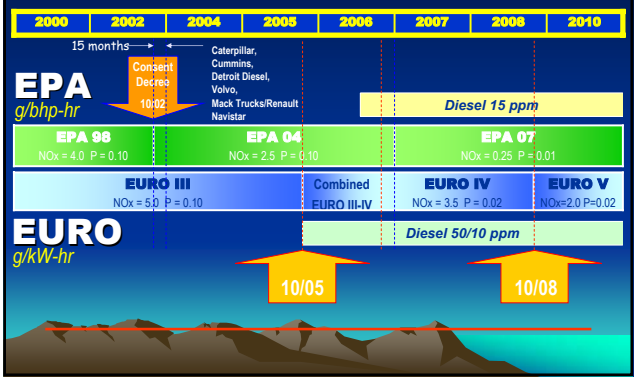
Why Low Sulfur Fuel?

- Lowers Emissions From Existing Vehicles
  - – SO_2 From All Vehicles
  - – PM From Diesel Vehicles
  - – CO, HC, NOx, Toxics From All Catalyst Vehicles
- Enables Advanced Technologies & Tight Standards For New Vehicles
- Enables Retrofit Technologies To Clean Up Existing Vehicles

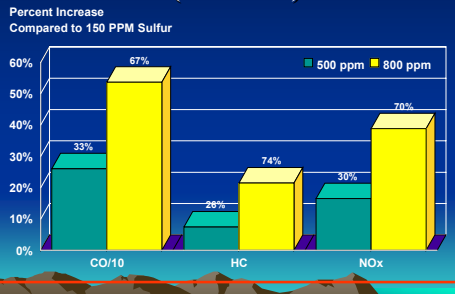
Linkage Between Fuel Sulfur and PM Emissions



Close Linkage Between Vehicle Emissions Standards and Fuel Sulfur Levels

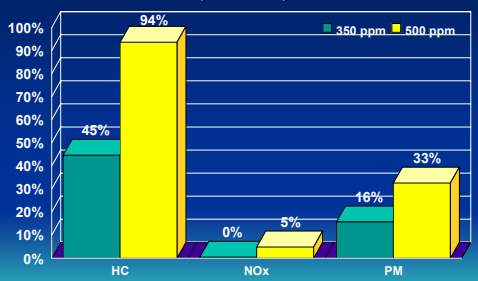


Increase in In-Use Vehicle Emissions in Bangkok Due To Sulfur in Fuel (Gasoline)



Impact on Vehicles Meeting EURO 3 Standards

Increase in In-Use Vehicle Emissions in Bangkok Due To Sulfur in Fuel (Diesel)

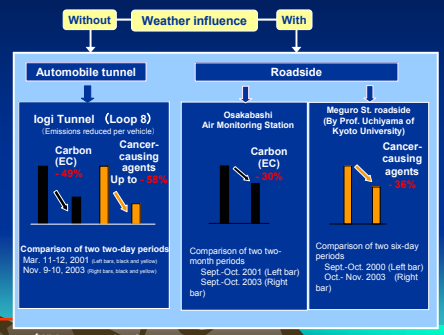


Impact on Vehicles Meeting EURO 3 Standards

Metropolitan in-Use Diesel Program

Tokyo Metropolitan Research Institute for Environmental Protection

Measurement results indicate that Diesel PM levels have been significantly reduced.
(By the Research Institute for Environmental Protection)



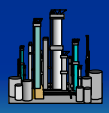
Tokyo Retrofit Program Began With Low Sulfur Fuels (<50 ppm)

(With cooperation from the Bureau of Construction)

Source: Professor Daisho

What a refinery does:

- Converts crude oil to usable products
- Adjusts yields to match product demand
- Adjusts qualities to meet product specifications.



Types of Refinery Processes

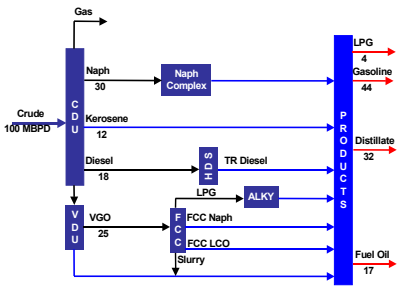
- Physical Separation Processes
  - Distillation/Fractionation
  - Extraction
- Chemical Processes
  - Cracking/Conversion
  - Combination/Reformulation
  - Hydrotreating

Refinery Configuration Overview

- **Topping** – Simple crude separation, no ability to change yield and quality
- **Hydroskimming** – Simple crude separation, no ability to adjust yield. Can increase octane, lower sulfur
- **Conversion** – Yield adjustment capability and quality improvement
- **Deep Conversion** – Large yield/quality flexibility, fuel oil minimization.

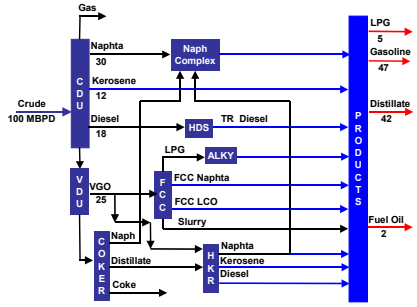
Conversion Refinery

Catalytic Cracking (FCC)



Deep Conversion Refinery

Catalytic Cracking, Coking & Hydrocracking



Diesel Hydrodesulfurization (HDS)

- Standard Diesel HDS:
  - Sulfur is catalytically removed in the presence of hydrogen
- Deep HDS
  - Higher activity catalyst and catalyst volume
  - More hydrogen consumed
  - High severity, high pressure operation
  - Loss of diesel yield

Fluid Catalytic Cracking (FCC)

- Vacuum and coker gasoil feeds
- Makes gasoline out of vacuum gasoil (a stream heavier than diesel).
- Using intense heat (about 1,000 deg F), low pressure and a powdered catalyst, the cat cracker converts heavy fractions into smaller gasoline molecules
- Product streams typically have high sulfur content

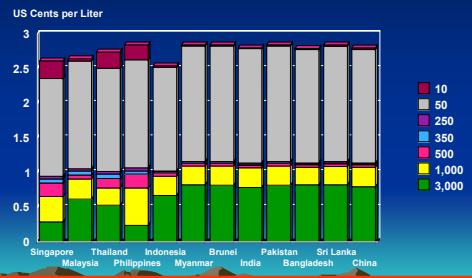
Hydrocracking

- Similar and preferably lighter feeds than cat cracking
- More flexible. Can optionally maximize gasoline, jet or diesel
- Uses a different catalyst, much greater pressure than FCC and a lot of hydrogen
- Products have minimal sulfur

Clean Gasoline Quality Changes
Severe sulfur reduction

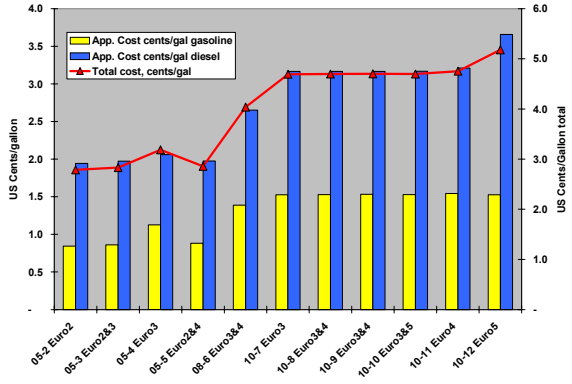
- Hydrotreat naphthas and FCC gasoline
  - Higher capital expenditure. Some octane loss.
- Desulfurize FCC feed
  - Higher capital cost.

Cost of Reducing Sulfur in Diesel Fuel in Asia
(High Sulfur Crude)

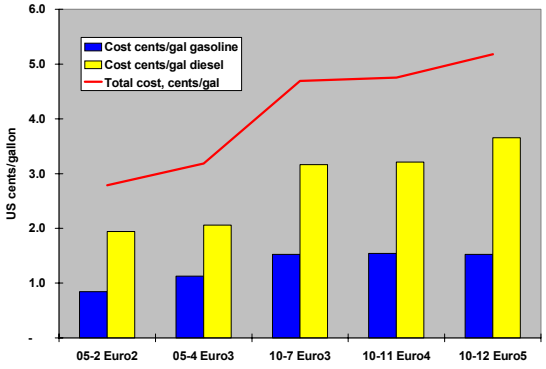


Source: Enstrat International

Gasoline and Diesel Reformulation Costs in China by Scenario



Gasoline and Diesel Reformulation Costs in China

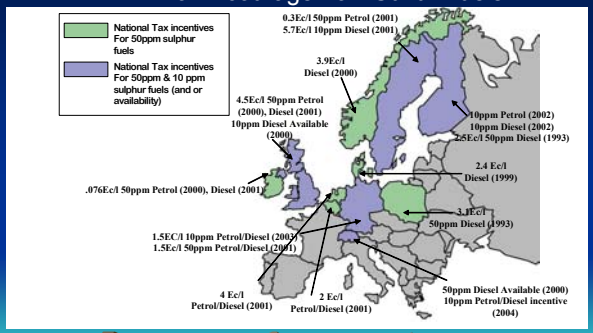


Source: Dr. Yamaguchi

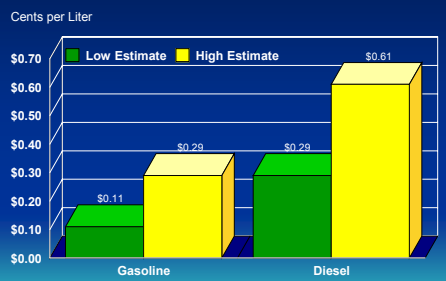
Costs for China

- Costs ranged from 2.8 to 3.2 c/g inclusive in 2005, 4.04 c/g in 2008, 4.7 c/g in 2010 except for EURO5 5.2 c/g.
- Diesel costs were roughly twice gasoline costs.
- Costs are well within acceptable parameters by US and European standards.
- Benefits may include emissions, fleet maintenance, fuel harmonization, ability to export

European Tax Incentives Schemes To Encourage Low Sulfur Fuels

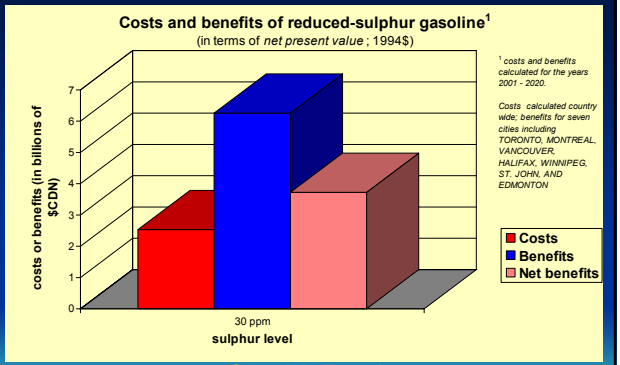


EU Estimate of Costs to Reduce Sulfur From 50 ppm to 10 ppm



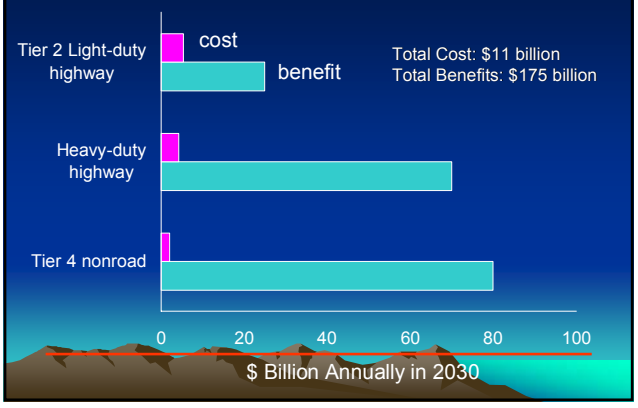
Benefits Exceeded Costs By Factor of 2 to 3 Times

Canada's Experience

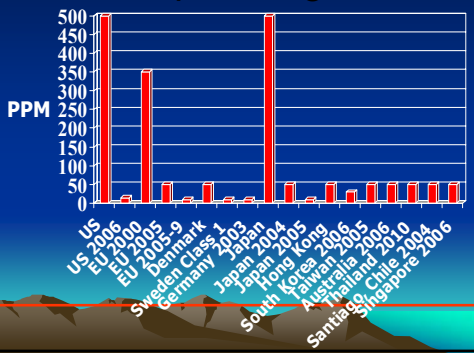


Benefits of Clean Fuel and Vehicle Programs in USA

Costs & Benefits of Clean Fuels and Vehicles



Ultra Low Sulfur Diesel Fuel Is Spreading



Conclusion

- Fuel Quality Is an Integral Part of a Complete Emission Control System for Both Gasoline- and Diesel-Powered Vehicles
- Fuel Sulfur Adversely Effects All Catalyst-Based Emission Control Technology and Needs to Be Reduced
- Using a Systems Approach with Ultra-Low Sulfur Fuel Combined with Advanced Engine Designs and Advanced Emission Control Technology, Cars, Trucks, and Buses Will Emit 99% Less Pollution As Compared to Vehicles in the 1960s

Fuel Sulfur Content: The Lower, the Better

Conclusion (continued)

- Introducing Low Sulfur Gasoline Fuel Will Immediately Improve the Emission Control Performance of Existing Catalyst-Equipped Vehicles
- Introducing Low Sulfur Diesel Fuel Will Enable Existing Engines to be Retrofitted with Advanced Control Technology

Conclusion (continued)

- Refinery Technology To Produce Low Sulfur Fuel is Well Understood and Advancing
- Cost are a few cents per gallon To go to Near Zero Sulfur Levels
- Every Available Study Indicates Benefits Will Far Outweigh Costs
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