Clean Fuels in China

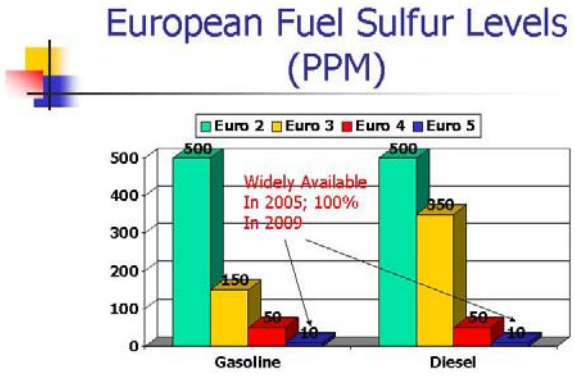
1. Background

Over the past 50 years, China has become the fifth largest oil producer in the world and its refining system the world's fourth largest. The technical foundation of the industry was initially adapted to handle the quality of Chinese crude, most of which is heavy, low-sulfur and waxy, and to the need to provide substantial quantities of fuel oil to industry. China's oil industry entered a new era in the 1990s as accelerating domestic demand for oil eroded the exportable surpluses of the 1980s. By 1993, China had become a net oil importer. In addition, growing concern over the environmental impact of rising oil consumption led to investments in new refining technologies and the revision of product specifications. Among the earliest policy targets was the elimination of 66 and 70 Motor Octane Number (MON) specifications for gasoline, raising the new minimum to 90 RON (Research Octane Number) and eliminating alkyl-lead additives for octane enhancement through the increased use of alkylates, reformate, and MTBE and other oxygenates in gasoline blending. New unleaded specifications for 93 and 97 octane (RON) gasoline were added as well.

2. Current Fuel Challenges

China is committed to increasing the quality of petroleum products, but the industry faces two broad challenges to achieving this goal. One area of challenge is the near-term feedstock and technology issues related to tightening specifications on products produced from China's 'traditional' crude slate of heavy, low-sulfur domestic crudes. The second, longer-term area of challenge is the technology and feedstock issues related to the maintenance or further tightening of product quality standards—particularly sulfur—in the face of the inevitable rise in the proportion of higher-sulfur imported crudes in China's processing slate.

To deal with the problems of air pollution, China has initiated a motor vehicle pollution control effort. As mentioned above, China moved quickly during the late 1990's to eliminate the use of leaded gasoline, followed rapidly by the introduction of EURO 1 standards for new cars and trucks[1]. It has also been decided to introduce the EURO 2 standards in 2004. To start the process, EURO 2 standards were introduced in Beijing on January 1, 2003 and in Shanghai on March 1, 2003. While this is a significant achievement, the emissions requirements for new vehicles in China still lag those of the industrialized world by almost a decade. In the current 10th Five Year Plan, however, China stated its goal to eliminate this gap by 2010. To achieve this goal, China will need to substantially upgrade fuel quality as the quality of fuels is inextricably linked to the emissions regulation of vehicles.



As noted above, China has been moving down the path of tighter and tighter vehicle emissions standards based on European Directives. As Europe's emissions standards have been tightened, however, there has been a parallel improvement in fuel quality, especially with regard to sulfur content as illustrated in the figure to the left. With regard to gasoline, the performance of the catalytic converter in reducing CO, HC and NOx emissions is closely linked to the sulfur in the fuel. Without low sulfur fuel, therefore, actual in use emissions will not approach the levels intended

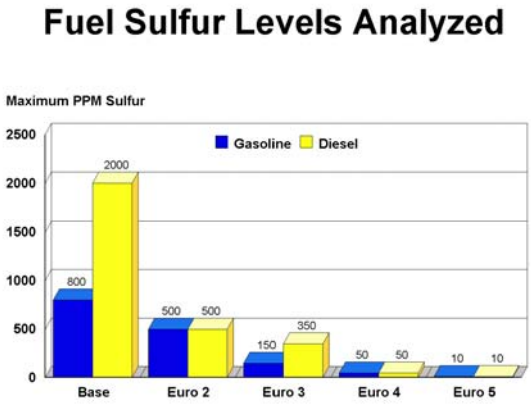
[1] These standards were introduced in the European Union in 1992.

by the emissions standards. With regard to diesel vehicles, the problem may be even more severe as high sulfur fuels can preclude the use of advanced PM and NOx control technologies because they are poisoned by sulfur. Even though China is introducing EURO 2 standards for vehicles and engines, as noted above, the national specifications for sulfur levels in gasoline and diesel fuel are 800 PPM and 2000 PPM, respectively, compared to 500 PPM as required in Europe. While some 500-PPM fuel is expected to be available in some cities, many vehicles will certainly be fueled outside these cities. Of the goal of achieving parity with Europe by 2010 is to be achieved, gasoline and diesel sulfur levels must be reduced to a maximum of 50 PPM by that time.

Solutions to this challenge are achievable though increased investment in the refinery sector. Since becoming a net importer of oil in 1993, imports of crude oil alone have risen dramatically, and are projected to reach at least 1.9 million b/d by 2005, and 2.16 million b/d or more by 2010.[2] In recognition that long-term supply stability requires dependence on the major Middle Eastern producers, China has begun to convert selected coastal refineries to process higher-sulfur grades, including refineries at Maoming, Guangzhou, Zhenhai, Shanghai, Jinling, and Qilu. Currently, total capacity to process higher sulfur crudes is about 370,000 b/d, and 200,000 b/d of higher sulfur crudes were actually processed in 1999.

3. Where Things Stand

The Energy Foundation has recently funded a study to examine what needs to be done with China's refineries to provide the necessary fuel quality.[3] This project examined China's current plans for upgrading its coastal refineries to handle higher-sulfur crudes, and on the basis of current investment plans, assessed the incremental costs of upgrades and measures that would be needed to produce cleaner-burning fuels under a variety of product specification scenarios.



The Figure to the left illustrates the various fuel sulfur levels analyzed. The intention was to start from the current requirements, the so-called base case, and then to track the requirements that are being phased in across the EU.

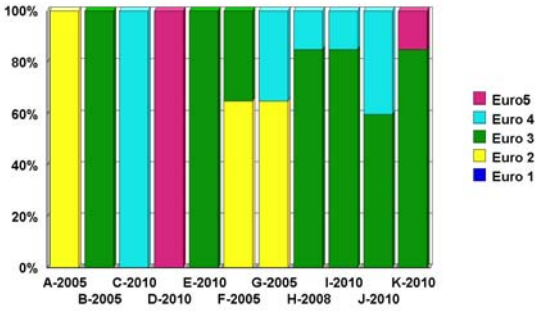
In addition to the Base case, eleven alternative fuel scenarios were analyzed, as shown in the Figure below. Scenarios A, B (both phased in by 2005), C, D and E (by 2010) consisted of a **complete** shift to Euro 2, Euro 3, Euro 4 or Euro 5 fuels. Scenarios F, G (both by 2005), H (by 2008 to coincide with the Beijing Olympics), I, J and K (by 2010) involved partial phase in schemes in which the cleaner fuels are initially delivered to one or major urban areas.

The costs of producing the various fuels were calculated both in terms of capital investment and per gallon with the results summarized below.

Converting to Euro 2 fuels (500 PPM maximum sulfur) across the entire country by 2005 (Scenario A) is seen to be feasible and relatively low in cost, less than $0.01 per gallon for gasoline and less that $0.02 per gallon for diesel. Scenarios F and G which mix 65% Euro 2 fuel with

[2] By 2010, Middle East higher sulfur crude is expected to account for 68% of imports.
[3] "Improving Transport Fuel Quality in China: Implications for the Refining Sector", Final Report, September 2002, Trans-Energy Research Associates, Seattle, WA, China Petrochemical Consulting Corporation, Beijing, Lawrence Berkeley National Laboratory, Berkeley, CA

Different Fuels Scenarios Which Were Analyzed

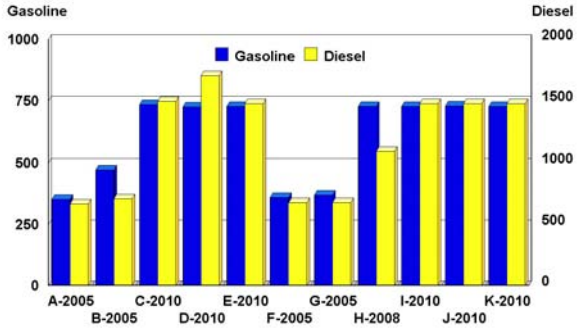


35% Euro 3 or Euro 4, respectively, cost only slightly more than 100% Euro 2; in fact, complete conversion to Euro 3 (Scenario B) fuel is also considered feasible and only slightly more costly.

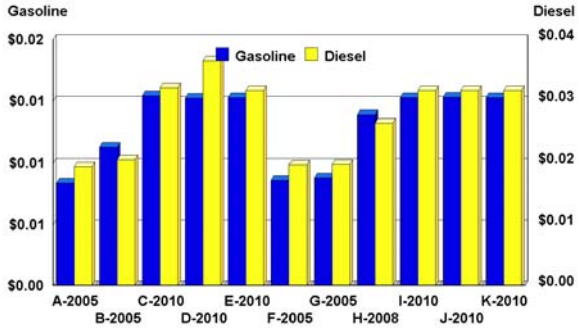
Incremental Cost Per Gallon Of Going Beyond 100% Euro 2 In 2005

	Gasoline	Diesel
35% Euro 3	$0.0002	$0.0003
35% Euro 4	$0.0004	$0.0004
100% Euro 3	$0.0029	$0.0012

Cost of Each Scenario $000/Day



Cost Per Gallon of Each Alternative Fuel Scenario



If Euro 3 fuel is introduced across the country by 2005, the next question is what is the incremental cost of going beyond that in 2008 or 2010. These costs are summarized in the table below.

	Gasoline	Diesel
15% Euro 4[a]	$0.00260	$0.0059
15% Euro 4[b]	$0.00398	$0.01107
40% Euro 4	$0.00402	$0.01107
15% Euro 5	$0.00398	$0.01108
100% Euro 4	$0.00412	$0.01151
100% Euro 5	$0.00394	$0.01595

a= 2008
b= 2010

As these results indicate, continuing beyond Euro 3 to Euro 4 or 5 fuels by 2010 would involve less than one-half cents per gallon for gasoline and about one cent per gallon for diesel.

4. Conclusions

As China's vehicle population continues to grow rapidly in coming years, continued stress will be placed on the environment. More stringent vehicle emissions requirements can substantially reduce this stress but in order to introduce these requirements as planned it will be necessary to improve fuel quality, especially sulfur levels. This problem is being compounded by the increasing fraction of higher sulfur crude being imported into the country. A recent Energy Foundation study showed that refinery modifications are possible and at reasonable cost, to provide the fuels that China's future vehicles will need. What is needed now is a decision to make the necessary investment.