I. Introduction

A. Background

In June 2003, the *Australian Department of the Environment and Heritage (ADEH)* agreed to allocate funds to the Asian Development Bank - *Clean Air Initiative – Asia (CAI-Asia)* for a fuel quality project in Asia. This funding was in support of Australia's participation in the "Global Partnership for Cleaner Fuels" announced at the World Summit on Sustainable Development held in Johannesburg, South Africa in August 2002.

CAI-Asia teamed up with the *International Fuel Quality Center (IFQC)* to develop a clean fuel workshop concept for five Asian countries, which currently do not have clear fuel quality strategies in place. It was agreed that the workshop and training manual would focus on current conventional gasoline and diesel fuel quality. Alternative fuels such as compressed natural gas (CNG), bio-diesel and other fuels commonly considered as alternative fuels would not be addressed.

Special Note: Please note that the views and opinions expressed in this publication are those of the authors or contributing experts, and do not necessarily reflect those of the Australian Government or the Minister for the Environment and Heritage.

1. Country Selection Criteria

Criteria for identification and inclusion or selected countries in the project was the following:

- Commitment to the introduction of cleaner fuels and willingness to make use of this project to further the development and implementation of a medium term fuel strategy;
- Set-up a team of three senior decision makers who would take part in the training and who would be available to take part in the in-country follow-up activities following completion of the training;
- Set up a participatory in-country dialogue involving all major stakeholders with the aim to arrive at a medium term fuel quality strategy, which has broad support.

The following countries fulfilled the criteria and were chosen to participate in the workshop:

- Bangladesh
- Indonesia
- Philippines
- Sri-Lanka
- Vietnam

The workshop will be given in October 2003 in Sydney, Australia to government officials from these countries with intent to assist them in the development and/or refinement of their countries fuel quality strategies. However, the scope of the project extends beyond the training workshop itself and provides some limited follow–up assistance to support the participants with their post training government and industry stakeholder dialogue. The follow-up support ensures that the knowledge gained by the participants from the training is applied in their strategic process once back in their home country. The training workshop proposed in this project enables government officials from these countries to advance the process for the development of medium term fuel quality strategies which have the potential to contribute in a significant manner to the reduction of emissions from their respective transport sector.

B. The Manual

A training manual developed by the IFQC in collaboration with CAI-Asia, was developed as a comprehensive reference guide to support drafting national fuel quality strategies. The manual complements the sessions and activities of the Fuel Quality Strategies Training Workshop, and to do so has been divided into five core Modules.

1) The importance of fuel quality strategies and the main building blocks
2) Technical issues and costs to consider when designing fuel quality strategies
3) Pricing and market regulation issues which influence the success of fuel quality changes
4) Monitoring and enforcement of fuel quality strategies
5) Steps to finalise fuel quality strategies and gather support for implementation

Subsequently, each chapter has been split into two main sections:

1) An explanatory section including case studies and links for further reading,
2) A classroom material section (Presentations delivered during the training are provided in separate document).

This format ensures that the trainees have the necessary background information and references up front, with additional supporting material provided during the workshop classroom sessions.

Once the trainees complete the workshop and digest the information contained in the manual they should have a sufficient knowledge base to support completion of their country's fuel quality strategies. In addition, due to the didactic and user friendly nature of the manual, it is expected that the content will serve as a reference guide to the trainees for years to come and that answers can be found within the text and the web links to further queries regarding the drafting process and future enhancements to their fuel quality strategies.

C. Authors

The Manual was principally written by the International Fuel Quality Center. This includes, core authors: Sandrine Dixson,-Decleve, Kristine Klavers and Liisa Kiuru. With the help of key contributors Joe Collucci, Frank Palmer, Paul Argyropoulos and Terry Higgens.

Case studies and material were also contributed by CAI- Asia and its experts Cornie Huizenga, Herbert Fabian, Michael Walsh, and John Courtis, as well as by Emma Campbell of ADEH.

II. Module 1 -
The Importance of Fuel Quality Strategies and the Main Building Blocks – Explanatory Section

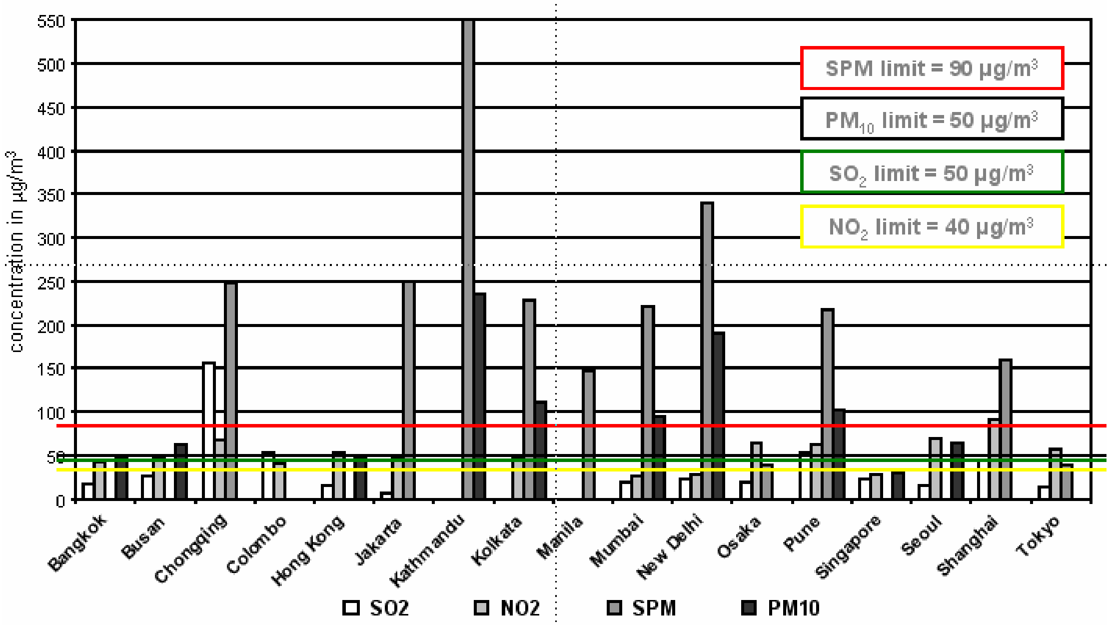
This Chapter will look at the policy process and the lessons learned in several countries having undertaken fuel quality strategies. It sets the tone for how to draft fuel legislation as well as establish auto oil programs. Completion of this Chapter and the related workshop activities should enable the trainees to undertake an initial Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of their own country initiatives and commence the fuel quality strategy drafting process.

A. Explanatory Section - The Importance of Fuel Quality Strategies in the Context of Asia

Multiple sources cause or contribute directly to air pollution. These include large stationary sources such as factories, power plants, smelters and refineries; smaller sources such as dry cleaners, fuelling facilities and degreasing operations; mobile sources such as cars, buses, planes, trucks, and trains; and natural sources such as wildfires, volcanoes and plants. Rapid urbanization, combined with a rapid growth in vehicle ownership and vehicle use has contributed to a situation in which most cities across the globe have some type of air quality problem. Asian cities suffer from the same plight. Figure 1 provides an overview of the ambient levels of a number of key pollutants in major Asian cities. These key pollutants are sulphur dioxides (SO2), nitrogen oxides (NO2), suspended particulate matter (SPM), and particulate matter (PM). Air pollution in Asian cities comes from different sources such as mobile sources; stationary sources or from smaller area sources, such as home cooking and garbage burning. In many Asian cities, mobile sources are the most significant contributor to air pollution. This is especially so for PM, carbon monoxide (CO) and NOx, the pollutants most often found to exceed the ambient air quality standards.

While the growth in mobility in Asia is a strong positive indicator in Asian countries of their continued economic development, at the same time, this exacerbates an areas air quality situation. In many cases, air quality in Asian cities does not meet the standards set by World Health Organization (WHO). Pollution levels above the WHO standards mean that the health of people breathing the air is negatively affected. More people die prematurely or get sick more often because of increased pollution. This results in considerable financial and economic costs for households and Asian economies.

Figure 2.1. Average Annual Pollution Concentrations for some Asians Cities (2000-2001)



Source: Asian Development Bank

WHO Limits

It is clearly documented in medical journals and governmental studies that poor air quality not only impacts the environment but also health in particular the respiratory system in the youngest and oldest population age groups, hospitalisation for heart or lung diseases, and even premature death. Table 2.1. below provides a summary of the local and global impacts of all air pollutants, including the major human health, environmental, and climate change impacts.

Table 2.1 Summary of major pollutants from transportation sources Pollutants Local Impacts Global Impacts Comments CO

Pollutants	**Local Impacts**	**Global Impacts**	**Comments**
Lead	Impairs the normal intellectual development and learning ability of children	Ground water pollution and particulates in air	
CO	Aggravates existing Cardiovascular diseases, impairs visual perception and dexterity	Indirect influence on warming through competition with methane for oxidation	Transportation can be responsible for up to 95% of CO emissions in urban areas. Globally distributed gas HC
HC	Range of health impacts including respiratory, neurological & carcinogenic Photochemical smog precursor	Class of compounds includes methane, a potent greenhouse gas Indirect warming influence through ozone formation	A range of natural and anthropogenic sources ensures that HC species are generally available as ozone precursors NOx

NOx	Respiratory irritant Visibility impairment Acid precursor Photochemical smog precursor	Indirect warming influence through ozone formation	Acid and ozone production impacts of NOx can be widely distributed through long-range transport of reservoir species O3
O3	Primary constituent of photochemical smog Severe respiratory impacts Material & crop damage	Global warming impacts due to increasing background concentrations	O3 has no direct emissions sources—NOx, HC, and sunlight are required for production SOx
SOx	Respiratory irritant Visibility impairment Acid precursor	Sulphate has some cooling impact due to light scattering	SO2 has a relatively long atmospheric lifetime leading to widespread acid impacts PM
Benzene	Classified as a human carcinogen (Group 1) by the International Agency for Research on Cancer		
PM	Cardiovascular & respiratory impacts Visibility impairment Includes acid species	Particles can influence warming or cooling, depending on carbon content & scattering abilities	Atmospheric lifetime varies with particle size GHG
GHG		Leading to global warming through long-term atmospheric accumulation	Transportation is a major source of CO2 but less important for methane & N2O

Source: ICCT and IFQC data, 2003

In addition, the estimated costs related to health issues from air pollution have been documented by national and international organisations. For example, the World Bank Environment Monitor Reports (2002) for the Philippines and Thailand show that health-related air pollution costs amounted to US$392 million for Metro Manila in 2001 and US$424 million for Bangkok in 2000. World Health Organization estimates of mortality indicate that on a yearly basis about 800,000 people die prematurely because of exposure to urban outdoor air pollution. Of these, about 500,000 are believed to be in Asia. The burden of disease expressed in Disability Adjusted Life Years (DALY) indicates that out of the 6.4 million affected, 3.8 million are in Asia. Air pollution can also significantly affect ecosystems. For example, ground-level ozone has been associated with reductions of agricultural and commercial forest yields, and airborne releases of

NOx are one of the largest sources of nitrogen pollution in certain water bodies. Like health costs, such damage is also a cost burden on society.

Table 2.2. Mortality (premature deaths) in Asia

Environmental Risks	Global Estimate	Asian Estimate	Asia as a percent of Global
Unsafe water	1,730,000	730,000	42%
Urban Outdoor Air	799,000	487,000	61%
Indoor Air	1,619,000	1,025,000	63%
Lead	234,000	88,000	37%

Source: WHO, 2002

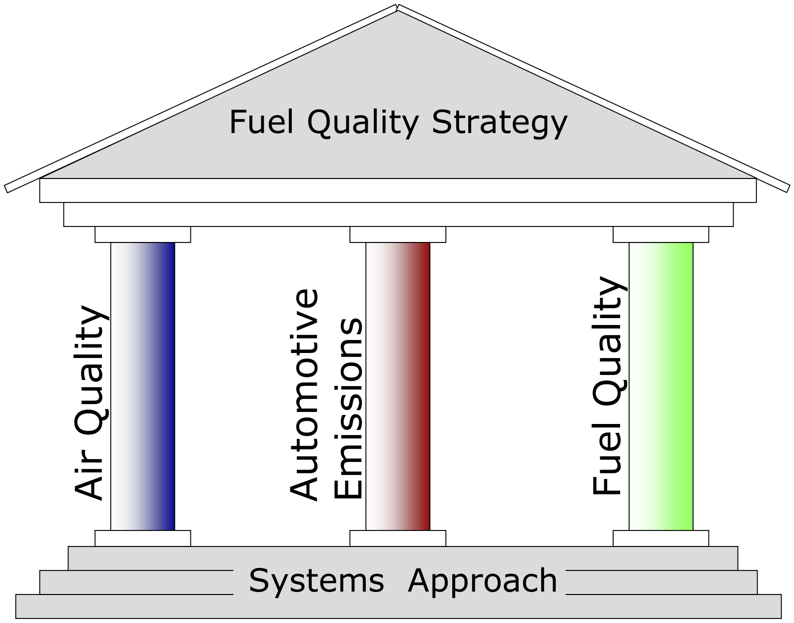
It is now recognized that urban air pollution can travel long distances, affecting areas outside the local and national boundaries in which the polluting event occurs. In addition, polluted air crosses regional and national boundaries, affecting health and environments in rural areas and in other countries. In response, more effective international action has been implemented and international guidelines on ambient air quality have been produced by organisations such as the WHO (WHO 1987), and international policies are being coordinated under conventions such as the Convention on Long-Range Transboundary Air Pollution (UNECE 1995; UNECE 1999). However, despite implementing the World Health Organization's (WHO) Air Quality Guidelines issued in 1999, many countries are not meeting their health-based standards for CO, NO2, sulphur dioxide and ozone, exceeding them in some cases by a factor of two. Although Sulphur dioxide (SO2) and nitrogen dioxide (NO2) ambient levels are dropping in many countries because of stationary and mobile source programs, ozone and particulate matter pollution are a serious problem around the world, even in developed countries that have taken aggressive action to reduce this kind of pollution. The countries that have phased out leaded gasoline have experienced a massive drop in lead emissions. Lead use is currently concentrated in just a few regions of the world, including Africa, Eastern Europe and parts of Asia. We expect the global lead phase out to be essentially complete (except for parts of Africa) by 2006. In addition, other key pollutants such as CO and HC has been reduced significantly in countries that have phased out lead and have introduced vehicle emission control equipment such as catalytic converters. In many cities across the globe, vehicles are the main source of air pollution, although there are differences with respect to the type of vehicles that are contributing the most to transport related air pollution. In some cases it is diesel-fuelled busses, while in other cases, especially in urban city centres, it is gasoline fuelled two-stroke vehicles.

It is important to note that the way in which countries across the globe have reacted and will react in the future to mobile source related air pollution and urban air quality issues is context specific and is influenced by a variety of factors including key air pollutants, climate change and energy security issues, the structure of their automotive and energy sectors, as well as socio economic and political factors.

Over the next few years, mobile source air pollution is expected hit crisis levels in some areas , particularly in Asia. Excessive pollution continues to be a quality of life issue, challenging regulators to find ways to make mega city living more sustainable and habitable for its residents. That is why when developing air quality standards it is not sufficient to draft standards without adopting a holistic systems approach.

This manual focuses on the establishment of fuel quality strategies and ultimately the setting of fuel quality specifications. In order to reach this ultimate goal, developed countries have come to the conclusion that there is one core concept, which must be applied; this is the “systems approach”. The “systems approach” was initially conceived and implemented in the United States. This approach focuses on three main pillars as seen below in Figure 2.2.

Figure 2.2. The “Systems Approach”



Source: International Fuel Quality Center (IFQC), 2003.

As shown above, it is these three pillars, based on the “systems approach”, which are the foundation for a successful fuel quality strategy. Each pillar although a separate entity is dependent on the other to up-hold the resulting fuel quality strategy. The impact of a vehicle on air quality is directly linked to the type of engine and after treatment technology on that vehicle and the quality of the fuel used in the engine. Therefore, the development of a fuel quality strategy must first be based on meeting certain air quality objectives. Once these objectives are defined and source apportionment has occurred (e.g. the actual impact of transport on urban air pollution has been calculated), determination of which automotive emissions must be reduced and by how much, can be made. This in turn will determine engine technology needs and the quality of fuels necessary to enable the engine and/or after treatment technology to meet the emission requirements.

B. Explanatory Section - The Systems Approach First Pillar: Air Quality Management

Countries across the globe contemplating the creation of a fuel quality strategy must first establish their air quality goals and then evaluate the impact mobile source emissions has on their air quality situation. To do so establishing an air quality monitoring program and assessing the emissions inventory is necessary to distinguish the percent contribution of emissions from the various sectors (i.e. stationary and mobile sources). It is only then possible to identify those emissions both in qualitative and quantitative terms directly attributable to transport and support setting specific emission targets.

The goal of air quality management is to maintain a quality of air that protects human health and environment. Government policy is the foundation for air quality management. Without a suitable policy framework and adequate legislation it is difficult to maintain an active or successful air quality management programme. This necessitates an integrated and cross cutting policy framework based on transport, energy, planning, development and the environment. Air quality objectives are more readily achieved if these interconnected government policies are compatible, and if mechanisms exist for co-ordinating responses to issues, which cross different areas of government policy. (Measures that have been adopted in many developed countries for integrating air quality policy with health, energy, transport and other areas are summarized in a report of the United Nations Economic Commission for Europe (UNECE 1995; UNECE 1999).

Unless there are legal constraints in a country blocking particular control options, the evaluation of control options must take into account technical, financial, social, health and environmental factors, as well as the speed with which they can be implemented and whether they are enforceable. Although considerable improvements in air quality have been achieved in some developed countries, the financial costs have been high, and the resource demands of some approaches make them unsuitable for less advantaged developing countries. Methodologies for evaluating air pollution control strategies have been developed for use in metropolitan areas, both in developed and developing countries, such as the methodology for evaluating options for improving air quality in Mexico City (Hardie et al. 1995).

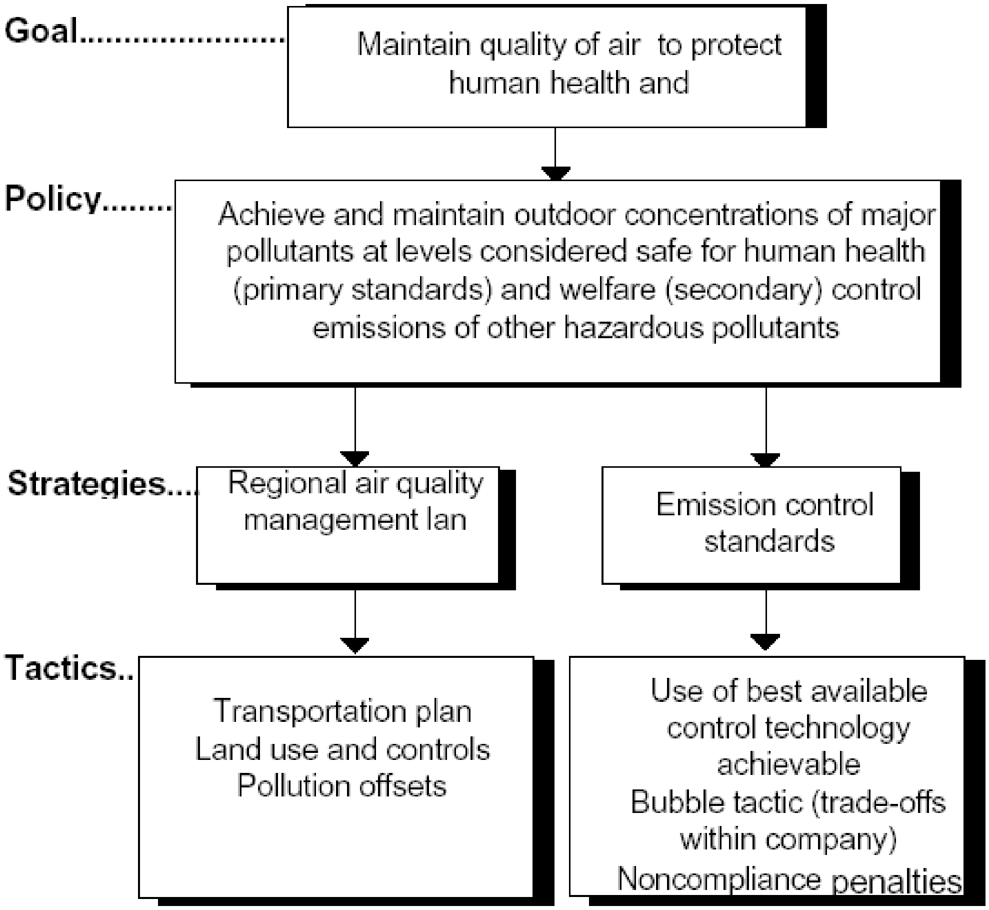
Air Quality Strategy Management:

The basic aspects of successful air quality strategy management are the following:

- Ambient Air Quality Standards,
- Ambient Air Quality Management,
- Source Emission Inventories,
- Emissions Control For Point, Mobile And Area Sources,
- Management Of “Non-Classic” Pollutants,
- Communication, and
- International Air Quality Management

In order to ensure proper air quality management and meet air quality goals, a policy framework is needed to provide a context for ambient air quality management. While there are many possible models, one example is illustrated below in figure 2.3.

Figure 2.3. The Structure of the U.S. Ambient Air Quality Legislation as Established by the Clean Air Act of 1970 and Subsequent Amendments (after Westman 1985).



Source: WHO, 1999.

When air quality goals and policies have been developed, the next stage is the development of a strategy or plan. The figure below summarizes the stages involved in the development of an air quality management strategy and can start with the development of ambient air quality standards or guidelines. It may also involve the development of an emissions inventory. The monitoring of both meteorological conditions and air pollutant concentrations would also normally occur, as these data are required by models used to estimate air quality, and to validate the model output.

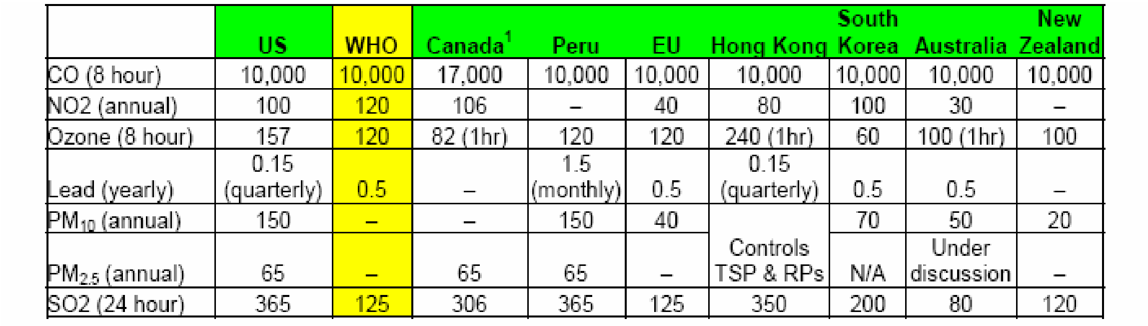
1. Developing Air Quality Standards

An air quality standard is a description of a level of air quality that is adopted by a regulatory authority as enforceable. At its simplest, an air quality standard should be defined in terms of one or more concentrations and averaging times. In addition, other data should be added, including information on the form of exposure (e.g. outdoor), on monitoring which is relevant in assessing compliance with the standard, and on methods of data analysis, quality assurance and quality control (WHO, 2002).

As can be seen in Table 2.3, many Asian countries have already legislated and adopted ambient air quality standards at the national level based on the prescribed guidelines set by the World Health Organization, and in some cases on the US National Ambient Air Quality standards. The WHO prescribed guidelines based on the perceived effect on human health. The recommended limits are actually concentration-based thresholds representing safe values with respect to human health.

The objective of WHO's Guidelines for Air Quality is to help countries derive their own national air quality standards. The guidelines are technologically feasible and consider socio-economic and cultural constraints. They provide a basis for protecting public health from the adverse effects of air pollution and for eliminating, or reducing to minimum, those air pollutants that are likely hazardous to human health (WHO, 2002).

Table 2.3. Ambient Air Quality Standards in Selected Countries, µg/m3



	US	WHO	Canada[1]	Peru	EU	Hong Kong	South Korea	Australia	New Zealand
CO (8 hour)	10,000	10,000	17,000	10,000	10,000	10,000	10,000	10,000	10,000
NO2 (annual)	100	120	106	–	40	80	100	30	–
Ozone (8 hour)	157	120	82 (1hr)	120	120	240 (1hr)	60	100 (1hr)	100
Lead (yearly)	0.15 (quarterly)	0.5	–	1.5 (monthly)	0.5	0.15 (quarterly)	0.5	0.5	–
PM_{10} (annual)	150	–	–	150	40	Controls TSP & RPs	70	50	20
$PM_{2.5}$ (annual)	65	–	65	65	–		N/A	Under discussion	–
SO2 (24 hour)	365	125	306	365	125	350	200	80	120

Note: 1) Maximum acceptable concentrations.

Source: Compilation of information from various organisations, including World Bank, WHO and U.S. EPA

These guidelines are not intended as standards. In moving from guidelines to standards, prevailing exposure levels and environmental, social, economic and cultural conditions in a nation or region should be taken into account. In certain circumstances there may be valid reasons to pursue policies, which will result in pollutant concentrations above or below the guideline values (WHO, 2002).

National standards also need to take into account the technical, social, economic and political factors within the nation. National approaches to the establishment of air quality standards in some developed countries are summarized by the Economic Commission for Europe (UNECE 1995; UNECE 1999). In some developing countries, reliable statistical information for producing accurate emission estimates is lacking. However, where action is needed to improve air quality, the absence of this information does not need to prevent the development of preliminary emissions estimates. Basic information about the population, transportation, industry, fuels and other information can be used to calculate preliminary emissions estimates, which can then be used to develop and implement air quality management plans. The preliminary emissions estimates can be revised as more accurate information becomes available. Sources of information on how to prepare rapid emissions inventories include WHO 1993a; WHO 1993b; WHO 1995h; WHO 1997b.

In some countries air quality standards are further qualified by defining an acceptable level of attainment or compliance. Levels of attainment may be defined in terms of the fundamental units that define the standard. For example, if the unit defined by the standard is the day, then a requirement for 99% compliance allows the standard to be exceeded by three days a year. The cost of meeting any standard is likely to depend on the degree of compliance required. Consequently, it may be sensible to consider carefully the costs and benefits of different levels of compliance when deciding on the standard.

It is important to remember that the development of air quality standards is only a part of an adequate air quality management strategy. Legislation, identification of authorities responsible for enforcement of emission standards and penalties for exceeding standards are all also necessary. Emission standards may play an important role in the management strategy, especially if exceedance of air quality standards is used as a trigger for abatement measures. These may be needed at both the national and the local level (WHO, 2002).

Air quality standards are also important in informing the public about air quality and are often used as a warning regarding threshold passages. In such cases, air quality indices are developed to convey in a more understandable manner to the public the attainment and non-attainment of air quality standards. This is an important communication tool and must thus be used wisely. For example, informing the public that the standards are being surpassed on a particular day or during a particular period must be properly qualified with accurate information on the potential long-term and short-term effect on health. It is important that the public is fully aware of the health consequences of exposure to high levels of air pollution.

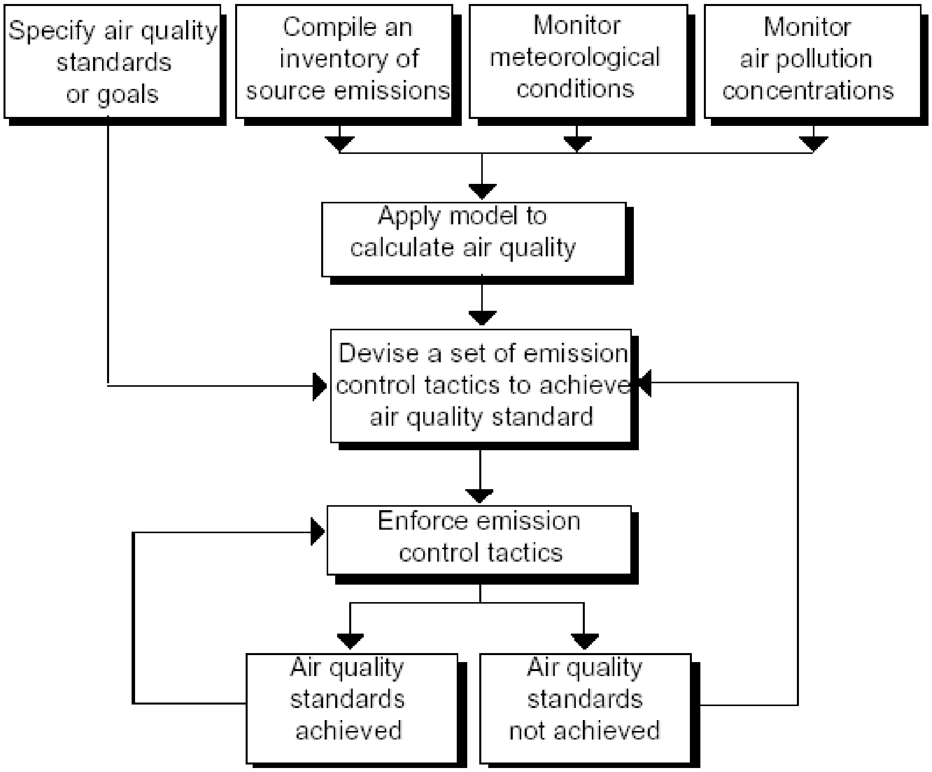
2. Source Apportionment

A crucial component of an air quality management plan is a reasonable quantitative knowledge of the sources of the various emissions as shown in the figure below of the stages involved in the development of an air quality management strategy.

An emissions inventory is essential. In some cases, emissions are described in source groups. These may be:

- Point sources - such as major industrial sites.
- Mobile sources - such as motor vehicles.
- Area sources- such as domestic emissions and emissions from light industry and commercial areas.
- Biogenic or natural sources.

Figure 2.4. Stages Involved in the Development of an Air Quality Management Strategy.



Source: Elsom, 1992.

With regard to mobile sources such as motor vehicles, there is considerable variation in the pattern of vehicle emissions at different locations and in different regions of the world. However, considering anthropogenic emissions on a global basis, it has been estimated that motor vehicles can account for about 25-30% of emissions of NOx, 50% of HC, 60% of lead and as much as 60% of CO (Faiz and de Larderer 1993). In city centres, vehicles may be responsible for 90-95% of CO and lead and 60-70% of NOx and HC. As vehicle emissions usually settle at head level, exposures can be high. Pollution in developing countries is rapidly worsening due to increasing vehicle fleet growth (Figure 6.3), concentrations of vehicle-related air pollutants over the last two decades have declined in most developed countries. For example, the decreases in ambient concentrations in the US from 1985 to 1994 were 28% for CO, 86% for lead, and 9% for NOx (USEPA 1995). With pressure to improve engine design and operating conditions, and improved tailpipe control technologies, vehicle emissions in many countries have decreased despite increasing number of vehicles and kilometres travelled. For example, while emissions of CO in the period 1980-1990 increased in France from 9 216 000 to 10 268 000 tonnes, they decreased subsequently to 8 850 000 in 1996 (UNECE 1999). In the period 1980-1996 CO emissions in Germany decreased from 15 046 000 to 6 717 000 tonnes, and in the European part of the Russian Federation from 13 520 000 to 9 312 000 tonnes (UNECE 1999). Although in the most wealthy of the developing countries significant improvements in air quality are occurring, in most other developing countries for which data are available, both vehicle emissions and ambient concentrations of vehicle-related air pollutants have increased (WHO 1997a). For example it is estimated that emissions of CO in Delhi increased from 140 to

265 tonnes in the period 1980-1990, and are projected to be 400 tonnes in the year 2000 (UNEP/WHO 1992).

3. Air Quality Management Strategies

The control of air pollutants involves a number of strategies, as the characteristics of sources are highly variable. These have been classified by the WHO Air quality guidelines 1999 as technical, regulatory, educational and market-based strategies.

Technical strategies involve investigating alternatives to existing polluting activities, and implementing cleaner production and pollution prevention technologies and best practices. They encourage the replacement of existing technologies with lower- or zero emission technologies.

Regulatory strategies involve legal enforcement of regulations at local and national government levels. This could involve banning of some emissions, banning of some open burning, or burning of materials during certain periods, increasing penalties, control of fuel quality, and restrictions on the types of combustion equipment available.

Educational strategies involve informing the community about sources of emissions and the impact of air pollution on health and the environment, and informing them about practices such as open burning, use of poor quality fuels etc, which lead to pollution.

Market-based strategies may involve polluter pays concepts. They include changes in cost structures to provide financial incentives for using clean fuels. They also involve reducing the costs of emissions licenses for adopting best practices, load-based emission charges and true cost pricing of resources. For some components of an emissions inventory accurate data may be available. For example, accurate emissions data may be available for some industrial sites from measurements of stack emissions. In other cases, emissions can be calculated from estimates of process inputs. For example, the emissions of SO2 from coal-fired electricity generation plants can often be calculated with reasonable accuracy from the knowledge of the throughput and sulphur content of the fuels and other information.

C. Explanatory Section - The Systems Approach Second Pillar: Automotive Emissions Management

Emissions from road transport usually come from two main sources, the tailpipe exhaust, and evaporation from fuel. The quantity and type of pollution is influenced by many factors, primarily dictated by the vehicle's engine and the fuel it uses.

Vehicles emit large quantities of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and toxic substances such as particulate matter (PM) and lead. The key emissions of concern differ depending on the engine and fuel used. For gasoline engines this includes CO, HC’s and NOx (although there has also been some recent discussions linking small particulates with gasoline aromatics), whereas for diesel engines the emissions of primary concern are NOx and PM. These pollutants, coupled with secondary by products such as ozone, can cause adverse effects on human health and the environment. This will be further discussed under module 2.

As seen below, emissions vary depending on a variety of factors. Here are some examples but not all, as there are numerous factors, which should be taken into account under each category:

- **Vehicle characteristics**: Engine type, size, age, and condition. Emission control equipment and condition, vehicle appliances e.g. air conditioning etc.. and maintenance issues
- **Fuel Characteristics**: Fuel type, properties and quality e.g. diesel versus gasoline, conventional versus alternative, contamination and adulteration issues, additives and detergents used
- **Operability Characteristics**: Speed driven and traffic congestion, driving pattern, altitude, temperature, and other ambient temperature.

During the second half of the twentieth century, the impact of vehicle emissions on air quality was well defined in developed countries, and the role of vehicles and their fuels was largely determined. Significant progress was made in:

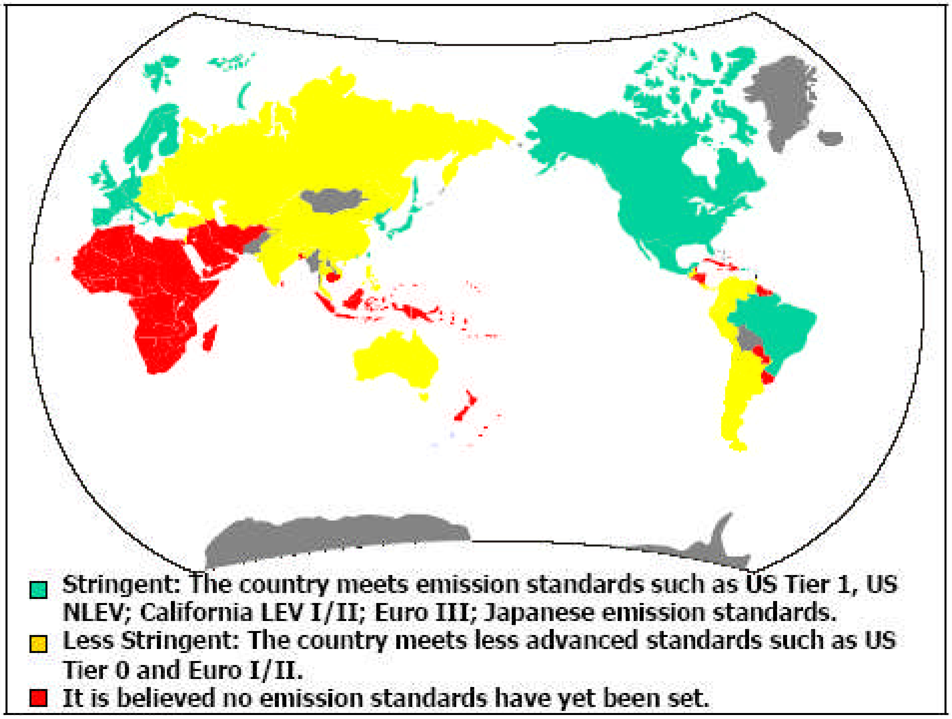
- Reducing regulated vehicle emissions of hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM)
- Improving vehicle fuel economy
- Reducing and eliminating lead emissions
- Defining the gasoline and diesel fuel properties that needed to be changed in order to reduce vehicle emissions

In North America, Western Europe, and Japan, vehicle emissions have been significantly reduced in both new vehicles (>95% reductions in HC, CO and NOx for gasoline-powered vehicles) and in-use vehicles. Despite significant air quality improvements, much more remains to be done in the 21st century. As outlined in the previous section of this report, air quality standards are far from being universally set and met. In some countries, air quality is deteriorating due to urbanisation and the use of vehicles and fuels that do not promote emission reductions. In the United States, Western Europe and Japan, there are continuing pressures to achieve “zero” vehicle emissions. It is likely that other countries around the world will follow, if and when they can afford the cost of doing so.

In addition to driving toward zero vehicle emissions, vehicle manufacturers have been asked to improve fuel economy both for energy conservation and greenhouse gas control to meet Kyoto Protocol commitments. Automakers around the world will be required to continue improving the traditional gasoline and diesel engines, and to develop technologies (such as hybrid and fuel cell vehicles) that will accomplish these twin objectives.

A corollary to the above is that in developing countries, where most of the potential growth in vehicles and fuels exists, national priorities are not the same as in developed countries. Thus, the need for advanced vehicle emission control technologies and fuels in these countries to improve air quality may not be high on their list of priorities. However, these countries can learn from experiences in the developed regions and leap frog to cleaner fuels vehicles, avoiding mistakes made earlier along in other countries processes. Some countries are better served by reducing in-use emissions with low cost technologies, fuel property changes, and traffic control strategies. Although the use of low sulphur fuels to enable new after treatment technologies is important and necessary once new vehicles are on the market, the first step in the Asian region should be to remove lead and significantly reduce benzene from gasoline for health reasons. This process is already occurring. Today the phase out of lead is well on its way in Asia. The rest of the developing world is quickly following suit. Thus, these countries can now use catalytic converter technologies on vehicles to reduce emissions and support air quality improvements. The important factor related to a lead phase out strategy is that it has immediate health and environmental effects in countries with less stringent or no emission standards (Figure 2.5.)

Figure 2.5. Summary of Current Vehicle Emission Standards Around the World



Source: International Fuel Quality Center (IFQC).2003.

Continuing improvements to traditional engines and their emission control systems are likely to result in new and more stringent gasoline and diesel fuel property controls. In addition, if fuel cell vehicles are commercialized and hydrogen is elected as the next fuel, this would require significant changes to current fuel production and distribution infrastructure to supply the hydrogen needed by the fuel cell to generate electricity.

There are two major findings from the recent past that must be considered as we embark on our discussion of automotive emissions and fuel quality controls. One of the most important research findings of the past 15 years is that vehicle emissions are the result of the fuel/vehicle “system,” as described before in this report and not of each individually. This has been recognized by regulatory authorities in the United States, Europe and Japan in the development of their latest round of vehicle emission controls and fuel quality standards. For example, the U. S. Environmental Protection Agency (EPA), the California Air Resources Board (CARB) and the European Commission have all enacted gasoline and diesel fuel standards that simultaneously define vehicle emission levels. The linkage of vehicle and fuel will guide what happens as vehicle technology evolves and revolutionary technologies (such as fuel cell vehicles and their fuels) are introduced.

The second important lesson of the recent past is the economic reality that the public will not buy a product for which no clear economic benefit can be seen. Thus, governments mandating technology, as had been done in California with zero emission electric vehicles, will not work. This has large implications for radical technologies such as hybrid and fuel cell vehicles, as well as biomass-derived fuels. Government subsidies and tax breaks can be used to help jumpstart these new technologies, but they cannot be sustained indefinitely.

1. The Asian Vehicle Fleet

In developing countries across the globe, the focus is not on zero emission vehicles but on reducing emissions from the existing car fleet. Currently, the developing world including Asia has the lowest number of vehicles per capita, but trends indicate that this is rapidly changing in particular in the Asian region. (Figure 2.6.).

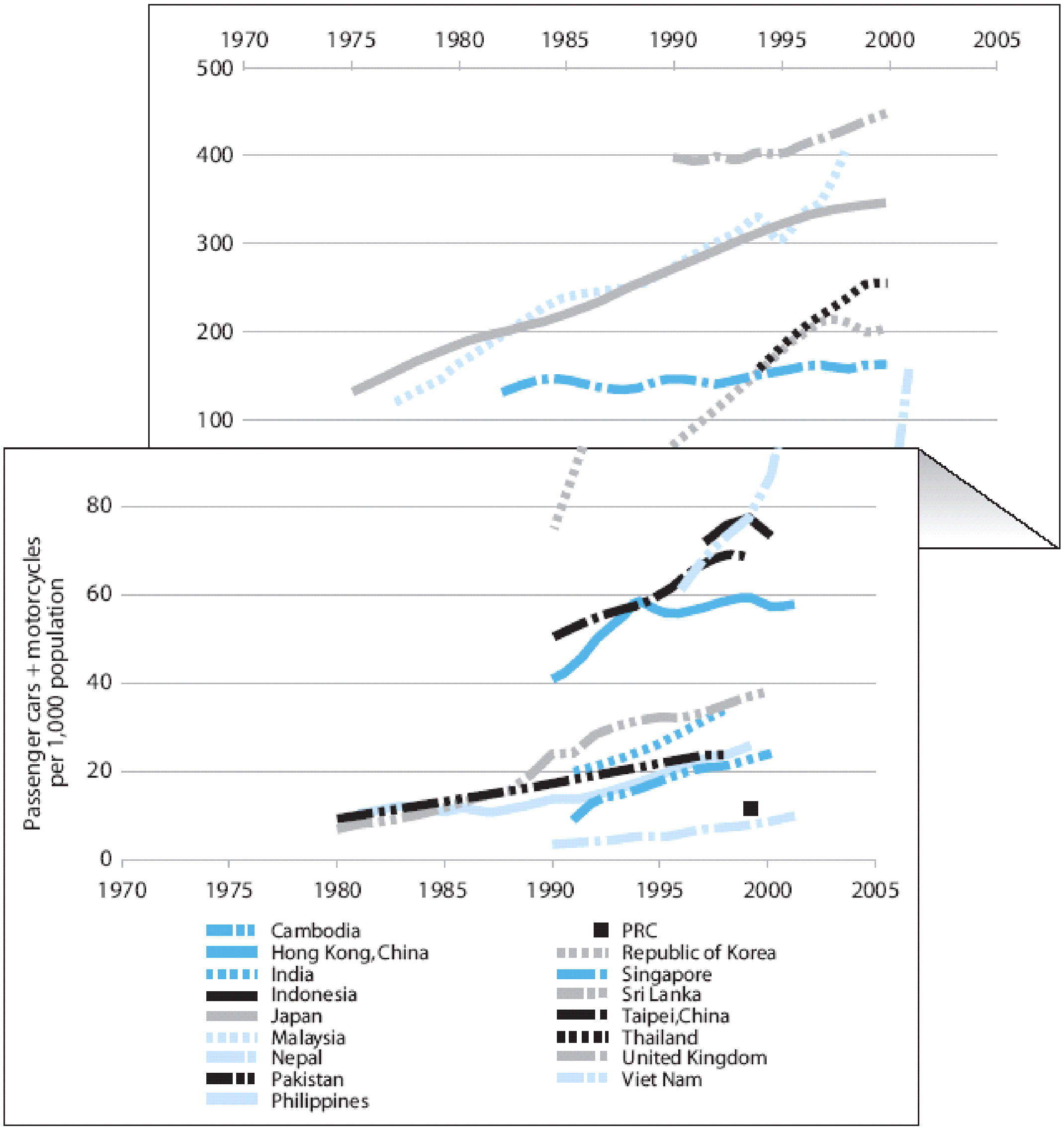
In addition, to the projected increase in motorization in Asia another significant fact regarding the region's vehicle fleet is that it is largely composed of 2 and 3 wheelers. In fact, Asia has the world's highest concentration of 2 and 3 wheelers, both in absolute terms and as a fraction of overall road vehicle population. In many Asian cities, these vehicles account for 50 to 90% of the total vehicle fleet, a situation unheard of in other parts of the world. Therefore, it is clear that priority must be given to developing and implementing pollution control strategies for two and three wheelers if Asian cities are to achieve clean, healthy air.

- Motorcycles and tricycles comprise up to 75% of Asia's vehicle fleet
- Up to 85% of them use 2-stroke engines
- They emit up to 70% of total hydrocarbons, 40% of total carbon monoxide, and a substantial amount of particulate matter

Two types of engines power these vehicles, 2-stroke and 4-stroke. The primary difference between these two engine types is that lubricating oil is mixed with fuel and burned in a 2-stroke engine.

The main pollutants of concern from 2-stroke engines are hydrocarbons (HC) and particulate matter (PM), whereas 4-stroke engines result in higher nitrogen oxides (NOx) emissions but lower carbon monoxide (CO), PM, HC, and fuel consumption. 2-stroke engines emit much higher levels of HC and PM than 4-stroke engines but lower levels of NOx. Since ambient PM levels in many urban areas in Asia are very high and cause adverse health impacts, there is great interest in replacing or cleaning up 2-stroke engines.

Figure 2.6. Passenger Cars and Motorcycles per 1,000 Population in Asia.



Note: (1) Motorization includes registered private cars and motorcycles (2) Vehicle registrations in some developing countries are known to overstate actual in-use fleet. In Thailand, for example, the in-use fleet was half of the 1999 registered fleet
Source: Asian Development Bank (ADB), 2003.

Several countries are introducing tighter standards to reduce emissions from both 2- and 4-stroke engines, and technologies such as catalytic converters are emerging and are increasingly required for new 2-stroke, two- and three-wheeled vehicles. However, concerns have been raised regarding the actual in-use durability of these catalytic converters under real driving conditions. Other technologies such as advanced fuel injection systems with isolation of the fuel and lubricant are also emerging. These should reduce HC, CO and PM emissions and improve fuel economy, but actual in-use experience with these systems on two and three wheelers in Asia is limited.

Rather than gradually tightening standards, many countries and cities are considering the outright ban, sales restriction or use of new, uncontrolled or inadequately controlled 2-stroke engines. This guarantees the reduction of HC and PM emissions although at the expense of somewhat higher NOx emissions. This relieves the government of the responsibility for assuring good in-use durability of catalytic converters or other advanced technologies. However, this can be very disruptive for industries that prefer a performance standard that they could achieve at the lowest cost to their customers.

In other cases, a combination of the carrot-and-stick approach has been followed. For example, in Taipei, China the stage four performance standards are set at tighter levels for 2-stroke motorcycles than for 4-stroke motorcycles. In addition, tax incentives are offered to 2-stroke vehicle owners who trade in their vehicles and replace them with cleaner electric vehicles or switch to public transportation.

Alternative fuels and advanced vehicle technologies offer opportunities for significant emission reductions and increases in efficiency of two- and three-wheeled vehicles. Two-wheeled vehicles are not seen as attractive candidates for conversion to alternative fuels and to date, there have been very few successful efforts to convert them, with the notable exception of electric motorcycles. With regard to three-wheeled vehicles, conversions to both LPG and CNG have been well established as a viable technology. For example, tuk-tuks in Bangkok have been operating successfully on LPG for many years. In India, three-wheeled vehicles are operating quite satisfactorily on CNG.

2. Country Experience in Setting Automotive Emissions Legislation

Experience in the United States, Europe and Japan shows that the development of a successful mobile source pollution control programme is dependent on four areas:

1) Automotive emissions legislation
2) Fuel quality specifications
3) Inspection and Maintenance (IM)
4) Traffic and demand management

Together these elements along with the creation of proper links to other sustainable transport and environmental policies form a holistic approach to the management of air pollution from transport. However, it is clear that depending on the region or country, the weight of one of these elements over another will differ even if in almost all cases it is the setting of auto emission standards and fuel quality specifications, which increasingly play the most important role. Many developing countries have found that improving fuel economy and emission standards, as well as encouraging the use of fuel-efficient vehicles and clean fuels, have the effect of both reducing costs and contributing to an improvement in air quality. Many middle-income countries have introduced most of the above measures. Some have implemented additional measures, including approval standards and testing of new vehicles, exhaust emission controls, fuel improvements, roadside emission checks, replacement of 2-stroke engines with 4-stroke engines, and use of low- or zero-sulphur fuels. Although IM programmes are seen as an important factor in air pollution management, such programmes will not be the focus of this training manual. Consequently promising approaches such as traffic management systems will also not be discussed.

Over the last 20 years the United States, Europe and Japan have conducted various studies to determine the impact of automotive emissions on air quality and the effect of different fuel qualities on automotive emissions. As in the case of air quality and fuel quality, the first studies were carried out under the US Auto Oil Programme, the EU EPEFE programme, and Japan's JCAP. However, it is important to note that each programme was quite different both in coverage and approach. The US AQIRP only looked at gasoline cars whereas Europe looked both at gasoline and diesel vehicles as well as Heavy Duty Diesel Engines. The Japanese programme is doing the same as Europe but also addressing future technology and hence future fuel needs.

Each of these programmes can serve as a good model for countries currently in the process of establishing emissions legislation. In this regard, countries must take note of how each region quantifies vehicle emissions through , the type of test cycle used e.g. driving cycle (for vehicles) or operating cycle (for heavy-duty engines), and the homologation fuel. Test cycles are an essential part of the programme as they measure in use driving patterns and potential emissions from the vehicle. so when developing their regulations/legislation, countries across the globe tend to choose between the U.S. Federal, the United Nations Economic Commission for Europe (ECE) regulation, and the Japanese test cycles. All three test cycles measure exhaust emissions produced while the vehicle is driven through a prescribed driving cycle:

- For light-duty vehicles, including private cars and motorcycles, emissions are measured by operating the vehicle on a chassis dynamometer
- For heavy-duty vehicle engines, emissions are measured on an engine dynamometer.

The specific driving cycle differs, however. Because emissions in urban areas are the principal concern of control programs, all testing is based on vehicles operating in stop-and-go driving conditions typical of urban areas.

To better compare emission results of different engines, special test procedures, test or driving cycles, have been established. In this manual we will only look at the light duty vehicle test cycles as an example. It is also important to note that when looking at driving cycles each cycle is quite different and cannot be compared with another. Therefore, in general engines are manufactured to pass one of the cycles not all. So when a country is in the process of developing emissions legislation it needs to assess, which regional approach it will undertake as a whole and adopt the same driving cycle as that regional approach. For example, the emissions legislation in the European Union, Japan and the US given further below are based on certain driving cycles.

Generally speaking a driving cycle is a standardized driving pattern, which is described through a velocity-time table. Off the road a vehicle can execute a driving cycle on a dynamometer. In the case of the internal combustion engine driven vehicles, the fuel consumption and emissions can be measured directly.

Usually, the test vehicle is soaked at a temperature between 20ºC and 30ºC. Some low temperature tests at -7ºC can also be run. This is done in order to standardize the vehicle condition in terms of the oil and coolant temperatures and catalyst condition and make the comparison of results more accurate. Following the soak period, the test vehicle is driven on a chassis dynamometer to a legislative drive cycle, which will be further discussed below. The resulting vehicle exhaust emissions are diluted throughout the test and a proportional sample of the diluted exhaust gas is extracted into inert sample bags for analysis. At the end of the test the concentrations of carbon monoxide

(CO), hydrocarbons (HC) and oxides of nitrogen (NOx) are measured. From the data acquired, the equivalent average mass per kilometre (g/km) is calculated for each pollutant, which can then help the comparison of different vehicles in terms of tailpipe emissions and energy efficiency.

These driving cycles can be divided into two groups: modal and transient. A modal driving cycles means that some parts of the cycles have constant speeds. These kinds of cycles are criticized for not representing real driving patterns. Most of the European and Japanese driving cycles are modal cycles, although some transient cycles have also been developed. The American test cycles are mostly transient. Countries may also look to developing their own specific driving cycles if the other cycles are not representative of their situation and would not effectively advance the goal of reducing emissions from the transport sector. However, most countries tend to use the US, EU, or Japanese cycle.

Case study 1: Japan Clean Air Program (JCAP)

Background - Japan has been implementing one of the most stringent automotive emission regulations in the world, further decrease in automotive emissions is required to achieve better air quality and environment. The U.S. and Europe, having similar problems to Japan, are carrying out air quality improvement programs by combining automotive and fuel technologies: the Air Quality Improvement Research in the U.S., and the Auto Oil Program (AOP) in Europe. To develop a similar program, suited to the specific Japanese context, the Petroleum Energy Center, in collaboration with automobile and oil industries in Japan, launched the Japan Clean Air program (JCAP) to estimate the future atmospheric environment and to investigate the most cost-effective combination of measures for the improvement of its air quality based on an analysis of the nation's unique social, industrial, geographical, and meteorological conditions.

Under a subsidy from the Ministry of Economy, Trade and Industry (METI), the Japan Petroleum Energy Center (JPEC) had the lead responsibility for JCAP. Since its inception in 1997, it has had the close cooperation of the Petroleum Association of Japan (PAJ) and the Japan Automobile Manufacturers Association (JAMA). JCAP I was a five year effort running from 1997 to 2002.

The objectives of JCAP I were:

(1) To evaluate the potential for improvements or modifications of fuel quality to reduce emissions, and
(2) To clarify the role of more advanced technologies for medium and longer term emissions reductions.

Continued….

…continued

JCAP II continues under the auspices of JPEC with most of the funding coming from METI. In this case a Research Committee was organized to lead the effort, with representation from government, academia and industry. Further, several technical committees have been set up with representation from academia and specialists to give technical advice regarding the JCAP studies.

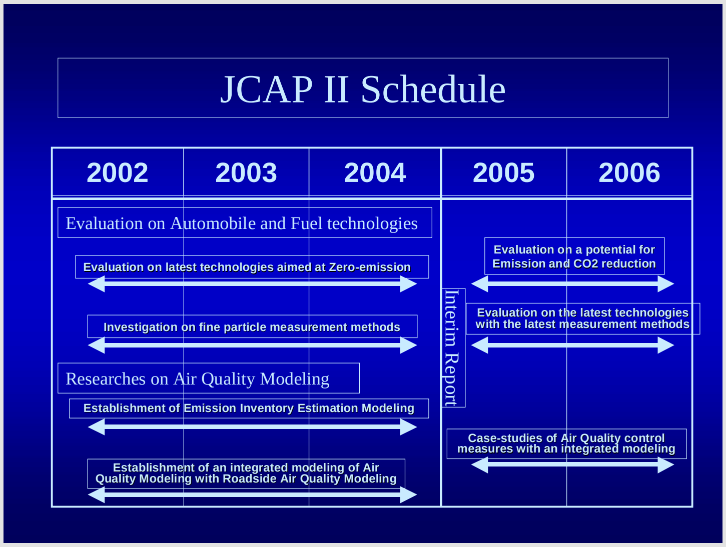
JCAP II will also run for 5 years, from 2002 to 2006 and its objectives are:

(1) To evaluate further impacts of fuels on exhaust emissions especially with regard to technologies aiming toward zero emissions, and
(2) To evaluate the impacts of fuels on fuel consumption (and CO2 emissions).

Issue Focus - The principle conclusions from JCAP I were as follows:

The sulphur content in gasoline had a great impact on emissions
The Reid Vapour Pressure of Gasoline had a great impact on evaporative emissions
Diesel fuel sulphur content had a great impact on exhaust emissions, and

Diesel Particulate Filters retrofitted to active use vehicles could not display sufficient capacity under urban driving conditions. The work plan of JCAP II is summarized as part of the time schedule pictured below.



Analysis / Lessons Learnt - JCAP I highlighted the important role that fuels can and will play as a central component of efforts to reduce motor vehicle pollution. Most important has been the focus on the role of sulphur in both gasoline and diesel fuel and as a result of this effort, aggressive efforts have been taken to introduce near zero sulphur (10 ppm) fuels in Japan.

The JCAP program has also demonstrated the value of bringing vehicle manufacturers and oil industry together in one program to arrive at effective strategies for emission reduction control.

JCAP II will broaden the scope to focus on near zero emitting technologies as well as high fuel economy or low CO2 emissions. The benefits of low RVP fuels were also highlighted.

What are the Asia Pacific's Automotive Emissions, and Future Automotive Technology Concerns?

Asian countries are at different stages when it comes to setting and revising emission standards. Most Asian countries are either currently implementing or planning to implement the European standards for automotive emissions and fuel quality. As the Asian region has predominantly followed the European approach it is worthwhile to take a look at how the EU regulates automotive emissions.

In the EU, motor vehicle emissions are regulated by Directive 70/220/EEC (light vehicles) and 88/77/EC (heavy vehicles) and amendments to those directives. The first set of amendments through the 1980's and 1990's established the Euro 1-2 standards for light duty and heavy duty vehicles. A series of amendments have been issued to gradually tighten the original Euro 1 and 2 standards, mainly as a result of the Auto-Oil Programme I and II findings. The Auto-Oil Programme also resulted in legislation on durability. That is that a manufacturer is responsible for emissions from light duty vehicles during the first five years or 80,000 kilometres (whichever occurs first) of use, providing the vehicle is properly maintained, and on the use of onboard diagnostic (OBD) systems.

Directive 98/69/EEC Relating To Measures to Be Taken Against Air Pollution from Motor Vehicles and Amending Council Directives 70/156/EEC and 70/220/EEC is the most important piece of legislation on vehicle emissions. Directive 98/69/EC went into effect in September 1999. Its promulgation was coordinated with Directive 98/70/EC, which set stricter standards for fuel quality for 2000 and 2005. Directive 98/69/EC covers what is commonly known as Euro III and Euro IV emission standards. Euro III regulates five vehicle classes: 1) passenger vehicles less than 2.5 tonnes; 2) passenger vehicles greater than 2.5 tonnes; 3) transport vehicles less than 3.5 tonnes; 4) transport vehicles greater than 3.5 tonnes but less than 12 tonnes; 5) transport vehicles greater than 12 tonnes.

Also, Directive 1999/96/EC amended Directive 88/77/EEC and went into effect in February 2000. This Directive set more stringent emission standards for heavy-duty vehicles and buses for 2000, 2005 and 2008.16 The European Commission estimates the 2000 limits will result in a 30% reduction over previous emission levels. Two new test cycles are included and limits for non-methane hydrocarbons and methane were introduced for gas engines. The limits for 2005 set even more stringent limits for particulate matter to push manufacturers into using particulate trap technology. In 2008, more stringent nitrogen oxide limits will be introduced.

The Euro standards are given in the tables below:

Table 2.4. EU Passenger Car Limits (type approval), 1970 -. All limits in either g/km or g/test as indicated.

Gasoline Cars

Directive	Year	Euro ?	CO	HC	NOx	HC+NOx	Units
98/69	2005	Euro 4	1	0.1	0.08		g/km
98/69	2000	Euro 3	2.3	0.2	0.15		g/km
94/12	1996	Euro 2	2.2			0.5	g/km
							g/km
91/441	1991	Euro 1	2.72			0.97	g/km
88/436 (> 2.0 l)	1990		25		3.5	6.5	g/test
88/436 (1.4 - 2.0 l)	1990		30			8	g/test
88/436 (< 1.4 l)	1990		45		6	15	g/test
88/76 (> 2.0 l)	1988		25		3.5	6.5	g/test
88/76 (1.4 - 2.0 l)	1988		30			8	g/test
88/76 (< 1.4 l)	1988		45		6	15	g/test
83/351	1983		84			23.5	g/test

Source: International Fuel Quality Center (IFQC), from the European Commission 2002.

Table 2.5. EU Passenger Car Limits (type approval), 1970 - . All limits in either g/km or g/test as indicated.

Diesel Cars

Directive	year	Euro ?	CO	HC	NOx	HC+NOx	PM	Units
98/69	2005	Euro 4	0.5	0.05	0.25	0.3	0.025	g/km
98/69	2000	Euro 3	0.64	0.06	0.5	0.56	0.05	g/km
94/12 **DI**	1996	Euro 2	1			0.9	0.1	g/km
94/12 **IDI**	1996	Euro 2	1			0.7	0.08	g/km
91/441	1991	Euro 1	2.72			0.97	0.14	g/km
88/436 (> 2.0 l)	1990		25		3.5	6.5	1.1	g/test
88/436 (1.4 - 2.0 l)	1990		30			8	1.1	g/test
88/436 (< 1.4 l)	1990		45		6	15	1.1	g/test
88/76 (> 2.0 l)	1988		25			6.5		g/test
88/76 (1.4 - 2.0 l)	1988		30			8		g/test
88/76 (< 1.4 l)	1988		45			15		g/test
83/351	1983		84			23.5		g/test

Source: International Fuel Quality Center (IFQC), from the European Commission 2002.

Table 2.6. EU Heavy Duty Truck & Bus Limits (type approval), 1982 -. All limits in g/kWh.

Directive	**Year**	**Euro ?**	**CO**	**HC**	**NMHC**	**CH4**	**NOx**	**PM**	**PM**	**Units**	
									<0,7dm3 etc		**Note**
1999/96 C (EEV)	-	-	1.5	0.25	-	-	2	0.02	-	g/kWh	New cycle (ESC)
1999/96 C (EEV)	-	-	3	-	0.4	0.65	2	0.02	-	g/kWh	New cycle (ETC)
1999/96 B2	2008	Euro 5	1.5	0.46	-	-	2	0.02	-	g/kWh	New cycle (ESC)
1999/96 B2	2008	Euro 5	4	-	0.55	1.1	2	0.03	-	g/kWh	New cycle (ETC)
1999/96 B1	2005	Euro 4	1.5	0.46	-	-	3.5	0.02	-	g/kWh	New cycle (ESC)
1999/96 B1	2005	Euro 4	4	-	0.55	1.1	3.5	0.03	-	g/kWh	New cycle (ETC)
1999/96 A	2000	Euro 3	2.1	0.66	-	-	5	0.1	0.13	g/kWh	New cycle (ESC)
1999/96 A	2000	Euro 3	5.45	-	0.78	1.6	5	0.16	0.21	g/kWh	New cycle (ETC)
91/542 B	1996	Euro 2	4	1.1	-	-	7	0.15	0.25	g/kWh	13 mode cycle (and refer directive 96/1)
91/542 A	1991	Euro 1	4.5	1.1	-	-	8	0.36	0.61	g/kWh	13 mode cycle
88/77	1988	Euro 0	11.2	2.4	-	-	14.4	-	-	g/kWh	13 mode cycle
Reg 49	1980		14.2	2.5	-	-	18	-	-	g/kWh	13 mode cycle

Source: International Fuel Quality Center (IFQC), from the European Commission 2002.

Table 2.7. EU Light Commercial Vehicle Limits (type approval), 1991 -. All limits in g/km.

Gasoline light commercial vehicles

Directive	**Year**	**Euro ?**	**CO**	**HC**	**NOx**	**HC+NOx**	**Note**
98/69 class I	2005	Euro 4	1	0.1	0.08		
98/69 class II		Euro 4	1.81	0.13	0.1		
98/69 class III		Euro 4	2.27	0.16	0.11		
98/69 class I	2000	Euro 3	2.3	0.2	0.15		
98/69 class II		Euro 3	4.17	0.25	0.18		
98/69 class III		Euro 3	5.22	0.29	0.21		
96/69 class I	1997	Euro 2	2.2			0.5	
96/69 class II	1997	Euro 2	4			0.6	
96/69 class III	1997	Euro 2	5			0.7	
93/59 class I	1991	Euro 1	2.72			0.97	
93/59 class II	1991	Euro 1	5.17			1.4	
93/59 class III	1991	Euro 1	6.9			1.7	

Class	**Vehicle reference mass**
I	< 1250 kg
II	1250 - 1700 kg
II	> 1700 kg

Source: International Fuel Quality Center (IFQC), from the European Commission 2002.

Table 2.8. EU Light Commercial Vehicle Limits (type approval), 1991 -. All limits in g/km.

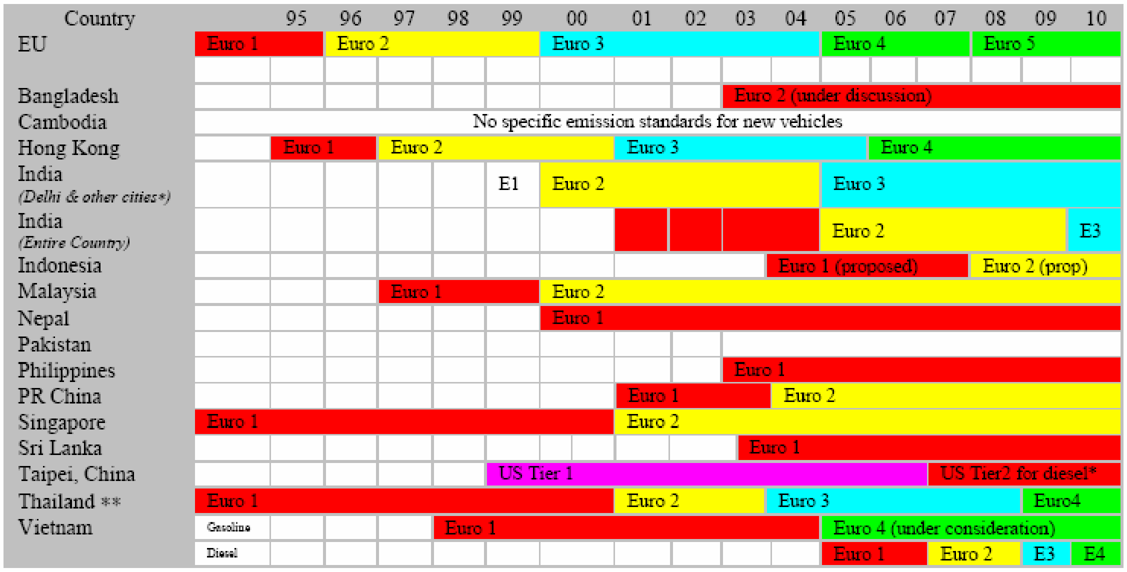
Diesel light commercial vehicles

Directive	year	Euro ?	CO	HC	NOx	HC+NOx	PM	Units
98/69 class I	2005	Euro 4	0.5		0.25	0.3	0.025	g/km
98/69 class II		Euro 4	0.63		0.33	0.39	0.04	g/km
98/69 class III		Euro 4	0.74		0.39	0.46	0.06	g/km
98/69 class I	2000	Euro 3	0.64		0.5	0.56	0.05	g/km
98/69 class II		Euro 3	0.8		0.65	0.72	0.07	g/km
98/69 class III		Euro 3	0.95		0.78	0.86	0.1	g/km
96/69 class I - **IDI**	1997	Euro 2	1			0.7	0.08	g/km
96/69 class I - **DI**	1997	Euro 2	1			0.9	0.1	g/km
96/69 class II - **IDI**	1997	Euro 2	1.25			1	0.12	g/km
96/69 class II - **DI**	1997	Euro 2	1.25			1.3	0.14	g/km
96/69 class III - **IDI**	1997	Euro 2	1.5			1.2	0.17	g/km
96/69 class III - **DI**	1997	Euro 2	1.5			1.6	0.2	g/km
93/59 class I	1991	Euro 1	2.72			0.97	0.14	g/km
93/59 class II	1991	Euro 1	5.17			1.4	0.19	g/km
93/59 class III	1991	Euro 1	6.9			1.7	0.25	g/km

Source: International Fuel Quality Center (IFQC), from the European Commission 2002.

As can be seen below under Figure 2.7., Asian countries are at various stages of applying the Euro standards. Although Japan's emission standards are of course among the most stringent in the world. Hong Kong also complies with Euro III emission standards, while most other Asian countries have adopted Euro I or II, or US Tier 0 standards. There are a few countries in the region such as Cambodia and Indonesia that have not set emission standards.

Figure 2.7. Asia Pacific in Use Emission Standards for New Light-Duty Vehicles



Country		95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
EU	Euro 1		Euro 2				Euro 3					Euro 4			Euro 5		
Bangladesh										Euro 2 (under discussion)							
Cambodia	No specific emission standards for new vehicles																
Hong Kong		Euro 1		Euro 2				Euro 3					Euro 4				
India *(Delhi & other cities*)*						E1	Euro 2					Euro 3					
India *(Entire Country)*												Euro 2					E3
Indonesia											Euro 1 (proposed)				Euro 2 (prop)		
Malaysia				Euro 1			Euro 2										
Nepal							Euro 1										
Pakistan																	
Philippines										Euro 1							
PR China								Euro 1			Euro 2						
Singapore	Euro 1							Euro 2									
Sri Lanka										Euro 1							
Taipei, China						US Tier 1								US Tier2 for diesel*			
Thailand **	Euro 1							Euro 2			Euro 3					Euro4	
Vietnam	Gasoline				Euro 1							Euro 4 (under consideration)					
	Diesel											Euro 1		Euro 2		E3	E4

Note: * Gasoline vehicles under consideration. Euro 2 introduced in Mumbai, Kolkata and Chennai in 2001. Euro 2 in Bangalore, Hyderabad, Khampur, Pune and Ahmedabad in 2003, Euro 3 to be introduced in Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad and Ahmedabad in 2005. Heavy duty diesel standards: up to 1999: Euro 1, 2000 – 2005 Euro 2, 2006 onwards Euro 3

Source: Asian Development Bank (ADB), 2003.

Long term, there will be pressure worldwide for automakers to achieve “zero” vehicle emissions. However, for the immediate future, it is clear that Asian countries must make wise choices in adopting cleaner vehicle technologies and fuels providing the highest value and success in reducing the key criteria pollutants of concern. Again this is where developing countries in Asia and around the world can learn from European, Japanese and US experiences and build on these programs whilst tailoring their own solutions to meet their individual goals.

The first step for developing countries to begin improving air quality is to reduce in-use emissions. There are a number of options or combinations of options available to support this initiative including implementing vehicle inspection programs, establishing traffic control/management strategies, retrofitting the existing fleet, eliminating the use of leaded fuels, and increasing the use of alternative fuels. Lets look at some of these options as well as the possibility of automotive technology advancements:

Inspection and Maintenance

Modern vehicles remain absolutely dependent on properly functioning components to keep pollution levels low. Minor malfunctions in the air and fuel or spark management systems can increase emissions significantly. Major malfunctions can cause emissions to skyrocket. A relatively small number of vehicles with serious malfunctions frequently cause the majority of the vehicle-related pollution problem. Unfortunately, it is rarely obvious which vehicles fall into this category, as the emissions themselves may not be noticeable and emission control malfunctions do not necessarily affect vehicle driveability. Effective IM programs, however, can identify these problem cars and assure their repair.

For countries with only minimal if any controls on vehicles, a simple IM program can be a good pollution control starting point as even vehicles with no pollution controls can benefit from improved maintenance. A simple idle check on CO and HC missions from gasoline vehicles or visible smoke check on diesel vehicles can be used to identify the highest polluters and those vehicles which would most benefit from remedial maintenance. Several years ago, Hong Kong, whose air quality problem was primarily excess particulate, trained a small group of smoke inspectors who then patrolled the streets, identifying vehicles with excess smoke and requiring them to be repaired or pay a fine. Such a program requires minimal capital investment and resources.

As vehicle technology advances, more sophisticated test procedures may be necessary including loaded mode tests that use a dynamometer to simulate the work that an engine must perform in actual driving.

Substantial advances are occurring in IM programs. For the most advanced vehicles, those equipped with electronic controls of air-fuel and spark management systems and equipped with catalytic converters to reduce CO, HC and NOx, a transient test which includes accelerations and decelerations typical of actual driving can provide additional emissions reduction benefits.

As a general matter, maximum IM effectiveness occurs with centralized IM systems. These programs also cost much less overall and are more convenient to the public.

Retrofits

Another approach to cleaning up older cars with little or no pollution controls is to retrofit them. This means installing pollution control devices after the vehicle is in use rather than during vehicle production. Retrofit programs can be mandatory or voluntary with both positive and negative inducements.

Heavy-duty vehicles last a long time. The expected median lifetime for heavy trucks from model year 1990, the most recent year estimated, is 29 years, and the median age for transit buses is 16 years (BTS 2001; Davis and Diegel 2002). In the U.S., early NOx and PM standards for heavy-duty vehicles (circa 1984) were 50 times higher than upcoming standards. Plus, emissions tend to increase as vehicles age, especially for older models where there were no durability limits. This means that the full emissions benefit of new standards will not be realized for many years. Programs to reduce emissions from older vehicles could therefore be beneficial to improve air quality.

Where low-sulphur fuels are available, retrofit technologies can reduce emissions from existing vehicles. Oxidation catalysts and particulate filters for heavyduty diesel vehicles are the most common retrofit technologies. Recent projects have also included EGR in combination with a DPF, for simultaneous control of NOx and PM. Diesel oxidation catalysts are the easiest, most flexible, and least expensive retrofit option. With use of reduced or low sulphur fuels, a DOC can achieve a 20 to 50% reduction in total PM, an over 90% reduction in CO and HC, and an over 70% reduction in toxic HC (Johnson 2000). While DOCs are less sensitive to sulphur than particulate filter technology, increasing fuel sulphur levels do result in reduced conversion efficiency of the catalyst and can lead to increased sulphate formation, resulting in even higher particle emissions than without a catalyst.

DPFs are also an easy, effective retrofit option but require at least low sulphur fuel use. (For maximum benefit, near-zero sulphur fuel is required, especially for retrofit programs with largely urban-use vehicles, tending to have lower exhaust temperatures.) Retrofit programs using CR-DPF and CDPF systems in the U.S. and Europe have demonstrated an 80–100% reduction of toxic contaminants found in diesel exhaust, an 85 to over 95% reduction in particle mass, and a 70 to over 90% reduction in HC emissions, with an insignificant impact on fuel economy (Friedrich 2000). Retrofit diesel buses are found to be as clean as, or cleaner than, CNG buses, reliably delivering lower emissions of PM, CO, HC, and carbonyls, and comparable NOx emissions.

Mandatory Scrappage

Accelerated vehicle retirement, or mandatory scrappage, programs encourage vehicle owners to voluntarily retire their vehicles sooner than they would have otherwise. These programs are usually voluntary, and vehicle owners decide whether or not the compensation is sufficient to induce them to turn in their vehicles.

Alternative fuel conversions

The possibility of substituting cleaner-burning alternative fuels for gasoline or diesel has drawn increasing attention during the last decade. The motives for this substitution include conservation of oil products and energy security, as well as the reduction or elimination of pollutant emissions.

Alternative fuels include:

- methanol
- ethanol
- ethers
- vegetable oils
- compressed natural gas (CNG) mainly composed of methane
- liquefied petroleum gas (LPG) composed of propane or butane
- electricity
- hydrogen
- synthetic liquid fuels derived from hydrogenation of coal and various fuel blends such as gasohol
- water/diesel fuel emulsions
- Gas-to-Liquids (GTL)

Although some alternative fuels do offer the potential for large, cost-effective reductions in pollutant emissions in specific cases, care is necessary in evaluating the air-quality claims for alternative fuels. In addition, it is important to assess whether these fuels necessitate engine alterations or could damage the engine or vehicle drivability in any way thus potentially increasing emissions and reducing chances of consumer acceptability. Before considering the mandatory use of an alternative fuel it is recommended to speak to local automotive manufacturers or consult the WWFC. Some alternative fuels are not recommended by the automotive sector. In fact, in many cases, the same or even greater emission reduction could be obtained with a conventional fuel, through the use of a more advanced emission control systems. Which approach is the more cost-effective will depend on the relative costs of the conventional and the alternative fuel including infrastructure costs and potential tax revenue loss e.g. tax exemption on bio fuels for market penetration.

Technology Advancements

Technology advancements may still play a key role in the path developing countries take, particularly if they enable the use of non-sulphur sensitive emission controls (e.g., the “Plasmatron Fuel Converter” being developed by MIT). Equally helpful would be devices that aim to reduce vehicle cold-start emissions by converting a small portion of the fuel to a hydrogen-rich mixture. This mixture when introduced in the combustion chamber with the conventional air/fuel mixture, allows for much leaner, more efficient combustion and lower engine NOx emissions.

The next step is to require emission controls on new vehicles that would provide the largest benefit for the lowest cost (e.g., oxidation catalytic converters). The “necessity” and “cost effectiveness” criteria would be applied to presumably generate a technology path similar to that previously followed in the United States, Western Europe and Japan.

D. Explanatory Section - The System Approach Third Pillar: Fuel Quality Management

1. Background

Since the invention of the motor vehicle, fuel quality has been continuously improved to enable the advancement of new technology, e.g, lead to increase octane, which in turn enabled compression ratios to improve the thermal efficiency of the internal combustion engine (ICE) and oxygenates to replace aromatics and improve combustion.

Today, the principal drivers for change in fuel quality standards are environmental concerns- that is, the need to provide fuels that enable emerging vehicle engine and emission control technologies to achieve their optimum performance in order to reach more stringent emission standards and meet air quality requirements. Fuel quality will continue to be an integral part of engine development throughout the life of the ICE.

Fuel quality is now seen as not only necessary to help reduce or eliminate certain pollutants such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and toxic substances such as particulate matter (PM) and lead directly but also a precondition for the introduction of many important pollution control technologies, through the elimination of, for example of lead and sulphur.

The introduction of cleaner fuels has an immediate impact on both new and existing vehicles in the market place. For example, new cars with tighter emission standards can take some ten – 15 years or even longer before they are able to penetrate the market in sufficient numbers to be fully effective, whereas lowering lead levels in gasoline reduces lead emissions from all vehicles immediately. However, not all aspects of fuel quality changes has the same dramatic effects in lowering the emissions of the older car population. The introduction of vehicles with more advanced emission control technologies has by far the greatest effect on lowering emissions. Therefore, changes in 'cleaner' fuel qualities should be looked upon as 'enabling' new engine and vehicle technologies to move forward.

Many countries in the initial stages of environmental fuel quality improvement tend to follow global or regional initiatives aimed at improving fuel specifications and automotive technology. Some of these initiatives have been spear headed by International organizations such as the World Health Organization (WHO), the UN/ECE, the UNEP and the World Bank as well as regional and national regulatory bodies. Until recently, the USA, European Union and Japan have lead developments related to improved fuel qualities. All three have also served as models for the rest of the world. However, since the late 90's, most of the globe's countries are increasingly establishing their fuel quality legislation on the European Union's legislative framework. This is predominantly due to the lack of complexity in the European Framework and a one size fits all approach, which does not give flexibility to different refiners as in the US. The desirability of this approach also could be due to the clear links to EU auto emission requirements e.g. Euro I-V.

Even so, it is important to remember that rather than importing 'en masse' legislation from other regions of the world, legislation of fuels and emission limits should be tailored to meet the specific air quality needs of a given country or region in order to ensure cost effective solutions. It is important to build your own fuels / air quality strategy!

In Asia, some countries, such as India and Hong Kong have already issued medium-term policies outlining fuel quality targets to be achieved by 2010. Others are in the process of setting fuel quality goals such as Malaysia and Thailand.

Many Asian countries however have yet to address the issue of fuel quality and are at the very beginning stages of even thinking about the establishment of a fuel quality policy. This is due to a variety of reasons, which are often country specific however, a common factor is the lack of comprehension of the issues at stake. It is recommended that decision makers in developing countries that lack adequate knowledge on fuel quality, related emissions and the intrinsic links with air quality should study the approaches taken by Europe, Japan and the USA. In this way, they can avoid the unnecessary and sometimes painful steps that had to be taken to achieve the level of air quality enjoyed in the developed regions of the world so that can obtain better air quality for the inhabitants sooner.

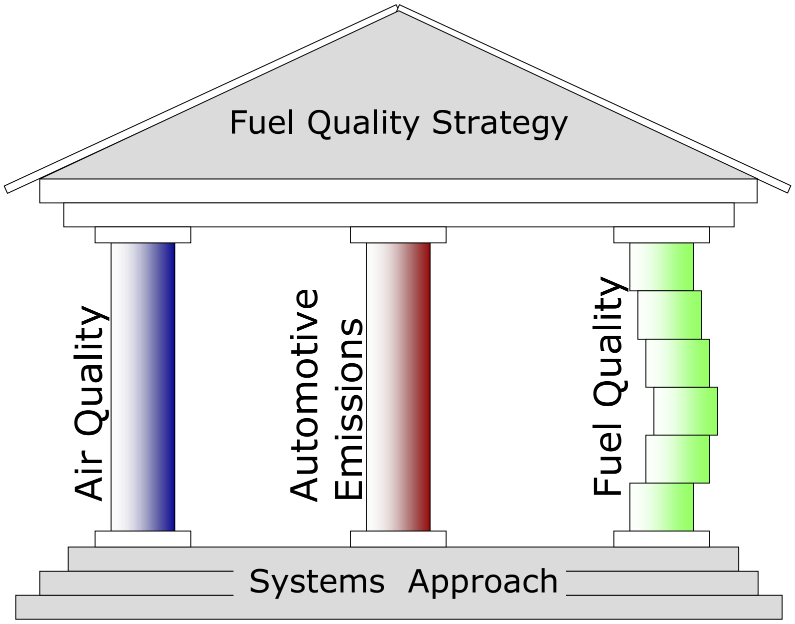
Fuel quality and regulations vary greatly from country to country in Asia – and often even between rural and urban areas in Asia. However, several Asian nations have made similar progress in the past and are in a similar situation in terms of automotive fuel quality and therefore in the same step in development. One important point out remember however is that the unique fleet composition in many Asian countries (including the high number of two and three wheelers, some of them with four stroke motors) must also be taken into consideration when thinking of fuel quality changes.

Asian countries have made a lot of progress in the last decade, especially in the last few years. In 1999 and 2000 many countries adopted new fuel specifications and will continue to tighten specifications in the future. Many of the countries have either regulated future fuel specifications or have at least made plans to do so. In general, Asian countries tend to follow the fuel quality developments in the European Union and to a lesser degree the United States (ASTM and CARB). The majority of the specifications are based on European standards. Still, automotive fuel quality developments in Asia are at very different stages. These stages vary from countries generally not having regulated fuel quality requirements to countries being at the stage of further reducing sulphur levels in diesel and/or reducing benzene, sulphur, aromatics and olefins levels in gasoline and at the same time often already optimizing the distillation characteristics.

E. How Do I Build A Comprehensive Fuel Quality Strategy?

The development of a comprehensive and successful fuel quality strategy very much depends on the development of the systems approach as described previously and the motivation of relevant stakeholders to work with the government concerned. However there are also a series of other determining factors, which must be considered when refining the systems approach into an actual fuel quality strategy. In fact these factors are absolutely necessary for the building of a successful fuel quality strategy. If we look at this graphically once again, the systems approach is the foundation to any strategy and we have three pillars: air quality, automotive emissions and fuel quality, which support the fuel quality strategy.

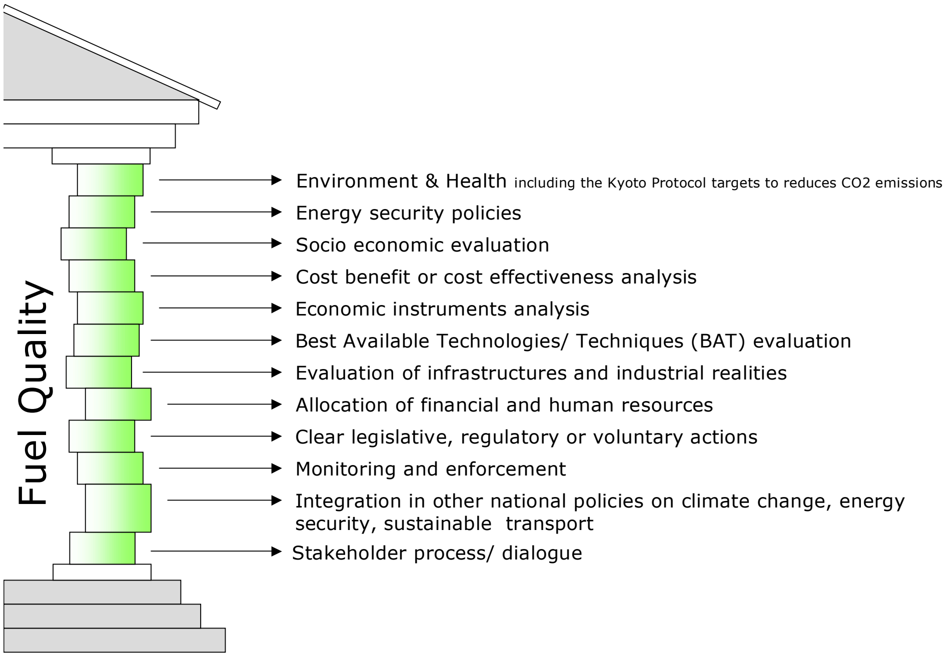
Figure 2.8. Fuel Quality Pillar: Building Blocks 1



Source: International Fuel Quality Center (IFQC), 2003.

As can bee seen above, if we take each pillar in turn, a series of building blocks hold that pillar together. Often these building blocks cut across each other but each pillar should be considered separately. In this particular, case we will only focus on the fuel quality pillar and the building blocks that are necessary to ensure a successful fuel quality strategy.

Figure 2.9. Fuel Quality Pillar: Building Blocks 2



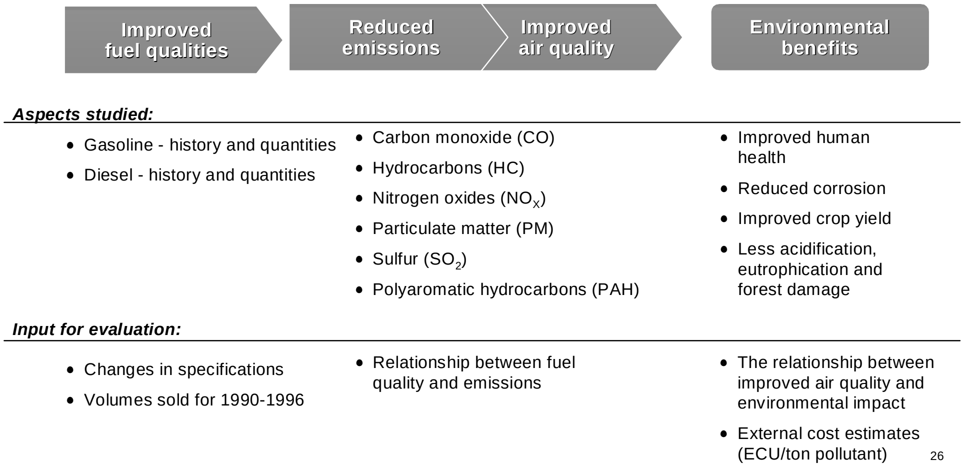
Note: The above building blocks are not necessarily listed in order of significance and others considered of importance, may not be listed.
Source: International Fuel Quality Center (IFQC), 2003.

The diversity of the above building blocks demonstrates that a successful fuel quality strategy is dependent on the development of a comprehensive approach. That said it is important that countries contemplating the launch of a comprehensive medium or long term fuel quality strategy do not find the complexity and extent of the above list an impediment to launching their own process. Asian countries, like other developing countries across the globe should build their tailor made system on the existing knowledge base e.g. cost/benefit analyses, scientific data, stakeholder processes, modelling and methodology derived from fuel quality programmes already in place. This does not mean that the development of personalised building blocks should be ignored and only foreign data entries used, in fact this would be discouraged, but the benefit of hindsight and existing experience should be maximised. This can occur in a variety of ways.

- Contact CAI-Asia or other organisations such as the IFQC for further information,
- Contact governmental colleagues in Europe, the US, Japan or other Asian countries to ask questions or exchange views and experience,
- Contact research bodies or consultancies carrying out relevant studies,
- Log on to relevant websites (a list is given in each chapter of this manual),
- Participate in conferences to collect relevant information,
- Use existing graphs/tables/models for tabulating national inputs

A good example of how to build on the existing knowledge base is Table 2.9. below. This table demonstrates the environmental and health building block in a fuel quality strategy. The table shows the methodology applied by the Swedish and Finnish governments when developing their fuel quality strategy (Source: Arthur D Little AB, Case Study Report- The introduction of improved transport fuel qualities in Finland and Sweden, July 1998). Note that although the approach and methodology used is interesting, the links are quite simplistic as the consultants (Arthur D Little) have made a direct link between fuel quality and emissions, whereas often the fuel has simply enabled the engine to reduce the emissions.

Table 2.9. The Relationship Between Improved Fuel Quality and Environmental Benefits.



	Improved fuel qualities	Reduced emissions → Improved air quality	Environmental benefits
Aspects studied:	Gasoline - history and quantities Diesel - history and quantities	Carbon monoxide (CO) Hydrocarbons (HC) Nitrogen oxides (NO_x) Particulate matter (PM) Sulfur (SO_2) Polyaromatic hydrocarbons (PAH)	Improved human health Reduced corrosion Improved crop yield Less acidification, eutrophication and forest damage
Input for evaluation:	Changes in specifications Volumes sold for 1990-1996	Relationship between fuel quality and emissions	The relationship between improved air quality and environmental impact External cost estimates (ECU/ton pollutant)

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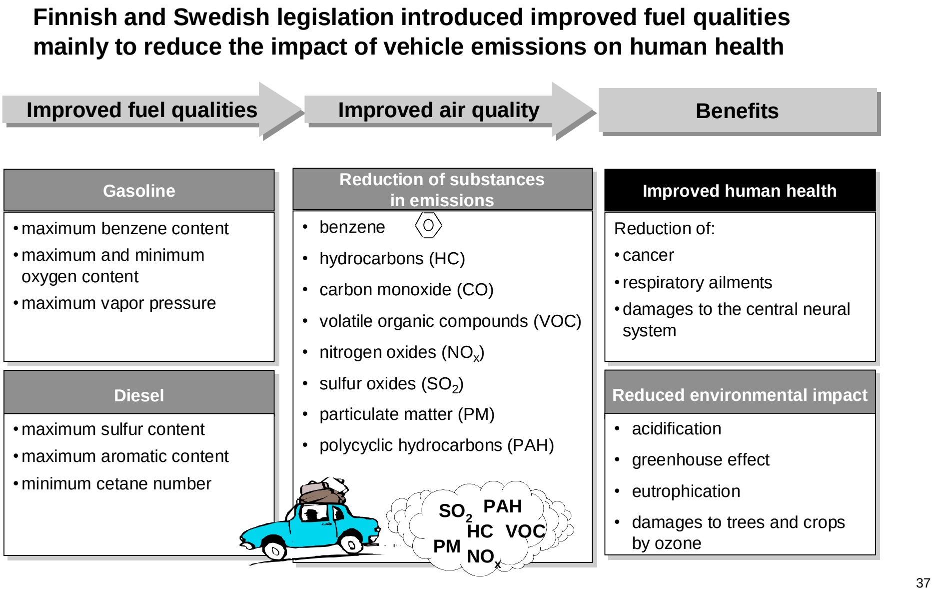
Source: Arthur D. Little, 1998. Case Study – The Introduction of Improved Transport Fuel Qualities in Finland and Sweden

The next 2 tables follow the same approach and are a good example of how a country can assess the environmental and health benefits of improved fuel qualities in general.

Table 2.10. Motivation and Introduction of Improved Fuel Qualities 1.



Finnish and Swedish legislation introduced improved fuel qualities mainly to reduce the impact of vehicle emissions on human health

Improved fuel qualities	Improved air quality	Benefits
Gasoline maximum benzene content maximum and minimum oxygen content maximum vapor pressure	**Reduction of substances in emissions** benzene hydrocarbons (HC) carbon monoxide (CO) volatile organic compounds (VOC) nitrogen oxides (NO_x) sulfur oxides (SO_2) particulate matter (PM) polycyclic hydrocarbons (PAH)	**Improved human health** Reduction of: cancer respiratory ailments damages to the central neural system
Diesel maximum sulfur content maximum aromatic content minimum cetane number		**Reduced environmental impact** acidification greenhouse effect eutrophication damages to trees and crops by ozone

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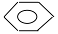
Note: it is important to remember when using such graphs that certain pollutants can come from other vehicle sources than just the exhaust e.g. VOC's also from the fuel tank and during re-fuelling
Source: Arthur D. Little, 1998. Case Study – The Introduction of Improved Transport Fuel Qualities in Finland and Sweden

Table 2.11. Motivation and Introduction of Improved Fuel Qualities 2.

The main benefit of improved fuels is expected to be improved health

Reduced substance in air	Benefit to society		
	Health	Environment	Other
	• Reduced cancer		
HC	• Reduced respiratory illness • Reduced cancer	• Reduced damage to plants and crops by ozone*	
CO	• Improved ability of blood to transport oxygen to the brain	• Reduced greenhouse effect	
VOC	• Reduced respiratory illness • Reduced cancer	• Reduced damage to plants and crops by ozone*	
SO_2	• Reduced respiratory illness	• Reduced acidification	• Reduced damage to buildings and stone materials
NO_x	• Reduced respiratory illness • Reduced cancer	• Reduced acidification and eutrophication • Reduced damage to plants and crops by ozone*	• Reduced damage to buildings and stone materials
PM	• Reduced respiratory illness • Reduced cancer		• Improved visibility
PAH	• Reduced cancer		

* NO_x, HC and VOC are sources to photochemical oxidation substances that produce ozone.

Source: Arthur D. Little, 1998. Case Study – The Introduction of Improved Transport Fuel Qualities in Finland and Sweden

1. Fuel Quality Strategy Building Blocks:

In order to properly understand the “systems” approach and the fuel quality strategy building blocks, let’s look at these blocks in turn. We can divide these blocks into 3 main types:

1) **Context related**; those blocks which set the back drop and put the strategy into context such as environment and health data, industrial realities etc.
2) **Process related**; those blocks which are related to the process of developing a fuel quality strategy such as creating a stakeholder dialogue and ensuring that links are made with other relevant polices e.g. energy security, climate change etc.
3) **Implementation focused**; those blocks strictly implementation focused such as investments into technology and BAT if possible, the allocation of financial and human resources etc.

Context Related Building Blocks

Environment and Health

The costs and benefits of each option should be assessed for health and environmental factors. This may involve use of dose-response relations, or risk assessment techniques. Some countries determine air pollution control requirements hence fuel quality changes on the basis of an assessment of the effects of the pollutants on health and the environment (effect-oriented). Increased emissions may be permitted where the assessment suggests there will be no health or environmental impacts, or ambient air quality standards will not be exceeded. Action may be taken to reduce ambient concentrations, and thus fuel quality parameters changed where impacts or exceedances of air quality controls are shown to occur. Other countries base their air quality management and fuel quality policies on the requirement for best available technology, or best available techniques not entailing excessive cost (source-oriented).

Most developed countries apply a combination of both source-oriented and effect-oriented principles (UNECE 1995;UNECE 1999).

One scientific evaluation undertaken for fuel quality and air pollutants in particular is a risk assessment. In many cases there is no "safe" level for these air pollutants or fuel components. They do not follow a threshold-type response, as health and ecological risk can increase with increasing exposure. Consequently, this approach requires an evaluation of health risks for the general or sensitive population, and establishes acceptable levels of health risk for these populations. Sources are required by regulation to implement techniques for reducing the levels of health risk to those prescribed. For example, recent risk assessments regarding fuel quality and health/environmental risks were undertaken in Europe regarding benzene, and MTBE (Source: EU MTBE Risk Assessment). An interesting outcome of the risk assessment process is that air quality is not the only environmental aspect addressed. All risks related to the handling and use (from producer to consumer) of a fuel component are addressed thus encompassing risks to health and to air, water and soil. In this regard the issue of substitution is important. That is that any substitute for a particular fuel component should also undergo a proper assessment before major fuel quality proposals are in place. It is important to note that the results of these risk assessments are public and can be referred to by countries developing their own fuel quality strategies.

Energy Security

When developing a fuel quality strategy, it is necessary to take into account energy security issues which impact fuel quality policy-making. This is all the more relevant now in a post 9/11 world where terrorist activity across the globe has heightened national energy security concerns. These concerns have been translated in a variety of ways and very much depend on the current energy structure of a country and other possible domestic energy sources such as natural gas and bio fuels. In most cases countries dependent on energy from outside sources are concerned and are actively looking to diversify their energy sources and looking for new energy alternatives. In fact, this objective also fits in nicely with current climate change strategies in place in some countries especially in Europe and Japan.

Today, energy diversification is seen as the solution to offsetting any possible interruptions in fuel supply. However, in this regard it is important to address a related issue, which is the fuel product supply and demand slate. For example, in Europe the demand for diesel is increasing whilst gasoline demand is decreasing. In essence the region is long in gasoline and short in diesel therefore diversifying in diesel alternatives such as natural gas, and bio diesel is seen as more useful than finding alternatives to gasoline.

The energy supply structure in selected Asian countries is given below. As can be seen in this table, most Asian countries are importing crude and some import natural gas. 60% of the crude needed in Asia is imported, of which approximately 90% comes from the Middle East. This dependency on crude imports is clearly an issue for most Asian countries. Most Asian countries are therefore looking at diversifying their energy sources predominantly through bio fuels and natural gas.

Table 2.12. Energy supply in selected Asian countries.

	Petroleum (1,000 barrels/day)			**Natural Gas (billion cubic feet)**		**Coal (Million Short Tons)**		**Electric Generating Capacity (Million Kilowatts)**
	Refining Capacity (1/1/99)	**Consumption (1998E)**	**Net Imports*(1998E)**	**Consumption (1997)**	**Net Imports* (1997)**	**Consumption (1997)**	**Net Imports* (1997)**	**Total (1/1/97)**
China	4,347	3,911	713	749	0	1553	-21	237
Hong Kong	0	170	170	0	0	7	0	10
Indonesia	930	893	-702	1,113	-1,261	15	-45	21
Japan	5,059	5,509	5,429	2,340	2,220	143	138	211
Malaysia	474	446	-338	593	-763	3	3	12
Philippines	389	343	339	0	0	3	2	9
Singapore	1,172	539	535	53	-53	0	0	6
South Korea	2,540	2,025	2,022	525	536	65	60	36
Taiwan	770	850	846	179	-146	43	43	24
Thailand	713	718	607	523	0	28	4	19
TOTAL	16,394	15,404	9,621	6,075	533	1860	184	585

Note: *Calculated as consumption minus production. A negative number indicates the country is a net exporter

Source: Energy Information administration (EIA), 2000.

Evaluation of infrastructures and industrial realities

Before setting fuel quality specifications and developing a holistic fuel quality strategy it is essential that an evaluation of the auto, oil and other related industries in the country is carried out. In addition, a certain understanding of infrastructure issues is necessary not only related to industrial sites but also to the industry as a whole e.g. pipes, service stations and number of pumps, storage tank issues, transportation issues etc.…Many government's already have these data based on a simple case of collecting and analysing the data. However, in some cases surveys or site visits may be necessary to gather further information.

Economic instruments analysis

Economic instruments such as tax incentives and price differentials are an important tool in facilitating the penetration of cleaner fuels on the market. During the drafting of a fuel quality strategy, it is necessary to carry out an in depth analysis of all possible economic issues, which could both hinder and facilitate the implementation of the strategy. For example, does the country have a liberalised energy market? Is there price fixing? Do subsidies exist or tax incentives already exist for fuel products or other products such as higher tax charges for leaded gasoline or higher sulphur fuels compared with unleaded gasoline; product charges and environmental taxes such as CO2 taxes on mineral oils versus alternative fuels; or reducing subsidies for energy use.

Again standard material on the use of economic instruments (as further explained in module 3) exists and should be used to assess national instruments already in existence.

Another market-oriented approach, which is increasingly used is a system of tradable emission permits. In this system, the regulating authority quantifies the total mass of emissions permitted in an area and issues an equivalent number of tradable emissions entitlements. These tradable permits can be freely bought and sold. They have the potential to achieve government policy objectives at the lowest cost to industry, and in some cases to government. An Emissions Trading Policy has been adopted in the US, in particular in the 1990 revision of the US Clean Air Act, which enables some trading of emissions permits for SO2 between stationary sources, and in Europe green house gases (in particular) CO2 emissions allowances are being traded under the EU Green House Gas Emissions Trading Scheme. It is considered that a trading system provides maximum flexibility to industry to pursue the lowest-cost options, while meeting government policy objectives.

A law is only as effective as the people that apply it. Many countries complain of fuel adulteration and non-compliance. Fuel Quality laws have been introduced but these are not respected. In most cases the lack of compliance is not due to wilful criminal activity but simply due to socio economic factors predominantly poverty, which drive certain consumers or related industries (transport companies) to stretch/break the rules. These possible socio economic issues should be addressed when putting in place a fuel quality strategy so that the poorer fractions of the population are not unnecessarily penalised from fuel quality changes. A discussion of these issues as well as possible solutions can be addressed during a stakeholder dialogue with relevant interest groups. An example of such a process is recent discussions between the UK government and farmers regarding the possible introduction of low sulphur non-road diesel across the EU. Currently UK farmers use high sulphur heating oil in their tractors. Heating oil is cheaper than on road diesel. Due to the current difficult economic situation of UK farmers, discussions are in place regarding a special tax concession on non road diesel, if 50 - 10 ppm sulphur levels are introduced.

Process Related Building Blocks

Cost-benefit analysis and other factors

The selected options must be financially viable and sustainable in the long term. This may require comparative cost-benefit assessments of options. These assessments must include not only the capital costs of bringing an option into operation, but also the costs of maintaining the expected level of performance in the long term. Costs here relate not only to industry investment but also to governmental subsidies, price assistance or tax incentives thus putting some strain on the countries Treasury.

The costs of reducing levels of air pollution through fuel quality changes should be weighed against the benefits produced. Cost-benefit analysis is one way of formally setting out this process, and it uses money as a common currency for costs and benefits. The concept is that pollutant concentrations are reduced at least until the associated costs and benefits are balanced: more strictly, emissions are reduced until the marginal costs and benefits are equal (WHO 2000 Guidelines). While the cost of abatement measures may be relatively easy to quantify, this may not be the case when non-technical measures are employed. In any case, it is likely to be more difficult to assign monetary values to the benefits obtained. Some aspects of reduced morbidity, such as a reduction in the use of hospital facilities and drugs, are comparatively easy to cost; others such as reductions in premature deaths and symptoms are not. Applying monetary values based on a "willingness to pay" basis has been suggested, and has been accepted as appropriate by many health economists. This approach has been seen as preferable to one based only on such indices as loss of production, earnings or hospital expenses.

However, there are many uncertainties related to carrying out such a cost benefit analysis, which truly evaluates all externalities. This is an issue, which all governments are ultimately faced with and is extremely complex as it entails the exact quantification of emissions through source apportionment and the accurate assessment of health costs and benefits from changing certain fuel quality parameters, which is a very difficult task. In fact due to the difficulty in assessing true costs, once again countries in the process of or considering their own cost benefit analysis are advised to consult existing studies from the United States, Europe, Japan or other Asian countries as an example of possible costs rather than carrying out a full analysis.

The external costs for all types of transport take into account not only tailpipe emissions and pollution caused during fuel production, but also the environmental impacts of vehicle production and infrastructure building.

Socio economic evaluation

The costs and benefits of each option should be assessed for social equity in its effects on people's lifestyles, community structures and cultural traditions. Considerations may include, disruption or displacement of residents or land uses, impacts on community, culture, and recreation. A key socio economic issue is pricing. A high priced cleaner fuel will negatively impact lower income households and reduce consumer acceptability. Finding an accurate fuel price, which addresses such socio economic issues will not only guarantee consumer acceptability but avoid fuel adulteration as further discussed under Modules 3 and 4 of this manual.

Stakeholder Process

In practice the strict theoretical precepts of cost-benefit analysis should be supplemented by broader social and economic considerations. Stakeholders are defined as those who have an interest in the outcome of a decision making process. The aim is to ensure as far as possible social equity and fairness to all involved parties. A Stakeholder process must thus involve all relevant parties including representatives from the auto, oil, and related technology suppliers as well as representatives of civil society e.g. environment, health, consumer and indigenous groups. An adequate and early involvement of all concerned stakeholders will increase the transparency of the process and is likely to increase the acceptability of the outcome. The involvement of stakeholders will be further discussed in Module 5 of this manual.

Fuel Quality Policy Integration into other National Policies and Vice Versa

Governments across the globe have increasingly realised that policy making on a particular issue cannot be made in a bubble and that in particular environmental issues are cross cutting. Therefore, today more and more governments try to apply an integrated approach to their policy making. Fuel quality policy is a perfect example of the need for an integrated approach. Not only should the “systems approach” apply and thus all air quality and automotive emissions policy (including R&D) be linked to fuel quality changes, but other policies and R&D efforts must also be linked this includes:

- Transport related policies
- Energy security policies
- Climate Change policies
- Mineral oil and vehicle taxation policies

It can be said that historically the links between fuel quality policy and transport policy have been made. This has also occurred to a certain degree within taxation policies as such polices have referred to the quality of the fuel or vehicle to be taxed or the possibility for exemptions. However, today there are two key policies, which are increasingly linked to fuel quality decision-making these are energy security and climate change.

Implementation Related Building Blocks

BAT and Technical Issues

A country needs to be confident that the selected technical options are practical within the resources of the region, and make sense based on the systems approach e.g. is the current or near future vehicle fleet going to benefit from refinery investments in zero sulphur fuels at this stage? This applies both to industry investments as well as government investments in monitoring equipment, sampling labs etc. (this can either be done in house or outsourced as is usually the case) refer to Module 4 for the costs related to monitoring.

A legislative push towards certain BAT for refinery upgrades and vehicle changes needs to be justified from a socio economic, environmental and financial standpoint otherwise implementation will not occur. When a government is looking at possible fuel quality changes to meet air quality targets and automotive emissions, the different BAT options should be assessed in order to understand more clearly possible investment needs both in terms of the refiner and the vehicle producer. However, it is not recommended that a certain type of technology be promoted but rather an end result. Due to daily market and product changes, vehicle manufacturers and refiners must be given the flexibility to use a certain type of technology as long as they meet their respective automotive emission and fuel quality goals.

Resource Allocation

Proper resource allocation is one of the necessary requirements for the successful implementation of a fuel quality programme. Although developing countries can build their fuel quality strategies on an existing “knowledge base” and therefore save on program costs, resources must still be specifically allocated to the implementation and enforcement of the fuel quality strategy. Clearly the exact budgetary needs will depend on the extent of the programme and the ultimate financial capabilities of the government. However, it must be stressed that no strategy can be fully implemented without a certain level of financial and human resource allocation. This means for example the allotment of governmental staff both for legislative drafting and review, and for enforcement. It also entails specific funds for monitoring and sampling equipment both at the pump and in the test laboratory.

Monitoring and Enforcement

Fuel specifications or standards, however strict they are, do not guarantee good fuel quality at the filling station. The foundation for clean fuels at the pump is linked on two issues – (1) National standards and (2) the ability to ensure and/or control fuel quality at the point of distribution – the filling station pump. The latter can only be achieved through implementation and commitment to an effective fuel quality monitoring program. Without the control of clean fuel at the pump, there is basically no foundation for a National standard for fuel specifications. Experience in the USA, Europe and Japan has shown this to be the potential weak link in many fuel programs and an area, which must be strengthened.

A good fuel quality monitoring (FQM) system ensures that product quality is in accordance with prescribed specifications, which have been set for environmental and technical reasons (i.e. that the fuel used does not harm the vehicle, its engine or the environment and that ambient air quality targets can be met). Furthermore, FQM also looks after the welfare of the consumers, making sure that the fuel pumped into the vehicle is of the quality they are purchasing. Further details regarding monitoring and enforcement will be given under Module 4.

Legislative, regulatory or voluntary actions

Command and control: Laws and regulations are at the heart of most management strategies including air quality and fuel quality management. The traditional approach for developing and implementing these strategies has been the "command and control" approach. This approach has several major features centred around the regulation of emissions. The command and control approach usually involves the development and regulation in law of emissions and fuel quality standards, the monitoring and reporting of fuel quality from the refinery gate to the pump, and penalties for exceeding license conditions. Under this system, the techniques to be used in areas are prescribed by government, and compliance with conditions is checked by government inspectors. Licences are issued, standards are set, compliance with standards are checked, non-compliance cases commonly go to court, mitigating circumstances are considered by the court, and penalties are imposed. New developments or major changes to sources are usually subject to environmental impact assessment, and new sources may be subject to tighter performance standards than existing operations.

The "command and control" approach is the most widely used technique around the world as it has many strengths. This system has some public confidence, and provides a degree of certainty to industry and the public. However, it is also time consuming, expensive and legalistic. As the penalties imposed by the courts may be light, the outcomes may be unsatisfactory for all involved. The command and control approach is also rigid, with the potential for arbitrary decisions and a focus on end-of-pipe solutions, instead of more comprehensive pollution prevention approaches. While it may establish a minimum condition, it provides no incentive to minimize emissions. It usually ignores equity, often requiring highly expensive best-available technology for new sources, while existing sources with a lower level of technology and performance continue to pollute. However, in some situations the command and control approach has worked extremely well, and many countries have reduced emissions of SO2, coarse particles and reduced or eliminated lead emissions from gasoline.

Nonetheless, in many countries the reform of regulations in the last 10-15 years has reduced dependence on the traditional command and control approach. In recent years, the trend in most developed countries has been towards increased use of other forms of regulatory control. One such approach is self-regulation as discussed below. It is argued that some industry groups, for example the chemical industry or the petroleum industry through responsible care and the adoption of environmental management systems, are familiar with current best practice within their own industry, and can set codes of practice, industry standards and targets. Individual companies conduct self-monitoring of compliance and are subject to audit. However, self-regulation measures can provide less certainty to industry and may inspire less public confidence than regulatory control by government.

Increasingly governments opt for a mix of both command and control measures and voluntary measures or market based measures to stimulate change. A good example of such as mix is the European Union's introduction of mandatory cleaner fuels legislation in 1998. Although the legislation was prescriptive and obligatory for all EU Member States, the legislation allowed the use of tax incentives as a stimulus for the earlier introduction of the better quality gasoline and diesel mandatory in 2000 and 2005. This approach has worked remarkably well also for the introduction of low sulphur and ultra low sulphur fuels before the required date. The use of tax incentives and other voluntary agreements in the area of fuel quality changes has also been widely used in Asia as seen below under Philippines Case study No. 2.

Case study 2: Phase out of Leaded Gasoline in the Philippines

Background - When the Clean Air Act of the Philippines was signed into law in 1999, lead phase-out was identified as the first priority action because of its serious health effects. This prioritization was widely supported by civil society groups throughout the development and public consultations on the law. The Act mandated the elimination of leaded gasoline by January 1, 2001, but after it became law, the major oil companies and the Department of Energy decided to advance the phase-out to April 1, 2000 in Metro Manila. The announcement of the early phase-out plans prompted a multi-sectoral group including government, business, civil society, and development institutions interested in the implementation of the Clean Air Act to meet and decide that the success of the phase out was hinged on public understanding and acceptance.

In February 2000, an ADB-US AEP supported workshop with over 150 participants from government, non-government organizations (NGOs), civil society, and the private sector was conducted to educate these stakeholders about the issues involved in the phase-out of lead and to enlist the participants in planning and executing a campaign to educate the public about the phase-out. Participation was high because of the high-profile and effective speakers and the momentum generated by the accelerated deadline for the Metro Manila phase-out. The workshop participants agreed to form the Lead-Free Coalition and launch a public awareness campaign with the following objectives:

- Inform motorists that the lead phase-out will occur on April 1
- Reassure motorists that their vehicle can safely use unleaded gasoline
- Underscore the physical/health benefits
- Explain the financial benefits from the use of unleaded gasoline

Issue Focus - The Lead-Free Coalition made effective use of a wide range of media and convinced the oil companies to include educational information in their print ads. The short time available and the small budget required the group to be creative and focused. The main challenge was the very short time-frame to develop and implement the campaigns before phase-out dates. The group addressed this by quickly pulling together the right partners and implementing an intensive campaign that lasted for three weeks and included seminars/press media publicity, TV and radio spots, print ads, and distribution of flyers, stickers, and posters. Non-traditional media were also used,e.g.,telephone hotlines, website

Continued….

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mailing inserts, and seminars. Some resistance was encountered from vehicle manufacturers and motorized tricycle operators. The opposition included concerns about the technical ability of all cars and motorcycles to safely switch to unleaded gas, and the higher cost of unleaded versus regular, low-octane gas. The federation of tricycle operators and drivers filed a temporary restraining order to stop the phase-out; however, the Coalition initiated an outreach effort and convinced the federation to drop the case. In Metro Manila, the decision-making process took place in several meetings with key partners before and after the February workshop, in which a large number of people from all concerned sectors were present and encouraged to give their opinion and get involved in the campaign. During the meetings, policy issues were discussed in an open, multi-sectoral forum that lead to greater understanding and faster action.

After the Metro Manila phase-out, the focus was on the nation-wide phase-out scheduled for January 1, 2001. It has expanded its campaign to include cleaner diesel and renamed itself the Coalition for Cleaner Fuels. Nine regional dialogues were held to raise awareness, answer questions, and put fears at ease in regions across the country—environmental NGOs, the transport industry, and the agricultural and fishing communities were particularly involved at the regional level. This network of local contacts was used for materials dissemination, feedback, and, later, compliance monitoring. The group achieved its objective of a smooth phase-out of leaded gasoline. The group (now called the Partnership for Clean Air) reports on its performance during the yearly General Assembly and has set up an external evaluation committee to evaluate the group' s work twice a year.

Analysis / Lessons Learned – The lead phase-out campaign in Metro Manila and the provincial dialogues and campaign were deemed successful because the phase-outs took place without any major resistance. This was an important accomplishment given the poor image of the oil companies and government (protests are regularly held when fuel prices are raised), short time and budget available. Because the passage of the Clean Air Act was very contentious, it was critical for the first action of the Act, which was the leaded gasoline phase-out, to be done in an inclusive manner with a great deal of two-way communication. The Coalition's efforts accomplished this. The Coalition also included cleaner diesel in its provincial campaign, ahead of the December 21, 2000 reduction of sulphur to 2 mg/litre. Eliminating lead from the air and reducing sulphur levels will have major impacts on the health of the population, especially the urban poor, and ecosystems. This effort also resulted in a sustainable, effective group that has evolved into the Partnership for Clean Air.

The group learned (and demonstrated) the value of multi-sectoral cooperation and strong partnerships to accomplishing a goal that involves many stakeholders. There were many naysayers and roadblocks during the initial meetings, and it was difficult to coordinate everyone's schedules and convince people who normally are at odds (NGOs vs. industry and one government department vs. another department) to work together on a common goal. But the momentum created by the February 2000 workshop and the success of the campaign convinced the group to continue working on other air pollution issues, to build on the foundation of the strong partnerships that were forged. The importance of the highly visible and important role played by the NGOs throughout the phase-out initiative was also given recognition. The president of the lead NGO, Concerned Citizens Against Pollution, was a very credible and convincing spokesperson on many TV and radio talk shows and in meetings with oil company executives and top government officials.

Co-regulation: As part of the process of regulatory reform, companies and their industry organisations have been included in discussions of options for regulation reform, and in the review of these options. This is usually carried out through a variety of different industry dialogues. This pro-active approach by industry organisations has led to a degree of co-regulation in certain aspects of fuel quality management. It has resulted in the adoption of regulations and guidelines considered to be practical and realistic by those affected, and have simplified and reduced the costs of compliance for national governments. In the area of fuel quality monitoring there are several examples, of co-regulation where government and industry have worked together to put in place a monitoring system that works. For example, Belgium, Germany, Hong Kong and Singapore all have industry self regulation and government command and control aspects. This process has resulted in the voluntary adoption by industry of the monitoring system and activities are carried out in a collaborative manner. In these cases, the industry supply the data for fuel quality produced and this quality is checked by governments at the pump. In addition, a series of guidelines are produced by the government to help industry carry out their self monitoring task. These government guidelines prescribe the necessary outcomes, but not the means to achieve these outcomes, and avoid being too prescriptive, as this can encourage a legalistic approach. Nonetheless, this is not a pure self regulation approach and the onus is still on industry to carry out the monitoring and meet the mandatory fuel quality specifications.

Self-regulation: Companies across the globe are increasing regulating themselves through a variety of programmes and company wide agreements. Environmental management systems, responsible care programmes for the chemicals industry, and voluntary agreements on key topics with governments e.g. UK industry Fuel Quality monitoring program, EU CO2 agreement with auto industry, and the introduction of low sulphur fuels in many Asian countries (refer to case study on the Philippines below) are good examples of industry self-regulation. The adoption of environmental management systems has also influenced the process by which governments define industrial emissions outcomes, while not prescribing to industry how these outcomes should be achieved. Governments are also using public education strategies to improve the actions of the public that can lead to air pollution. In many cities, area sources of air pollution and vehicle sources together comprise the largest component of emissions, and it is the actions of individuals that decide the scale of these emissions. While technical strategies have a major role, education and public information programmes can also contribute to reducing the magnitude of these sources.

F. Drafting Fuel Quality Legislation

Once an air quality management programme is in place, source apportionment has occurred and the impact of transport has been evaluated, automotive emissions can be set and fuel quality needs determined. Again in order to determine these fuel quality needs and build a holistic fuel quality strategy a series of building blocks should be looked at. It is these building blocks, which will give all of the necessary inputs for determining the fuel quality parameters, which should be set and the type of legislation, which should be put in place. As indicated above this legislation could encompass a variety of different approaches including the more traditional command and control approach and the increasing use of self-regulation.

As indicated earlier in this chapter, the US, EU and Japan have lead developments related to improved fuel qualities. Although the EU tends to be the region most followed, it is important to note that historically it is the US Clean Air Act Amendments (CAAA), which are the first legislative text in the world referring directly to the systems approach and the link between air quality, automotive emissions and fuel quality. Because of this new mandated link in the US, the amended Act included the legislative requirement for the development and implementation of the U.S. Reformulated Gasoline (RFG Program). In order to understand some of the terminology and reasoning behind changes or the “reformulation” of fuels it is important to take a brief look at the US model.

Prior to the RFG amendments, Federal legislation and resulting regulations from the Clean Air Act and its subsequent amendments had focused primarily on changes in vehicle technology to reduce emissions. Most pollution control strategies required manufacturers certify the new vehicle fleets to attain more stringent exhaust and evaporative emission standards. This was the same in Europe and Japan. However, in the US there was one major fuel quality change legislated in the 1970’s that significantly changed the face of the refining industry and enabled a dramatic switch to a new automotive after treatment technology. That was the introduction of unleaded gasoline.

In the 1980’s, when the U.S. Congress began the process of drafting the next set of amendments to the Clean Air Act, the automotive industry began advocating that if further vehicle emission standards were legislated, fuel quality controls may also be necessary to allow automotive manufacturers to optimise the efficiency of new emission control systems. A similar argument would be used 10 years later by the European automobile industry when lobbying to strengthen the original fuel quality specifications proposed by the European Commission.

It is important to note, that the CAAA and later the adoption of European Directive 98/70/EC on the quality of gasoline and diesel fuels would deviate from the previous setting of technical standards for fuel. Both of these legislative texts make the historic link between engines/fuels and environmental impacts. From this day forward, legislation would apply the systems approach in its entirety and refer to environmental parameters. Standards on the other hand such as the ASTM in the US and the CEN in Europe would complement the environmental parameters with the technical guidelines necessary for the proper functioning of any vehicle. This is very clear in the case of the European Union, which has adopted Directive 98/70 as environmental legislation primarily concerned with the impact of certain fuel parameters on engine emissions. This legislation is complemented by the European CEN standards EN228 for gasoline and EN590 for diesel, which apply all of the environmental parameters legislated under directive 98/70 as well as give technical guidelines for other parameters of significance to the engine. It is also the standards both in the EU and US which determine testing methodology etc..

The issue of reformulating fuels is very important. US, Japanese and European experience has shown that by improving certain fuel parameters, emissions will be reduced from all vehicles whether old or new. Developing countries who have also followed this approach have seen immediate benefits as well. Through these many programmes most notably the US and EU Auto Oil programmes, and JCAP it has been determined that there are key properties in gasoline and diesel fuel, which must be changed or certain compounds eliminated e.g. lead to attain air quality goals and auto emission standards. One major difference in approach however, was that the US program focused on gasoline vehicles whereas both the Japanese and European programmes included an in depth analysis of diesel vehicles. This is predominantly due to the fact that in comparison with the large diesel passenger car fleet in the EU, and growing interest by the Japanese government in diesel for domestic use and export, the

U.S. light-duty (LD) diesel car fleet is less than 1 percent of the US light-duty market and the US government had labelled diesel vehicles as dirtier than gasoline vehicles (this trend is slowly changing). Therefore, emissions from diesel passenger cars were not a priority in the re-authorization process for the CAAA in comparison with the European Auto Oil Programme. That said, the 1990 CAAA did require that on-road diesel fuel meet a 500 ppm sulphur cap by October 1993 to enable the 1994 tech engines to comply with the new on-highway heavy duty diesel emission standards and the new Tier III low sulphur rules will apply a 15ppm sulphur cap to on-road and non-road diesel by 2006

Defining Environmental Fuel Parameters:

The product specifications for automotive fuels define the range of values for a large number of physical and chemical properties. Only a small number of these properties are believed to have a significant impact on the emissions from diesel and gasoline engines. Due to the different composition of diesel versus gasoline, these key parameters will differ as well depending on the fuel.

Let us not forget that the principal driver for change to fuel quality standards is the environment, that is the need to provide fuels that facilitate the adoption of emerging vehicle engine and emission control technologies to reach more stringent emission standards and meet air quality requirements. Such standards need to be consistent with engine development practices and provide reliable and long-life compliance. Table 2.13. below shows the environmental parameters for which specifications have been set in the US, EU and by global automakers in their World Wide Fuel Charter (WWFC).

Table 2.13. The Main Gasoline and Diesel Fuel Properties Affecting Emissions.

GASOLINE	**EU**			**USA**		**WWFC**
	EN 228 1993 *"Euro II"*	**Dir 98/70: 2000 *"Euro III"***	**Dir 98/70: 2005 *"Euro IV"***	**CARB Phase 2: 1996**	**CARB Phase 3: 2003**	**Category 3**
Aromatics, vol%.max	**-**	**42**	**35**	**30**	**35**	**35**
Olefins, vol%, max	**-**	**18**	**18**	**10**	**10**	**10**
Benzene, vol%, max	**5.0**	**1.0**	**1.0**	**1.2**	**1.1**	**1.0**
Oxygen, wt%, max	**-**	**2.7**	**2.7**	**1.8 - 3.5**	**1.8 - 3.5**	**2.7**
Sulfur, ppm, max	**500**	**150**	**50 (10)**	**80**	**60 / 30**	**30**
RVP, kPa	**35 - 100**	**60 / 70**	**60 / 70**	**48**	**44 - 50**	**45-60 ***
Lead, g/l, max	**0.013**	**none**	**none**	**0.0013**	**0.0013**	**none**

DIESEL	**EN 228 1993**	**Dir 98/70: 2000**	**Dir 98/70: 2005**	**CARB current**		**Category 3**
Polyaromatics, vol%, max	**N/A**	**11.0**	**11.0**	**-**		**2.0**
Sulfur, ppm, max	**2,000**	**350**	**50 (10)**	**500**		**30**
Cetane number, min	**49**	**51**	**51**	**48**		**55**
Density @ 15 °C, kg/m^3	**820 - 860**	**845**	**845**	**820 - 870**		**820-840**
Distillation, T95, °C, max	**370**	**360**	**360**	**-**		**340**

Note: * depends on ambient temperature and season
Source: International Fuel Quality Center (IFQC). May 2003.

The WWFC has been used as a comparison with the national fuel quality specifications because it is a long-term vehicle emissions standard and fuel quality strategy pushed by auto makers across the globe, and is a useful guide for Asian countries in the process of setting up their own fuel quality strategies. The objective of the WWFC is to push for cleaner gasoline and diesel fuel legislation to match Euro 4 standards for light duty vehicles, and Euro 4 and 5 standards for light duty and heavy-duty diesel vehicles, respectively whilst conceding that Euro 1-2 standards or category 1 and 2 emissions standards do not need much cleaner fuels. The WWFC provides an insight into what auto manufacturers perceive future fuel quality needs to be, as well as other key fuel quality demands such as a reduction in gasoline’s driveability index (DI) and the need for deposit control and removal additives for both gasoline and diesel fuels. Deposits in critical parts of the engine (such as on intake valves, fuel injectors and combustion chamber walls) adversely affect engine emissions, efficiency and performance. This manual does not focus on additives and lubricants but it is important to note that both are absolutely necessary for the proper functioning of the engine and a real complement to improved fuel quality in fact in some instances they are a precondition to meeting cleaner fuel specifications.

Most fuels require additives. Although there are many types and uses of additives, one of the most important of these is deposit control or detergency additives that are needed to help keep fuel injectors, inlet valves and combustion chambers as clean as possible to aid efficient operation of the engine.

In addition, diesel fuels, with low levels of sulphur, (ca. <1,000 ppm) usually require lubricity improver additives to prevent premature wear in the fuel pump as well as other damage to the rest of the fuel injection system.

Interestingly enough, no country has currently mandated detergency additives even though they play an essential role in keeping the entire intake and combustion system operating at peak performance in addition to keeping injectors from clogging. Even lubricity improving additives are, by and large, not mandated either in most countries, despite the vital role they play in preventing excessive wear and erosion in diesel fuel systems. However, as fuel sulphur levels approach 'zero', the mandated use of lubricity improving additives is likely to become widespread. With respect to engine lubricants, these are now becoming a focus of attention by automotive manufacturers and legislators and developed countries since they can adversely affect the performance of exhaust after-treatment emission control devices as well as the composition of exhaust derived particulate matter. Therefore, legislation in this area may be forthcoming.

What are the main fuel quality properties of concern, which should be regulated?

Today, the most important impediment to adopting state-of-the-art new vehicle emission technology equivalent to the EU’s Euro 3 and 4 standards or WWFC category 4 in Asia is the fuel quality, especially the level of lead, aromatics, benzene and sulphur in gasoline and the level of sulphur in diesel. In order to meet Euro 3 and 4 standards, these parameters are extremely important and must be taken into account when developing medium- and long term fuel quality strategies. However, as can be seen further below other fuel parameters also play a significant role in reducing emissions and thus a medium to long term strategy must address reductions in other key parameters such as aromatics, benzene, olefins and RVP in gasoline, and cetane, PAH, distillation and density in diesel.

The following section highlights the main fuel properties regulated across the globe, which influence vehicle emissions, and the operability, performance and longevity of engines and emission control systems. This section also gives an overview of international trends for each fuel parameter. It is to be noted that the list of parameters examined is by no means all-inclusive. We have attempted to focus on those fuel parameters, which have an environmental impact only, and have received attention by regulators across the globe in the recent past and/or are likely to be revisited in the future.

This section includes a discussion of the following fuel properties of environmental importance for gasoline and diesel.

Figure 2.14. Summary Of Fuel Parameters That Influence Emission

Gasoline Properties	Diesel Properties
Octane	Cetane
Lead	Sulphur
Lead replacement – octane enhancement	Distillation
Aromatics and benzene	Aromatics and polyaromatics (PAH)
Volatility (RVP)	
Oxygen content	
Driveability	

Source: International Fuel Quality Center (IFQC), 2003.

Gasoline Properties:

Octane

Octane is a measure of gasoline's ability to resist auto-ignition. Vehicles are designed and calibrated for a certain octane value. When a customer uses gasoline with an octane level lower than that required, knocking might result. Knocking needs to be controlled to avoid potential engine damage due to the build-up of heat in the combustion chamber.

The motor octane number (MON) historically has be used to control high-speed knocking whereas research octane number (RON) tends to correlate with knock at low speed, part throttle accelerating conditions. RON values are typically higher than MON and the difference between these values is the sensitivity, which is usually controlled in the range 8-10, again for good anti-knock reasons.

For those countries that are in the process of phasing out lead or have recently eliminated its use, they may find the need to adjust their blending processes to use higher components. Alternatively, they may have to accept lower octane fuels. This issue is further explained in Module 2.

Table 2.15. MON and RON in Various Countries.

2002	Regular			Premium		
	MON	**MON+RON/2** [b]	**RON**	**MON**	**MON+RON/2** [b]	**RON**
Canada	82	87		82	89	
Mexico		82			93	
EU	80		91	85		95
China		85	90		88	93
India		84	88		88	93
Japan			89			96
S. Korea	83		91	87		96
Australia	82		91	85		95
WWFC [a]	82		91	85		95

Note: a) As recommended by the global automobile manufacturers. b) RON + MON/2 is an anti-knock control mainly used in the USA. Historically, this was used to control mid-speed knock. It is important, however, when choosing the most suitable parameters to control knock, that not all three parameters, namely, RON, MON and RON + MON 2 are used together as this could hinder knock control and also cause unnecessary restrictions in the refinery in fuel blending operations.
Source: International Fuel Quality Center (IFQC), 2003.

Lead in Gasoline

Lead is one of the most important environmental fuel quality parameters. Emissions from lead come from a variety of sources including leaded gasoline, paint (houses, cars), smelters (metal refineries); manufacture of lead storage batteries. With regard to fuels, lead originally enabled improvements in the energy efficiency of engines, higher compression ratios, better fuel economy, higher speeds and torque. However, there were a variety of growing issues with leaded fuel such as high combustion chamber deposits, spark plug fouling, etc.

In the 1970's the United States, followed by some Northern European countries (UK, Sweden) started phasing out lead first to enable new catalyst technology to be used. This enabled major reduction in exhaust pollutants such as hydrocarbons (HCs), carbon monoxide (CO), nitrogen oxides (NOx) and air toxics. The other argument against using lead additives was the increasing evidence of serious health effects such as brain and other nervous system damage in particular in high-risk groups, e.g. children and the elderly.

When the first major step in fuel quality improvement was taken in the early 1970s, nearly all the world's gasoline contained lead, generally at levels about 0.4 g/L or more. In 1990, leaded gasoline represented more than 57% of the total worldwide gasoline market. However, in the four years from 1996-2000, the market for leaded gasoline shrunk from 40% to less than 20%. About 35 countries (both developed and developing economies) had completely phased out lead by 1999. As of mid 2002, we estimate that 88 countries still supply leaded gasoline although the total leaded gasoline volume is only about 9% of the global pool.

The phase out of leaded gasoline in Asia has advanced relatively rapidly. Many countries progressed from gasoline lead levels substantially greater than 0.15 mg/l in 1996 to virtually unleaded fuel in 2000. Of the bigger countries in Asia, only Indonesia still allows leaded gasoline in the market. Indonesia supplies unleaded gasoline to its market in the greater Jakarta area, Ceribon in West-Java, Northern parts of the Java

Island, Bali and Batam; the rest of the country is expected to phase out leaded gasoline by 2005. The most recent countries to introduce unleaded gasoline to their market are Bangladesh, Nepal, Pakistan and Sri Lanka.

Lead Replacement – Octane Enhancement

Although most of the adverse engine effects (e.g., lubricity) associated with switching from leaded gasoline to unleaded gasoline can be accommodated, refiners are often challenged by the related octane loss. In addition to lead removal, reduction in the allowable level of aromatics in markets around the world frequently results in an octane-deficient gasoline pool. As we will see in Module 2, octane deficiency can be solved in many ways; however, some avenues are easier for refiners than others. Changes to refining configurations are usually costly and time-consuming; as a result, other “quick” solutions are often sought. Since increasing aromatics is not a desirable solution, refiners have turned to hydrogenation and isomeration as possible means to balance octane needs. Other tend to utilise oxygenates such as ethers or alcohols. This will be further discussed in the next section on oxygen content.

In some cases, metallic compounds such as MMT (methylcyclopentadienyl manganese tricarbonyl) are relied upon to make up the octane deficit. MMT is an organometallic compound used as an additive to boost gasoline octane typically by about 2-3 RON. The use of MMT is being discussed in many parts of the world. However, the auto industry is very outspoken in its opposition to MMT as they feel it can contaminate the engine and exhaust after treatment emission systems. Accordingly, the world automakers do not recommend the use of MMT. Environmental and health organizations also strongly oppose metallic additives while the refining industry generally views them as cost effective means to correct the octane level.

Aromatics and benzene

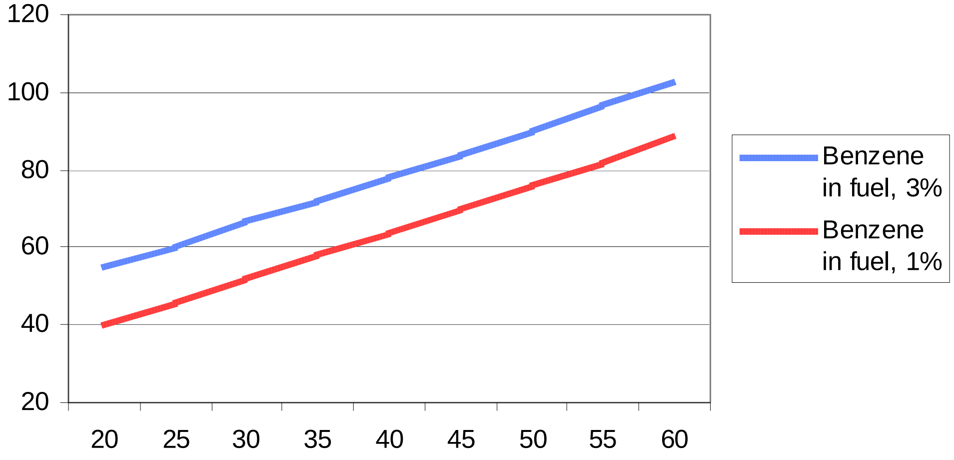
Aromatics can be found in both gasoline and diesel. In general aromatics are a good octane component for gasoline however they can be a source of benzene, NOx and particulate emissions. Also, heavier aromatics have been linked to engine deposit formation, particularly combustion chamber deposits. In general, reducing aromatics and T90 can enable reductions in exhaust mass NMHC and CO emissions to be achieved.

The fuel aromatic content will affects combustion and the formation of particulate and PAH emissions. Of particular concern among the general family of compounds we describe as “aromatics” is benzene, which is a known human carcinogen. Numerous studies have shown that the benzene and aromatics strongly influence exhaust benzene emissions.

Control of benzene concentration is recognized to be the most direct and cost-effective way to limit benzene emissions. As a result, regulators have mounted a concerted drive to lower gasoline benzene content over the last decade. In US and Europe the tendency is to limit benzene content at about 0.8 vol%. However, apart from some countries like Japan, Korea and Hong Kong benzene levels remain high or unregulated in most Asian countries.

Like benzene, strict gasoline aromatics levels are often not regulated in Asia or other developing countries. Countries realizing lead phase out or selling higher octane fuels often experience high aromatics concentrations. However, limits have been set in the EU, US, and Japan. The current gasoline aromatic limits in the European Union of 42 vol% will be reduced to 35 vol% by 2005. Through the US reformulated gasoline program aromatics levels are limited to about 25 vol%. Besides the US and Europe, many countries have recently started to introduce limits to the total aromatic level that are following the European regulation.

Figure 2.10. Benzene & Aromatic Concentrations in Fuel Versus Benzene Emission.



Source: Clean Air Act: “Simple Model”.

Olefins

Olefins in gasoline are good octane components however, they are found to be sources of evaporative emissions and also can cause gum formation and engine deposit.

Studies have shown that reducing olefins increases exhaust mass NMHC emissions; however, "the ozone forming potential" of the total vehicle emissions are reduced overall. The US EPA has declared that “NOX emissions were lowered by reducing olefins, raised when T90 was reduced.”

In most countries across the globe limitations on olefin content have not yet been introduced however as of 2000 the European Union introduced a limit of 21 vol% for regular (80/91) and 18 vol% for premium (95/98) gasoline, and California limits their current olefin content to 10 vol%. With regard to Asia, China has a maximum limit of 35 vol%. However, several countries are introducing the European limits or going even further. For example, Hong Kong followed the European Union specifications from 2001, S. Korea from 2002 with a further proposed decrease to 8 vol% from 2006, Australia will follow the EU from 2004, Taiwan from 2007 and Thailand has proposed a limit between 6 and 8 vol% to be introduced some time in the latter half of this decade.

Oxygen Content

The oxygen content parameter refers to the oxygen content allowed in fuel. This oxygen comes from fuel compounds called oxygenates. Oxygenates are used as octane boosters and volume extenders and include MTBE, ethanol, methanol, ETBE, TBA, Iso propyl alcohol, Iso butyl alcohol to name but a few. They replace high-octane aromatic hydrocarbons and lead. The most well known oxygenates used today are MTBE, ethanol, ETBE (in Europe), Iso-octane/iso-octene and TBA.

Adding oxygen carrying components to gasoline reduces the resultant fuel calorific value. For engines with non-sophisticated fuel metering systems, the mixture will become leaner that ensures a more complete combustion and reduces emissions, whereas for engines with adaptive learning engine management systems, these will compensate thereby counter acting (neutralising any effects of fuel composition)

One issue, which is increasingly mentioned regarding oxygenates is the use of MTBE. Under the US CAAA and the implementation of RFG programme, MTBE was mandated predominantly as an octane replacement for lead, and due to its air quality benefits. High volumes of MTBE were therefore used in the US during the 90's, and unfortunately due to very weak storage tank legislation (storage tanks could legally leak up to 3% of gasoline per day) gasoline leaks were rampant across the States. These leaks were increasingly discovered as MTBE has certain properties, which facilitate its rapid migration into drinking water. Due to its odour and taste threshold, a move is underway today to eliminate the use of this particular oxygenate in gasoline across the US. California has already announced a ban. The EU on the other hand, which also allows for MTBE in fuels but does not mandate its use, has undertaken a risk assessment on MTBE and has come to a very different conclusion than the US. The EU claims that the MTBE issue is not an environmental or health risk issue but a tank management issue and does not require banning of the product if storage tanks are properly managed. Today, most Asian countries have decided to follow the European approach although some such as Australia are looking at banning the product.

There are several important lessons from this issue:

- All substitutes for a chemical substance (in this example it was lead) should be analysed from a health and environmental perspective before use, and a balanced approach should be applied e.g. gasoline itself is carcinogenic, as is benzene. No chemical compounds should be found in water period,
- Certain air quality benefits should also be compared to the possible impact on other environmental media e.g. water and/or soil contamination,
- Storage tanks must be properly legislated and managed to avert leaks of any kind.

Volatility: Distillation and Reid Vapour Pressure (RVP)

Distillation (or boiling range) is a reference to the volatility of the fuel. The distillation or boiling range of the fuel is a consequence of the chemical composition of the fuel meeting other fuel property requirements such as vapour pressure, viscosity, flash point, and density. Vehicle refuelling emissions are also strongly affected by fuel volatility.

Gasoline volatility indicates the ability of a fuel to vaporize either directly (through the measurement of vapour pressure at a particular temperature) or indirectly (through correlation with the distillation characteristics of the fuel). The "front-end" distillation (or boiling range) of the fuel refers to the temperature at which the fuel starts to boil when heat is applied to it at a certain pressure (i.e., its "initial boiling point)," as well as the temperature at which the first 10 vol% of the fuel volatilizes under such conditions (i.e., "10 percent distillation temperatures").

Instead of a temperature scale, evaporative volume percentage points can be used to convey the same information (e.g., E100 expresses the percentage of fuel that can be expected to evaporate at 100 deg C). These distillation properties, along with the fuel's measured vapour pressure, are critical parameters in ensuring smooth engine starting, efficient fuel combustion and evaporative emission controls. In addition, the combination of correct vapour pressure and distillation characteristics is essential to prevent hot fuel handling problems such as vapour lock and carbon canister overload.

Reid Vapour Pressure (RVP) is identified as one of the most important parameters for evaporative emission (VOC) reductions contributing to low level ozone formation. RVP is directly impacted by the use of alcohols and thus an important parameter to look at when setting ethanol limits. As many Asian countries are considering the use of ethanol as an octane booster, it is important to note that ethanol is highly volatile when blended at lower levels to 10%.

RVP can be relaxed in cold climates as is the case under the EU Directive where arctic regions are allowed a higher RVP of 70 kPa, but efforts to relax RVP to allow for greater blending of ethanol have already created concerns regarding an increase in emissions as recently as this summer in California.

Vehicle Driveability for gasoline vehicles is sometimes referred to by the Driveability Index (DI), a measure to control volatility. The relationship between Driveability and gasoline distillation properties was quantified in the U.S. during the 1980s as:

$DI = 1.5(T10) + 3.0(T50) + 1.0(T90)$

T10 is the temperature (degrees F) at which 10 percent of the fuel vaporizes, and T50 and T90 are the temperatures (degrees F) at which 50 percent and 90 percent of the fuel vaporizes. DI values generally range from 1,100 to greater than 1,300. DI was included in the American Society for Testing and Materials (ASTM) D 4814 gasoline specification in 1999. Currently there is a 1250 cap (maximum) measured at the refinery gate. In general, automakers believe that DI values above this limit may cause driveability problems.

When calculating DI using temperatures in degrees C, the equation is the same as the one given above. The calculated DI values, however, will be much lower. For example, a DI of 1200 based on temperatures in degrees F is equal to a DI of 568 based on temperatures in degrees C. One can convert a DI based on degrees F to one based on degrees C by the equation:

$(DI \text{ in } {}^{\circ}C) = 5/9\ (DI \text{ in } {}^{\circ}F) - 98$

DI has not received the attention globally that it has in the United States. However, Canada has had a DI maximum of 1238 for several years. California has a “de-facto” DI specification by virtue of existing controls on T50 and T90. Japanese gasoline is very similar to California Clean Burning Gasoline (CBG), i.e., it features a similar DI distribution. European gasoline has a wider distribution of DI values, similar to that in the United States. However, DI is not used in Europe since vehicle driveability is controlled by other means.

Gasoline Sulphur

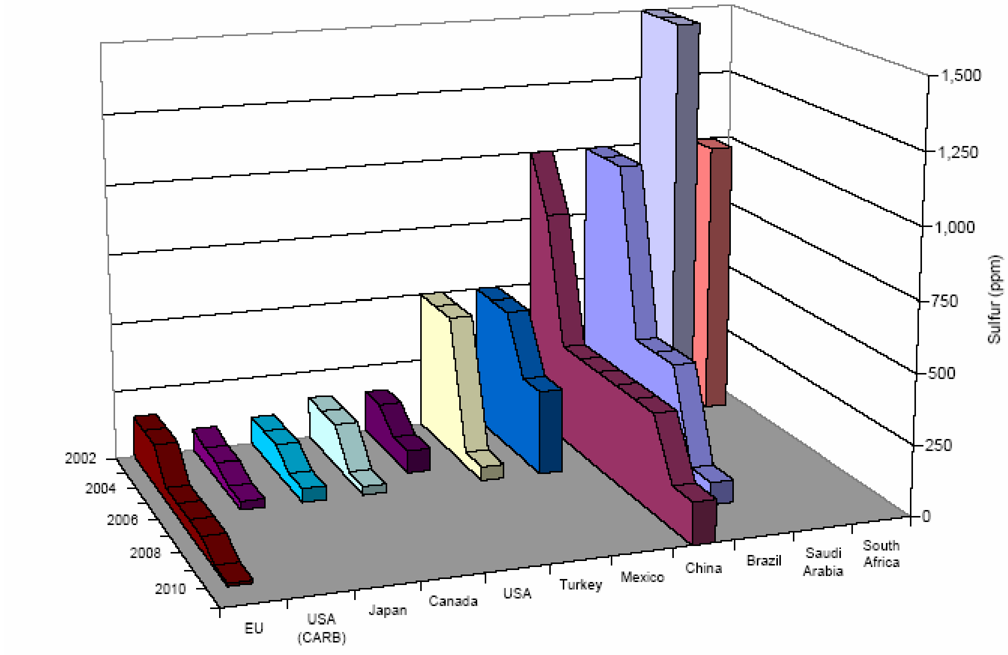
Recent fuel quality improvements focus on sulphur reductions to enable advanced vehicle exhaust after treatment technologies to work at their optimum efficiencies. Also for traditional vehicle technologies sulphur is one of the most important parameters for emission reductions especially for SO2, PM and NOx. Sulphur naturally occurs in crude oil. As highlighted in Module 2, some crude’s especially from the Middle East/Africa are higher in sulphur than others.

Fuel sulphur affects the performance and durability of many exhaust treatment and on-board diagnostic systems on gasoline and diesel vehicles alike. Reducing fuel sulphur cuts emissions of particulate matter, nitrogen oxides, hydrocarbons and carbon monoxide from all vehicles. Emissions of ultra fine particles and especially benzene, which are the focus of health concerns, are particularly sensitive to fuel sulphur content.

Studies have demonstrated that Lowering sulphur in gasoline lowers emissions of CO, HC, VOC's and NOx from catalyst equipped cars as noted by the US Auto-Oil study, Based on the Auto/Oil study, it appears that NOx would go down about 3% per 100 ppm sulphur reduction. For future gasoline cars, sulphur free fuel will help ensure significant reductions in CO2 emissions can be made without exceeding 2005 Euro 4 NOx emissions limits. For diesels sulphur free fuel will improve the prospects of meeting 2005 Euro 4 standards for emissions of particulate matter and expected 2008 Euro 5 NOx emissions limits.

Automotive manufacturers who plan to commercialise lean burn direct injection gasoline engines with a fuel efficiency performance similar to the best diesel engines as part of their strategy to reduce CO2 emissions, claim that they require zero sulphur gasoline. The exhaust from this kind of engine is different from conventional exhaust. Oxygen levels are much higher and this prevents standard three way catalytic converters from controlling NOx emissions. Advanced NOx exhaust catalysers have to be used and these are highly sensitive to the presence of sulphur.

Figure 2.11. Gasoline Sulphur Trends in Various Countries – Current and Expected.



Source: International Fuel Quality Center (IFQC), 2003.

Diesel Properties:

Diesel Sulphur Content

Sulphur naturally occurs in crude oil. It the sulphur is not removed during the refining process it will contaminate vehicle fuel. It is found that sulphur can have a significant effect on engine life.

Diesel fuel sulphur also contributes significantly to fine particulate matter (PM) emissions, through the formation of sulphates both in the exhaust stream and, later in the atmosphere. Sulphur can lead to corrosion in and wear in engine systems. Furthermore the efficiency of some exhaust after-treatment systems is reduced as fuel sulphur content increased both in the exhaust.

In the European Auto Oil I programme it was predicted that a reduction from 500 ppm to 30 ppm will result in PM emission reductions of 7% from light duty vehicles and 4% from heavy duty trucks. However, the predictive equations do not take into account the absolute PM level or the fuel consumption. 2005 Euro 4 particulate emissions limits require the use of particle filters on heavy diesel engines and possibly on light commercial vehicles and the largest passenger cars. These filters perform better with sulphur free fuel. Some filter systems require fuel with less than 10 ppm to meet Euro 4 limits. Others will tolerate 50 ppm except at low temperatures. 10 ppm fuel would be required to ensure all vehicles could meet Euro 4 standards in all operating conditions (this applies particularly to urban buses operating in a stop-start mode in very cold winter conditions). Filter systems incorporating a catalyst in the fuel do tolerate 50 ppm diesel but at the cost of increased fuel consumption. For optimal performance it appears that particle filters may require diesel limited to 10 ppm.

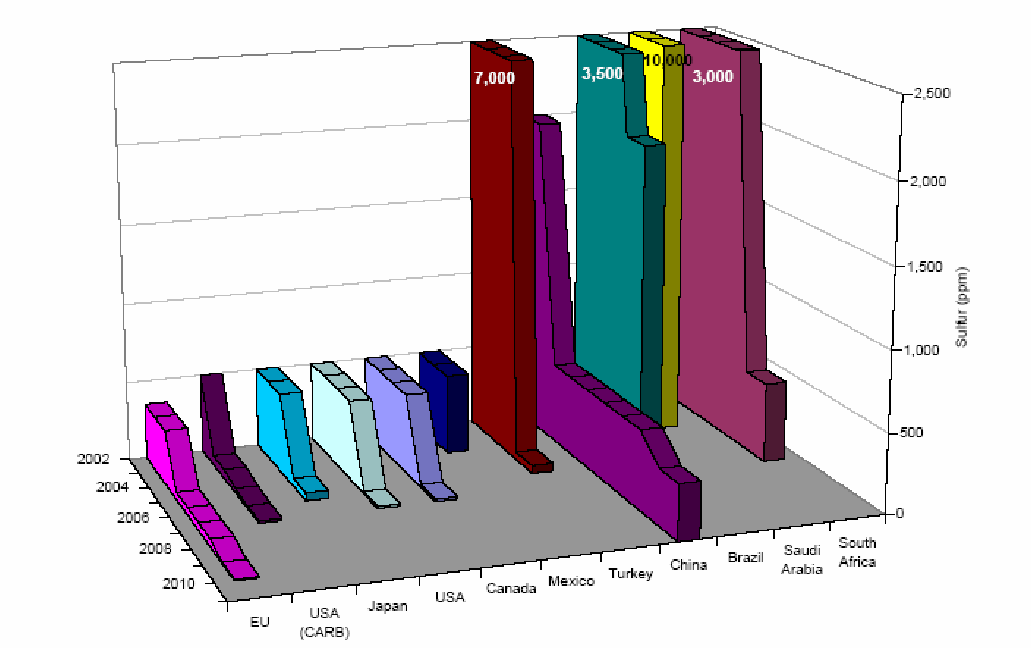
2005 Euro 4 standards for NOx emissions from heavy diesel engines can be met with 2005 Euro 4 diesel but standards under consideration for 2008 could require advanced exhaust treatment systems which are generally more sensitive to fuel sulphur. The smallest diesel passenger cars will probably not require advanced exhaust after-treatment to meet Euro 4 NOx emissions standards but the biggest cars and light commercial diesel vehicles probably will require advanced NOx catalysers. 10 ppm sulphur fuel would therefore facilitate meeting future NOx emissions limits.

As sulphur levels are reduced, fuel stability requires special attention. The industry is currently in the process of developing a "Standard Test Method for High Temperature Stability of Distillate Fuels" (ASTM D 6468) for thermal oxidative stability. Inadequate thermal stability can result in fuel filter plugging. As fuel injection system pressures and temperatures increase, it may be more appropriate to measure the thermal oxidative stability of diesel fuel rather than only long-term storage stability.

Figure 2.18. indicates that the degree of required reduction in sulphur levels varies around the world. In the industrialized countries where vehicles soon have to follow the most advanced emission limitations for NOx and CO2, ultra low sulphur fuels at 10 ppm have been requested by the automotive industry. In general, the next step for countries that have finalized the phase out of leaded gasoline is to reduce sulphur levels in gasoline and diesel. Although the timeline is different for every country, the drive is to reduce sulphur in gasoline and diesel to 50 ppm (or below) by the end of this decade.

In addition to its role as a technology enabler, low sulphur diesel fuel gives benefits in the form of reduced sulphur induced corrosion and slower acidification of engine lubricating oil, leading to longer maintenance intervals and lower maintenance costs. These benefits would apply to new vehicles and to the existing heavy-duty vehicle fleet beginning in 2006 when the fuel will be introduced. These benefits can offer significant cost savings to the vehicle owner without the need for purchasing any new technologies.

Figure 2.12. Global Diesel Sulphur Level Trends - Current and Expected.



Source: International Fuel Quality Center (IFQC), 2003.

Cetane

Cetane is a measure of auto-ignition quality. It is dependent on fuel composition and relates to the delay between when fuel is injected in the cylinder and when ignition occurs. It can affect many different aspects of emissions. A higher number generally implies a better environmental performance. Incomplete combustion leads to white smoke emissions, especially for start-up.

Dependent on the vehicle technology and the emission regulation, the world auto manufactures recommend cetane levels of around 45-50.

It should be noted, as also highlighted in Module 2, that cetane and indeed, most fuel properties are inter-related so changes to one fuel property can have either adverse of beneficial effects on emissions. Diesel is a very complex fuel and far more complex than its gasoline counterpart.

Table 2.16. Global Diesel Cetane Numbers

2002	**Cetane Number**		**Cetane Number**
USA	40		
Canada	40	Egypt	55
Mexico	48	China	45
EU	51	India	48
S. Korea	45*	Japan	50
Australia	46*	WWFC	45/50/52/52

Source: International Fuel Quality Center (IFQC), 2003.

Total Aromatics and PAH

Diesel fuel aromatic content influences flame temperature, and therefore, NOx emissions during the combustion. Polyaromatics in the fuel affect the formation of particulates and the polyaromatic hydrocarbon (PAH) emissions from a diesel engine.

Testing in Europe (ACEA follow-up programme to EPEFE) demonstrated that a reduction of the total aromatic content from 30 to 10% yields significantly lower NOx emissions. While an excess concentration of poly-aromatics (PAH) is bad for emissions it also bad for the engine due to the formation of increased deposits. PAH are only controlled by the European Union and the Californian CARB diesel regulations. EU currently allows a maximum of 11 wt% while CARB sets a limit of 1.4 wt%. Car manufacturers would like to see a reduction in PAH to around 2%m/m. Only a few countries limit total aromatics in diesel. The US has a maximum set of 35 vol%, Mexico of 30vol% and recently Taiwan agreed on a total of 35 vol% from 2007.

Other parameters specific to engine function

There are a number of other fuel parameters which are important to engine function but do not appear to have as significant an effect on emissions as the preceding parameters. To ensure lifetime optimum operation of many of the vehicle and emission parts limits are also added to additives, lubricity, cloud point and cold filter plugging point.

1. The EU Example of Fuel Property Analysis

A good example of the process needed to fully assess the different fuel properties we have seen above, their emissions impact and potential costs can be seen under the EU's Auto Oil II programme. Although this programme was used to assess the next stage of fuel quality changes and rather than the first stage of changes as currently being identified by the Governments participating in this workshop, the analytical process and use of the TREMOVE model is still useful.

The Auto Oil II Programme was run through seven key working groups addressing different topics of relevance. Working Group 3 was tasked with an analysis of fuel choices whereas Working Group 7 was tasked with carrying out a cost effectiveness analysis with the help of the Bechtel Consulting Group. In particular WG7 had to ensure the consistency and comparability of the analysis across the various categories of scenarios (i.e., working groups).

The choice of fuel packages undertaken by Working Group 3 of the Auto Oil II programme presented some methodological challenges because most parameter changes in fuels will result in changes in all emission components. Therefore, a meaningful set of parameters could only be chosen after an iterative calculation.

The process used by the EU gives a good example of the type of data necessary for adopting certain fuel scenarios and parameter changes. For each of the fuel scenarios, Bechtel estimated the technical feasibility and the incremental costs, including the total investment & operating cost for the refinery industry (EU15). These costs were then translated into costs per litre based on EU15 (15 EU Member States) volumes estimated by Bechtel and that information was used as input into a transport policy simulation tool (TREMOVE) (WG7 experts also developed a decision support tool (LEUVEN II) to help a identify cost-effective strategy for reaching air quality objectives at least cost. Due to delays in inputs from WG1, that tool could only be demonstrated towards the end of the programme. Due to the limited validation, it has not been used in support of AOP-II conclusions). Emission impacts for CO, NOx, VOC, Benzene, and PM were calculated using the EU EPEFE equations contained in the TREMOVE model. Impacts on CO2 from road transport were estimated via changes in fuel consumption computed by TREMOVE. In parallel, a detailed transport base case was constructed, including reference values from 1990 through 2020 for traffic volumes, vehicle stocks, fuel qualities and volumes, cost and prices (including taxes), etc.

The reference case for the Auto Oil II scenarios was based on the specifications already agreed by the EU for 2000 and those already fixed for 2005, i.e. sulphur in gasoline and diesel and aromatics in gasoline. Market averages rather than specifications were used as proposed by WG3. Also, fuel quality parameters were assumed to be equal across all countries, except for Finland, in line with the assumptions taken in the fuel quality working group (WG3) (The values used for Finland are: sulphur content (both in gasoline and diesel): 35 ppm in 96, 30 ppm from 2000 onwards; aromatic volume content: 35% in 1996, 30% from 2000 to 2020; for gasoline, from 96 onwards, E100 = 57, E150 = 87, benzene content is 0.6% vol; for diesel, from 1996 inwards, density = 825, CN = 52, T95 = 300, PCA=5). The assumptions related to the quality of motor fuels under a business-as-usual scenario are listed below.

Table 2.17. Base Case of Fuel Quality Defined in the TREMOVE Model.

AOPII base case fuel quality assumptions EU9, except Finland

Paramete	**Unit**	**AOP 1 (1990-**	**1996 average 1999)**	**2000 regulatory specificatio**	**2000 market quality (2000-**	**2005 specificatio**	**2005 market qualit (2005-**
				Gasolin			
RVP	Kpa	**81**	**81**		**70**		**70**
RVP s	Kpa	**68**	**68**	60	**60**	60	**60**
Trace	g/l	**0.005**	**0.005**	0.005	**0.003**	0.005	**0.003**
E100	%	**53**	**52**	46	**52**	46	**52**
E150	%	**84**	**86**	75	**86**	75	**86**
Aromatic	%vol	**40**	**39**	42	**37**	35	**33**
Sulphu	ppm	**300**	**165**	150	**130**	50	**40**
Oxigenate	%O2	**0.6**	**0.4**	2.7	**1**	2.7	**1.5**
Olefin	%vol	**11**	**10**	18	**10**	18	**10**
Benzen	%vol	**2.3**	**2.1**	1	**0.8**	1	**0.8**
				Diesel			
Density at	kg/m3	**843**	**840**	845	**840**	845	**835**
Sulphu	ppm	**450**	**400**	350	**300**	50	**40**
PCA	%vol	**9**	**9**	11	**7**	11	**5**
Distillation range	°C	**355**	**350**	360	**330**	360	**320**
Cetane	--	**51**	**51**	51	**53**	51	**53**

Source: Gasoline 1996 data from CONCAWE report 5/98, Diesel Data from Paramins winter survey 1998. Future data from DG XVII

The key element in assessing benefits from fuel quality changes was the equation relating fuel parameters to emissions in various vehicles. The work done in Auto-Oil I to define these equations (i.e., the EPEFE programme) provided the basis for all evaluations in Auto Oil II.

Table 2.18. Gasoline Scenarios – Main Results in 2010 (EU9).

	EU-9 - 2010								
	Cost and impact on transport				Impact on emissions (tonnes)				
	Total additional cost (NPV 2005-20)	Budget impact in 2010	Total passenger demand (Mpkm)	Total freight demand (Mtkm)	NOx	PM	VOC	NMVOC	CO2 (kt)
Basecase level	-	-	5,474,409	2,253,687	1,463,540	61,202	789,472	730,441	660,513
Fuel - MQ1	1,532	-27	-427	22	15,444	81	-9,045	-8,087	-46
Fuel - MQ2	3,517	-59	-955	41	31,539	84	-25,112	-22,762	-134
Fuel - MQ3	2,367	-40	-641	28	19,904	82	-16,323	-14,729	-90
Fuel - MQ4	3,833	-66	-1,056	49	25,409	85	-21,112	-19,106	-149
	Impact on transport (%)				Impact on emissions (%)				
Fuel - MQ1			0.0%	0.0%	1.1%	0.1%	-1.1%	-1.1%	0.0%
Fuel - MQ2			0.0%	0.0%	2.2%	0.1%	-3.2%	-3.1%	0.0%
Fuel - MQ3			0.0%	0.0%	1.4%	0.1%	-2.1%	-2.0%	0.0%
Fuel - MQ4			0.0%	0.0%	1.7%	0.1%	-2.7%	-2.6%	0.0%

Source: European Programme on Emissions, Fuels and Engine Technologies, ACEA/EUROPIA [1996]

Table 2.19. Gasoline Scenarios – Main Results in 2020 (EU9).

	Total additional cost (NPV 2005-20)	Budget impact in 2020	Total passenger demand (Mpkm)	Total freight demand (Mtkm)	NOx	PM	VOC	NMVOC	CO2 (kt)
Basecase level	-	-	6,202,855	2,676,762	889,371	38,958	579,027	522,541	664,780
Fuel - MQ1	1,532	-30	-378	28	8,262	55	-5,966	-4,960	-48
Fuel - MQ2	3,517	-63	-838	50	16,782	64	-16,417	-13,883	-144
Fuel - MQ3	2,367	-43	-562	34	10,623	58	-10,699	-8,995	-97
Fuel - MQ4	3,833	-71	-930	61	13,542	66	-13,819	-11,663	-161
	Impact on transport (%)				Impact on emissions (%)				
Fuel - MQ1			0.0%	0.0%	0.9%	0.1%	-1.0%	-0.9%	0.0%
Fuel - MQ2			0.0%	0.0%	1.9%	0.2%	-2.8%	-2.7%	0.0%
Fuel - MQ3			0.0%	0.0%	1.2%	0.1%	-1.8%	-1.7%	0.0%
Fuel - MQ4			0.0%	0.0%	1.5%	0.2%	-2.4%	-2.2%	0.0%

Source: European Programme on Emissions, Fuels and Engine Technologies, ACEA/EUROPIA [1996]

Table 2.20. Diesel Scenarios – Main Results in 2010 (EU9).

	EU-9 - 2010								
	Cost and impact on transport				Impact on emissions (tonnes)				
	Total additional cost (NPV 2005-20)	Budget impact in 2010	Total passenger demand (Mpkm)	Total freight demand (Mtkm)	NOx	PM	VOC	NMVOC	CO2 (kt)
Basecase level	-	-	5,474,409	2,253,687	1,463,540	61,202	789,472	730,441	660,513
Fuel - DQ1	2,025	-13	-121	-395	-2,816	-1,122	-7,092	-5,740	-49
Fuel - DQ2	3,660	-22	-217	-743	-8,582	-1,903	-8,725	-6,358	-89
Fuel - DQ3	5,610	-33	-326	-1,137	-14,142	-3,875	-6,374	-5,791	-137
Fuel - DQ4	3,684	-22	-217	-751	-9,254	-1,677	-11,693	-9,152	-90
Fuel - DQ5	5,634	-33	-326	-1,146	-14,963	-4,646	253	-1,694	-138
	Impact on transport (%)				Impact on emissions (%)				
Fuel - DQ1			0.0%	0.0%	-0.2%	-1.8%	-0.9%	-0.8%	0.0%
Fuel - DQ2			0.0%	0.0%	-0.6%	-3.1%	-1.1%	-0.9%	0.0%
Fuel - DQ3			0.0%	-0.1%	-1.0%	-6.3%	-0.8%	-0.8%	0.0%
Fuel - DQ4			0.0%	0.0%	-0.6%	-2.7%	-1.5%	-1.3%	0.0%
Fuel - DQ5			0.0%	-0.1%	-1.0%	-7.6%	0.0%	-0.2%	0.0%

Source: European Programme on Emissions, Fuels and Engine Technologies, ACEA/EUROPIA [1996]

Table 2.21. Diesel Scenarios – Main Results in 2020 (EU9).

	EU-9 - 2020								
	Cost and impact on transport				Impact on emissions (tonnes)				
	Total additional cost (NPV 2005-20)	Budget impact in 2020	Total passenger demand (Mpkm)	Total freight demand (Mtkm)	NOx	PM	VOC	NMVOC	CO2 (kt)
Basecase level	-	-	6,202,855	2,676,762	889,371	38,958	579,027	522,541	664,780
Fuel - DQ1	2,025	-7	-113	-353	-1,697	-942	-7,045	-5,788	-34
Fuel - DQ2	3,660	-12	-201	-660	-5,584	-1,460	-8,488	-6,352	-61
Fuel - DQ3	5,610	-18	-303	-1,013	-9,050	-3,075	-6,425	-5,836	-93
Fuel - DQ4	3,684	-12	-202	-667	-5,967	-1,264	-11,348	-9,099	-62
Fuel - DQ5	5,634	-18	-303	-1,020	-9,306	-3,735	-282	-1,859	-94
	Impact on transport (%)				Impact on emissions (%)				
Fuel - DQ1			0.0%	0.0%	-0.2%	-2.4%	-1.2%	-1.1%	0.0%
Fuel - DQ2			0.0%	0.0%	-0.6%	-3.7%	-1.5%	-1.2%	0.0%
Fuel - DQ3			0.0%	0.0%	-1.0%	-7.9%	-1.1%	-1.1%	0.0%
Fuel - DQ4			0.0%	0.0%	-0.7%	-3.2%	-2.0%	-1.7%	0.0%
Fuel - DQ5			0.0%	0.0%	-1.0%	-9.6%	0.0%	-0.4%	0.0%

Source: European Programme on Emissions, Fuels and Engine Technologies, ACEA/EUROPIA [1996]

As can be seen above, each fuel scenario whether for gasoline or diesel had a different cost and emissions impact depending on the changes in property limits. Four gasoline scenarios were considered aiming at reducing VOC emissions (i.e. an ozone precursor) whilst focusing on changing the boiling point (E150), the olefin content, and the oxygen content. Also, five diesel scenarios were tested to reduce PM emissions through modifications of the cetane number, the density, the boiling point (T95), and the PAH content. In addition, 2 combined gasoline/diesel packages were considered to explore possible scale effects.

An important result of the work carried out by WG 7 and Bechtel was the analysis carried out on city fuels. When countries carry out fuel quality strategies the issue of urban versus rural air quality must be addressed so as to determine where the most cost effective fuel quality solutions should be applied. When analyzing the environmental impacts of European fuel scenarios at the city level, their effects typically differed from national averages with a few percentage points. The fact that fuel impacts can differ in urban areas compared to non-urban areas as well from country to country and city to city provided an additional opportunity to look for cost-effective solutions by allowing some margin to be determined by local authorities. Although the costs could only be estimated on a pro-rata basis from EU fuel scenarios, they will ultimately depend on the area covered for selling the fuels and it is obvious that a sufficiently wide range around the city boundaries would have to be chosen in order to obtain the desired effects. Other solutions could include the supply of captive fleets although more important effects may be generated with alternative fuels. In the case of many developing countries, the introduction of cleaner low sulphur city fuels in the short to medium term, is often seen as the most cost effective solution for urban air quality improvement. Countries such as India and Brazil have successfully set fuel quality specifications for cleaner city fuels in urban centres prior to countrywide coverage. That said, this approach is not recommended for unleaded gasoline as vehicles fitted with catalytic converters need availability of this fuel both inside and outside urban centres.

G. How Do I Go About Drafting Country Specific Fuel Quality Specifications?

The above section has set out the fuel properties and limits, which those leading countries in the field, predominantly the EU, US and Japan have traditionally seen as important to meet their air quality targets. It also refers to recommendations made by automakers in their WWFC. The EU TREMOVE modelling process also gives an indication of the type of process which can be used to assess different fuel quality scenarios both in terms of cost and environmental impact. It is certain that this and further information in the following chapters of this manual, has been included as a useful tool for those Asian countries currently in the process of developing fuel quality strategies *but it must be noted that the data inputs in this manual or from any other source should not form the only input upon which to base these country specific strategies*.

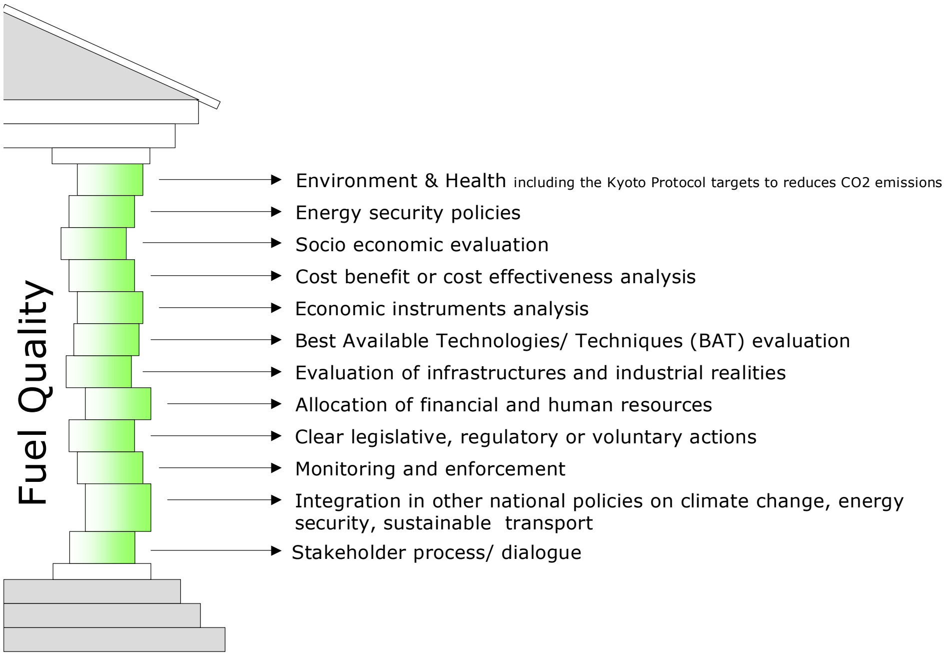
When starting to draft fuel quality specifications, it is important to go back to the "systems" approach and make the links between the **national** air quality targets and automotive emission standards set or planned and the fuel quality needed to meet these standards. For example, large reductions in aromatics (greater than 35%) may not be necessary at this stage if CO is not an air quality problem in your country. Europe opted for this option in comparison with the US RFG programme, which cites CO as a key problem. It is also important to look at the key air quality areas in the country and assess whether the most cost effective solution in the short to medium term mandating cleaner city fuels rather than setting stringent national fuel quality specifications.

When drafting a legislative text on fuel quality there are a series key elements, which must be incorporated, these are:

1) Detailed reasoning behind the chosen specifications e.g. refer to building block outputs such as environmental and health effects, costs, automotive technology needs etc..,
2) A series of definitions should be given regarding the products concerned e.g. conventional gasoline and diesel fuels,
3) Reference to economic instruments and allowance to use tax incentives (if agreed by relevant Ministry or department)
4) Mandated timeline for adoption of new fuel quality specifications,
5) Mandated list of fuel quality properties and limits (usually in table form)
6) Review procedures so that the legislation can be reviewed due to technology changes, priority changes etc…
7) Monitoring and reporting requirements including methodology
8) Enforcement Measures e.g. penalties, fines and sanctions

The basis for most of the legislative text is the information gathered under the building blocks used in the development of the fuel quality strategy. As a reminder these are listed in Figure 2.13 below:

Figure 2.13. Fuel Quality Pillar: Building Blocks 2



Source: International Fuel Quality Center (IFQC), 2003.

Again each building block does not necessarily need to be developed from scratch and can be built upon existing information and expertise from across the globe. However, although it is acknowledged that all of the data inputs can be useful for countries drafting their own fuel quality strategies, it is absolutely essential that each Asian government participating in this workshop adopt a fuel quality management strategy that makes sense for that country and is not solely founded on non-country specific data.

Although many countries, especially the US, EU and Japan are adopting similar fuel quality specifications and fuel quality strategies around the same timeline, and automakers are pushing for harmonised fuel quality specifications through the WWFC, each countries existing fuel quality strategy is personalised and founded on slightly different priorities. This can also be seen in the fuel quality strategies undertaken in the Asian countries such as Australia, Hong Kong, Korea, Taiwan, Singapore, Thailand, and India just to name a few. Therefore, legislative texts from these countries and the US, EU and Japan can be used for inspiration if necessary but again to be successful a national fuel quality strategy must be tailor made to meet country specific needs.

Case Study 3: Malaysia

Air Quality Issues - The air quality problems phased by the government of Malaysia appear to be moderate. The main area of air pollution concern is the Klang Valley. The air quality data indicate that there are a significant number of days in the Valley when ozone concentrations are above the health standards and a number of days when the ambient PM10 concentrations are above health levels. The meteorological conditions, and the high concentration of mobile and other pollution sources in the Valley create conditions that are conducive to higher pollutant levels. It appears that the fuels and motor vehicles are the major contributing sources to pollution in the Valley.

Since there is a significant growth in motor vehicle population, the emissions from motor vehicles will continue to increase. Consequently air quality problems will become progressively worse unless measures are taken.

Governmental Approach - The government of Malaysia is in the process of taking a preventive approach against air pollution through a series of measures. Among other actions:

- Malaysia has established a governmental cooperation with GtZ. GtZ is providing the government of Malaysia with expert technical assistance on a number of areas where there is a lack of expertise. The assistance provided by GtZ to the government of Malaysia is critical in their efforts to implement an air quality strategy.
- Malaysia is in the process of restructuring the environmental agency in order to allocate more resources and assign higher priority on air quality issues.
- Malaysia has been expanding the air quality monitoring- network, and has been collecting an emissions inventory for both stationary and mobile sources in order to identify the contribution of various sources to the air quality problem.
- Fuels and motor vehicles standards are an important component of the Malaysian strategy. The government of Malaysia has been evaluating the options of implementing standards for fuels and motor vehicles as a preventive means to emissions' reductions.

Fuels Strategy - The existing Malaysian standards for diesel and gasoline specifications are not legally binding. The Ministry of Domestic Trade and Consumer Affairs has the responsibility to set retail (pump) prices of fuel, but it does not have the authority to set fuel quality standards. An Oil Industry Technical Committee has been formed, consisting of the 6 oil companies represented in Malaysia (Shell, Petronas, BP, Caltex, Esso and Mobil), for working with the government on fuel quality issues. Table 1 bellow provides a comparison of gasoline quality in Malaysia with Thailand, USA, California, and EU.

Continued….

…continued

Comparison of Malaysian Gasoline Properties to CA, USEPA, EU, Thailand, MVMA:

Fuel Property	Malaysia	Thailand	CA	USEPA	EU	MVMA
RVP, psi	10.0	9.0	7.0	7.2	7.0	Varies
S, ppm	1500	300	20	130	50	30, 200, 1000
Aro. vol%	40-45	35	25	25	35	35,40,50
Benz.vol%	3-5	3	0.8	1.0	1.0	1.0,2.5,5.0
Ole. vol%	18	18	6.0	8.5	18	10.0,20.0,-
Ox. wt%	---	0.4	2.0	2.0	---	2.7,2.7,2.7
T90,deg F	356	---	305	320	290	----*
T50,deg F	239	---	213	210	200	----*

Currently the Malaysian government has established a dialogue with the oil industry, and it is considering the implementation of Euro 2, Euro 3, and Euro 4 fuel standards. Three potential approaches are being considered:

Approach A: Implementation of Euro 2, Euro 3, Euro 4 standards consecutively over a period of 10 years.

Approach B: Implementation of Euro 2 standards within a short time interval to be followed by Euro 4 implementation in a 4-6 years time frame.

Approach C: Implementation of Euro 2 and Euro 3 standards within a 4-6 years time frame. Evaluation of the air quality to determine the need for implementation of Euro 4 on a later date.

Issues:

- The need to choose a preferable approach and implementation schedule.
- Changes are needed in the regulatory structure in order to allow an effective implementation and fuel quality monitoring.
- Refiners object to the changes in fuel quality because of concerns regarding their ability to recover costs of compliance. Since fuel prices are regulated, refiners are unable to increase fuel prices in order to recover capital and operating costs. Various governmental organizations (Dept. of Taxation, Dept. of Finance, Dept. of Environment, and others) are cooperating in an attempt to define an acceptable mechanism that would allow refiners to recover the costs of reformulation. Refiners have provided their own views on the issue. The fact that some fuel marketers do not produce fuels at the local level but rely on imports compounds an additional level of complexity.

Continued….

…continued

Lessons Learned:

- The ability to recover the costs of compliance is a critical issue.
- Even when the air quality has not reached a critical stage, it is prudent to implement a fuels program as a preventive measure and to meet the needs of motor vehicles
- Resources as well as infrastructure are needed in order to implement a fuels program
- A fuels program requires the cooperation of a number of governmental agencies.

Case Study 4. Thailand

Air Quality Issues - High ozone concentrations occur at a number of locations in Bangkok and almost all locations in the Bangkok area exceed the air quality standards for PM 10 and TSP. Toxic air pollutants emissions are dominated by diesel PM and benzene. The data indicate that CO emissions have been significantly reduced but still remain a concern.

Governmental Approach - Since the early-1990s, the government of Thailand has contacted a number of evaluations and studies in order to determine the contribution from various source categories to the air quality problem. These evaluations have determined that mobile sources are the major contributors to the air pollution concerns in all metropolitan areas.

Fuels Strategy - A number of strategies were pursued in order to reduce emissions from motor vehicles and fuels. On the fuels side:

- Implementation of lead phase -out program in gasoline
- Implementation of the first phase of improvements in fuel quality
    - Establishing limits on RVP of gasoline
    - Implementing reductions of sulphur content for both the gasoline and diesel fuels
    - Implementing reductions in the aromatics content for gasoline to 35% by volume
    - Requirement for the use of oxygenates in gasoline
    - Requirement for the use of deposit control additives
    - Requirement for the use of lubricity additives for diesel fuels
- Performance of an evaluation of the second phase of fuel reformulation requirements, while taking into consideration both current and future air quality needs, the needs of the vehicle fleet, and the costs to the refining industry and to consumers
- Development of capacity for monitoring fuel quality
    - Labs, personnel, training
    - Legal and administrative infrastructure

The Table below shows the levels of fuel properties for gasoline fuels marketed in Thailand during 1999.

:**Continued…**

…continued

Summary of Baseline Fuel Properties for Gasoline; (1st Quarter 1999)

Fuel Property	Units	Unleaded Gasoline			
		87	91	95	Average
Reid Vapor Pressure	Psia	8.7	8.4	8.6	8.5
Sulfur Content	ppmw	30	224	156	175
Aromatic Hydrocarbons	vol %	34.1	32.7	42.6	39.6
Olefin Content	vol %	0.6	9.6	7.5	8.1
Benzene	vol %	2.9	2.4	2.5	2.4
Distillation Properties					
T10	^{o}C	56	58	58	58
T50	^{o}C	86	86	93	90
T90	^{o}C	143	152	158	156
End Point	^{o}C	172	180	189	186
MTBE	vol %	0.0	0.0	6.7	4.6
Additives	------	No	Yes	Yes	--

Issue Focus - Recent air quality evaluations indicate that both the motor vehicle and fuel standards had positive impacts on air quality. Ambient levels of lead are very low and ambient concentrations of CO have been reduced significantly. However, particulate matter is still an issue, ambient levels of ozone are still high, and there are indications that the levels of benzene are high. Overall additional improvements of fuel quality are needed to: (a) meet the needs for new vehicle technology, and (b) achieve additional emission reductions from the exiting fleet of vehicles.

Concerns that need to be addressed on implementing a second phase of fuel reformulation:

- Magnitude of reformulation
    - Sulphur
    - RVP
    - Benzene
    - Others
- Refineries object to the need of further changes to fuel properties on the basis of
    - Significant capital costs and limited ability to recover the costs of reformulation
    - Air quality needs
- Other issues on fuels that need to be addressed
    - The use/removal of MTBE (advantages/disadvantages)
    - The use of Ethanol (advantages/disadvantages)
- Timing for implementation is debated.

Lessons Learned:

- Costs and the ability to recover the cost of compliance are major issues.
- There is a tendency to implement the Euro standards. However, local air quality needs may require adjustments and tailoring.
- Future population and motor vehicle growth would adversely impact air quality and would require a continuous process of more stringent standards. An optimum strategy could be developed by taking into consideration both present and future needs.
- An open and transparent process whereby all stakeholders are participating is the preferable approach.

H. Classroom Material

The purpose of a Strengths Weaknesses and Opportunities (SWOT) Analysis is to carry out a structured analysis of a given situation or problem before starting to formulate a solution to the problem. If conducted properly a SWOT analysis will make it easier to identify components of a solution strategy, it will help in identifying who needs to be involved in the formulation and implementation of a problem strategy and will also help in determining the time frame for the implementation of the strategy.

Applying SWOT analysis in support of the development of fuel quality strategies

In this case we are applying the SWOT analysis to the topic of fuel quality strategies for your country.

A SWOT analysis consists of four parts:

Strengths: Identify factors, which you feel are present in your country, which will make it easier to develop medium term fuel quality strategies, which can facilitate the introduction of cleaner fuels. This can include factors like: country has a tradition of forward planning or good technical knowledge.

Weaknesses: Identify factors, which according you are typical of the present situation, which make it difficult to formulate medium term fuel quality strategies in your country. This can include obvious ones like limited technical understanding or capacity but also factors like absence of coordination between fuel producers and vehicle manufacturers and government.

Opportunities: Identify factors, which you can use in arguing for the introduction of fuel quality strategies. This can include pressure of public for cleaner air, or refiners who want to have clarity on future regulations in order to make investment plans.

Risks: what are risk factors, which will make it difficult to successfully formulate and introduce medium term fuel quality strategies in your country.

Please enter the results of the brainstorming in your group in the following chart.

Strengths	Weaknesses	Opportunities	Threats

After this conduct a group discussion and select what you feel are the two most important factors in each of the 4 categories. In your presentation of the results of this exercise you will be requested to explain why these are the most important and also how you will make use of these (Strengths and Opportunities) or address the (Weaknesses and Threats) in the formulation of your strategy.

Select a spokes person who will present the results to the group and ….. you are ready!!!

Good luck

I. For Further Reading

Description	URL
Air Quality Management	
Clean Air for Europe Program	http://www.cleanfuelsworld.net/documents/EU_CAFE_Program.pdf
Directive 89/427/EEC air quality limit values and guide values for sulphur dioxide and suspended particulates European air quality limit values and guide values for sulphur dioxide and suspended particulates	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31989L0427&model=guichett
Directive 82/884/EEC European limit value for lead in the air	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31982L0884&model=guichett
Directive 85/203/EEC on air quality standards for nitrogen dioxide	http://www.europa.eu.int/cgi-bin/eur-lex/udl.pl?COLLECTION=lif&SERVICE=eurlex&REQUEST=Seek-Deliver&GUILANGUAGE=en&LANGUAGE=en&DOCID=385L0203
European Air Quality Framework Directive 96/62/EEC on ambient air quality assessment and management	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31996L0062&model=guichett
Directive 96/61/EC concerning integrated pollution prevention and control	http://www.europa.eu.int/cgi-bin/eur-lex/udl.pl?COLLECTION=lif&SERVICE=eurlex&REQUEST=Seek-Deliver&GUILANGUAGE=en&LANGUAGE=en&DOCID=396L0061
United States National Ambient Air Quality Standards	http://www.epa.gov/oar/oaqps/greenbk/40cfr50.html
WHO Air Quality Guidelines issued in 1999	http://www.who.int/environmental_information/Air/Guidelines/Chapter2.htm
WHO Air Quality Guidelines, 2000	http://www.who.dk/air/Activities/20020620_1
The World Bank Environment Monitor Reports (2002)	http://www.worldbank.org.ph/envmonitor2002.htm
A searchable database containing several thousand bibliographic citations for journal articles, conference papers, and technical or government documents related to health effects of engine exhaust and selected other types of atmospheres	http://www.nercenter.org/enex.htm
Japan Clean Air Program	http://www.pecj.or.jp/jcap/framebase1-jcap-e.htm
South Asia Regional Initiative for Energy Cooperation and Development	http://www.sari-energy.org/
Vehicle Emissions Management	
Auto Oil II Main Report	http://www.europa.eu.int/comm/environment/autooil/auto-oil_en.pdf

Directive 70/220/EEC laws of the Member States relating to measures to be taken against air pollution by gases from positive-ignition engines of motor vehicles (light vehicles)	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31970L0220&model=guichett
Directive 88/77/EEC the laws of the Member States relating to the measures to be taken against the emission of gaseous pollutants from diesel engienes for use in vehicles (heavy duty vehicles).	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31988L0077&model=guichett
Directive 98/69/EEC (Amendments to Directive 70/220/EEC for light vehicles)	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31998L0069&model=guichett
Directive 98/70/EEC European Directive relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC)	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31998L0070&model=guichett
Directive 99/96/EEC provides the Euro 3 (from October 2000), Euro 4 (from October 2005) and Euro 5 (from October 2008) emission standards (Amendements to Directive 88/77/EEC)	http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=31999L0096&model=guichett
US Auto Oil Programme	http://www.tremove.org/currentmodel/autooil2/autooil2.htm
ADB Policy Guidelines on Vehicles Emissions Standards and Inspection and Maintenance	http://www.adb.org/documents/guidelines/Vehicle_Emissions/inspection_maintenance.asp
ADB Policy Guidelines on Cleaner Fuels	http://www.adb.org/documents/guidelines/Vehicle_Emissions/cleaner_fuels.asp
ADB Policy Guidelines on Cleaner Two and Three-Wheelers	http://www.adb.org/documents/guidelines/Vehicle_Emissions/wheelers.asp
ADB Policy Guidelines on Transport Planning and Traffic Management	http://www.adb.org/documents/guidelines/Vehicle_Emissions/transport_planning.asp
Accelerated Leaded Gasoline Phase-out in Metro Manila, Philippines: A Partnership Effort	http://www.globalleadnet.org/advocacy/bestpractices/details.cfm?bpID=1011
Phasing Lead out of Gasoline: An Examination of Policy Approaches in Different Countries	http://www.un.org/esa/gite/iandm/unep-lead.pdf
In-Use Emission Standards for Diesel Vehicles in Asia	http://www.adb.org/vehicle-emissions/ASIA/docs/DieselInuse.pdf
In-Use Emission Standards for Gasoline Vehicles in Asia	http://www.adb.org/vehicle-emissions/ASIA/docs/GasolineInuse.pdf
Emissions Standards for New Motorcycles in Asia	http://www.adb.org/vehicle-emissions/ASIA/docs/NewMotorcycles.pdf
Emissions Standards for In-Use Motorcycles in Asia	http://www.adb.org/vehicle-emissions/ASIA/docs/InuseMotorcycles.pdf
A CRRI Study on Losses of Petroleum Products at Traffic, Intersections due to idling of vehicles at Delhi	http://www.pcra.org/ecc-crri.html
The Implementation of Stringent Emission Standards and Fuel Specifications, a Hong Kong Example	http://www.cse.polyu.edu.hk/~activi/BAQ2002/BAQ2002_files/Proceedings/PosterSession/50.pdf

Fuels Issues	
EU MTBE Risk Assessment	http://www.efoa.org/fr/mtbe_environment/risk_assessment.htm
World Wide Fuel Charter	http://www.autoalliance.org/fuel_charter.htm
Worldwide Fuel Quality Trends: Focus on Asia	http://www.cse.polyu.edu.hk/~activi/BAQ2002/BAQ2002_files/Proceedings/Subworkshop4/sw4b-4Kiuru_revpaper.pdf
Worldwide Gasoline Fuel Quality Trend	http://www.acfa.ws/pp3.ppt
Gasoline Description	http://www.adb.org/vehicle-emissions/General/gas.asp
Diesel Description	http://www.adb.org/vehicle-emissions/General/diesel.asp
Impact of Fuel Composition Changes on Emissions of Current Light-Duty Diesel Vehicles (Table)	http://www.adb.org/vehicle-emissions/General/diesel.asp
Components Potentially Affected by Lower Sulfur Levels in Diesel Fuel (Table)	http://www.adb.org/vehicle-emissions/General/diesel.asp
European Commission proposal to reduce sulphur content of Petrol and Diesel fuels to 10 ppm	http://europa.eu.int/comm/environment/sulphur/index.htm
The costs and benefits of lowering the sulphur content of petrol & diesel to less than 10 PPM	http://europa.eu.int/comm/environment/sulphur/cbloweringsulphurcontent.pdf
Petroleum Products Specifications Regulations 2002	http://www.ess.govt.nz/rules/pdf/2002regs.pdf
Brochure on Fuel Quality –New Zealand	http://www.ess.govt.nz/safety/pdf/how_good_your_fuel.pdf
Online information service on clean diesel engines and diesel emissions	http://www.dieselnet.com/
Diesel Days Workshop	http://www.worldbank.org/wbi/cleanair/global/learningactivities/diesel_days/index.html
Is Clean Diesel Fuel an Option for Developing Countries?	http://www.ccities.doe.gov/international/pdfs/dieselfuel.pdf
Bangladesh	
Updates and Information on Bangladesh’s Fuel Issues	http://www.adb.org/vehicle-emissions/BAN/fuel.asp?pg=bangdesh
Unleaded Gasoline in Bangladesh: an Overnight Success Bangladesh marks one year anniversary of going "lead free"	http://lnweb18.worldbank.org/sar/sa.nsf/Countries/Bangladesh/E8864F3B7624F84885256914004B4773?OpenDocument
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/bangla.html
Cambodia	
Fuel Standards in Cambodia	http://www.adb.org/vehicle-emissions/CAM/fuel.asp?pg=cambodia
China, PR	
Updates and Information on China’s Fuel Issues	
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/china.html
Gasoline Quality and Regulatory Development in China	http://www.acfa.ws/pp9.ppt

Hong Kong	
Updates and Information on Hong Kong's Fuel Issues (fuel standards)	http://www.adb.org/vehicle-emissions/HKG/ful-con.asp?pg=hongkong
India	
Updates and Information on India's Fuel Issues	http://www.adb.org/vehicle-emissions/IND/fuel.asp?pg=india
Auto Fuel Policy Report	http://www.petroleum.nic.in/afp_con.htm
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/india.html
Indonesia	
Updates and Information on Indonesia's Fuel Issues	http://www.adb.org/vehicle-emissions/INO/fuel.asp?pg=indo
Country Analysis Briefs for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/indonesa.html
Malaysia	
Updates and Information on Malaysia's Fuel Issues	http://www.adb.org/vehicle-emissions/MAL/fuel.asp?pg=malaysia
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/malaysia.html
Nepal	
Updates and Information on Nepal's Fuel Issues	http://www.adb.org/vehicle-emissions/NEP/fuel.asp?pg=nepal
Clean Energy Nepal's position paper on Benzene	http://www.adb.org/vehicle-emissions/NEP/docs/Benzene_position.pdf
Pakistan	
Updates and Information on Pakistan's Fuel Issues	http://www.adb.org/vehicle-emissions/PAK/fuel.asp?pg=pakistan
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/pakistan.html
World Bank's ESMAP Clean Fuels Project	http://www.worldbank.org/html/fpd/esmap/publication/pakistan_cleanfuels.html
Philippines	
Updates and Information on Philippines' Fuel Issues and Standards	http://www.adb.org/vehicle-emissions/PHI/fuel.asp?pg=phils
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/philippi.html
Singapore	
Updates and Information on Singapore's Fuel Issues	http://www.adb.org/vehicle-emissions/SIN/fuel.asp?pg=sing
Country Analysis Brief for Energy and Fuel	http://www.adb.org/vehicle-emissions/SIN/fuel.asp?pg=sing
Sri Lanka	
Information on Sri Lanka's Fuel Standards	http://www.adb.org/vehicle-emissions/SRI/fuel.asp?pg=srilanka
Sri Lanka Motor Fuel Quality Improvement	http://www.adb.org/vehicle-emissions/SRI/docs/SriLankaFuel.pdf

Taipei,China	
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/taiwan.html
Thailand	
Updates and Information on Thailand's Fuel Issues	http://www.adb.org/vehicle-emissions/THA/fuel.asp?pg=thailand
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/thailand.html
A Study on Changes in Specifications for Gasoline and Diesel Fuels in Thailand	http://www.adb.org/vehicle-emissions/THA/docs/thailandfuel.pdf
Viet Nam	
Updates and Information on Viet Nam's Fuel Issues	http://www.adb.org/vehicle-emissions/VIE/fuel.asp?pg=vietnam
Country Analysis Brief for Energy and Fuel	http://www.eia.doe.gov/emeu/cabs/vietnam.html

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III. Module 2- Refining & Automobile Technical Issues & Costs To Consider When Designing Fuel Quality Strategies

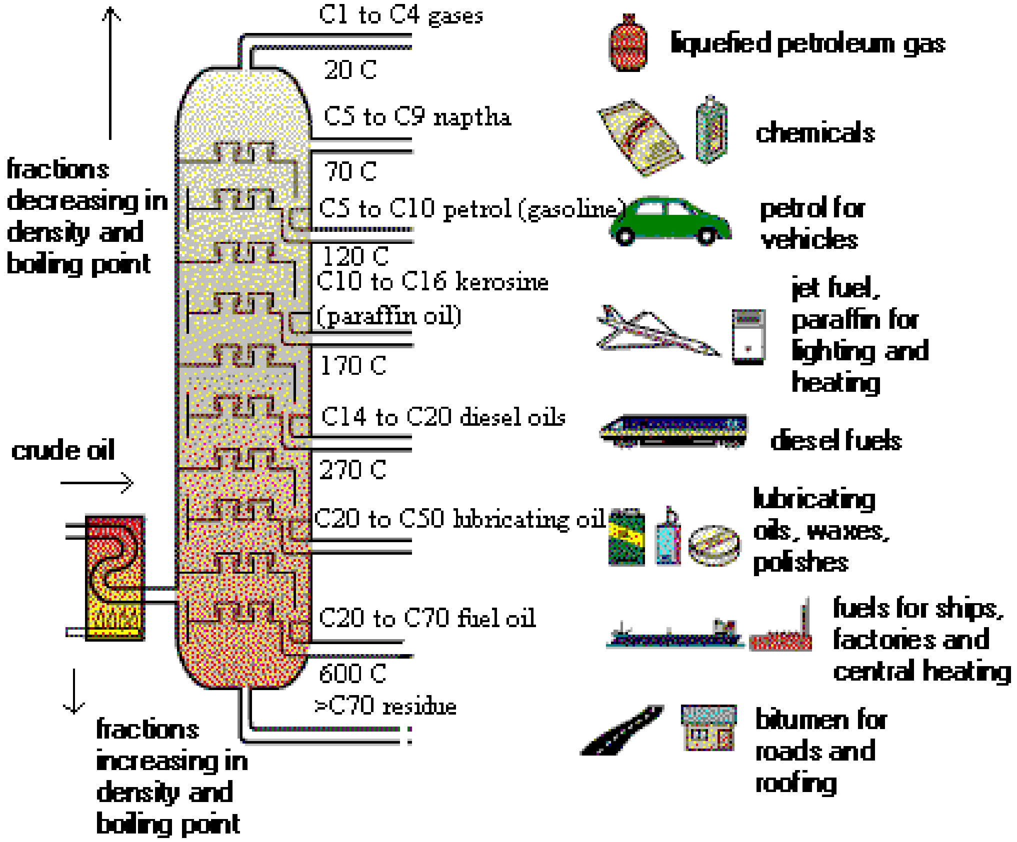
Module 2 looks at key refining and automotive technology options and addresses technical restrictions and relevant investment issues linked to conventional fuel quality changes.

A. Explanatory Section - The Refining Industry

One of the main building blocks of the fuel quality pillar is an analysis of technology options and Best Available Technologies/Techniques (BAT). When developing a fuel quality strategy, regulators are often confronted with numerous costs regarding the implementation of cleaner fuel quality specifications. These costs, which tend to be presented by the oil industry, are usually very detailed and refer to the complexity of refining technology and the uniqueness of refinery configurations across the globe. Most regulators do not have the technical expertise to truly assess these costs, nor should they necessarily, but what is important is to have at least some broad understanding of different refining technology and BAT options. This module attempts to assist in the development of this broad knowledge base.

The petroleum industry was developed with the successful drilling of the first commercial oil well in 1859, and the opening of the first refinery in the US two years later. The original demand for oil was to produce kerosene as a cheaper and better source of light than whale oil. It was only in the late 1800's with the development of the internal combustion engine, that gasoline and diesel fuels were produced. Then the evolution of the airplane created a need first for high-octane aviation gasoline and then for jet fuel, a sophisticated form of the original product, kerosene. Due to the development of these different transport modes, and the demand for refined oil products, present-day refineries, as illustrated in figure 3.1, now produce a variety of products including many required as feedstock for the petrochemical industry.

Figure 3.1. Products Produced by Refineries



When looking at these different products, it is important to keep in mind that although every refinery is built on the same concept of converting crude into useable and valuable products, they are all different! Each refinery configuration is extremely complex and unique as it depends on many variables. A few of those variables are:

- Requested product demand either from local and/or export market(s),
- Product quality requirements,
- Availability of raw materials,
- Date of construction,
- Technology availability,
- Financing availability.

Today, most refiners are built or altered to optimise the production of either gasoline and/or diesel.

1. Crude oil impact on automotive fuel quality.

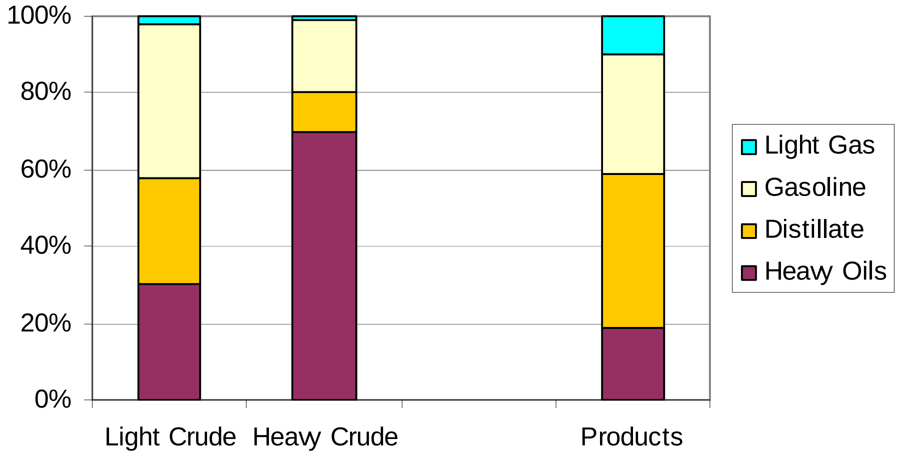
The key role of an oil refinery is to turn crude oil, which has limited use as raw material, into a refined product suitable for end use consumption. Raw crude oil straight from the well is a complex mixture of chemicals classified as hydrocarbons, consisting primarily of carbon and hydrogen. Crude oil contains thousands of different hydrocarbon molecules, which collectively determine its physical and chemical characteristics and the type and degree of refining required to produce a desired menu of refined products. Crude oil also contains non-hydrocarbon chemicals, such as sulphur, which will impact refining requirements as well as product quality. Within the refinery, high sulphur levels can lead to corrosive mixtures and undesirable air emissions of sulphur compounds. Additionally, as we have seen in Module 1, sulphur in automotive fuels also leads to undesirable emissions of sulphur compounds and can interfere with vehicle emission control systems.

The quality, or chemical makeup, of crude oil will vary considerably between production fields and therefore will require varying configurations of refining and/or will limit refined product yield. The primary quality parameter used to characterize crude oil is its gravity (density), which provides an indication of how light or heavy the crude is. A lighter crude contains a larger portion of smaller molecules characteristic of gasoline and other transportation fuels. A heavier crude contains a greater portion of larger molecules found in heavy industrial fuels, asphalt, etc., for which there are more limited markets.

Figure 3.2 shows the quality range of light (API of 35) versus heavy crude (API of 25) in terms of the natural yield of light gas, gasoline, middle distillate and heavy oils. Also shown for comparison is a breakdown of the demand for the same product categories. Light crude oil contains roughly 68 percent of gasoline and distillate (diesel) material and 30 percent heavier oils. In comparison the heavy crude oil contains only 29 percent of the lighter gasoline/distillate and 70 percent of heavy oil.

In contrast, gasoline/distillate demand in Asia represents about 78 percent of all refined product and heavy fuel makes up only 14 percent. The yield of heavy product from either the light or heavy crude is greater than demand and therefore some heavy material must be transformed to lighter material through the refining process (as discussed in following sections). Furthermore, the yield of heavier oil from the heavier crude is more than twice that of the light crude indicating a greater refinery conversion requirement.

Figure 3.2. Typical Natural Yields from Light to Heavy Crudes.



Source: Hart Downstream Energy Services, 2003

Crude oils are also classified by sulphur content that, like gravity, varies significantly across crude types. Typically crude is referred to as sweet (low sulphur) when its sulphur level is less than 5,000 ppm and sour (high sulphur) above this level. The majority of sour crude has sulphur levels in the 10,000 ppm to 20,000 ppm range, but can contain sulphur in excess of 40,000 ppm. Crude with sulphur in the 5,000 to 1,000 ppm range are sometimes referred to as intermediate sulphur crude.

Table.3.1. Typical Sulphur and API Levels of Different Crudes.

Crude Type	**Sulphur Level (ppm)**	**API Gravity**
Arabian Light	19,000	34.0
Arabian Heavy	28,500	28.5
China – Daqing	1,000	32.3
North Sea – Brent	4,000	37.0
Asia Pacific	1,500	35.8

Source: Hart Downstream Energy Services, 2003

Asian refineries traditionally have had access to relatively low sulphur local crudes as seen in table 3.1. This remains true of much Asian crude production. However, with demand through the 1990's rising sharply at the same time as local supply failed to increase, the region has increasingly had to buy higher sulphur crudes from elsewhere.

There has been a sharp increase in imports of light, relatively low sulphur West African crudes but imports from the Middle East have also risen. As mentioned under Module 1, 90% of imported crude to the Asian region is from the Middle East. Continued growth is expected in crude imports from these regions as well as from Russia, which will increasingly become a more important source. Due to the expected growth in higher sulphur crude imports, this will inevitably lead to requirements for more complex processing, especially when combined with the need to make cleaner fuels.

2. Automotive Fuel Blending

Before discussing refining processes and technologies it is important to understand that the blending of automotive fuels is a very complex process and depends on legislative restrictions, raw material availability, product and process availability, and cost-effectiveness. Some flexibility is available to refiners who can export to areas with less restrictive specifications, or who are not regulated on all of their products.

As seen in previous Module, globally fuel quality trends are apparent. In all countries around the world, although at different stages, the trend is to eliminate lead, reduce benzene and aromatics, reduce vapour pressure and density, distillate curve control, increase octane and cetane numbers, and reduce sulphur content.

As summarized in table 3.2, for each restriction on a fuel quality property refiners face different key issues all with varied solutions.

Table 3.2. Quality Changes and Solutions Affecting the Refiners.

Fuel Quality Change	Key Issues	Key Solutions/Limitations
Lead phase out in gasoline.	Selecting alternative octane sources.	• Increased use of butane. Cheapest source of high octane replacement however it's use is limited by its high RVP. • Increased use of oxygenates. Good blending properties with extremely high motor and research octane number. Availability depends on refinery processes and import possibilities. • Increased use of catalytic reforming. Where capacity available, may be able to increase octane of product at low cost. New capacity is high cost. Reforming option again is limited by availability and possible benzene and aromatic restrictions. • Increased use of alkylate with great blending properties however its use is limited by availability. Alkylation relies on catalytic cracking or petrochemical operations for feed. New alkylation capacity is expensive. • Increased gasoline production from FCC unit that again might be a limited possibility for refiners faced with olefin, sulphur, and aromatics restrictions. • Increased use of isomerisation. Capacity costs are moderate. Total amount of octane improvement available is limited and isomerisation use may be limited by RVP.

Fuel Quality Change	Key Issues	Key Solutions/Limitations
Reduced RVP in gasoline.	Octane and small volume loss. Current RVP of gasoline streams too high and require modification.	• Limit use of butane by minimizing direct butane blending and 0ptimizing cut point of gasoline fractionation. May require low cost refinery fractionation investment. Will reduce octane. • Increased use of ethers provides the volume and reduced vapour pressure. • Make up octane loss with reforming or isomerisation as above.
Reduced benzene content in gasoline.	Removal of benzene and aromatics contents lead to reduced volume and octane components.	• Implement benzene extraction facilities. Extremely high cost and reduces gasoline volume. • Increased use of ethers, alcohols and/or alkylates provide the dilution because of added volume and high-octane substitutes. Limited availability as above. • Modify fraction on crude units to minimize benzene formation in gasoline streams. May require low cost fractionation investment and may result in some octane loss. • Modify fractionation and utilize isomerisation to minimize benzene formation in gasoline, reduce benzene in some streams and provide makeup octane. • Implement Benzene Saturation facilities. Moderate to high investment cost and some loss of octane.
Increased octane number.	Increased use of high-octane components.	Similar solutions as for lead besides not only octane needs to be replaced but also volume.
Progressive reduction in gasoline sulphur content.	Remove sulphur from raw material or blending stream. Processing options might reduce octane.	• Increased use of crude with low sulphur content. • Optimise cut point of gasoline fractionation (heavier portion of gasoline shifted to distillate). Reduced production of desired product. • Hydrotreat gasoline related streams. High cost and results in octane loss that may be replaced with options discussed above. • Increased use of ethers, alcohols and/or alkylates provide the dilution because of added volume and high-octane substitutes. Limited availability as above. • Desulphurize catalytic cracking feed. Extremely expensive, but will provide some yield and diesel sulphur reduction benefits.
Progressive reduction in diesel sulphur	Remove sulphur from raw material or blending stream.	• Increased use of crude with low sulphur content. • Optimise cut point of diesel fractionation

Fuel Quality Change	Key Issues	Key Solutions/Limitations
content.		(heavier portion of diesel shifted to other distillate uses or heavy fuel oil). Lead to reduction in diesel product production. • Hydrotreat the stream used for diesel. For first reduction steps use conventional processing (removal of about 90 percent of sulphur from feed). Treating larger portion of diesel streams will progressively reduce sulphur. For lower sulphur steps, utilize more severe procession (higher investment and operation cost). For very low sulphur must treat all diesel blend streams. • Desulphurise catalytic cracking feed. Extremely expensive, but will provide some yield and gasoline sulphur reduction benefits. • Install hydrocackers. Extremely expensive but provides refinery flexibility to increase light product production, particularly low sulphur distillates. • Hydrotreaters/hydrocracking options require varying degrees of hydrogen production. • GTL diesel. Extremely expensive, but ultra low sulphur diesel with excellent properties.
Increased cetane number.	Increased cetane is related to reduced aromatics content.	• Introduction of cetane additives/improvers that might be a cheaper alternative than reducing aromatics. Engine testing facilities required. • Instalment of advanced desulphurisation or hydrocracking systems. May be extremely expensive and have very high hydrogen requirements.
Reduced aromatic content in diesel.	Reduced aromatics is related to increased cetane.	• Changing distillation operation however might lead to reduced production of desired product. • Instalment of advanced desulphurisation or hydrocracking systems as above.

Source: International Fuel Quality Center.

Table 3.2 shows that the more restrictions added to the refining product(s) the more alternatives a refiner needs to be able to meet such specifications. Less complex refiners (toppers, skimmers) have fewer alternatives available than the more complex (conversion) refineries. For some refiners new specifications might even be too restrictive for them to remain viable, and as a result the refining industry might see some degree of rationalization.

3. Different Refining Configurations Related To Automotive Fuel Qualities.

A refinery's configuration refers to the type, size, number of process technologies and facilities employed, and the flow sequence. Refinery configurations depend on what crude oil quality, product mix and quality, and environmental, safety, economic or other constraints were specified with its design. No two refineries are exactly alike, but refineries can be characterized into generic groups defined by the availability of the technologies.

A refinery's complexity is typically referred to within four configurations. These configurations are listed in table 3.3 together with their available process technologies and their yields.

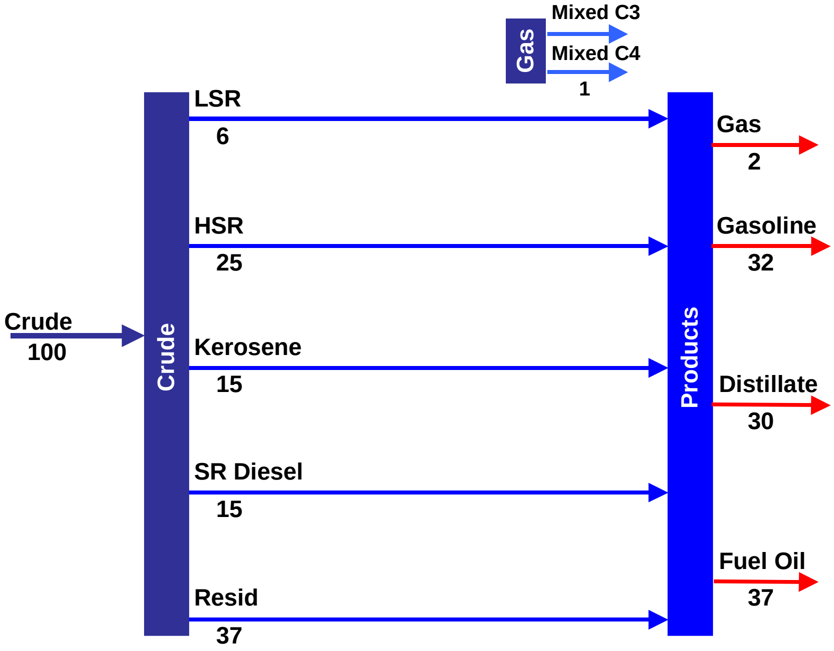
Table 3.3. Refining Configurations and Their Yields.

Configuration Group & Process Technologies.	**Product & Yield (vol%)**				**Comments**
	Gas	**Gasoline**	**Diesel**	**Fuel Oil**	
Topping • Crude distillation	2	32	**30**	**37**	• Product sulfur levels similar to crude's sulfur. • Distillate contains lots of heavy products. • Gasoline has low octane value.
Hydroskimming • Crude distillation • Hydrotreaters • Refomer	3	28	**30**	**37**	• Allows refiners to adjust product slate. • Provides new possibilities to improve fuel quality, especially for gasoline.
Conversion • Crude distillation • Hydrotreaters • Refomer • FCC • Some upgrade units	3	**49**	**30**	17	• Allows high yield of gasoline and distillate.
Deep Conv/Complex • Crude distillation • Hydrotreaters • Refomer • FCC • Many upgrade units	3	**47**	**43**	4	• Addition of coking allows minimal production of low valued fuel oil.

Source: Hart Downstream Energy Services

The most basic refining configuration, referred to as *topping* refinery, consists of only crude distillation and basic support operations. The topping refinery separates the crude oil into light gas and refinery fuel, naphthas, distillates (kerosene, jet fuel, diesel and heating oils), and residual or heavy fuel oil. The naphthas are gasoline boiling range materials, a portion of which may be suitable as very low octane gasoline in some cases. The volume and quality of all the products is entirely dependent on the crude oil feed. The topping refinery flow and typical yields (based on an average quality crude) are given in figure 3.3.

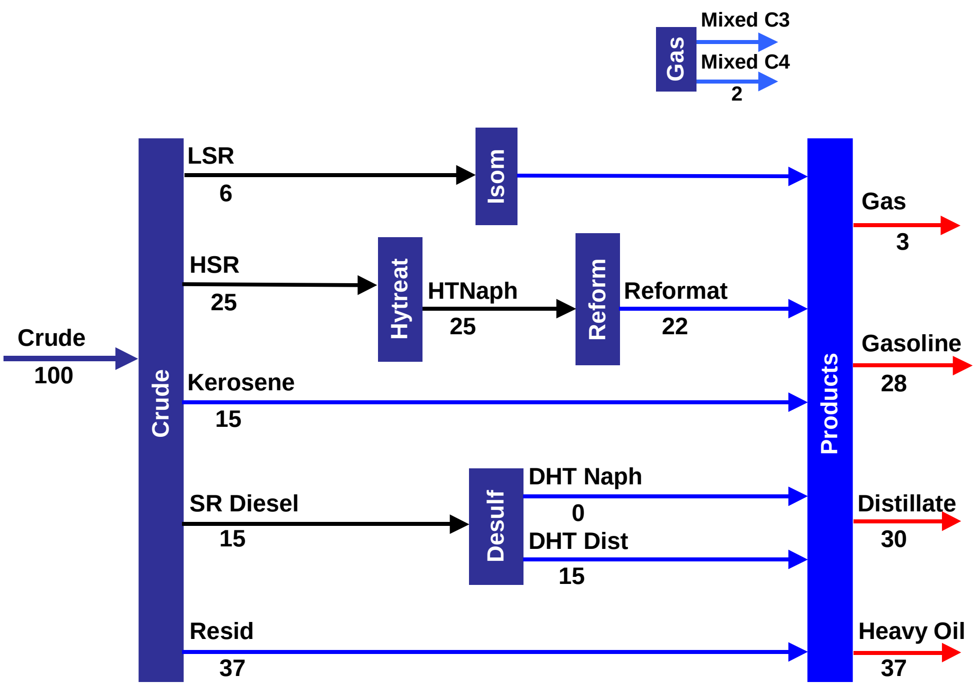
Figure 3.3. Topping Configuration With Typical Yields.



Source: Hart Downstream Energy Services, 2003

The next level of refining complexity is the *hydroskimming configuration*. A typical simple hydroskimming configuration includes crude distillation, hydrotreating and blending while a more advanced hydroskimming refinery, as illustrated in figure 3.4, also includes catalytic reforming. The reforming capacity allows naphtha to be upgraded to gasoline octane quality and provides hydrogen needed for any hydrotreating employed. The hydrotreating provides sulphur removal to meet product specifications and/or to allow for processing higher sulphur crudes. As in the case of the topping refinery the yield of products is entirely dependent on the crude oil feed. In the hydroprocessing configuration, gasoline can be produced in place of naphtha and fuel sulphur quality can be adjusted.

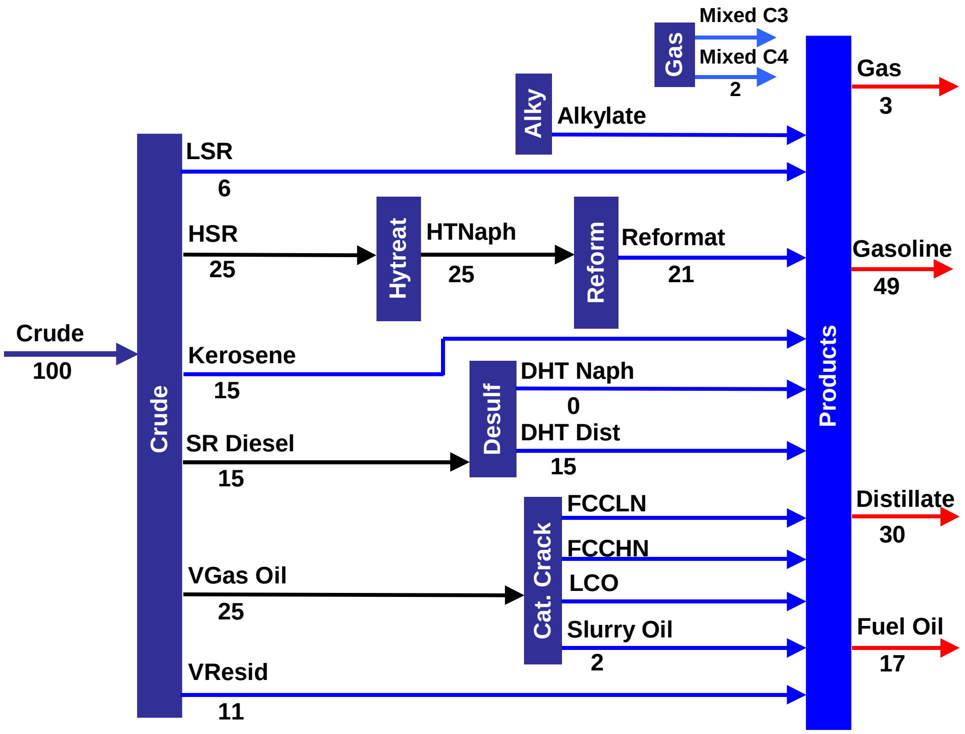
Figure 3.4. Hydroskimming Configuration with Typical Yields.



Source: Hart Downstream Energy Services, 2003

The topping or hydroskimming refining capability is significantly enhanced under the *conversion configuration*. This configuration adds cracking and/or hydrocracking capacity. The addition of conversion facilities allows the refiner to adjust refined product yields to match product demand. The actual yield can vary significantly depending on the type and capacity of the conversion capacity employed. Figure 3.5 illustrates conversion configuration yield with average crude quality, a relatively high level of heavy oil processing, and a mix of catalytic cracking and hydrocracking capacity.

Figure 3.5. Conversion Configuration with Typical Yields.

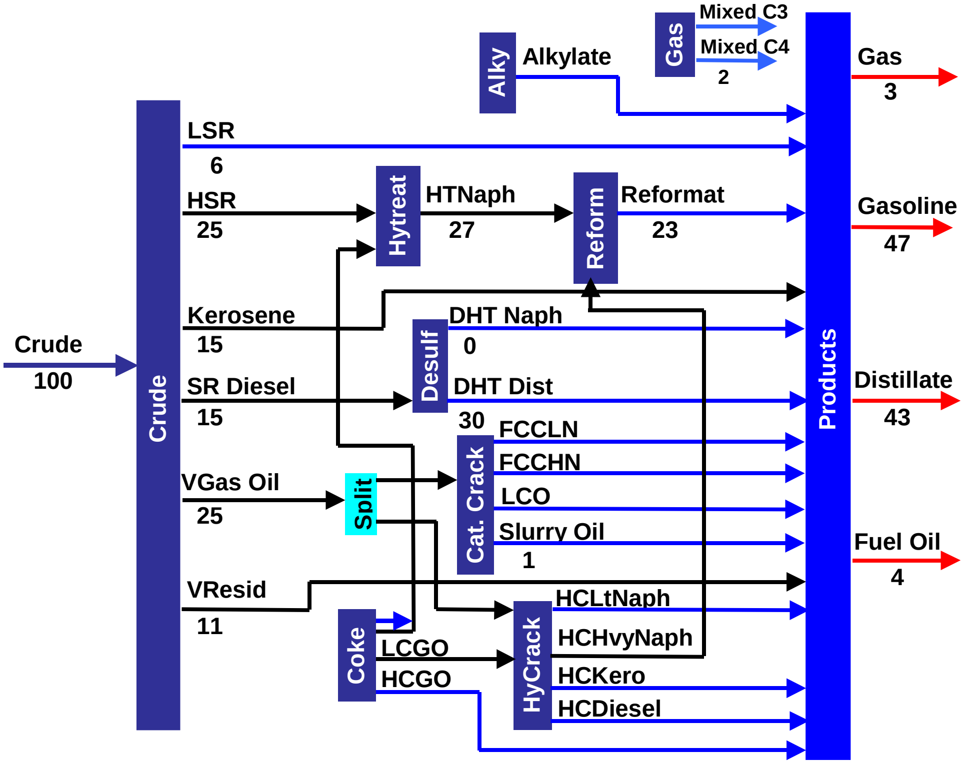


Source: Hart Downstream Energy Services, 2003

The conversion operations are central to the economics of the refinery because of the high yield of gasoline and distillate and the ability to adjust feed types and product yields. The natural yield of light products (gasoline, and distillates) from crude falls short of market demands and the increment must be made up through conversion operations. The light products generate a price premium based on overall product supply and demand and the cost (operating and capital) of the incremental conversion processing.

With the final *deep conversion (complex) configuration*, as illustrated in figure 3.6, product yields can be adjusted beyond that of the conversion configuration. Specifically, the addition of coking allows for minimal production of lower value heavy fuel oil, most being converted through coking and subsequent processing, to gasoline and distillate products.

Figure 3.6. Deep Conversion/Complex Configuration with Typical Yields.

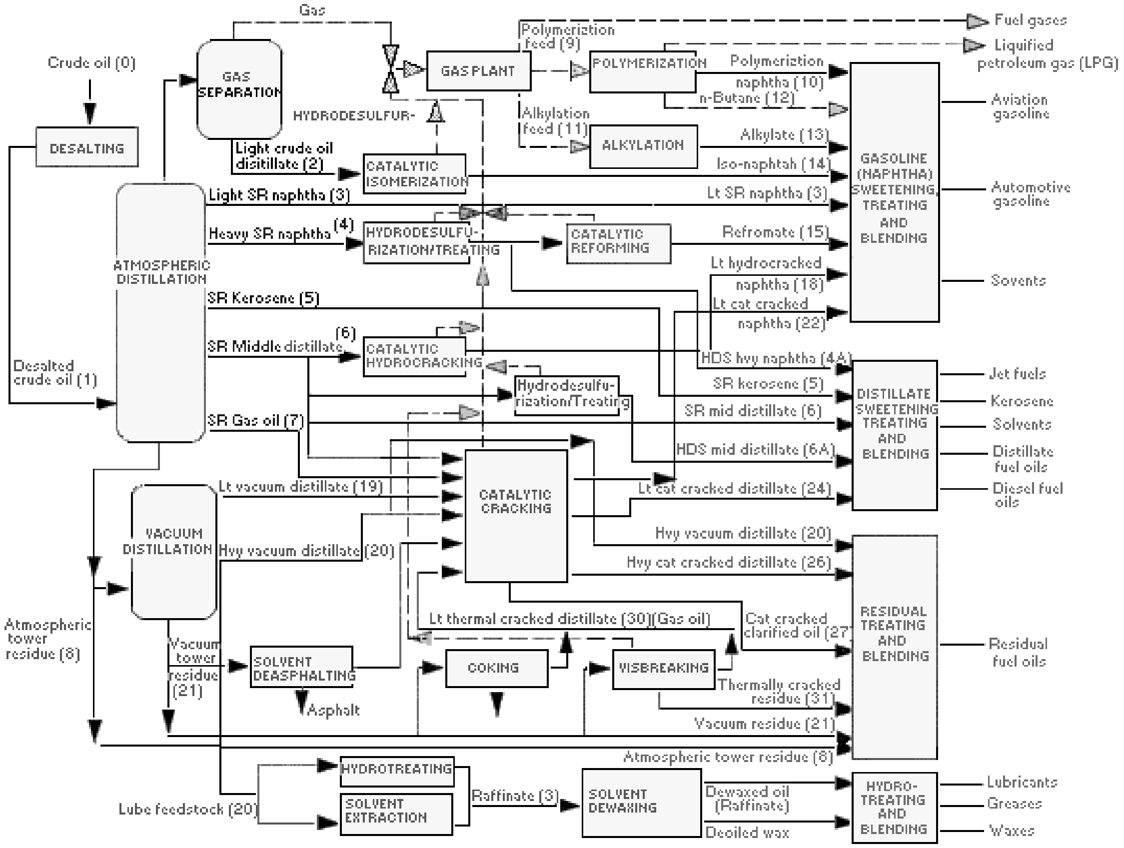


Source: Hart Downstream Energy Services, 2003

4. What Are The Different Refining Process Technologies?

Refineries are comprised of a number of individual technology based processing facilities with varying objectives, and integrated as necessary to meet product targets. The types, size, number and flow sequence of a specific refinery (i.e., refinery configuration) will vary depending on crude oil quality, required product mix and quality, and environmental, safety, economic or other constraints. The major refinery processing steps or technologies can be categorized into six functional areas: separation, conversion or cracking, combination, reformulation, treating and other specialty or support operations. All these steps and technologies are included in figure 3.7 that illustrates a complex refinery configuration.

Figure 3.7. Complex Configuration Including Most Available Refining Technologies.



Source: International Fuel Quality Center (IFQC).

a. Separation Technologies

Separation processes involve, segregating crude or intermediate streams into different groups or fractions based on physical properties, without changes to specific hydrocarbon molecules. The most common use is *crude distillation* where the raw crude is separated into intermediates characterized by volatility (boiling) range. As shown in all previous flow-diagrams, this is the first step in the refining process, and essentially all crude oil undergoes this distillation step. Refinery capacity is typically characterized by its crude oil distillation throughput capacity.

The distillation operation yields light gas and refinery fuel, naphthas, distillates, gas oils and the bottoms or residue. The naphthas are gasoline boiling range materials typically sent for further octane improvement treating and then gasoline blending. The distillates, including kerosene, usually undergoing further treatment and then blending to jet fuel, diesel and home heating oil. The heavier gas oil is sent to downstream processing for conversion into lighter (gasoline, distillate) streams. Finally, the bottoms or residue is blended to heavy industrial fuel or asphalt, or routed to final heavy residue processing.

b. Conversion or Cracking

Conversion or cracking operations, as listed in table 3.4, involve chemical reactions that "crack" large, heavy hydrocarbons (of limited market value) into smaller, lighter hydrocarbon molecules suitable for gasoline or other premium fuels, or for further chemical processing. The conversion operations allow the refinery to adjust crude yield to match refined product demand.

The primary conversion processes are fluid catalytic cracking, hydrocracking and coking. Fluid catalytic cracking is the second most prominent refinery processing facility in terms of throughput and provides the primary economic driver for the overall refinery operation. The process employs a catalyst at high temperature and low pressure to convert heavy gas oil to light gases, gasoline and other distillates. The feed is heated and mixed with a solid catalyst where the cracking reactions occur. The products are separated first from the catalyst and then into gases, light and heavy products.

The *catalytic cracker* is central to the operation and economics of the refinery because of its high yield of gasoline and distillate, its ability to adjust feed types and product yields, and the high margins between feed and product. Typical yields of gasoline plus distillate will exceed 60-70 percent of the feed and, in a large gasoline/distillate oriented refinery, will account for over 60 percent of the total refinery gasoline plus distillate output. Cracking also produces significant quantities of light gases categorized as olefins. Light olefins are relatively reactive chemicals that provide valuable petrochemical feedstocks and can be further processed (via combination processes) to high octane gasoline and oxygenated compounds, such as methyl tertiary butyl ether (MTBE), valuable for clean gasoline blending.

A second conversion application found in a significant number of complex refineries is *hydrocracking*. Like catalytic cracking this technology is used to convert heavy oils to gasoline and distillates. It differs from catalytic cracking in that hydrogen is introduced and consumed, operating pressures are substantially higher (in excess of 2000 psi) and temperatures are lower. The process has an advantage over catalytic cracking in that treating is added to the process. The hydrogen chemically reacts with the cracked streams to produce ultra-low sulphur (treated) products and improve other properties.

The yields of specific products from hydrocracking will depend on how the unit is operated. The unit can produce essentially all gasoline with volumetric yields of 100 percent of feed. Alternatively, yields of 85 to 90 percent jet fuel plus diesel can be achieved concurrent with a small amount of gasoline. Hydrocracking is more effective in converting heavy gas oils and producing low sulphur products than fluid catalytic cracking, but it is also more expensive to build and operate.

The products from hydrocracking are particularly useful blending components for clean fuel applications. They are nearly free of sulphur and low in aromatics. Aromatics are ring-shaped molecules that have poor diesel fuel performance and emission characteristics. Hydrocracking chemical reactions open up and convert heavy aromatic components producing jet fuel and diesel products with excellent fuel characteristics. Because of this capability, the hydrocracker is commonly used to upgrade low quality, high sulphur distillate streams from catalytic cracking and coking as opposed to heavy oil conversion. The products from this mode of operation are high quality gasoline intermediates, jet fuel and diesel.

Coking is a thermal, non-catalytic process that cracks the heaviest residue from crude distillation into a full range of lighter intermediates for further processing. The cracked products consist of light gases and low quality gasoline and distillates and gas oils which are further processed into final product.

Coking provides the refining system with the final means of converting the heaviest portion of the crude into useful lighter products. While a relatively small volume of the residue can be processed in other catalytic conversion facilities, such processing is limited due to the level of contaminants in the heavy residual feed and the resulting yield economics.

Table 3.4. Summary of Separation and Conversion/Cracking Technologies.

Process Technology	Typical Products Slates	Typical product Characteristics
Séparation Technologies		
Crude distillation	Separates crude oil into products: Light gas, refinery fuel, light and heavy naphthas, distillates, gas oils, bottoms or residue.	Oldest available technology forms the hart of any refinery and determines the capacity of the refinery. Products typically are low valued with sulphur content similar to the crude processed and product needs to be further refined to meet today's specifications.
Conversion/Cracking Technologies		
FCC, Fluid Catalytic Cracking	Breaks (cracks) heavy (large) oil molecules into lighter (smaller) more valuable molecules like LPG, Gasoline (50-60%), Distillate, Light olefins for chemical processing, heavy oil. Products often optimized for petrochemical feedstocks.	Increases product value from the Crude Unit. Products, unless treated, still contains similar quantities of sulphur as from the crude. Untreated FCC products are main source of sulphur for gasoline.
Hydrocracking	Breaks (cracks) heavy (large) oil molecules into all gasoline and/or jet and diesel and reduces sulphur and aromatic content by hydrotreating.	Provides high valued lighter products with low sulphur and aromatic content. Investment value for such units is significantly higher than FCC units.
Coking	Breaks (cracks) the heaviest oil molecules from the crude unit into low valued gasoline, distillates and gas oil.	Upgrades heaviest most low valued stream from crude into lighter products still containing high concentrations of metals and sulphur.

Source: International Fuel Quality Center (IFQC)

c. Combination

Combination processes, as listed in table 3.4, link two light gaseous streams together to form a larger higher valued fuel product. At least one of the gas streams used in the combination process is a reactive olefin hydrocarbon molecule produced via fluid catalytic cracking, coking or outside petrochemical operation. The major combination processes are alkylation, etherification and polymerization.

Alkylation combines the lighter FCC products (olefins, usually butylene or a mixture of butylenes and propylene, with a non-olefin) to produce a higher octane gasoline stream. The olefin and isobutane are reacted in the presence of a strong liquid acid and the final products separated in a fractionation section. There are two conventional alkylation processes that are differentiated by the type of acid catalyst used, hydrofluoric acid (HF) or sulphuric acid (H2 SO4).

Both alkylation processes pose potential environmental and public health concerns. With HF concern centres on possible release of a toxic vapour cloud that could harm refinery workers and the public. H2 SO4 is less hazardous than HF, but presents handling, storage, and transportation concerns.

Etherification combines lighter products from FCC unit (various light olefins) with alcohols (methanol, ethanol) through a low temperature and pressure process resulting in an oxygenated compound called ether, such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE) and tertiary amyl methyl ether (TAME). The process employs a solid catalyst system. The most common ether, MTBE, is a gasoline component with high octane number and other characteristics valuable in clean gasoline production. It is the primary source of gasoline oxygen required in clean gasoline regulations.

Polymerization combines two light olefins, also to produce a high octane gasoline component. The process employs a fixed catalyst bed at low temperatures and pressure. The process is relatively inexpensive, the product is less desirable than alkylate or ether. Polymerization product consists primarily of olefins that are unstable in gasoline (gum forming).

Table 3.4. Summary of Separation Technologies.

Process Technology	Typical Products Slates	Typical product Characteristics
Combination Technologies		
Alkylation	Combines FCC low octane reactive molecules (olefins) with a less reactive light component to produce high valued, high octane, gasoline component.	Increases octane yield over either HF or H_2SO_4 catalysts.
Etherification	Combines FCC reactive olefins with alcohols (i.e. methanol, ethanol).	Produces MTBE, ETBE are high octane clean gasoline components.

Polymerization	Combines two light olefins into high octane gasoline component.	Improves gasoline yield and octane number. Although process is relatively inexpensive the products typically have lower octane value than products from etherification or alkylation units.

Source: International Fuel Quality Center (IFQC)

d. Reformulation

Reformulation processes, as listed in table 3.5, alter the chemical composition of hydrocarbons in refinery intermediate streams in such a way as to enhance the performance characteristics of the final fuel. The primary reformulation processes are catalytic reforming and isomerisation, both of which are widely used to increase the octane of gasoline blending components.

Catalytic Reforming is used to upgrade low octane gasoline boiling streams (naphthas) to high octane blending streams. There are a number of chemical reactions in the reforming process, but the primary reactions involve production and/or rearrangement of compounds characterized as aromatics. Aromatics are ring shaped molecules that exhibit high octane characteristics and in pure forms constitute valuable feedstocks for the petrochemical industry. The aromatics can be extracted in a separate process for petrochemical use.

Catalytic reforming has traditionally been the primary octane generator and control process for most gasoline oriented refineries. It is capable of producing a gasoline stream at over 100 octane and can vary product octane over a broad range with minor operating adjustments. However, the aromatic compounds produced and responsible for the higher octane, particularly benzene, have more recently been found to exhibit negative gasoline toxics characteristics. This has introduced pressure to seek lower aromatic octane sources.

Isomerisation involves chemical alteration of low octane (paraffin) hydrocarbon to higher octane formulations (isoparaffins). Isomerisation is also used (more recently) to reduce the benzene content of gasoline components as a toxic control measure.

e. Treating

Treating processes involve the removal of undesired chemicals (i.e., sulphur, nitrogen, heavy metals) from refinery streams. The primary treating process is *hydrotreating* (also referred to as *hydrodesulphurisation* and *hydrorefining*) that utilizes hydrogen to remove sulphur for meeting final fuel product specifications. It is used on a wide range of intermediate or final product feedstocks from naphtha to heavy residue. In the role of treating intermediates, it is used before reforming to protect the catalyst and before catalytic cracking to reduce regeneration sulphur emissions, eliminate nitrogen and metal contaminants, reduce product sulphur and improve cracking yields. On the product side, it is used to meet final product sulphur specifications for gasoline, jet fuel and distillates. Hydrotreating can also be used to modify other product characteristics (i.e., diesel cetane or lubricating oil properties) to improve fuel quality.

Other treating processes such as Merox are used to eliminate specific sulphur molecules from final gasoline and jet fuel products. In addition, newer sulphur reduction technologies are being introduced to remove sulphur from fuels without requiring the hydrotreating process.

f. Specialty and Support Operations.

There are a number of miscellaneous processing facilities of varying complexity and purpose required to support the refinery operation, produce specialty products (lubricants, asphalt, etc.) and to provide for environmental control. Outside of specialty product facilities, major support facilities include hydrogen systems, sulphur recovery facilities, light gas handling, product blending, utilities (steam, electricity and water) and wastewater treatment.

The final step in the refinery process is blending refinery streams into final products. In gasoline blending, an automated system meters and mixes blend stocks and additives. Properties are tested with online analyzers supplemented by laboratory facilities, and computer control is employed to adjust blends to target specifications. Blending of other products usually involves less analysis and does not employ computer control.

Steam and electricity are used in processing operations, for heating, and for pumping and compression energy. Refineries purchase utilities or generate them on-site. On-site generation involves steam boilers and traditional power generation facilities. Cogeneration is also used for optimizing refinery energy. Cogeneration refers to the efficient integrated production of electrical power and steam.

Petroleum refineries are very energy intensive and through the numerous processing storage and handling create the potential for emission of airborne pollutants, water contamination, and hazardous waste generation. Emissions are also generated through the combustion of fuels required to provide heat and utilities, and to regenerate catalysts.

Table 3.5. Summary of Reformulation Technologies.

Process Technology	**Typical Products Slates**	**Typical product Characteristics**
Reformulation Technologies		
Catalytic Reforming	Rearranges low valued, low octane naphtenes and paraffins, gasoline components into higher valued, higher-octane aromatics.	Products have high octane value and typically high aromatics content less attractive for more advanced fuel formulation.
Isomerisation	Rearranges low valued, low octane normal paraffins into higher valued, higher octane, iso-paraffins.	Produces both environmentally (reduced olefin and benzene content) and economically high valued gasoline components.
Treating		

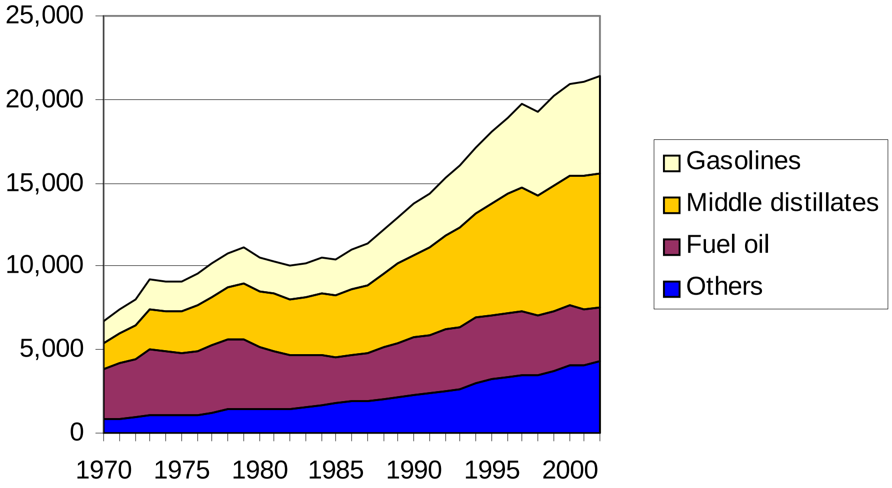
Hydrotreating	Removes undesired chemicals (sulphur, nitrogen, heavy metals) from products.	Upgraded product quality of intermediate and final products.

Source: International Fuel Quality Center (IFQC)

5. Regional and National Refinery Makeup and Capabilities in Asia

As indicated below in figure 3.7, the Asian Pacific region experienced a dramatic growth in oil product demand until the onset of the 1997/98 Asian economic crises. Like most parts of the world, demand growth in Asia is increasingly focused on gasoline and mid-distillate. The growth in travel is causing increased demand for jet fuel, gasoline and diesel at a time when there is a decreased demand for fuel oil.

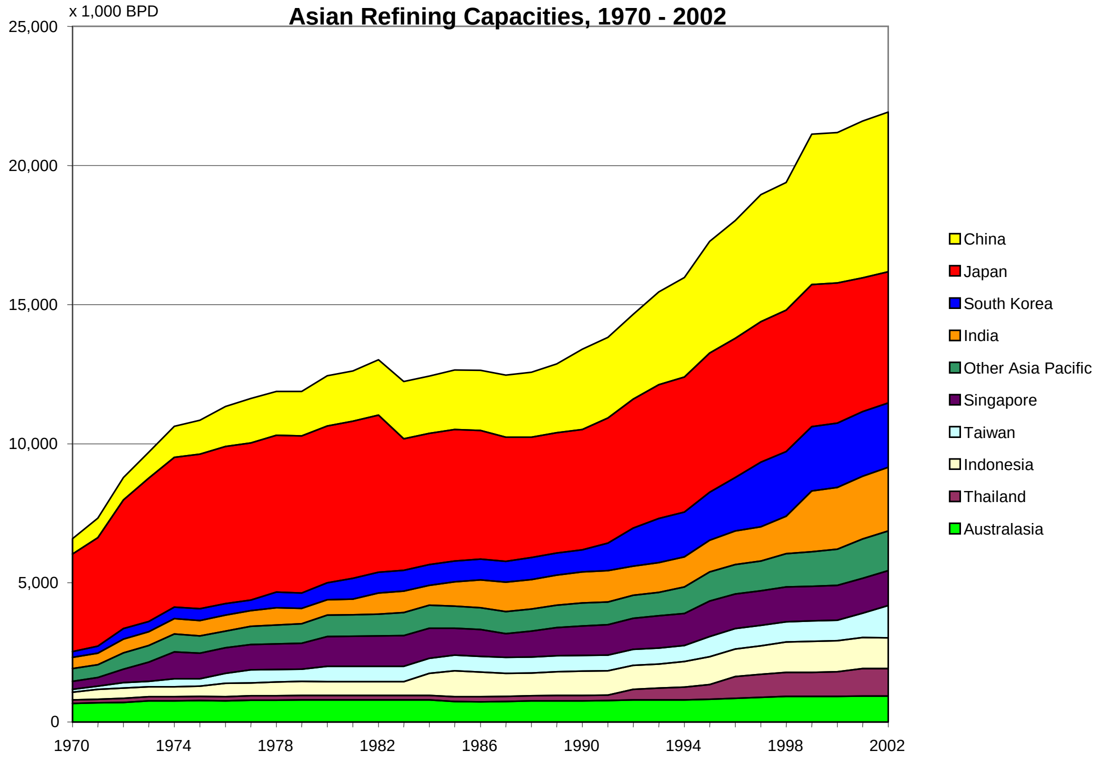
Figure 3.7. Asian Refinery Production from 1970 - 2002.



Source: BP, Jan. 2003

As indicated in figure 3.8, in the 1990's, refining responded to anticipated growth with aggressive capacity expansion. Refining capacity in China, India and South Korea more than doubled during this period. In the early 70's the regions refining industry became dependent on crude imports. With further anticipated growth in product demand, the region will grow increasingly more dependent on imported crude and refined products and struggle with investments required to implement clean fuel legislation.

Figure 3.8. Asian Refining Capacity from 1970 to 2002.



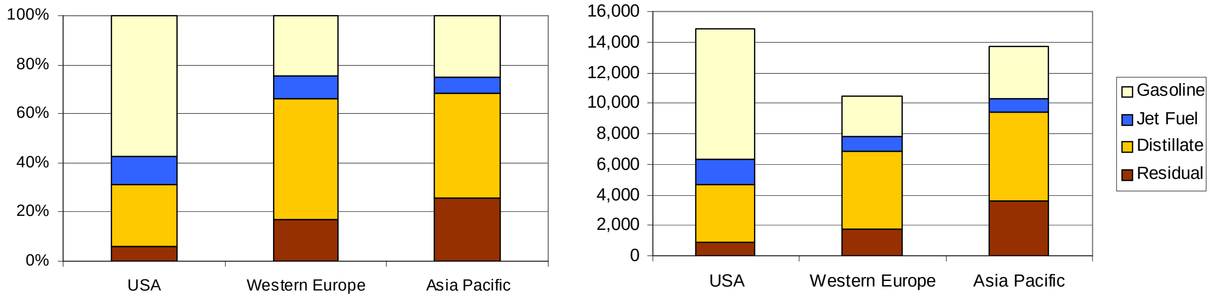
Source: BP, Jan. 2003

With the construction of refineries their configuration is determined by their local crude oil quality and their local demand. Generally speaking, as seen in previous parts of this module, although Asian crudes also differ from source to source, they typically are waxier and contain less sulphur than crudes from other parts of the world. Many Asian refineries have been built to meet their large demand of fuel oil (large number of topping and hydroskimming refineries). When most Asian refineries were built, higher valued products, like gasoline, jet kerosene and diesel were secondary in the output slate, and little upgrading was available to increase production of these fuels.

As a result of rapid economic development, most Asian countries have experienced an increase in jet fuel, diesel and gasoline consumption due to an increase in travel and use for transport, agriculture and power plants. As is the case in many parts of the world, Asia is experiencing a decline in fuel oil use and untreated crude oil that typically was their sources for power plants and boilers due to more stringent legislation in this area. Currently, Asia is the 2nd largest crude processing region in the world, after the US and before the EU. Due to high economic growth, the region is increasingly requesting more transport fuels such as gasoline, jet and diesel as well as an increased demand for raw material for petrochemical production. As shown in figure 3.9, the main fuel required for Asia, overall, is distillate. Volumetric product requirements are more comparable with Europe than with the US that always has been and is driven by the large gasoline consumption.

Not only is the Asian refining industry experiencing shortage in local crude supply having to look for new sources of different quality but also they are experiencing a large shift between products requested and their qualities.

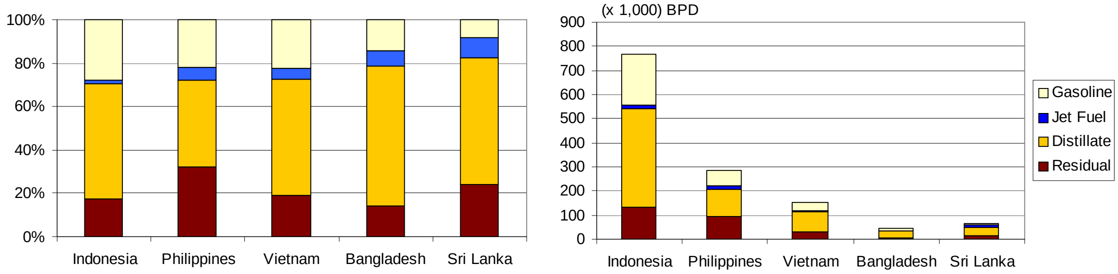
Figure 3.10. Typical Product Slates in USA, Western Europe and Asia Pacific.



Source: Energy Information Administration (EIA), 2000.

Similarly, as illustrated in figure 3.11, for the Asian countries chosen for this training, diesel is the dominant transport fuel. Diesel represents 60 to 80 percent of the transportation demand for these countries as compared to slightly less than 60 percent for EU and less than 30 percent for the U.S.

Figure 3.11. Typical Product Slates in Some Asian Coutnries.



Source: Energy Information Administration (EIA), 2000.

Asia has 200 refineries representing the largest regional crude distillation capacity in the world. As the Asian refining sector has traditionally focused on the production of fuel oil there are generally less gasoline upgrade units such as FCC's than in the US. Seen from the simple ratio of catalytic cracking capacity to crude capacity we see that Asia overall at only 14% is outpaced by the US at 34%. However it is more similar to the EU's capacity at 15%. As already discussed, this is partly because the Asian and European markets are driven by large diesel demand while the US is driven by gasoline demand. However the amount of available equipment also indicate the upgrade capacities available.

Table 3.4. Asian Refining Capacities (2002).

x 1,000 BPD	# of Refineries	Crude	Coking	FCC	Reformer	Hydro cracker	Hydro treater	Alkylation	Polym.	Isom.
Australia	9	848		234	198		376	20	8.5	41
Bangladesh	1	33			1.8	1.2	2			
Brunei	1	9			5.7					
China	95	4,500	306	892	157	122	355	27		
Taiwan	4	920	15	123	115		313			26
India	17	2,134	45	167	41	56	228			
Indonesia	8	993	32	101	93	100	23	16		
Japan	34	4,767	90	867	734	170	4,405	48	7	21
Malaysia	6	516	19		77	28.5	146			8
Myanmar	2	57	5							
New Zealand	1	106			28	29	61			
Pakistan	4	234			26		45			
Philippines	4	419		25	62		193			
Singapore	3	1,258		65	144	94	592	7	4	
South Korea	6	2,560	19	168	231	120	1,018	5		
Sri Lanka	1	48			5		18			
Thailand	4	703		77	92	43	459			

Source: Oil and Gas Journal

Source: Oil and Gas Journal.

There are large differences between the Asian countries and their refineries. As shown in table 3.4, in general Japan, S. Korea and Taiwan have a more sophisticated refining industry with relatively larger possibilities to upgrade the heavier fractions into lighter products. On the other hand, some Asian countries and several refineries only have topping refineries (Myanmar) with no upgrade capacities available, many countries and refineries are simple hydroskimmers with very limited upgrade capacities like for Bangladesh, Pakistan and Sri Lanka.

6. Technical Issues And Costs Related To Refinery Upgrades

There is no single answer to what refinery upgrading will cost. Every refinery around the world is unique and it's operating, maintenance and investments costs depend on available processes and equipment, location, crude being processed, supply of catalysts, available capital and so fort. The only common driver among all refiners is economics. Every refinery aims to optimize their tools to run a profitable business. Any refinery investment is generally capital-intensive.

Profitability is effected by many factors for example local and global commodity markets including competition, regulatory restrictions, pricing of imports of raw material and products, capacity utilization and capital expenditures. Also, today to a large extent, investment in clean fuels technology is being forced by legislation. Investment is been driven by a desire to survive in the market, rather than to boost profitability. In such situation, it is not surprising to find that refiners have generally seen negative returns from related investment.

There is a broad range of possible modifications and additions to existing refineries to meet emerging automotive fuel specifications including the following:

- Introducing operating changes to available technology.
- Changing the crude oil supplied to the refinery.
- Modifying the fractionation process(es).
- Introducing new processing facilities.
- Increased and optimized use of utilities including hydrogen, energy etc.
- Changing the catalyst used and/or its quantity.

- Upgrade offsite facilities to enable the handling of higher specification products.
- Upgrade and exchange equipment (pipelines, valves, tanks etc) make them resistant (corrosion, erosion etc) against new product qualities.

Refinery modification strategies are always project-specific and linked to desired objectives. A multi pronged program including reduced or eliminated lead, limited benzene and aromatic levels, RVP control, front-end octane improvement, and sulphur reduction could include many new process options while a more modest program might need only a few of those options. The increased investment costs and operating costs of even a modest reformulation program might be substantial, in some instances changes could even be a fatal combination.

In summary, it is difficult, even impossible, to give guidelines on costs and cost-effectiveness of fuel modification, because refinery characteristics differ so widely. In fact any cost figures, which may be publicised are typically based on assumptions rather than facts. This is not only because of the time involved to make such calculations but also because typically the refining industry does not have any desire to share detailed processing data to external public sources.

However, whist keeping this in mind, the following section gives an overview of existing studies on refinery investment costs for lead phase out, isolated sulphur reductions and overall clean fuels supply:

i. Refinery Costs Implications from Lead Phase Out.

In several studies (Abt Associates, 1996, Thomas, 1995, Hirshfeld and Kolb, 1995a and 1995b), the typical cost of phasing out leaded gasoline – including the annualized refinery investment costs amortized over the life of the investment, the incremental operating costs of producing gasoline without lead, and/or the costs of gasoline additives – has been estimated in the range of US$ 0.01 – 0.02 per litre. The cost difference between the productions of leaded (0.15g/l) and unleaded gasoline in Germany, for example, was estimated at US$ 0.01 per litre. Even in technologically less developed skimming refineries, the cost of total phase out of leaded gasoline has been estimated under US$0.03 per litre (Hirshfeld and Kolb, 1995a).

Again, we need to highlight that each refinery, has a unique technical structure and set of alternatives to replace lead, and the costs of required investments and technical measures necessary to support the phase-out of lead should be evaluated on a case-by-case basis.

ii. Refinery Implications from decreased sulphur demand.

The process requirements and costs needed to reduce diesel from relatively high (i.e. 2,000 ppm) to ultra low sulphur levels (around 10 ppm), such as other changes in refinery production and objectives, depend on the specific refinery crude and product slate and refinery configuration. The process requirements may necessitate installation of a number of new state-of-the-art processing facilities added to the existing refinery facilities. Conversely, where some level of existing desulphurisation exists, the requirements for the 10 ppm target may be limited to revamping of existing facilities to accommodate more severe operations.

In the simplest refining configuration, 2,000 ppm diesel can be produced through simple crude distillation (topping plant). A topping refinery using low sulphur crude oil can produce 2,000 ppm diesel without further processing. In this situation the sulphur can be reached by building a new, high severity desulphurisation unit incorporating the latest technologies (catalyst, hydrogen clean-up and purification, etc.) A new unit can be designed to process the diesel to 10 ppm.

In other situations, the refiner may already have desulphurisation facilities in place, but the desulphurisation is not adequate to meet a 10 ppm sulphur target. In many of these cases, the existing desulphuriser can be modernized/revamped to accommodate higher severity operations and produce 10 ppm quality product. The revamps typically include such things as the latest high active catalyst, changes to the internals of the reactor vessels, addition of a reactor providing for additional catalyst volume, and new or upgrade of hydrogen stream treating and purification facilities. Adjustments in operations can also in some cases be used to aid in production of the lower product sulphur (higher temperatures and shorter lengths of time on stream between required shutdowns).

The extent of modification required for the modernization/revamp depends again on the type and capabilities of the existing hardware and the processing environment. The revamp requirements are not simple, but can provide facilities for meeting 10 ppm product at much lower cost than a new unit (on the order of half the capital cost). The revamp option is not economical for all refining circumstances.

The only way to provide any cost estimate of refinery changes is to do so on a refinery specific basis. All other studies tend to generalize refineries and situations, investment possibilities, availability of raw material etc. and can only provide indicative values. Also, the requested investment of technologies might change, when looking at past studies emerging technologies tend to become less capital intensive over time, product market changes etc. For example the costs of achieving low-sulphur levels depend primarily on the current state of refining equipment being used. However, once the initial investment is made for refinery upgrades there may be relatively little price difference as sulphur levels decline, even to low and near-zero levels.

The many quoted incremental costs for near-zero sulphur diesel refining range from 0.3-2.8 cents per litre, although most estimates appear to fall in the range of 0.5-1.5 cents per litre. As made from the European market, real-world experience has confirmed this lower range of costs. Many countries (note not refineries), like Belgium, Denmark, Finland, Germany among others only gets 50 ppm sulphur fuels to their markets after providing a 1.5 – 3.84 cents/litre tax cut.

The following section highlights some recent refining related costs studies starting with the most recent:

Cost of Diesel Fuel Desulphurisation in Asia, January 2003

This study, Costs of Diesel Fuel Desulphurisation for Different Refinery Structures Typical of the Asian Refining Industry, includes 12 Asian countries with different refining capacity and demand as well as varying degrees of current refinery investment and capacity to produce reduced sulphur diesel.

After several simplifications such as the cost to include sulphur reduction of the entire diesel pool and holding the diesel demand static. This ADB study estimates that costs associated with lowering sulphur levels in diesel fuel are roughly constant, at around 1.1 cents per litre, for product levels ranging from 3,000 to 250 ppm sulphur. There is a gap in sulphur levels considered, from 250 to 50 ppm, over which costs more than double. At around 2.7 cents per litre, costs are again roughly constant for 10 ppm and 50 ppm sulphur diesel fuel, increasing by less than 1% to up to 9%, depending upon the country.

In exploring the price gap between 250 and 50ppm sulphur, this study finds that investment in hydrocracking capacity is the least costly alternative for achieving the lowest sulphur limits, whereas all higher limits were achieved with hydrotreating units using varying pressures. For each case, above and below 250 ppm, the study finds that investing directly in more efficient technology from the outset is less costly than moving through a range of intermediate technologies. The study states, "[these findings] reinforce the desirability of avoiding intermediate sulphur specification levels, which may be achieved through the deployment of relatively less advanced refining technologies, which may become ineffective or partly obsolete if subsequently stricter sulphur limits are going to be mandated" (Enstrat 2003).

Improving Transport Fuel Quality in China, 2002

The intent of this study was to explore China's refining options in light of changing gasoline and diesel fuel specifications.

A key hypothesis of this study was that, although Chinese refining has expanded enormously and has many plans on the books for continued investment, the current and planned refinery configuration would be insufficient to meet growing domestic demand for EURO-style fuels. To test this hypothesis, the team built and employed a linear program model of the Chinese refining sector and used scenario analysis to test the ability of the Chinese refining sector to produce fuels of EURO 2, 3, 4 and 5 standards in 2005, 2008 and 2010. Twelve scenarios were developed which varied by year, fuel quality and fuel volume. The model was given the option of building refinery technologies to meet the specifications, with input in Chinese demand by fuel type and Chinese capital costs provided by CPCC.

The study allocated capital costs to gasoline and diesel, and calculated that reformulating diesel in the year 2010 would add around 3.2 cents per gallon (0.85 cents per liter) capital cost to the refining sector, rising to around 3.7 cents per gallon (0.98 cents per liter) under the EURO 5 scenario. Gasoline costs were around 1.5 cents per gallon (0.40 cents per liter) across the board. In general, the results showed some cost savings when China's major metropolitan areas went to the new specifications first and rural areas followed, but the differences were not huge.

In summary, the study noted that the Chinese refining industry had already undergone a major build-up program, and additional investments are continually taking place. Yet the investments made will not be sufficient to allow the industry to meet demand for higher-quality EURO fuels. Technologically, it is possible for Chinese refiners to produce EURO standard fuels, yet economically and logistically it will yet prove a challenge. For example, building a million barrel per day of heavy feed hydroprocessing would be an Herculean labour by any standard, and the total equipment capital costs in the scenarios of 2010 were calculated at around US$2.3 million per day.

Ultra Low sulphur Gasoline and Diesel Refining Study, 2000

This study, ULS Gasoline and Diesel Refining, assessed the costs of lowering fuel sulphur levels from a maximum of 50 ppm to a maximum of 10 ppm in Europe. The study, which again contains many assumption (only FCC refineries, no octane loss, low sulphur level in crude etc) found costs to achieve near-zero sulphur levels were much lower once initial reductions to 50 ppm had been made. Incremental costs were expected to range from 0.3-0.5 cents per litre in Northern Europe and 0.5-0.7 cents per litre in Southern Europe.

Ultra Low Sulphur Studies by the EPA and Other sources, 2000

In 2000, U.S. EPA proposed a 15 ppm sulphur limit for highway diesel fuel, reduced from the current cap of 500 ppm. EPA used a refinery-by-refinery approach to estimate the incremental and capital costs of the new ruling. Costs of the new standard were predicted to start at a national average of 1.0 cents per litre and increase to 1.1 cents per litre in 2010. U.S. aggregate capital costs in 2010 were expected to be around $5.3 billion (EPA 2000).

Other cost studies were undertaken and submitted as part of the rulemaking. In general, the studies include EPA's estimates for incremental costs within their range, although many include alternate scenarios with higher estimates. Capital cost estimates are both higher and lower than EPA but generally relatively close.

In October 1999, a **MathPro study**, Refining Economics of diesel sulphur standards, analyses the refining economics controlling the sulphur content of diesel fuel (both on-highway and off-highway) to low limits. The objective was to estimate the average incremental cost, investment requirements, and technical implications of reducing the sulphur content of diesel fuel meet various specified standards. This analysis represents refiners achieving diesel fuel sulphur control using commercial desulphurisation technology: severe conventional hydrotreating.

The study provides the estimated average cost, annual cost and investment requirements for many different cases. The per gallon costs of desulphurisation standards ranges from 2.6 – 8 cents per gallon dependent on sulphur level and refinery configurations. The related annual costs ranges from $1,000 million to $3,500 million.

A study commissioned by the **Engine Manufacturers Association**, used a linear programming model to evaluate several final sulphur endpoints for both on-road and off-road diesel fuel. The study estimated that a 15 ppm cap for highway diesel only would increase costs by approximately 0.8-1.4 cents per litre (MathPro 2000). Capital costs ranged from $3.4 to 6.1 billion, with a figure of $3.9 billion estimated to match the EPA assumption of 80% revamp and 20% new units (EPA 2000). In response to the EPA proposal to extend the 15 ppm sulphur cap to nonroad diesel fuels a supplement to the original MathPro study included a 15 ppm cap for all diesel fuel. The extension of the 15 ppm sulphur cap to non-road diesel was expected to raise the estimated range of incremental costs to 1.2-2.0 cents per litre (MathPro 2000). In all of these estimates, the high values appear to reflect a less realistic approach to refinery upgrades that allows for less flexibility and does not provide the option of retrofitting existing units.

An **Ensys study** commissioned by the Department of Energy in the US found results based upon either conservative or optimistic technology assumptions. EPA (2000) reported that DOE's conservative technology assumption included only commercially available technologies and resulted in higher costs of U.S. .3-1.6 cents per litre. The optimistic technology scenario appears to have used assumptions more similar to EPA and resulted in incremental cost values very similar to EPA, 1.1-1.2 cents per litre. The full range of capital costs reported was $2.7-6.5 billion, and under assumptions similar to EPA's conservative scenario predicted $4.4 billion and the optimistic scenario $3.1 billion (EPA 2000).

After the standards were proposed, the Energy Information Administration (EIA) undertook a study at the request of the Committee of Science, U.S. House of

Representatives. Using a modelling approach, EIA reported an initial range of 1.2-1.9 cents per litre, rising to 1.7-2.4 cents per litre after 2010, with total costs ranging from $6.3-9.3 billion (EIA 2001). EIA also reported on a study done by Argonne National Labs, which found a similar range of incremental costs, 1-2 cents per liter, but even higher capital costs of $8.1-13.2 billion (EIA 2001).

Studies commissioned by the **American Petroleum Institute** (API) and the National Petroleum Council (NPC) provided different estimates and tended towards higher incremental costs, although they fell within the ranges reported by other studies. A study by **Charles River Associated**, Inc. and Baker and O'Brien, Inc., commissioned by API, predicted the average cost to produce 7 ppm sulphur diesel (in order to meet the 15 ppm cap) from 500 ppm sulphur diesel to be 1.8 cents per litre. The capital investment predicted was $7.7 billion (EIA 2001). The NPC estimated an incremental cost of 1.6 cents per litre for 30 ppm sulphur diesel, with an investment of $4.1 billion (EIA 2001).

Refinery Implications from overall Asian Improved Fuel Qualities .

The objectives of this study were to follow-up on a previously conducted analysis (the role of petroleum based and alternative transport fuels in reducing emission in the APEC Region) that had examined motor fuel quality enhancements necessary to improve air quality in Asia pacific Economic Cooperation member economies. This study aimed to gain an appreciation of the supply impacts that several specification scenarios are likely to have on the region over the coming 10-year period. Study is not yet in public domain.

Cost-benefit Analyses of Near-zero Sulphur Diesel

Cost-benefit analyses in the U.S. and Europe have consistently found that the benefits of reducing sulphur in transportation fuels far outweigh the costs, regardless of the very different assumptions used. The U.S. EPA found the benefits of stricter fuel and emissions standards for diesel to be roughly 16 times higher than the increase in refining and vehicle costs required. In Europe, the analysis investigated only the shift in sulphur levels, assuming new emissions standards were not contingent on sulphur standards. Air quality played a less important role in this analysis, which focused more on increased fuel economy resulting from design modifications made possible with near-zero sulphur fuels.

EPA performed a cost-benefit analyses for the Heavy-duty Engine and Vehicle Standards, assuming that near-zero sulphur diesel was integral to meeting the new emissions standards and thus in achieving the expected benefits. Reduction in premature mortality due to reduced PM levels was the dominant benefit. Additional benefits included reduction in health impacts (such as chronic bronchitis), visibility impairments, and crop damage. The predicted benefits totalled $70.4 billion, with predicted costs of $4.3 billion and a net benefit of $66.1 billion by the year 2030 (EPA 2000). Also it was estimated that the new regulations save 8,300 premature deaths, 750,000 respiratory illness and 1.5 million lost workdays.

Several aspects of the EPA analysis, including the timeframe, introduced considerable uncertainty into the final numbers. Yet, because many benefits were not monetized, one can still assume that the final numbers are an underestimate of the total benefits. In fact, a plausible alternative to EPA's analysis based on the Krewski-Harvard Six Cities study found a more than 150% increase in total benefits, resulting in a net benefit of $177 billion (EPA 2000).

In contrast, the analysis performed by the **Directorate-General Environment** (2001) of the European Union looked only at the shift from 50 to 10 ppm sulphur fuels, assuming all vehicle emissions standards remained constant. In this context the primary benefit was increased fuel economy of new models taking advantage of near-zero sulphur fuel to achieve modest 2-3% increases in fuel efficiency. Gasoline and diesel fuels were considered together, with diesel expected to achieve lower efficiency gains (2%) at higher costs (0.3-1.0 U.S. cents per litre) but with smaller increases in CO2 emissions from refineries. The reduction in pollutant emissions estimated from use of near-zero sulphur fuel in older vehicles was relatively minor, only a 5% reduction in PM for diesel vehicles.

Monetary benefits were predicted for seven different scenarios, ranging from a full introduction to a phase-in of near-zero sulphur fuel over the timeframe of 2005 to 2011, with the benefit analysis stretched out to 2020. The net present value of the benefits of the various scenarios (including both gasoline and diesel) ranged from $1.7 to $3.2 billion U.S. (Directorate-General Environment 2001).

While the analysis by the Directorate-General predicted only moderate air quality benefits from existing vehicles for the incremental decrease in sulphur levels, the actual air quality benefits associated with reducing sulphur levels have been dramatic. A study in Denmark, one year after the level of sulphur in diesel fuel was reduced from 500 ppm to 50 ppm, revealed a significant decrease in ultra fine particle concentrations in the ambient air. The study related the drop in ambient concentrations to a 56% reduction in average particle emissions from diesel vehicles (Wåhlin et al. 2000).

These examples demonstrate that the benefits outweigh the costs of lowering the sulphur standards under a variety of assumptions. And benefits are even greater when sulphur levels are reduced from a higher baseline. The U.S. EPA, in comparing the heavy duty standards to past measures, found the cost-effectiveness to be in line with earlier regulatory efforts to strengthen emissions standards and reduce sulphur levels, although some past measures had been more cost-effective. At the same time, the European analysis demonstrates that the benefits, purely in terms of fuel costs, continue to be positive down to the level of near-zero sulphur fuels.

Case Study 5. CAI-Asia Dialogue for Cleaner Fuels in Asia

Recognizing the fact that the oil industry is one of the major contributors to the over-all sources of pollution in the urban area due to the available quality of fuel, the Clean Air Initiative for Asian Cities initiated a dialogue with the major international oil companies operating in the region and the major national oil companies in each country.

The objective of the meeting was to establish a dialogue between the oil industry and the Clean Air Initiative for Asian Cities (CAI-Asia) for the production and distribution of cleaner fuels in Asia.

The launch meeting was held on July 2003 in Singapore and was attended by representatives from 12 oil companies, (Bangchak Petroleum Public Company, BP, Chevron Texaco, ExxonMobil, Indian Oil Corporation, Pakistan State Oil, Petron Corporation, PTT Public Company Ltd., Shell, Showa Shell Sekiyu K.K., Singapore Petroleum Company and Thai Oil Company Ltd.) the Chairperson and representatives from the CAI-Asia Secretariat.

The dialogue resulted in the adoption of the “Singapore Statement”.

“Singapore Statement”

We, the oil companies, that produce and/or provide oil products for the Asian market, which have gathered here in Singapore for the purpose of discussing cleaner air in Asia, share the concerns that air pollution is a serious developmental problem and that for Asia to develop further it is important that citizens are able to enjoy air of a quality which, by recognized standards, such as those recommended by the World Health Organization, should not cause them harm.

Air quality is impacted by emissions from a number of varied sources but we recognize that the rapid growth in mobility in Asia has contributed to an increase in emissions in many cities, and that the expected continued growth in number of vehicles will further add to the problem. Countries and cities in Asia experience different levels and types of air pollution, and actions taken to reduce air pollution need to take this into consideration. Any action taken to address air pollution should be based on sound science.

To enable ambient air quality in Asian cities to meet appropriate standards will require the identification and implementation of location- and context-specific initiatives, which are based on sound science and which recognize the necessary balance between economic, environmental, and societal needs and impacts. In this regard, we believe it is appropriate that a range of solutions be considered with the aim of identifying those which leads to the most balanced, cost-effective initiatives involving an acceptable overall cost to society, government and the stakeholders.

We are committed to working with key stakeholders, including governments, academia, civil society, and equipment/vehicle manufacturers to contribute to the identification of sources of pollution, as well as the formulation of solutions, particularly those designed specifically to reduce emissions from mobile sources.

Fuel quality is one of four equally important enablers to reduce vehicle emissions, the others being cleaner engine technology, better vehicle and engine maintenance, and effective traffic management and transport planning schemes. All four of these need to be taken into account when considering optimum, sustained solutions, the implementation of which will require integrated measures from a number of stakeholders.

We, the oil companies, appreciate the role taken by the Clean Air Initiative for Asian Cities (CAI-Asia) to initiate a dialogue among oil companies in Asia, and we express our full support for the goal of the dialogue: “To contribute to better air quality management in Asia.”

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The dialogue on cleaner fuels in Asia is a significant contribution towards the objectives of the Partnership for Clean Fuels and Vehicles, which was set up at the World Summit on Sustainable Development (WSSD) in Johannesburg in September 2002 by a group of committed partners from governments, international organizations, industry, and non-governmental organizations

(NGOs). This global partnership intends to help reduce vehicular air pollution in developing countries through the promotion of clean fuels and vehicles, and will focus initially on two priority areas (i) the elimination of lead in gasoline and the phase down of sulfur in diesel and gasoline fuels, concurrent with, (ii) the adoption of cleaner vehicle technologies.

The active commitment and support of the auto industry to the Dialogue process will be vital for its success.

Singapore, 21 July 2003.

Case Study 6. Phase Out of Leaded Gasoline and Delayed Decision-Making on Investments

Background - Indonesia represents a country which has a major refiner who has not invested in refinery upgrades over several years and is now resisting the complete introduction of lead free fuel and low sulfur fuel.

Detailed, independent specifications of fuels in Indonesia are not currently available..

Issue Focus - There has been a Ministerial Decree that requires nationwide ULG by Jan. 2003. PERTAMINA and the Ministry of Energy and Mineral Resources (which issued the ULG Decree) announced however at the US-AEP/USEPA seminar in June 2002 that they will not be able to fulfill the requirements of the Decree, and the soonest they plan to supply ULG outside Jakarta is 2005.

Ministry of Energy recently proposed to the Ministry of Environment that the Decree be revised, pushing the date back to Dec. 31, 2004. Given the delays accompanying finance deals for refinery modifications, it seems that even by this date the refinery modifications are unlikely to be complete.

It should be noted that there is number of non-governmental organizations based in Indonesia that are actively campaigning against lead. They held a number of informational meetings and workshops and have been engaged in educating the public and the legislature on the benefits of unleaded gasoline. Their objective is trying to create a public pressure to remove lead from gasoline.

The Ministry of Environment has been engaged in high-level talks in response to the Ministry of Energy proposal to change the Decree. The essence of the response is that the Decree should not be altered and Ministry of Energy and PERTAMINA must take an alternative approach to supply ULG (e.g. blend in another octane booster at the refineries as an "interim strategy" rather than just waiting several years until the refinery upgrades are complete). The concern is that the date will be pushed back again and again, as has already happened many times.

The reason for the delays given is that the absence of lead creates an octane deficit that can only be addressed by investing in refinery infrastructure. It has been argued that the economic situation in Indonesia does not allow significant capital investments.

The price of gasoline used to be lower than international market price, but last year Indonesian gasoline prices rose to very near the Singapore Platts price. The price is still at that level, despite the fact that the quality of gasoline remains markedly worse than that of Singapore. While the supply of unleaded gasoline to the capital city, which began in July 2001, is a big step forward for cleaner fuel (ambient lead concentrations have reduced since one year ago) the quality of the gasoline by both environmental and engine performance standards is not commensurate with its current price. Because unleaded gasoline is not supplied outside the Jakarta area (except Cirebon and Bali or a few isolated pumps), catalytic converters - which would make a big difference in vehicle emissions - can not yet be phased in anywhere.

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The result is that consumers are paying a high price but inhabitants are still saddled with heavy vehicle pollution. In Indonesia, leaded gasoline is still a serious public health and environmental issue.

The Ministry of Environment has recently decided to mandate Euro 2 emissions norms but the actual timing may be constrained by fuel quality..

Detailed, independent specifications of fuels in Indonesia are not currently available..

Analysis / Lessons Learned:

- Analyze steps in phasing out lead in gasoline in the country
- The requirements for capital investments is an obstacle
- NGOs have been effective in educating the public in trying to create a public pressure to remove lead from gasoline

B. Explanatory Section - The Automobile Industry

As discussed under Module 1, an integral part of the systems approach is automotive emissions and thus vehicle and aftertreatment technologies. As pointed out previously, many fuel components such as lead, sulphur, volatile compounds, heavy components etc. affect emissions control systems. Therefore, prior to setting a fuel quality strategy it is essential that a country analyses the characteristics of its vehicle fleet.

Changes in engine technology and emission control devices are typically driven by legislation and, in most cases, by countries with large automotive markets. If a country is constrained by domestic automobile production then it is likely to import vehicles with the same technology sophistication as from the exporting country. Therefore, the only manner in which to promote cleaner vehicles and new engine technology for domestic use is for domestic legislation to set strict standards for all vehicles produced inside or outside the country. This sends a clear signal to vehicle producers selling on the market and is increasingly seen as a positive rather than a negative development as due to economies of scale today's global automotive producers find it more economical to produce one type of vehicle for several markets rather than tailor make vehicles for often smaller markets. In addition, as explained in the previous section it is then easier to voice their fuel quality demands for these vehicles.

To build on the previous Module, this Module, will now look in more detail at the fuel quality required to enable these different technology options and to optimise the efficiency of existing and new emission control systems.

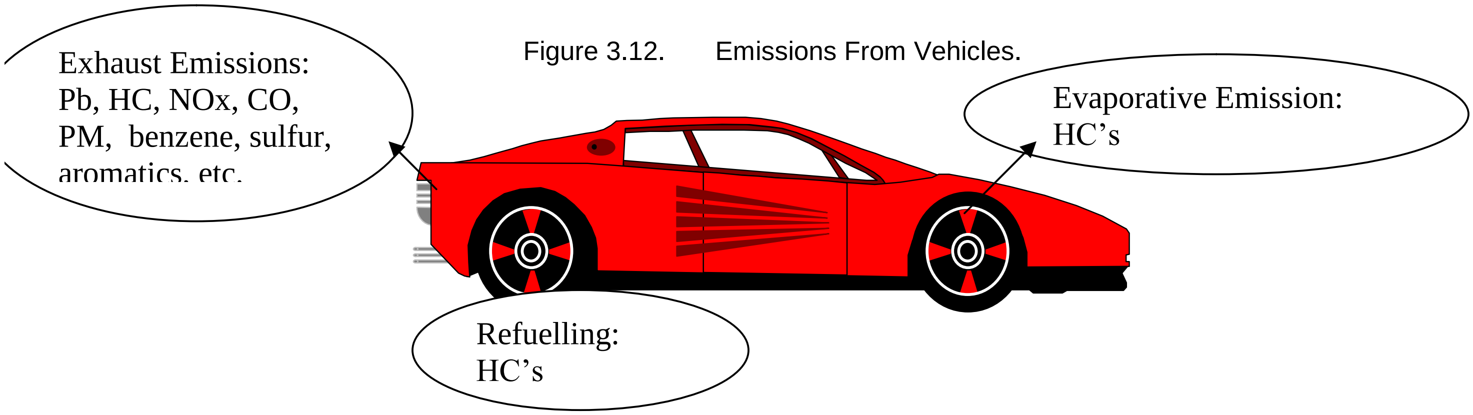
1. Engine Emission Control Devices And Engine Technology Options.

This chapter gives an overview of what automotive engine technologies and emission control devices are available, what they do, what emissions they control, and how are they affected by fuel composition?

After a brief introduction, specific information on the primary emission control devices will be given as follows:

- Name
- How does it function?
- What emissions are controlled?
- What fuel factors affect it's operation?

Figure 3.12. Emissions From Vehicles.



Source: International Fuel Quality Center (IFQC)

As seen above under Figure 3.12. and the previous module, the automotive emissions of primary concern are HC, CO and NOx for gasoline engines and NOx and PM (particulate matter) for diesel engines. Control of these emissions to extremely low levels is now recognized to be a joint responsibility of the emission control hardware and the fuel to be used. It is important to recognize that modern emission control systems are combinations of many of the devices described. The newer systems are so complex that they require powerful on-board computers to control their operation.

Over the years, many studies have been conducted to determine the relationship between fuel quality and it’s effect on emissions. Examples of these studies are US Auto/Oil, EPEFE and JCAP that are being explained in other modules.

Table 3.5 summarizes what automotive emission control devices are available, what emissions they control, and how are they affected by fuel composition. In summary, we see that gasoline car emissions are effected by many of the fuel parameters such as distillation, RVP, aromatics, olefins, sulphur while the main determining component for diesel emissions is sulphur.

Table 3.5. Overview Of Emission Control Systems, Their Functions And Fuel Response

Emission control system	**Emissions Controlled**	**Fuel factors affecting operation**
Gasoline Spark-Ignition Engines		
Positive Crankcase Ventilation (PCV) Valve	HC	-
Engine Combustions controls	HC, CO, NOx, PM	RVP, distillation, aromatics and olefins
Evaporative emission controls	HC	RVP and front-end composition
Exhaust Gas Recirculation (EGR)	NOx	Minimum deposits required
Oxidation Catalytic Converter	HC, CO	Lead and phosphorus
3-way catalyst (TWC) and O2 sensor	HC, CO, NOx	Sulphur and silica compounds
Fuel Injection systems	HC, CO, NOx	Minimum deposits required
On-board computers	All	-
NOx Storage Traps/ NOx Absorber Catalysts	CO2	Sulphur
Diesel Compression - Ignition Engines		
Engine combustions and Fuel Injector Controls	HC, PM	-
Exhaust Gas Recirculation	NOx	-
Improved Fuel injection Systems	HC, NOx, PM	-
Oxidation Catalytic Converters	HC, CO	Sulphur
Particulate Traps/Filters	PM	Aromatics and distillation temperatures, sulphur

Lean NOx Catalysts/NOx Traps	NOx	Sulphur
Selective Catalytic Reduction	NOx	-

Source: International Fuel Quality Center (IFQC).

2. Gasoline Spark-Ignition Engines and Emission Controls

The first emission control on spark-ignition engines was in the early 1960's in the United States when the crankcase positive ventilation valve (PCV) was installed. It was followed by rudimentary and then sophisticated controls on the engine combustion process, and then by the introduction of the unleaded gasoline/oxidation catalytic converter combination in the mid 1970's. The carburettor gave way to fuel injectors in the early 1980's, and computer-controlled engines with 3-way catalysts soon followed. Today's modern vehicles mainly rely on very sophisticated engine controls, fuel metering systems, and 3-way catalysts with oxygen sensors. The current levels of emission control would not be possible without computer-controlled systems and the use of "clean" or reformulated gasoline.

Evaporative emission controls, which prevent escape of fuel vapours from carburettors, fuel tanks and refuelling, first started in the late 1960's and early 1970's. They have also become more sophisticated with time as the demand for lower and lower emissions has progressed.

Positive Crankcase Ventilation (PCV) Valve

The valve is used to channel the crankcase blow-by gases into the engine intake system (to be burned as part of the intake change), instead of venting them to the atmosphere. The blow-by gases enter the crankcase after having passed by the engine piston rings during the combustion process. These gases contain unburned fuel and oil vapours.

The PCV is a relatively low cost valve that eliminates emission of the HC rich gases in the crankcase. PCV can easily be adopted on the in-use- engines without such device. It is also important to note that fuel composition does not directly affect the PCV valve.

Engine Combustion Controls

Many engine operating factors, such as air-fuel (A/F) ratio and spark timing, influence the engine's production of HC, CO, NOx and PM. Early studies led to lean A/F's and retarded spark timing to reduce HC and CO emissions.

Gasoline's physical properties and chemical composition greatly affect the engine's production of emissions. Gasoline front-end volatility (Reid Vapour Pressure) has to be sufficiently high to allow quick engine starts, especially in cold weather. Cold start is a major contributor to HC and CO emissions. Distillation temperatures, especially T50 and T90, affect HC emissions. Aromatic and olefin concentrations are directly related to the reactivity of the exhaust hydrocarbons. Fuel deposit control additives are essential to keep intake systems, fuel metering systems and combustion chambers as clean as possible to reduce production of HC.

HC and CO emissions are reduced, but NOx emissions are increased, with lean A/F. In addition, retarded spark timing reduces HC and NOx, but decreases fuel economy.

Evaporative Emission Control Systems

Gasoline is a very volatile liquid, and it will evaporate and cause HC emissions. In vehicles, gasoline can evaporate when the vehicle is operating, and when it is not. Evaporation can occur from the fuel metering system, from the fuel tank, and from leaks. Also, these vapour emissions can occur during refuelling when the liquid fuel displaces the vapours in the tank. Evaporative emission control systems were developed in the late 1960’s and commercialized in the early 1970’s to capture these emissions. At this time, activated charcoal pellets were used in a canister to capture and store the HC emissions, which are purged from the canister and into the engine during its operation. Control of refuelling emissions can be done at the service station pump, as is the case in California and many cities in the United States.

Control of gasoline volatility (Reid Vapour Pressure) and front-end composition (mainly C4 and C5 hydrocarbons) are critical for reducing evaporative emissions and their contribution to atmospheric ozone. However, it is important to note that only HC emissions are reduced with evaporative control systems.

Exhaust Gas Recirculation (EGR) System

Nitric oxide (NO) production is a function of engine combustion temperature. Already in the 1970’s, it was recognized that the engine controls then in use would not sufficiently reduce NOx emissions. Thus, the EGR system was developed to recycle engine exhaust gas to the intake charge, and thereby reduce combustion temperature and NOx production. Only NOx emissions are controlled with EGR.

Fuel does not directly effect EGR system operation. However, fuel related deposits have to be minimized to keep the EGR metering valve operating.

Oxidation Catalytic Converter/Unleaded Gasoline

In the late 1960’s and early 1970’s, it became apparent that engine controls alone would not meet the more stringent emission standards that would come into use in the United States in 1975. Thus, the oxidation catalytic converter was developed. It uses a precious metal, originally platinum, to enhance the reactions in the exhaust stream between HC and CO to produce CO2 and water in this way, HC and CO emissions are reduced.

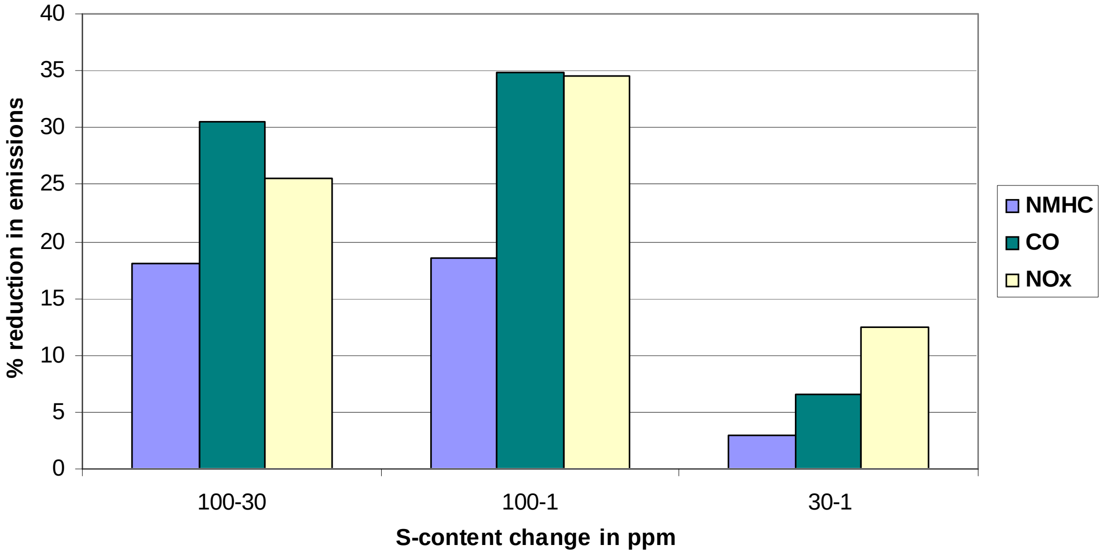
Lead in gasoline was quickly determined to be a major poison to oxidation catalysts, leading to the advent of unleaded gasoline. Although sulphur in gasoline was early on recognized as a poison, it was not as bad as lead, and efforts to reduce it were not fruitful until the 1990’s. Phosphorus was also recognized as a poison and phosphorus containing gasoline additives were eliminated. Phosphorus in engine oil was reduced.

Three-Way Catalysts and Oxygen Sensors

As emission standards became progressively more stringent, and NOx reduction became more important, the need arose to reduce all three simultaneously in the exhaust system. Because of the chemistry involved, the engine had to operate at the stoichiometric A/F, allowing just enough O2 to fully oxidize the carbon and hydrogen in the fuel, and an exhaust system sensor was needed to ensure that it did. Thus was developed in the late 1970’s and early 1980’s, the three-way catalyst, oxygen sensor system. Because it required tight A/F control, on-board computers would also be needed. This type of technology reduces HC, CO and NOx simultaneously.

As indicated in figure 3.13, it was subsequently determined that gasoline sulphur content adversely affected the performance of these systems. Also, gasoline contaminated with silica compounds can readily kill oxygen sensor operation and result in greatly increased emissions. The impact of these contaminants increases with more efficient and advanced catalytic controls.

Figure 3.13. Sulphur Influence On Emission with TWC.



Source: Volvo, 2000

Fuel Injection Systems

Carburettors had been used for many years to meter gasoline to the engine. However, they were very poor for precise metering, and they were subject to problems from build up of fuel-related deposits. Thus, in the late 1970’s and early 1980’s, fuel injection systems were developed to give more precise fuel metering (lower emissions, better fuel economy, and improved driveability and cold starting). Fuel injection systems were more readily controlled using on-board computers than carburettors. Initially, there were throttle-body fuel injection systems, whereby a single or two injectors were mounted in the normal carburettor position and injected fuel into the intake manifold. They were subsequently replaced in the middle 1980’s with port-fuel injection (PFI) systems, which used an injector at each intake port. PFI provided very precise fuel metering. Fuel injection systems helped reduce HC, and provided some benefit on reducing CO and NOx.

The key fuel factor influencing these systems is the presence of good deposit control gasoline additives to prevent deposit formation in the small opening at the tip of each injector and on the intake valves and in their ports.

On-Board Computers (Electronic Control Module)

This is the heart of all modern emission control systems. The computer, in combination with a variety of sensors, is used to monitor and control all of the components of the emission control system, such as the engine’s combustion settings, fuel metering, idle speed, oxygen sensor, three-way catalyst, evaporative emission controls, etc. Also, all On-Board Diagnostics of emission-related problems are monitored and stored in the computer.

All emissions are affected by the operation of the On-Board Computer. However, fuel has no direct impact on the On-Board Computer.

NOx Storage Traps/NOx Absorbtion Catalysts

In order not to trade off higher fuel efficiency for increased pollutant emissions, lean-burn engines requires new aftertreatment technology for the control of NOx. NOx storage traps are currently the most efficient NOx control technology available. These traps not only reduce NOX but simultaneously reduce CO2. However, this technology is sensitive to sulphur hence recent demands from automotive manufacturers for 10 ppm sulphur fuels.

3. Diesel Compression-Ignition Engines and Emission Controls.

For many years, emission controls on diesel engines took a back seat to controls for gasoline engines. However, in the past 20 years or so, the emphasis on diesels has grown rapidly, and now they are receiving much more attention than gasoline engine emission controls, which are quite mature.

Compression-ignition (diesel) engines have been the backbone of the worldwide vehicle freight business for many years. Although many have advocated banning diesel engines because of their “harmful” emissions, this is unlikely to happen. Considering the tremendous improvements that have been made in reducing diesel emissions of NOx, particulates, smoke and odour, it is more likely that use of diesel engines will grow, especially in light-duty vehicles. Light-duty diesel engines have been a tremendous recent success in Europe. Although they cost more than the comparable spark-ignition engine, the buyer can make up the difference because of substantially better (25-30 percent) fuel economy.

For most of their duty cycle, diesel engines operate with considerable excess oxygen, resulting in generally low HC and CO emissions, and fairly high NOx emissions. However, during high-load conditions, they operate close to stoichiometric, or even under oxygen-deficient conditions, and generate large emissions of NOx and PM. Thus, the critical emissions of concern are NOX and PM, and they are the most difficult to control to low levels.

Diesel fuel is much less volatile than gasoline. Thus, there is no need for evaporative emission control with diesel engines.

Engine Combustion and Fuel Injector Controls

Quite early on it was discovered that a significant reduction in HC emissions could be achieved by ensuring that diesel fuel injection nozzles had a positive shut off at the end of their injection phase. Improved fuel injector timing, aiming and spray patterns were also utilized. In this way, HC and PM emissions were reduced.

Luckily, fuel did not play a significant role in the above.

Exhaust Gas Recirculation (EGR)

As with gasoline engines, EGR systems were developed for diesel engines to reduce .NOx emissions. Again, fuel did not play a significant role.

Improved Fuel Injection Systems

During the 1990's, the emphasis on reducing diesel emissions grew, significant progress occurred in diesel engine combustion to reduce HC, NOx, and PM emissions. Key factors included: improved combustion chamber shape; improved fuel injection systems. The latter included: unit injectors; common fuel rails; higher injection pressures; fuel injection rate shaping; multiple injections during the combustion event. To make the above possible, on-board computers were introduced. These systems were capable of reducing HC, NOx and PM emissions. Luckily as in the case of the previous systems, Fuel composition and properties did not play a major role. However, pressure began to increase in Europe and the United States to reduce diesel fuel aromatic concentration and the top end distillation temperatures. The US auto manufacturers also began pushing for increased Cetane quality (from the low 40's to above 50, as in the case in most of the rest of the world). The advent of low sulphur diesel fuel and increased fuel system pressures has resulted in the need for lubricity additives in the fuel to prevent pump and injector wear.

Oxidation Catalytic Converters

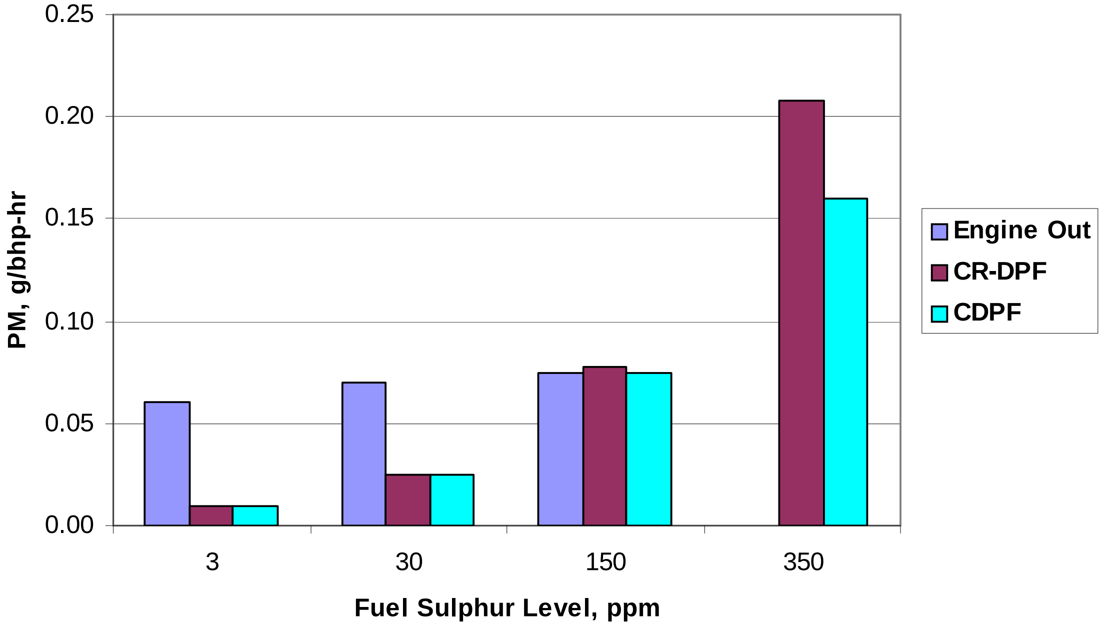
These systems are similar to their gasoline counterparts. However, their task is more difficult because diesel engine exhaust is generally not as hot as that of gasoline engine exhaust. Such catalysts reduce HC and CO PM is also slightly reduced. In this case, diesel fuel sulphur content is the only parameter which impacts the catalyst.

Particulate Traps/Filters (DPF, diesel particulate filter)

To date, achieving the extremely low levels of PM emissions required by the most stringent U.S., European and Japanese standards has not been achievable with the devices so far described. Thus, in the 1990's, the development of particulate traps and filters accelerated. These devices, similar to catalytic converters, utilize a silicate substrate to essentially filter the carbonaceous particles from the diesel exhaust gas as it passes through. The systems would eventually "fill" with particles, causing an increase in exhaust system backpressure, and a loss of power. Thus, the systems have to be periodically regenerated by burning diesel fuel in the exhaust ahead of the trap. This increases exhaust gas temperature to a high enough level to combust the trapped particles. Control of this process is delicate and critical. Today, several types are under development, including catalysed DPF (CDPF), continuously regenerating DPF (CR-DPF), microwave-regenerated DPF.

With the use of the particulate trap, PM emissions are reduced by up to 90%. Reduction of fuel aromatic content and lower top end distillation temperatures can reduce engine PM production, as can reduced fuel sulphur level.

Figure 3.14. Sulphur Influence on PM Filter Technology.



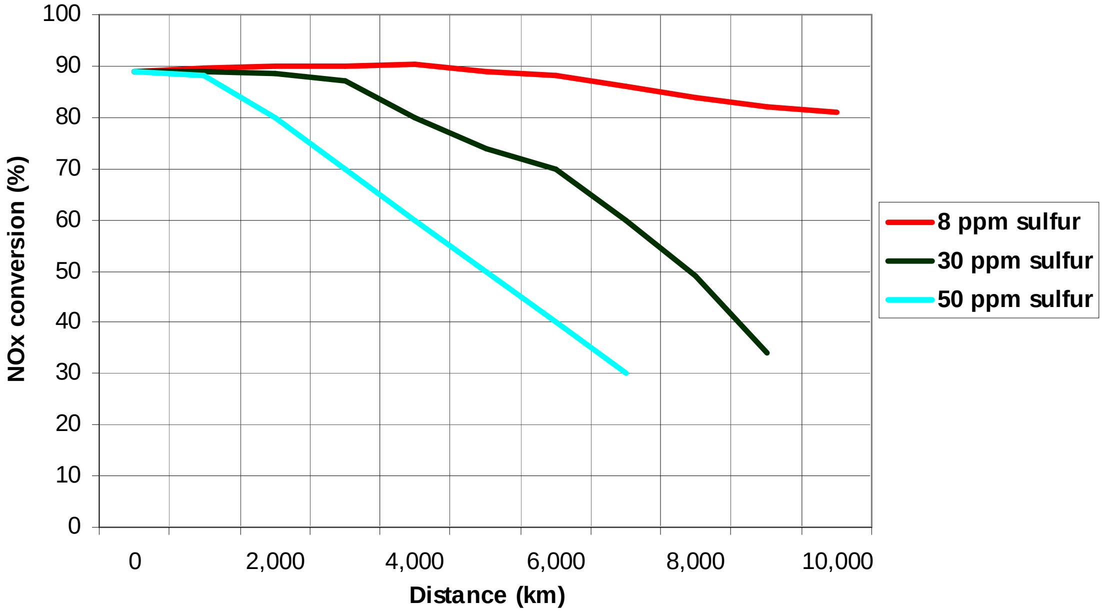
Source: DECSE Program, 2000

Lean NOx Catalysts/NOx Traps

Since one device has yet to be discovered that can simultaneously reduce diesel PM and NOx, special devices were explored for NOx reduction in the 1990's. The two prime candidates, at least in the U. S., are lean NOx converters and lean NOx traps, each of which would be used in a systems approach along with an oxidation converter and a PM trap, making a very complex and costly system. The lean NOx converter requires a catalyst to react the NOx in the exhaust with a reductant, usually HC in the exhaust gas, to generate nitrogen and water. The NOx trap stores the exhaust NOx on a substrate. The NOx is periodically purged by running the engine under rich conditions to generate HC in the exhaust, which reduces the trapped NOx to nitrogen and water. The chemistry for both devices is "delicate" and still being improved.

For example, NOx is greatly reduced up to 90% for both gasoline and diesel, however, ammonia, NH3, can be produced if the chemistry is upset. As in the case of gasoline, the NOx trap, is sensitive to sulphur as higher sulphur content poisons the lean NOx catalyst, requires more frequent regeneration of the NOx trap, and results in decreased fuel economy with both devices.

Figure 3.15. Sulphur Influence On NOx Trap Efficiency.



Source: Volkswagen

Selective Catalytic Reduction (SCR)

Because of the uncertainty regarding commercialization of lean NOx catalysts and NOx traps, SCR has been extensively explored, especially in Europe to meet stricter limits like set by Euro 4 and 5 heavy duty. SCR relies on use of a reductant, an aqueous solution of urea, added to the diesel exhaust gas, to reduce the NOx emissions. The primary issues with SCR are the availability and use of the urea solution, and avoiding what is called “ammonia slip” (the production of ammonia in the exhaust).

With SCR, NOx emissions are reduced, and the benefit of this technology is that fuel properties are not thought to affect SCR; however since it would have to be used in a system with an oxidation catalyst and a PM trap, diesel fuel sulphur content will have to be very low.

Exhaust Plasma Devices

Exhaust plasma devices have also received a great deal of attention in the past ten years to reduce NOx and PM. Some were thought to be sulphur insensitive. Although these devices may have promise, none have made it to production, and interest may be waning. One possibility being explored for in-cylinder reduction of NOx and PM is Homogeneous Charge Compression Ignition (HCCI). This concept uses residual gases in the cylinder as ignition sources for the next combustion cycle. So far it has not been successful under all engine load and speed conditions. Fuel needs for this type of technology are still not fully known.

Case Study 7. The Indian Example

As part of the recent study conducted under the Indian Auto Fuels Policy different engine and emission technologies were selected as necessary to meet the needed to meet improved emissions limits. Together with such analysis they also included a cost analysis. The table below summarises these very important findings. For more information refer to India's Auto Fuel Policy.

Table. Internal Combustion Engine & Emission Control Technologies for Different Emissions.

Level of emission norms	Technology Options
Euro I (India 2000)	• Retarded injection timing • Open/re-entrant bowl • Intake exhaust and combustion optimisation • FIP-700-800 bar, low sac injector • High swirl • Naturally aspirated
Euro II / Bharat Stage II	• Turbocharging • Injection pressure>800 bar, moderate swirl • High pressure inline/rotary pumps, incjection rate control • VO nozzles • Re-entrant combustion chamber • Lube oil consumption control • Inter-cooling (optional, depends on specific power) • EGR (may be required for high speed car engines) • Conversion to CNG with catalytic converter
Euro III / Bharat Stage III	• Multi-valve • Low swirl – high injcection pressure?120 bar • Rotary pumps, pilot incjection rate shaping • Electroinc fuel injection • Critical lube oil consumption control • Variable geometry turbocharger (VGT) • Inter-cooling • Oxycat & EGR • CNG/LPG • High specific power output
Euro IV / Bharat Stage IV	• Particulate Trap • Nox Trap • On board dianostic system • Common rail injection - incjection pressure>1600 • Fuel Cell • CNG/LPG

Source: Automotive Research Association of India (ARAI), August 2002.

Continued….

…continued

Table Spark Ignition Combustion Engine & Emission Control Technologies for Different.

Level of emission norms	**2/3 Wheelers***		**4 Wheelers**
	2-Stroke	**4-Stroke**	**4-Stroke**
Euro I (India 2000)	• Intake, exhaust, combustion optimisation • Catalytic converter	• 4-stroke engine technology	• Intake, exhaust, combustion optimisation • Carburetor optimisation
Euro II / Bharat Stage II	• Secondary air injection • Catalytic converter • CNG/LPG (3 wheelers only)	• Hot tube • Secondary air injection • CNG/LPG (3 wheelers only)	• Fuel injection • Calalytic converter • Fixed EGR • Multi-valve • CNG/LPG
Euro III / Bharat Stage III	• Fuel injection • Calalytic converter	• Fuel injection • Carburetor + Calalytic converter	• Fuel injection + Calalytic converter • Variable valve timing • Multi-vavle • On-board disgnostics system • CNG/LPG
Euro IV / Bharat Stage IV	• To be developed	• Lean burn • Fuel injection + Calalytic converter	• Direct Cylinder injection • Multi-brick calalytic converter • On-board diagnostic system

*Euro norms are not applicable for 2/3 wheelers in India

Source: Automotive Research Association of India (ARAI), August 2002.

:Continued…

…continued

Table Incremental Vehicle Cost For Technology Upgradation.

Vehicle technology change	**Per vehicle incremental costs (excluding taxes)**
Trucks and Buses (HCV)	
Bharat Stage II	Rs 1.25 lakh
Euro III	Rs 2.25 lakh
Euro IV	Rs 4.00 lakh plus
Passenger Cars	
Euro III	Rs 0.50 lakh
Euro IV	Not possible to predict now
Two and Three Wheelers	
Euro III	Rs 5,000 – 10,000
Euro IV	Not possible to predict now

Source: Society of Indian Automobile Manufacturers (SIAM), August 2002.

C. Classroom Materials

Technical issues are important in the design of a medium term fuel quality strategy. If we speak about technical issues we can broadly divide them in: (i) issues related to the refineries that produce the fuel, (ii) the vehicles that use the fuel. The purpose of this exercise is to get an overview of what the most important technical issues are in your country with respect to these two areas. We expect that you will be able to make use of the information that we asked you to collect before coming to the training course in Sydney. Please be aware that it is not intended in this exercise that you come up with the solution to the issues or problems that you identify.

Detailed Assignment

Please try to complete the following overview. The best way to approach is to ask yourself the question: “what are the technical issues for refining in my country if I want to introduce cleaner gasoline or diesel?” or “ What are the technical issues we will face with our vehicles if we want to reduce emissions from these vehicles by introducing cleaner gasoline or diesel”?

Technical Issues - Refining	**Why is this an Issue?**	**Technical Issues - Vehicles**	**Why is this an Issue?**
Gasoline		**Gasoline Vehicles**	
Diesel		**Diesel Vehicles**	

Upon completion of the exercise rank the technical issues in order of priority whereby 1 is the highest priority, 3 is medium priority and 5 is low priority.

Select a person to present the results to the plenary.

Good luck!

D. For Further Reading

Description	URL
Cost of Diesel Fuel Desulphurisation for Different Refinery Structures Typical of the Asian Refining Industry	http://www.adb.org/vehicle-emissions/ASIA/docs/EnstratSulphurReport.pdf
Low-Sulfur Gasoline and Diesel: The Key to Lower Emissions	http://www.cleantransportcouncil.org/docs/Sulfur_Report.pdf
Refinery Technology Online (RTOL) is an independent platform for sharing and exchange of technical information within the Oil Refinery Industry	http://www.r-t-o-l.com/index.php
Oxygenated Fuels Association Website	http://www.cleanfuels.net/
Improving Transport Fuel Quality in China: Implications for the Refining Sector	http://china.lbl.gov/pubs/china_refining_study_final.pdf
What is the US Doing about MTBE and other Clean Fuels	http://www.acfa.ws/pp5.ppt
Indian Auto Fuel Policy	http://www.autofuelpolicy.org/contents.htm
Ultra-Low Sulphur Gasoline and Diesel Refining Study	http://europa.eu.int/comm/environment/sulphur/uls.pdf

E. Endnotes

Abt Associates, 1996, Thomas, 1995, Hirshfeld and Kolb, 1995a and 1995b

Clean Transportation Fuels Supply Security Study. 2003. For the Asian pacific Economic Cooperation, conducted by Hart Downstream Energy Services.

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Hirshfeld and Kolb, 1995a

Improving Transport Fuel quality in China: Implications for the Refining Sector. 2002. Funded by the Energy Foundation, conducted by TERA, China Petrochemical Consulting Corporation and Lawrence Berkeley national Laboratory.

ULS Gasoline and Diesel Refining Study. 2000. Prepared for the European Commission, conducted by Purvin & Gertz.

IV. Module 3 - Pricing and Market Regulation Issues which Influence the Success of Fuel Quality Changes

This Module will focus on the impact of pricing, competition and market regulation on the successful implementation of fuel quality polices. It will show how countries that have market and pricing constraints have more difficulties in switching over to cleaner fuels versus countries without these constraints. Economic and other policy issues to consider in developing fuel strategies including the use of tax differentiation and economic instruments to promote the use and facilitate the penetration of cleaner fuels and refinery modification are also discussed. Case studies from outside Asia and one or two from within Asia are included.

A. Explanatory Section: Fuel Pricing, Taxation, and Market Regulation Issues

As indicated under Module 1, one of the key building blocks to a fuel quality strategy is the use of economic instruments. In this regard, tax incentives and price differentials are an important tool in facilitating the penetration of cleaner fuels on the market.

During the drafting of a fuel quality strategy, it is necessary to carry out an in depth analysis of all possible economic issues, which could both hinder and facilitate the implementation of the strategy. For example,

- Does the country have a liberalised energy market?
- Is there price fixing?
- Do energy subsidies or price support exist?
- Do tax incentives already exist for fuel products or other products e.g. higher tax charges for leaded gasoline or higher sulphur fuels, CO2 taxes on mineral oils versus alternative fuels.

Again this should not be an ominous task as standard material on the use of economic instruments exists and should be used to assess national instruments already in application.

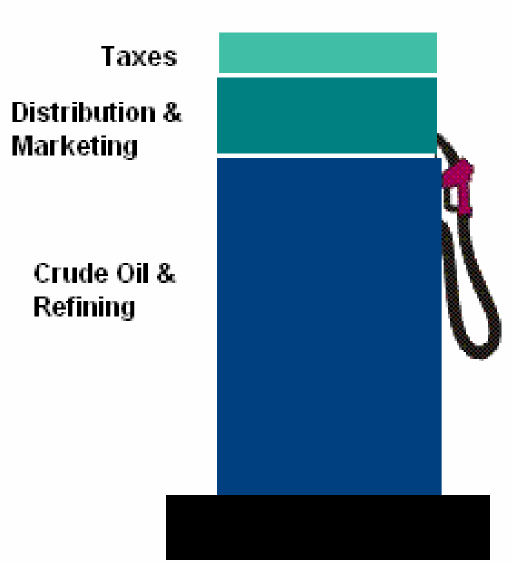
If we look at fuel pricing in detail, there are various factors that have an influence on the price of refined products, some of which cannot be influenced and others that are dependent on government decisions or logistics etc. In general, the price of fuel or a refined product at the pump to the consumer is made up of following parts - production costs (including raw material and related costs), tax and distribution and retailing gross margin (see figure 4.1.). Subsidies also may play a part in fuel price, but this issue is discussed later:

1) **Production cost including raw material** – the majority of the cost of the fuel is the price of purchasing the raw material i.e crude oil; also included in this is the cost of refining the raw material into the refined product itself and related transport costs. In the recent years there has been some variation in crude oil price, which is depicted in the table below. While crude oil prices are very difficult to influence and predict, oil can also be traded on futures markets (but not generally to supply physical volumes of oil) as a mechanism to distribute risk.

2) **Tax** – this can be divided into various taxes, e.g. excise tax, carbon tax and GST (goods and services tax) etc. Not all taxes are levied in all countries. See table below for example on taxes in South Korea.

3) **Distribution and retailing gross margin** - this is the difference between the pump price and the cost (i.e. product cost including tax - the first two parts of the cost). This addition to the price is not profit, but the needed difference to cover costs of distribution and retail from the refinery gate to the refueling station. In addition to that the retailer may add a profit margin on top. The profit margin varies greatly depending on factors like location and time of the week etc

Figure 4.1. Fuel pump price



Source: Adapted from the Energy Information Administration (EIA) webpage, www.eia.doe.gov

1. What is Fuel Taxation?

As can be seen above, fuel taxation is a fraction of the total cost of fuel. However, depending on the country and taxation polices, that tax fraction can be quite substantial. To demonstrate let’s look at South Korea. As can be seen in the table below, South Korea levies various taxes on their refined products. The figures are from May 2002. In total, the taxes make up about 65%, 27 %, 27% and 45% of the retail price of gasoline, kerosene, heating oil and diesel respectively. In 1999 the total tax portion for gasoline, heating oil and diesel was 77%, 32% and 49% respectively. The production price (cost of producing the product at the refinery) accounted for 30%, 57%, 58% and 50% of the retail price for gasoline, kerosene, heating oil and diesel respectively in May 2002.

Table 4.1. Taxation of Petroleum Products in South Korea as at May 2002; (Unit Won/L; 100 Won ≈ 8.7 US cents)

		Gasoline	Kerosene	Heating Oil	Diesel
Refinery Price		390.91	340.89	340.07	326.13
Tax	**Special Excise**	588.00	82.00	82.00	185.00
	Educational	88.20	12.30	12.30	27.75
	Value Added	181.09	69.72	68.74	77.29
	Total (% of refinery price)	857.29 (219%)	164.02 (48%)	163.04 (48%)	290.04 (89%)
Shipment Price		1,248.20	513.91	503.11	616.17
Whole Sale		1,258.97	530.63	519.32	620.72
Retail Price		1,301.90	592.36	586.95	649.97

Source: Korean Petroleum Quality Inspection Institute (KPQII)

The South Korean example shows that the pump price is based on different taxation factors. It is important to note however that in addition to taxation there are numerous other factors, which could also have an impact on pump price. These range from the overall supply/demand for crude oil or for finished products, freight rates/logistics, crude market and regional as well as domestic market competition. The price at the pump can also be influenced by macro economics as well as local and global politics (wars, sanctions etc.)

Fuel taxation is a simple instrument, which can impact vehicle travel demand and fuel use but has no direct influence on congestion and transport management. To date, the main purpose of fuel taxation has been to raise road infrastructure or public transport revenue.

In Europe, fuel taxes are widely used and can amount to more than 75% of the price at the pump (see figure 4.2 below). Comparatively, gasoline taxes in Canada represent approximately 40% of the price at the pump, with variations between provinces and territories. In the U.S. on the other hand, the tax percentage is closer to 10%. The differences in taxation exist due to different goals the various governments want to achieve in the country. Taxes can also be dispersed differently in countries (GST, vehicle taxation, road tax) which all in the end one way or another effect vehicle emissions and the transport sector - e.g. the more you drive, and hence the more fuel you use, the more you pay.

Taxes for fuels can also be levied on certain components in fuel. For example, a country can apply a “sulphur tax”, which means that fuels are taxed based on their sulphur content. This means the higher a fuels sulphur content the more taxes producers of that fuel will have to pay. This sort of tax encourages refiners to produce lower sulphur fuels so as to pay less tax. The flip side of the “sulphur tax” is the sulphur tax incentive. Tax incentives can be placed on fuels with certain cleaner properties (e.g. low sulphur fuel, reformulated gasoline etc). This is discussed in more detail in the case studies below on Sweden and Finland. Tax incentives for cleaner fuel properties are used in a variety of ways to stimulate the market penetration of such fuels. For example, in Italy, France and the UK a tax incentive is used for emulsified diesel, commonly known as “white diesel”, which is a blend of conventional diesel and water. Not only do producers of this fuel claim large reductions in NO_x and PM, but the water portion of the fuel is considered a renewable property and thus is not taxed in most countries. This untaxed portion can amount to up to 20% of the fuel depending on the blend. Fuel taxes also have other advantages. They smooth out the fluctuations of prices at the pump.

With a higher tax share, the high price fluctuations on world markets have less impact. For example Europe was much less affected in the short term than North America by the recent surge in crude oil prices. A doubling of the before-tax price increases the after-tax price by 70% in the US, compared to only 25% in England. For environmental purposes there is a valid case to tax both gasoline and diesel fuel use. Policies on fuel taxation need to be evaluated carefully to avoid the possible and as higher fuel prices lead to less fuel consumption, foreign dependence is reduced in the long term.

Taxes vary from country to country. Generally speaking, however, the average tax per litre in higher-income countries is two and a half times that of developing countries for both gasoline and diesel. This difference is also reflected in the higher gross prices of OECD countries, see Table 4.2.. According to a World Bank paper (Bacon, Rober. 2001), the tax as share of the final price of gasoline and automotive diesel was 67% and 59% in OECD countries (in 1999). In non-OECD countries the percentages were 44% and 40% respectively. Additionally, kerosene was taxed in non-OECD countries (23%), where as this was not case for OECD countries.

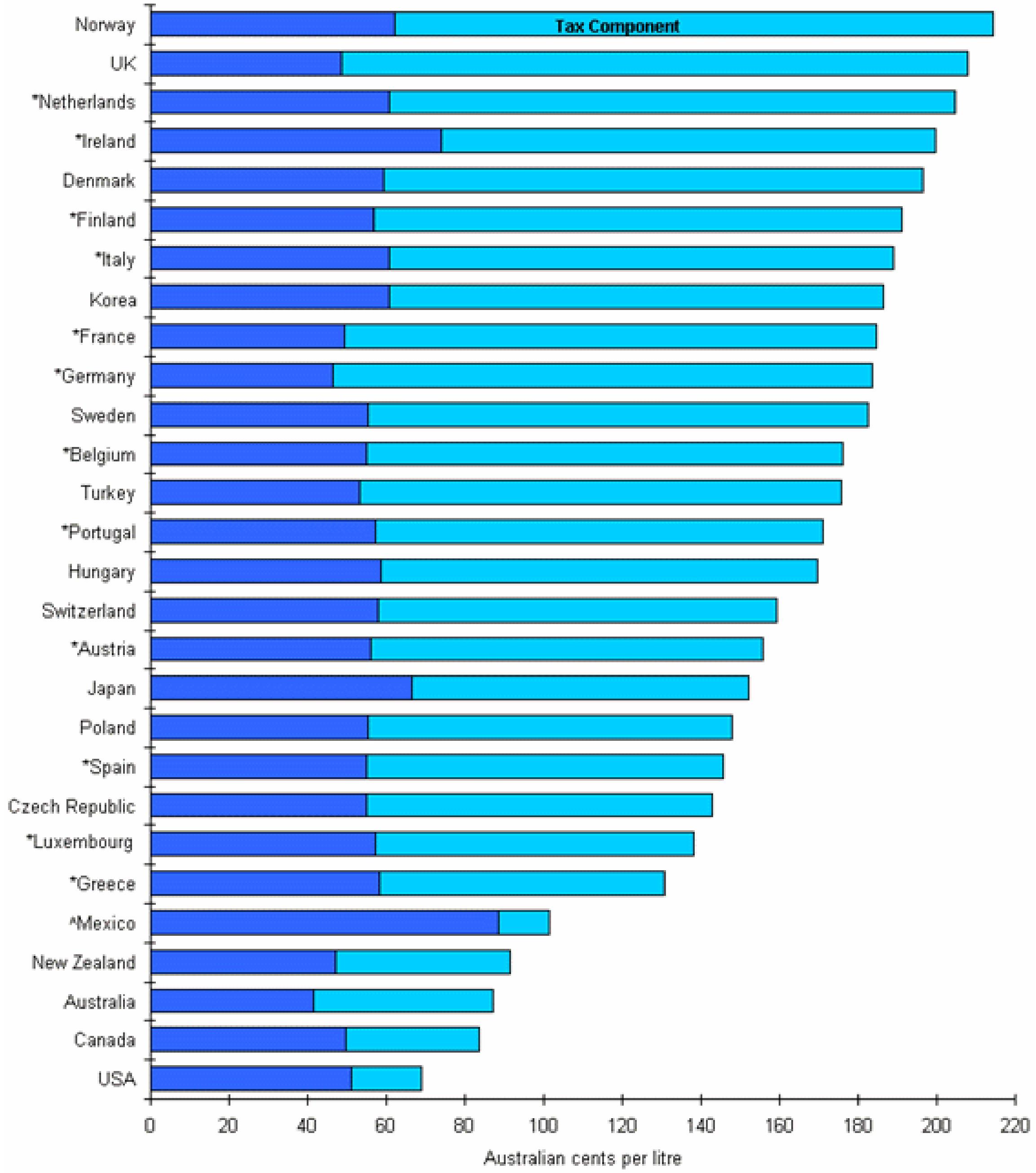
Table 4.2. Average Petroleum Product Taxes and Prices in OECD and non-OECD countries, 1999

Fuel and Country Group	**Tax as share of final price (%)**	**Tax (US cents/L)**	**Net price (US cents/ L)**	**Gross price (US cents/L)**
Gasoline				
OECD countries	67	58.1	25.2	83.3
Non-OECD countries	44	22.9	26.9	49.7
Diesel			.	
OECD countries	59	42.4	25.0	67.4
Non-OECD countries	40	16.6	22.8	39.4
Kerosene				
Non-OECD countries	23	5.1	12.3	17.4

Note: The table shows data from 22 OECD countries (Excluding the Czech Republic, Hungary, Mexico, Poland and Turkey) and 37 non-OECD (mostly developing) countries.

Source: Bacon, Rober. 2001. Petroleum Taxes, Private Sector and Infrastructure Netweorj: The World Bank Group.

Figure 4.2. Gasoline Prices and Taxes in OECD (Organisation for Economic Cooperation and Development) Countries; December Quarter 2002



Source: Australian Institute of Petroleum (AIP), www.aip.com.au

In industrialized countries with a highly sophisticated tax system, fuel taxes play an increasingly important role. In developing countries, the collection of taxes (income and sales) as the main sources of state revenue is quite difficult and much in arrears. For example, in the sub-Saharan Africa, fuel taxes on petroleum products accounted for 35% of the government’s total tax revenues for 1990.[2]

Nonetheless, policymakers in developing countries need to be mindful of how taxes (or subsidies) affect the relative prices of fuel, since too large a difference in prices between products can lead to fuel switching and adulteration, adversely affecting both the government tax take and pollution levels. In other cases, however, these instruments may encourage the use of cleaner fuels and speed up the market penetration of certain fuels. Thus to avert these complications any taxation policy should be well prepared, possible socio economic impacts addressed, as well as the adverse effects of inter-fuel substitution, misuse and the adulteration of fuels.

From the point of view of national revenue growth, goods that have the highest value should bear the highest tax rates. In India for example this means that products, which are regarded as a luxury goods like (regular and premium grade) gasoline are taxed higher. Automotive diesel on the other hand is taxed less severely due to its importance in the mining, agricultural, and as goods transport industry. Fuel oil, heavy diesel oil and also LPG are mainly used for electricity production and other industry purposes and therefore taxes are even less than for automotive diesel. Furthermore, kerosene, which is often used by low income groups for cooking for example, remains untaxed for social as well as environmental reasons (to help prevent deforestation). In some countries cases kerosene may even be subsidized.

More often than not lower taxes are set on kerosene (in some cases even subsidies may be given) as a way to reduce its cost and assist its primary users; lower income households. This however can erode the total tax collected, as when kerosene is substituted for or mixed into gasoline or diesel, the tax collected from the latter two is ultimately less. On the other hand, higher taxes on kerosene can also hurt lower income households, which tend to spend larger share of their budgets on this fuel than better-off households. Therefore, in this particular instance, if governments wish to offset the effect of higher kerosene taxes on poor households, they can do so through targeted assistance rather than across-the-board kerosene subsidies.

2. How do Government’s use Fuel Taxation as an Environmental Instrument?

Environmental taxes are used to stimulate the use of more environmentally sound products or processes and/or penalise the use of “dirtier” products. In order to replace dirtier fuels with cleaner fuels set out by environmental policies, it is necessary to make the producer and the consumer substitute the dirty fuels with environmentally friendlier fuels e.g. unleaded gasoline for leaded gasoline and low sulphur gasoline/diesel for high sulphur gasoline/diesel.

As explained under Module 1, there are a variety of different legislative and non-legislative instruments, which can be used to implement a fuel quality strategy. In this regard, there are two specific sets of instruments that can be used to influence changes in fuel quality and fuel production processes:

Economic instruments or market based instruments (emission fees, differential vehicle taxation, fuel taxation, parking charges etc.)

Command and control regulations (fuel specifications, voluntary agreements (self regulation), emissions standards, inspection and maintenance systems, fuel quality monitoring systems etc)

This chapter will concentrate on economic instruments such as fuel taxation and related issues such as subsidies and price distortion. Other economic instruments such as emission fees, permits, parking charges etc are not the focus of this manual, but should be considered when developing a fuel quality strategy.

Table 4.3. Taxonomy of Policy Instruments for Controlling Auto Pollution

	Market based incentives		**Command and Control Regulation**	
	Direct	**Indirect**	**Direct**	**Indirect**
Vehicle	Emission Fee	• Tradable permits • Differential vehicle standard taxation. • Tax allowances for new vehicles.	Emissions	• Compulsory inspection and maintenance of emissions control systems. • Mandatory use of low polluting vehicles. • Compulsory scrappage of old vehicles.
Fuel	-	• Differential fuel taxation • High fuel taxes.	• Fuel composition. • Phasing out of high polluting fuels.	• Fuel economy standards. • Speed limits.
Traffic	-	• Congestion charges. • Parking charges. • Subsidies for less polluting modes.	• Physical restrain traffic • Designated routes.	• Restraint on vehicle use. • Bus lanes and other priorities.

Source: Button, Kenneth. 1993. Transport, The Environment and Economic Policy. Edwards Elgar Publishing Ltd. UK.

So, apart from control measures such as bans or standards or voluntary agreements, which also in a way anticipate quota-enforcement (as seen above under Table 4.3.), the main tools for changing production and consumption patterns are market based or economic instruments such as taxes and subsidies. With these tools, governments can modify the price of goods based on their environmental credentials. This in turn will modify consumer behaviour and towards the purchase of cleaner goods thus increasing the ratio of clean versus dirty product output.

At best there are only limited applications of economic instruments in the design of pollution control strategies. Generally speaking, economic instruments are applied according to the principle of lowest political and consumer resistance. There are also fiscal bias' in the use of economic instruments as there is a larger focus on revenue generation than on environmental effectiveness. In fact if a tax or a subsidy has a beneficial environmental impact, it could be incidental and not pre-planned. For even though the benefits of taxation on altering consumer behaviour towards more environmentally friendly products are becoming increasingly understood, most fiscal legislation today still does not make this direct link.

3. Tax Incentives and Subsidies

Economic instruments can also be used to offset the cost of refinery upgrades to enable clean fuel production as well as price distortions as mentioned above. There are three economic instruments which can assist in reaching market objectives and increasing the ratio between improved and non-improved fuels. These are:

Taxes on the non-improved fuel

Tax incentives on the improved fuel

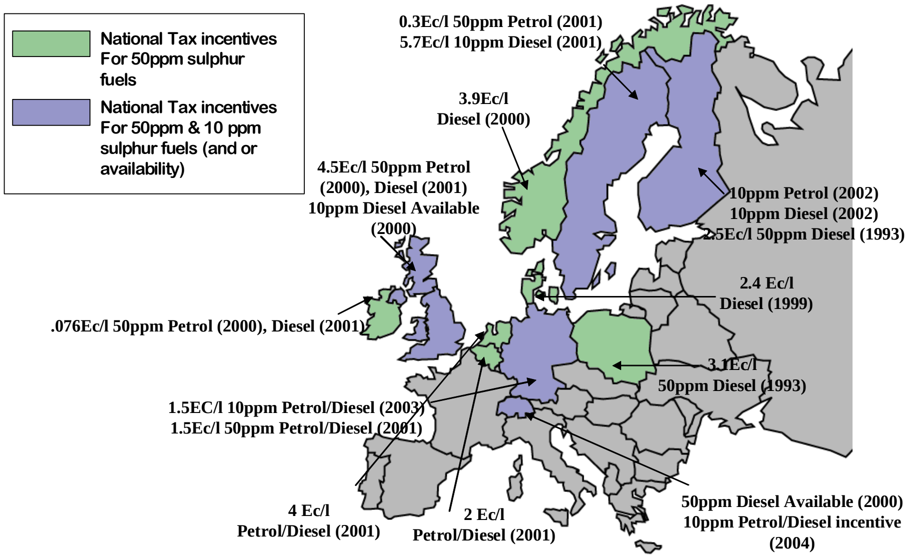
Subsidies for pro active market players.

In Northern Europe (e.g. Finland, Norway, Sweden), where fuel prices are generally high due to high taxes (refer Figure 4.2.), there is more maneuverability between the actual cost and the pump price. As indicated before, this therefore allows for greater flexibility in the use of tax incentives. Sweden is a case in point. Sweden developed its tax incentive program to create price differentials between clean and dirty fuels as well as pump price flexibility to offset investment costs to refineries, This allowed refiners to produce and sell both highly taxed dirty fuels and clean fuels eligible for a tax incentive at the same time, and created a greater price differential between the clean fuel and the dirty fuel, which drove the user towards the cheaper greener alternative, in this case the cleaner fuel (due to tax incentives). This is discussed in more detail in the case study below.

Tax incentives have been widely used in Europe to introduce cleaner fuels before the mandated deadline. The current maximum limit for sulphur in gasoline and diesel in the EU is 150 ppm and 350 ppm respectively. Starting January 1 2005, the maximum limit for both fuels will be 50 ppm. At the same time, however, EU Member States have to ensure that gasoline and diesel fuels with a sulphur content of max 10 ppm are available on a balanced geographic basis and that these fuels comply in all other respects with the other fuel quality requirements (as set out in Annex III, IV of Directive 98/70/EEC). Not until 2009 will complete market coverage of max 10 ppm sulphur fuels be required in the EU.

Interestingly, due to the use of tax incentives (see figure 4.3.) in several European countries market penetration of cleaner fuels has been much swifter than the mandated regulatory deadline. For example, today there is almost almost full penetration of 10 ppm sulphur diesel in Germany, even though the tax incentive for 10 ppm was only put in place in January 2003. In fact what has been observed, is that the use of tax incentives has facilitated the introduction of low sulphur fuels, especially in the countries that have higher tax margins. As Belgium and The Netherlands are not in this category and they have lower tax margins, it is currently more profitable for their refiners to export their low sulphur products to Germany, where the tax margins are a lot higher. This is also in part why Germany has been able to virtually penetrate its market with zero sulphur fuel already now.

Figure 4.3. Tax incentives in the European Countries



Source: The International Fuel Quality Center (IFQC), 2003

While providing tax incentives is one option to influence the introduction of improved fuel grades, subsidies is another option. Subsidies are usually a set sum per year or a percentage of the investments provided by the government used to upgrade the refinery. So whereas tax incentives are market mechanisms that push for the introduction of cleaner fuels, subsidies to promote the introduction of cleaner fuels, are not market oriented but assistance driven It is important to note that traditionally, subsidies are more commonly used in developing countries, whereas developed countries are more inclined to use tax incentives.

Case Study 8. Hong Kong Fuel Pricing

Background - Hong Kong has no oil production or refining capacity or vehicle production capacity but imports both vehicles and fuels from abroad. By the mid to late 1980's, it was apparent that motor vehicles were the dominant pollution source with NO2 and PM the major concerns. In an effort to address the problem initially with gasoline fueled vehicles, Hong Kong decided that it needed to introduce tighter standards for new vehicles. However, it became apparent that before it could do so, it would need to improve gasoline quality since the major producers of cars coming into the country were installing catalytic converters on all new vehicles and these systems required the use of unleaded gasoline. As a very small market, Hong Kong concluded that it would be very difficult to mandate a switch to unleaded gasoline. One concern was that many stations had only one gasoline pump and so could only sell one grade of the fuel; requiring the installation of an additional pump in a very congested and highly developed urban area. On the other hand, there was strong resistance by some vehicle owners that their vehicles would experience mechanical problems if forced to use lead free gasoline.

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To solve this problem, Hong Kong decided to introduce a tax incentive scheme that resulted in the price at the pump being cheaper for lead-free fuel than for leaded. Within one month of the introduction of this tax scheme, approximately 70% of the fuel being sold in Hong Kong was unleaded and the introduction of stringent new vehicle standards proceeded without difficulty. On April 1, 1999, the sale of leaded gasoline was banned completely in Hong Kong. In order to assure that benzene levels would not rise with the introduction of lead free fuel, on April 1, 2000, the benzene content of gasoline was set at a maximum of 1%..

Issue Focus - By the late 1990's it became clear that the most difficult remaining problem is to reduce emissions, especially PM, from diesel vehicles. While diesels are only 30% of the vehicle population, they drive 58% of the mileage and emit 75% of the NOx and 98% of the vehicle related PM. It also became clear that the key to reducing both new and in use diesels was fuel quality. Therefore the government focused on two principle fuel related measures:

(1) Shifting diesel taxicabs to LPG fuel instead of diesel fuel, and
(2) Encouraging the introduction of ultra low sulphur (<50 PPM) diesel fuel, to enable further tightening of new vehicle standards and retrofit of existing vehicles

With regard to low sulphur diesel fuel, the authorities looked to their experience with lead free gasoline and decided to introduce tax incentives. On July 7, 2000, the following incentive scheme was introduced.

US$/gallon	500 ppm S	50 ppm S
Fuel Duty	1.04	0.56
Pump Price	3.32	3.24

Not surprisingly, since the retail price of low sulphur fuel was lower than the retail price of high sulphur fuel, by August 1, 2000, the Hong Kong domestic market was 100% low sulphur fuel. In 2002, to assure that there would be no backsliding, the government made the use of ultra low sulphur fuel mandatory.

Analysis - Hong Kong demonstrates the important role that fuel pricing and taxation policy can plan in stimulating the introduction of clean fuels. This has enabled the introduction of stringent standards for new vehicles; Euro III was introduced in 2002 and a major retrofit program involving over 40,000 diesel trucks and buses is underway

Case Study 9. Sweden

Fuel specifications stipulated in Directive 98/70/EEC for 2000 have been implemented in EU Member States. Interestingly, some countries have gone already beyond the 2005 specification by deciding to phase-in even cleaner fuels via tax incentives. Interestingly Member State has opted to do so differently. This case study will show how Sweden used its tax incentive program and price differentials between clean and dirty fuels, and related pump price flexibility to offset investment costs to refineries.

Background - Sweden as one of the fore runners in introducing clean fuels in Europe has had clean fuel programs in place since the early 1990s. With the help of tax differentials Swedish environmentally classified diesel qualities (MK1 and MK2) were first introduced in 1991 and Swedish MK2 gasoline was introduced in 1994.

The government of Sweden has supported the introduction by differentiating taxes so that cleaner fuel grades have lower taxes than standard quality fuel. Through these tax differentials refiners could invest and pro-actively introduce the improved fuels to the market. In effect the complete market was transformed in which cleaner fuels dominated.

Issue Focus In the 1990's it was thought that the majority of consumers would not switch to cleaner fuels if these were priced higher and that in industry would not invest beyond legal requirements to produce clean fuels. To create the market incentives, taxes were differentiated so that more polluting fuels were taxed more. Therefore the introduction of cleaner fuels was facilitated through the following tax incentives scheme: MK1 diesel (10 ppm) has a tax incentive versus MK3 (350 ppm) diesel of SEK 524/m3 (ECU 59.94/m3).

The aim was to (1) eliminate the cost advantage of lower quality fuels in consumer pricing since improved fuels in general cost more to produce, (2) catalyze refinery investments so that the fuels could be produced on a large scale even before the mandatory legal requirements and (3) offset increased refinery costs associated with improved fuel grades.

Generally oil companies in Sweden did not take the lead in introducing improved fuel qualities before tax differentials were in place. But following the introduction and further widening of tax differentials the refiners invested to manufacture improved quality fuels.

Following are the differentiated taxes on diesel:

1990:	Standard	ECU 127 / m3	
1991:	MK1 (10 ppm)	ECU 107 / m3	(tax decreased by ECU 20 / m3)
	MK2 (50 ppm)	ECU 131 / m3	(tax increased by ECU 4 / m3)
	MK3 (350 ppm)	ECU 148 / m3	(tax increased by ECU 21 / m3)

January 1, 1991 tax differentials were introduced by the Swedish government, which lead to the increase of the marketshare of MK1 diesel to 85%. Then in December 1, 1994 the Swedish government introduced tax differential on gasoline after which in June 1995, Swedish petroleum companies voluntarily agreed to only sell MK2 gasoline.

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MK1 diesel virtually replaced MK2 (50 ppm) through tax incentives and now has 94% of the market whereas MK3 predominantly used by HDVs has 6% of the market. The tax incentive between MK1 (50 ppm) MK2 (1250 ppm) gasoline is SEK 0.03/L (ECU 0.01/ L). In most instances the tax differential is a fraction of the normal annual price fluctuation caused by world markets, i.e. tax differential for gasoline was ECU 0.007 / L – the price variation during 1996 was ECU 0.07 / L.

The tax differentials in Sweden were large enough to motivate the industry to invest without increasing the price to the consumer for the improved fuels. In effect, higher sales volumes of improved fuels covered the extra cost and investment with increased price per liter for the refiner. At the same time, however, they were small compared to tax revenues from transport fuels.

In 1991-1996 the value of differentials due to the use of improved fuel qualities (tax reductions) was ECU 0.6 billion and the value of differentials due to he use of poorer fuel qualities (tax revenues) was ECU 0.5 billion. Therefore, the revenue excluding differentials was ECU 18.5 billion. Industries response to the tax differentiating policies was to invest approximately ECU 540 million over this period.

Analysis - Tax differentiation is a quick and effective method to change market conditions so that improved fuel qualities for road transport can be introduced. They should, however not be considered as a tax revenue gain or loss.

If consumers are not willing to pay a higher price for less polluting fuels, then tax differentials need to be large enough to cover extra investment and net increased operating costs in ordered to encourage refiners to produce the improve fuels.

After the new fuels have been introduced and the appropriate investments have been made a new steady state" has been achieved – tax differentials can then be altered to reflect new market condition. The important thing to remember is that the size of the tax differentials in most instances needed to change market conditions are small

4. Price Distortion

Price distortion is most commonly found in developing countries, and can be seen in the relative price difference between gasoline and diesel. In India for example, the price of gasoline compared to diesel is kept high through the use of taxes. It could be assumed that the reasoning behind the price difference is that gasoline vehicles are presumed to be more prestigious and therefore owners of such vehicles are seen to have higher incomes and a higher buying power to pay even though the external costs of gasoline vehicles are lower than those of diesel vehicles. Price distortions can also be observed for other fuels such as kerosene (used for cooking purposes).

In most countries the gross price for gasoline is much higher than that for diesel. This reflects a general tendency to encourage the use of diesel as is the case in Europe and also in Asia. In the case of many Asian countries, however the old car fleet and thus prevailing outdated engine technology coupled with poor fuel quality increases diesel emissions in megacities. This therefore justifies the need to equalize gasoline and diesel prices.

In India for example, customs tax for petroleum fuel ranges from 10 to 20 %, excise tax between 16 to 32 % and state tax between 4 to 40 % depending on fuels. The lowest tax is levied on CNG and kerosene and the highest on diesel and gasoline. The latter two are also subjected to additional excise taxes of Rs. 1 / L and Rs. 7/L respectively. The taxation of different fuels in India continues to be distorted which leads to adulteration, e.g. mixing of lowered priced fuel with costlier fuels and diversion of fuels to other uses etc. Still, encouraging the use of diesel fuel for mass transit (public transport) may be desirable as a way of relieving congestion.

5. Competition and Market Regulation

The motivation for Finland (and Sweden) to introduce improved fuel qualities was to reduce vehicle emissions that have a negative effect on human health and the environment. The market drivers for this were created by differentiating taxes on gasoline and diesel grades, where more polluting fuels were given higher taxes. While fuel tax differentiation was the main market driver for introducing improved fuel qualities, different grades were brought onto the market in different ways depending on refinery configuration and gasoline versus diesel production capacity.

The deregulation of the Finnish market made refineries responsive to environmental challenges and higher value added products. But one of the the key motivators for Fortum to introduce a cleaner fuel grade in Finland wad to protect its market share from dirtier fuel imports from neighbouring Russia. Additionally this enabled Fortum to be a front runner in the production of clean fuels in Europe but also in other parts of the world which in turn helped them gain marketshare and promote themselves with a “clean image”. For example, Fortum was one of the first European producers to be able to provide reformulated gasoline to the California market according to their strict CARB requirements

A closed market with a state energy supplier will not facilitate the production and market penetration of cleaner fuels unless the government clearly mandates a switch to cleaner fuels and finds ways to assist the state energy suppliers. Fortum Oy Finland previously Neste is a good example of government and state oil company cooperation in the production and market penetration of cleaner fuels with mandatory legislation and tax incentives for swifter market penetration. The deregulation of the Finnish market resulted in the introduction of improved fuels (e.g. oxygenated gasoline) before tax differences were even put in place. The Finnish refineries were therefore able to protect their domestic market share whilst penetrating other markets with their cleaner fuels such as the Swedish and California markets. The case study of Finland is discussed in more detail below.

Also Japan has set a timeline to introduce 10 ppm sulphur we still need to come to an agreement on this fuels in the future. Although 10 ppm sulphur gasoline and diesel will not be required (mandated until January 2008 and January 2007 respectively, the introduction of these fuels to the market will already be started earlier, in 2005. To achieve early market penetration of these fuels, the Ministry of Economy, Trade and Industry (METI) is studying the possibility of providing a fiscal scheme to support the local oil industry in their marketing efforts in introducing zero sulphur fuels.

6. How can I use Tax Incentives as a Fuel Quality Strategy Tool?

Tax differentials are a quick and effective method to change market conditions so that improved fuel qualities for road transport can be introduced. They change the market conditions in a way that improved fuels can be rapidly introduced. If consumers are not willing to pay a higher price for less polluting fuels (as is often the case), then tax differentials need to be large enough to cover extra investments and net increased operating costs, the associated extra costs for producing improved qualities less general productivity improvements due to investments associated with improved qualities in order to encourage refiners to produce the improved fuels. The principal behind the tax differential is that the consumer of the lower quality fuels contributes to tax revenue, i.e. "polluter pays". All in all, the tax differentials on transport fuels gave the refiners in Europe an incentive to invest and in some instances provided positive effects on operations, i.e. more productivity and flexibility.

In addition to that, if tax differentials are carefully planned the loss of tax revenue to the government can be minimized or even neglected. This principle is shown in the case study on Fortum below, where the overall tax increase on gasoline in Finland sponsored the diesel tax incentive that enabled the quick introduction of reformulated diesel. This means that the tax on gasoline was purposefully raised by the government to cover revenue loss from the tax decrease on reformulated diesel. This is a "zero sum" gain as no tax revenue loss has occurred due to the equal distribution between revenue loss from the tax incentive and revenue gained from the higher priced gasoline. This process is encouraged in developing countries where tax revenue is essential and any loss of such revenue cannot be justified.

Case Study 10. Fortum Oy (previously Neste)

A closed market with a state energy supplier will not facilitate the production and market penetration of cleaner fuels unless the government clearly mandates a switch to cleaner fuels and finds ways to assist the state energy suppliers

Background - Fortum Oy Finland previously Neste is a good example of government and state oil company cooperation in the production and market penetration of cleaner fuels with mandatory legislation and tax incentives for swifter market penetration and offsetting investment costs.

Issue Focus - The motivation of Finland for introducing improved fuel qualities was to reduce vehicle emissions that have a negative effect on human health and the environment. At the same time it opened the opportunity to protect its marketshare as Russia was not able to produce the improved fuel grade. To create the market drivers, taxes were differentiated on gasoline and diesel grades. Compared to Sweden however, Finland brought the fuels into the market in quite a different way.

The deregulation of the Finnish market made refineries responsive to environmental challenges and higher value added products. This resulted in the introduction of improved fuels before tax differences were in place (for oxygenated gasoline). Oxygenated gasoline "City Gasoline" was introduced to the market in 1991. It was marketed by Neste and purchased by consumers ahead of the introduction of the EU requirements. The marketing companies absorbed the higher production costs at this time.

Additionally, the Finnish refiner responded not only to tax differentials signaled by their government but also by Swedish tax differentials already in place. In comparison, the Swedish oil companies only started investing when the tax differentials were widened.

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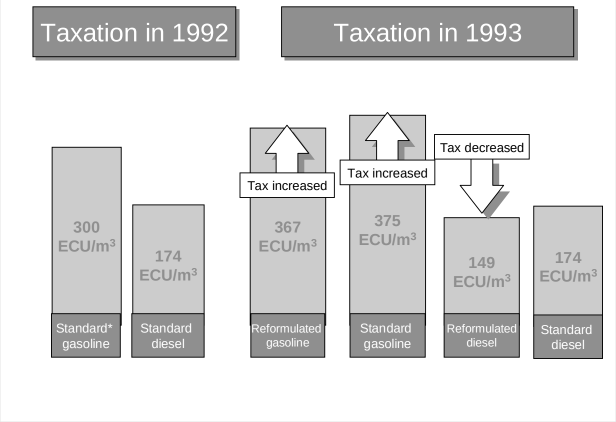
Two years later, in 1993, specifications on improved fuel qualities were introduced in Finland together with tax differentials. To support consumer demand for diesel; the Finnish government policy was to increase gasoline taxes to compensate for tax incentive on diesel (see Figure 4.4.). So, compared to the taxation in 1992, tax on gasoline was further increased and tax on reformulated diesel was reduced.

Figure. Taxation in Finland in 1992 and 1993.



Source: Arthur D Little AB. 1998. *Case Study Report- The introduction of improved transport fuel qualities in Finland and Sweden*.

Finland's final taxation program in 1993 was based on the following:

- general tax for gasoline was increased by ECU 67/m3 (from ECU 300/m3)
- standard gasoline tax was further increased by ECU 8.3/m3 compared to reformulated gasoline
- ECU 3.3/m3 of the overall tax raise on gasoline sponsored the diesel tax differentiation
- reformulated diesel tax was reduced by ECU 25/m3 compared to standard diesel

The tax differentiation strategy was to promote the use of reformulated gasoline and low-sulphur diesel through tax differentiation by levying lower excise duty rate on these products compared to the "old" qualities of gasoline and diesel. In order to permit the same retail price to new and old qualities of these products and to compensate the difference in production costs between them, the amount of the duty graduation was equal to this difference. The idea was to carry out the strategy without any tax revenue losses. Therefore the excise duty rates on old qualities were raised whereas the new qualities could benefit from the duty rates applied on the old qualities before. It is important to note that the tax differential in most cases was a fraction of the normal annual price fluctuation caused by world markets.

The graduation strategy succeeded well - in the short period of two years almost 100 % of all motor gasoline sold in Finland appeared to be reformulated unleaded gasoline, refer Figure 4.5. Similar results were reached in the market share of low-sulphur diesel.

The total value of tax differentials to introduce improved fuel grades in Finland for the years 1993 to 1996 were approximately ECU 0.25 billion, representing about 5% of the total revenues from transport fuels. The use of more polluting fuels provided an additional tax revenues of ECU 0.10 billion (3%).

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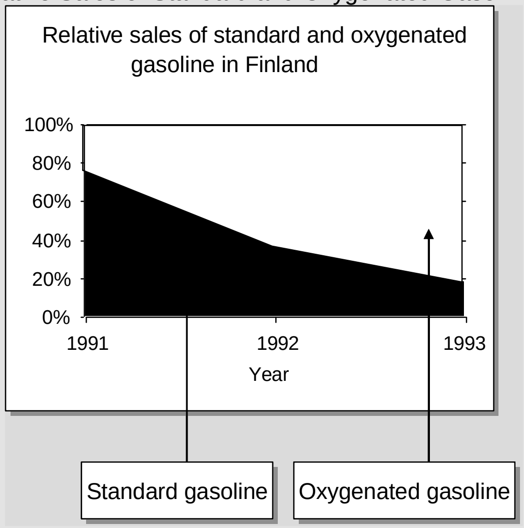
Figure. Relative Sales of Standard and Oxygenated Gasoline in Finland.



Source: Arthur D Little AB. 1998. *Case Study Report- The introduction of improved transport fuel qualities in Finland and Sweden*.

Analysis - Tax differentiation is a quick and effective method to change market conditions so that improved fuel qualities for road transport to be introduced. If consumers are not willing to pay a higher price for less polluting fuels, then the tax differentials need to be large enough to encourage refiners to produce the improved fuels. The differentials will then need to sufficiently cover both investments and net increased operating costs.

The tax differential policies gave Finnish (and Swedish) refiners an incentive to invest. Additionally, in Finland, the refiner was able to reduce his initial investment by switching to a sweet crude slate; in other countries this may not be possible as major global crude oil reserves are located in the Middle East and are sour.

B. Classroom Material

One of the key issues with respect to cleaner fuels is the pricing issue. Pricing, taxation and incentives are important instruments to encourage refiners to produce cleaner fuels and also to encourage consumers to buy cleaner fuels. Experience shows that different countries have taken different approaches in this respect. The objective of this exercise is to brainstorm about what could be possible approaches in your country.

1. Current incentives and subsidies

As first step please list any current pricing incentive/ subsidy/tax incentive you have in place in your country and describe whether they were put in place for environmental or other reasons.

	Pricing **Incentive / subsidy / tax incentive**	**Analysis**
Import crude		
Refining Equipment		
Diesel end product		
Gasoline end product		
Vehicles		

2. Future incentives and subsidies

As a second step in this exercise please think deeply what possible incentives and subsidy schemes can be applied in your country with the specific aim to promote the production and the adoption of cleaner fuels in your country. In this case you need to explain in the description column whether this is a temporary measure or whether it is permanent, also is it industry wide or only for early adopters. In the column on affordability please summarize what the implications of the proposed incentive or subsidy will be for the treasury.

	Proposed Pricing incentive/subsidy/tax incentive	**Description – temporary- for all or for few etc**	**Affordability**
Import crude			
Refining Equipment			
Diesel end product			
Gasoline end product			
Vehicles			

Please select a person who will present this to the plenary and good luck!!!!

C. For Further Reading

Description	URL
MTBE Supply and Demand	http://www.efoa.org/fr/what_mtbe/supply_demand.htm
The Auto-Oil II Cost-Effectiveness Study (using TREMOVE model) with base case scenarios for various EU countries	http://europa.eu.int/comm/environment/enveco/auto-oil/index.htm
Fuel Prices and Taxation (1999) – GTZ	http://www.zietlow.com/docs/..%5Cgtz/fuel.pdf
Fuel Prices and Vehicle Taxation (2001) – GTZ	http://www.zietlow.com/docs/Fuel%202000.pdf
A Primer on Gasoline Prices in the U.S.	http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/primer_on_gasoline_prices/html/petbro.html

D. Endnotes

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V. Module 4 - Monitoring and Enforcement of Fuel Quality Policies

This Module will demonstrate that fuel quality strategies cannot be fully successful without proper monitoring and enforcement mechanisms and will show through an on site visit and fuel quality monitoring system (FQMS) examples from the US, EU, Australia and several other countries from the Asian region, that a variety of monitoring systems exist but that the success of these systems is fully dependant on effective design, including deterrents, resources, oversight and full implementation.

A. Explanatory Section

This section will look at how a fuel quality strategy must include a monitoring system, even if it is a self monitoring system, and that fuel quality specifications cannot be set, and then expected to be met, unless effective enforcement mechanisms are in place. It will also discuss issues related to fuel adulteration and the difference between post production offences, and fuel quality which does not meet the required specifications due to production errors or contamination during transport. In addition, this section will touch upon different socio-economic factors which play an important role in the success of the program (e.g. poverty in India).

1. Importance of Monitoring Fuel Quality and Enforcement Policies

The most important implementation building block for any fuel quality strategy is monitoring and enforcement. Fuel specifications or standards, however strict they are, do not guarantee good fuel quality at the filling station. The foundation for clean fuels at the pump is based on two key elements –

1) National standards and
2) The ability to ensure and/or control fuel quality at the point of distribution – the filling station pump.

The latter can only be achieved through implementation and commitment to an effective fuel quality monitoring program. Without the effective monitoring of cleaner fuels at the pump, there is no basis for a National standard for cleaner fuel specifications. Experience in the US, Europe and Japan has shown this to be the potential weak link in many fuel programs and an area which must be strengthened.

Failure to establish a fuel quality monitoring system (FQMS) and enforcement policy could render clean fuel specifications irrelevant as it is the enforcement policy, which provides the incentive to comply with the regulations, especially if there are appropriate penalties acting as a deterrent (criminal or civil actions, administrative penalties, injunction, penalties, warnings and closure of non-compliant businesses).

It can be said that most countries and regions agree that there are two distinct parts to a fuel quality monitoring program:

- Monitoring fuel quality to ensure that the fuel sold at the pump is in compliance with the specifications set under national and/or local fuel quality legislation. This includes industry reporting and sampling requirements;
- Policing and enforcing fuel quality requirements to ensure compliance and sanctioning those actors not in compliance.

However, depending on various factors such as a countries economic situation, culture and traditions etc, the onus is either put on the industry to report fuel quality, as is the case for example in Hong Kong and Singapore, or the onus is put on the legislator as in the case of the US and most countries in the EU. The US system is a clear example of a legislative/regulatory system founded on nine fuel quality programs nationwide each of which is overseen by the US Environmental Protection Agency and has its own set of monitoring and enforcement mechanisms to ensure compliance. The US program relies on various monitoring mechanisms, including product sampling; record keeping/reporting; facility audits; attest engagements; certification; pump labelling; fuel product and batch registration and surveys. In addition, the US system has a detailed enforcement policy, which is unique to its extensive criminal justice system.

Many of these mechanisms are seen as necessary for an effective FQMS. However, once again developing countries do not always have the same financial or human resources as a large developed country such as the US, and therefore cannot invest in as extensive a system, nor in many cases is it necessary to do so. In addition, each countries unique socio economic, cultural, geographical and legislative situation must be taken into account when developing an FQMS.

What is the primary objective of an FQMS?

The primary objective of an FQMS is to ensure that the quality of the fuel is in accordance with prescribed specifications, which have been set for environmental and technical reasons (i.e. that the fuel used does not harm the vehicle, its engine or the environment and that ambient air quality targets can be met). This objective is directly linked to the secondary goal of the system, which is to protect consumers and guarantee that the quality of fuel pumped into each vehicle matches the product specifications of the fuel they are supposed to be purchasing.

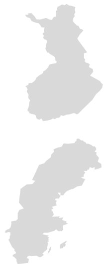
Fuel can be off spec through intentional or unintentional actions. The latter usually refers to non-compliance as a result of poor product management, either in the production or distribution process. , has resulted in the product not being in compliance. The first refers to fuel adulteration, which is discussed in the next paragraph. It is important to note, however, that fuel can be adulterated yet still pass some of the sampling tests and not be classified as off spec, due to test methods that are not capable or sophisticated enough to test within acceptable test variations and tolerances. For example, in India, controversial results on failure rates of samples conducted by various parties have led the Center for Science and Environment (CSE), a non-governmental organization, to conclude that the fuel quality limits in India are currently too lenient to allow for the proper detection of fuel adulteration. According to CSE, the current broad permissible range for each fuel property allows for a margin of adulteration without violating specifications. Therefore, it is difficult to assess the true effect of adulteration in India as the current fuel quality monitoring system really only detects violation of the fuel quality specifications, and not adulteration as it is still possible to adulter fuel and stay within the regulated fuel specification limits LK is the Indian example linked to test methods or the fact that there is too little of a difference between the specs and adulterated fuel.

Furthermore, existing tests methods used to verify adulteration are often found to be inadequate. Countries who have put in place an FQMS coupled with a proper sampling program recommend the use of adequate tests, such as gas chromatography (GC) or even gas chromatography coupled with mass spectroscopy (GC-MS) be used so as to identify adulteration. Other recommendations include improving the sealing system of the transportation vehicles and introducing a quick and adequate penalty for adulteration

FQM is a way of deterring fuel adulteration, which generally has nothing to do with the fuel quality itself and everything with the cost of the fuels thus socio-economics and evading taxes. Most fuel quality adulteration issues across the globe have been directly linked to cutting costs. In depressed socio-economic areas this is the number one reason for fuel adulteration and non-compliance. In fact, as much as fuel quality monitoring programs have been instituted to ensure environmental compliance with stringent fuel specifications, they have also been instituted to protect a government from tax evasion. Finding and penalizing tax evaders is actually the foremost priority, and whatever environmental benefits ensue as a result of finding the non-complier and bring fuel into compliance is simply a secondary bonus. The Belgian fuel quality monitoring program for example was initially developed purely as a tax recovery system. Now with new stringent European fuel quality legislation the system functions very well for real fuel quality monitoring purposes but this was not its initial role. On the other hand, the Australian approach is the opposite where the priority for the fuel standards setting process is an environmental one in the first instance and any penalizing of tax evaders is the secondary bonus.

FQM can also have other financial implications in addition to tax evasion. As fuel quality specifications are set from a technical as well as an environmental/health perspective, fuel that is off-spec can mean increased vehicle emissions. This is turn means increased costs to the government through health care. For examples, in India the Anti Adulteration Cell under the Ministry of Petroleum and Natural Gas reports a loss of about US$20.7 million a year. This does not include other costs such as damage to the vehicles and engines and other environmental and health costs. And a World Bank study conducted in 1995 concluded that the annual health costs due to ambient air pollution levels exceeding WHO guidelines ranged between US$517 and US$2,102 million. The study did however, not isolate the impact of vehicle emission on urban air pollution from other sources including indoor air pollution. As another example, table 5.1. below shows the environmental cost reductions associated with improved fuels in Finland and Sweden.

Table 5.1.. Estimated reduction in Environmental Costs due to Improved Fuel Qualities in Finland and Sweden for the years 1992 to 1996. Methodology used: ExterneE. Figures given are in million ECU.



	1992	1993	1994	1995	1996	SUM
Finland			**8 to16**	**9 to 17**	**9 to 17**	**26 to 50**
Gasoline			3 to 10	4 to 10	3 to 10	10 to 30
Diesel			5 to 6	5 to 7	6 to 7	16 to 20
Sweden*	**21 to 22**	**34 to 35**	**34**	**44 to 46**	**51 to 52**	**184 to 189**
Gasoline			2	11 to 13	12 to 13	25 to 28
Diesel	21 to 22	34 to 35	32	33	39	159 to 161

*Swedish estimates include the contribution from off-road vehicles and machines that use diesel.

Source: Arthur D Little AB. 1998. *Case Study Report- The introduction of improved transport fuel qualities in Finland and Sweden*

Adulteration is not specific to any certain region or country; however it is more prevailing in countries where products of comparable quality have different tax rates or where consumers have trouble distinguishing products of two distinct qualities or quantities. The way to tackle this is for the governments to:

- Minimize incentives for malpractices, especially if they arise from market distortion (such as fixed retails margins that are too low)
- Establish effective monitoring and enforcement regimes.

2. What Are the Key Elements of Good Monitoring and Enforcement Programs?

Controlling fuel quality at the pump is not easy nor is it cheap, but it is feasible and can be undertaken in many different ways. This section will address the key factors necessary for a successful fuel quality monitoring system (FQMS) as determined through regular IFQC research most recently undertaken for the Australian Department of the Environment and Heritage. It will also address sampling requirements, man power needs, financial resource issues, and penalties/sanctions. Although there are fundamental differences when comparing different country and regional approaches in fuel quality monitoring, generally it can be said that most countries have followed the U.S. “systems” approach established under the Clean Air Act of 1972 which sets air quality targets and then identifies accordingly the necessary changes to fuel quality and vehicle emissions.

Figure 5.1. shows the schematics on how a fuel quality monitoring system should be set-up. It must be noted, however, that it only shows the steps; it is not feasible within the scope of this Training Manual to define all of the fine detail and information needed for establish a bona fide FQMS.

Figure 5.1. Basic Schematic Steps to Establish a FQMS

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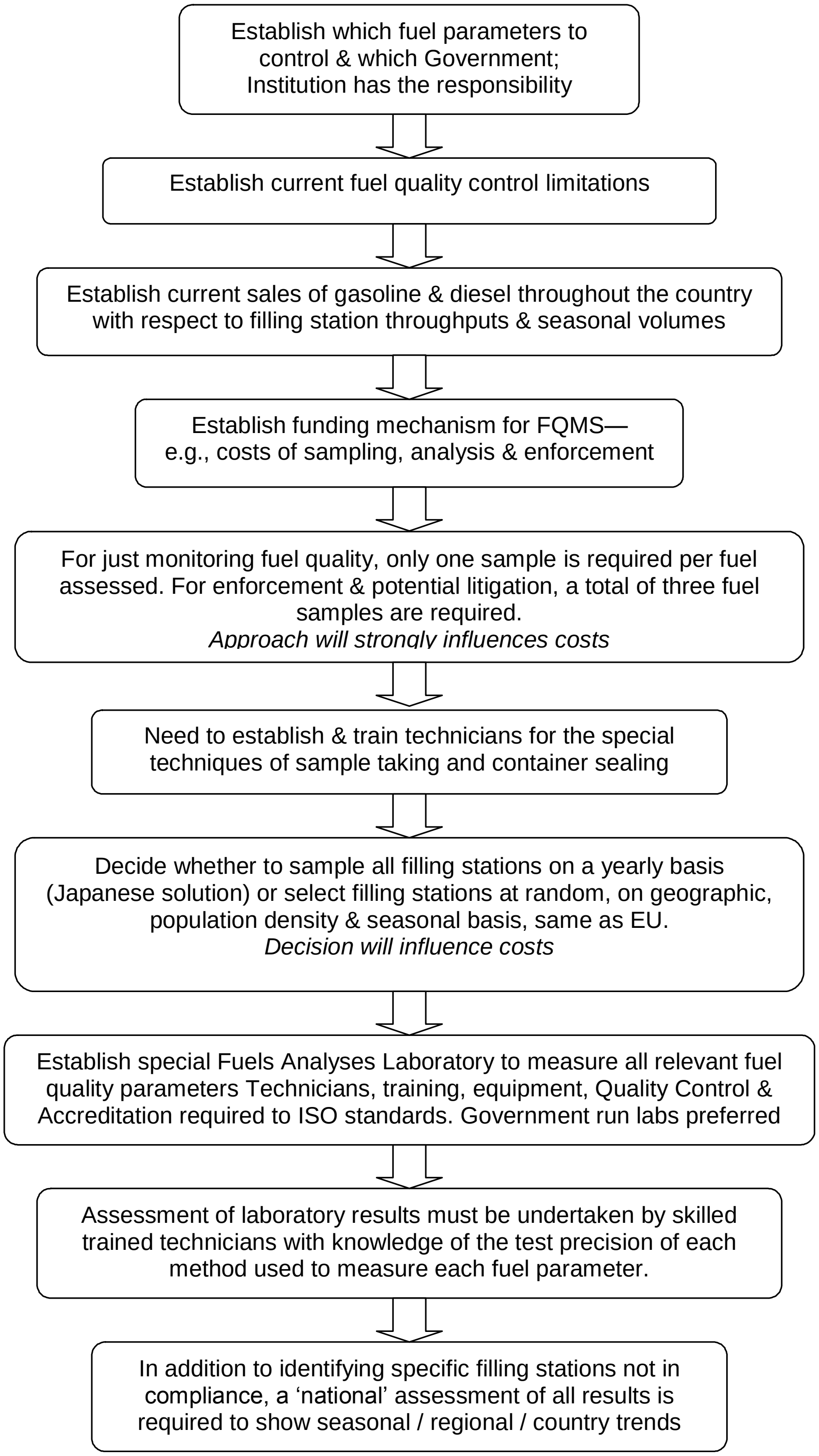

Establish which fuel parameters to control & which Government; Institution has the responsibility

Establish current fuel quality control limitations

Establish current sales of gasoline & diesel throughout the country with respect to filling station throughputs & seasonal volumes

Establish funding mechanism for FQMS— e.g., costs of sampling, analysis & enforcement

For just monitoring fuel quality, only one sample is required per fuel assessed. For enforcement & potential litigation, a total of three fuel samples are required.

Approach will strongly influences costs

Need to establish & train technicians for the special techniques of sample taking and container sealing

Decide whether to sample all filling stations on a yearly basis (Japanese solution) or select filling stations at random, on geographic, population density & seasonal basis, same as EU.

Decision will influence costs

Establish special Fuels Analyses Laboratory to measure all relevant fuel quality parameters Technicians, training, equipment, Quality Control & Accreditation required to ISO standards. Government run labs preferred

Assessment of laboratory results must be undertaken by skilled trained technicians with knowledge of the test precision of each method used to measure each fuel parameter.

In addition to identifying specific filling stations not in compliance, a 'national' assessment of all results is required to show seasonal / regional / country trends

Source: International Fuel Quality Center (IFQC), 2003.

There are several good examples of fuel quality monitoring systems, where countries have used these steps with success. This can be seen in the Australian, Belgian, South Korean and US systems, some of which are discussed in the case studies at the end of this Module. When establishing an FQMS, however, it is important to design, develop and implement your own program. This is not mean that for example the European example can't be used as a template, but because all countries are different regarding culture; geography (e.g. size of the country, the role of local/regional governments compared to the national government); infrastructure (e.g. means of transport from the refinery/depots to the pump) and socio-economics (e.g. poverty, taxes, prices, government investments) and other influences, one cannot adopt another countries' fuel quality monitoring and enforcement system as such.

These differences may also account for the fact that a country like India, with a seemingly structured monitoring and enforcement system in place continues to have difficulty in achieving fuel quality compliance. India's system includes sampling and stringent enforcement measures such as imprisonment, but due to its sheer size, cultural diversity, poverty and infrastructural issues, India has not been able to reduce fuel adulteration and non-compliance.

Furthermore, depending on the country, fuel quality concerns are often quite different. Where one country is struggling with introducing unleaded gasoline, another country may be experiencing non-attainment with another fuel property, or issues with cross-border trafficking in fuels. Therefore each country needs to assess the details of its FQMS separately including what the issues are, how the program will be undertaken and which stakeholders will be involved in the process. For example, consideration should be given to involvement of the customs authorities, especially in countries where there is a lot of cross-border traffic of fuels and their components.

When looking at the above schematic steps for the implementation of an FQMS, there are series of core issues, which must be taken into consideration prior to implementation that should be taken in to consideration. These are:

- Identification of the responsible Authority
- Industry Cooperation
- Operating Budget
- Capacity – staff
- Capacity – Equipment
- Sampling
- Sanctions and Penalties for Non-Compliance
- Fuel Quality Reporting

Responsible Authority

The governmental organization prescribing the fuel quality standards must either hold the authority to monitor and enforce the provisions of the fuel quality strategies monitoring and enforcement requirements or must work closely with the governmental sector that holds that authority. In many cases, fund appropriations should be coordinated to assure that resource allocations are allocated to monitoring and enforcement. In some countries, monitoring authority may reside with the organization setting the standards, yet the legal authority to enforce the standards may reside in another department or Ministry. It is imperative that in these situations, each department coordinate closely and make a commitment to support the process so that the goals of the system can be attained.

Each country's legislative, regulatory and legal framework may vary and therefore, the structure and support for establishing and implementing the process is very much dependant on a countries individual circumstances. It should also be noted that for "national" (e.g. government owned or controlled) industries a unique set of compliance issues may exist .

For example, In Belgium the Ministry of Economic Affairs is responsible for the FQMS due to its traditional role in enforcing excise duty payments for diesel and gasoline. In other countries it is the Ministry of Energy or the Ministry of Environment, which has this responsibility.

Industry Cooperation

Industry cooperation is essential for any FQMS to function properly. However the level of cooperation very much depends on the type of FQMS in place in a particular country. In some countries, particularly smaller countries such as Hong Kong and Singapore, industry has been actively involved in the system. In the case of Hong Kong, international oil companies import all fuel to the area and are required to assure that the fuel meet legally binding specifications. This self monitoring system is then complemented by a small percentage of random government sampling of retail outlets to ensure compliance. A similar system is undertaken in Singapore and no compliance problems have been encountered.

In addition, industry competition and image can also act as a driver for the involvement of industry in promoting appropriate fuel quality. In Pakistan for example, one of its refiners started testing the fuel sold at their branded gas stations to ensure t it met with the national fuel quality specifications. This testing was launched not only to ensure compliance but also to win over consumer trust and enhance image as a company who cares about the customer and product quality Other oil companies in Pakistan have yet to copy this behaviour.

The US on the other hand, only partially relies on industry involvement for self enforcement based on regulatory requirements. This entails a number of efforts usually including self sampling, testing, surveys, submission of report forms to the federal government etc. In addition, the Environment Agency employs its own inspectors (35 persons) or contract's with companies to conduct inspections to sample, test and evaluate the fuel programs. Data collected by both methods are used to verify compliance and/or to issue violations, collect violation fees and / or enter into litigation against an alleged violator.

Operating Budget

Adequate financial resources are necessary to fund staff, equipment and carry out a sufficient level of sampling and testing. If limited financial resources are allocated, therefore limiting your sampling and testing capabilities, it will be difficult to verify compliance across a geographically balanced and representative area. Insufficient financial resources can also have a limiting effect on the number of fuel properties that can be tested per sample and the equipment used for the sampling and testing.

It is difficult to provide an accurate resource cost estimate for a fuel quality monitoring system as it depends on a variety of factors all of which are dependent on the countries situation and the system it needs to develop. Some of the factors that play a role in the costs of the FQMS are the:

- Breadth of the system,
- Complexity of the system, i.e. number of samples to be taken and properties tested
- Laboratory equipment and test methods used
- System framework- who is responsible for the sampling, a government, refinery and/or independent laboratory
- Resources (personnel) required to oversee monitoring etc.

In the U.S., due to the layout of the fuel quality monitoring system as explained earlier, the costs for the self sampling, testing, surveys, and submission of industry reports to the federal government are borne by the industry. While some funds are made from the settlement of violations or through litigation, these funds, collected from the industry violators, do not get re-invested in the budget of the enforcement office. In most cases these funds are deposited in a general fund from which money is allocated to federal Agency's and in some cases specific efforts or programs. Additionally, State and local government conduct sampling and testing. These costs are allocated by the state or local government, not by the US government.

In Belgium both the private sector and the government agreed that the establishment of a jointly run and funded monitoring program would decrease the costs for each actor. The oil industry had evaluated that by establishing their own system this would cost approximately € 1.2 million per company per year whereas a joint system was estimated to cost approximately € 2 million per year for everyone. Therefore, in 1995 a fund was created, under the Royal Act of February 8, 1995 establishing the modalities for the functioning of the Petroleum Products Analysis Fund (amended by Royal Act of November 16, 1999 and the Royal Order of May 26, 2002). The Fund for the Analysis of Petroleum Products (Fapetro) was to be financed by two key fiscal routes:

- Tax on the consumer of BF 10 (approximately US 25 cents) per 1,000 Liters. This was later reduced to BF 1 (US 2.5 cents) per 1,000 Litres in the second half of 2000;
- A tax on the oil sector (to be determined).

The Belgium program calls for approximately 10,000 samples to be taken annually across the country and has a strong enforcement element based on excise duty tax evasion. Belgium's Fapetro reported that the total cost for FQM in 2002 was € 2.059 million (about US$2.39 million). In total there were 9,847 samples taken. Tables 5.3 and 5.4 below give an example of sampling prices in Belgium and Australia respectively and table 5.2. shows the how the costs of fuel sampling in Belgium is allocated.

Table. 5.2. Fuel Quality Monitoring Costs in Belgium in 2002.

	Cost in €	**Cost in US$**
Buying samples	84,347	98,294
Laboratory costing (analysis)	1,550,576	1,806,912
Fuel costs (for monitoring fleet)	15,445	17,998
Monitoring fleet maintenance	12,753	14,861

Insurance	4,356	5,076
Personnel	223,217	260,122
Computer	10,855	12,650
Office (supply etc...)	5,622	6,552
Monitoring supply	71,201	82,973
Miscellaneous	3,027	3,527
Mobile phone supply	2,240	2,610
Mobile phone calls	5,455	6,357
Financial costs	3,927	4,576
Quality control	65,245	76,029
Traveling costs abroad	530	618
Total	2.059 million	

Source: Fund for the Analysis of Petroleum Products (Fapetro), 2003.

Belgium’s FQMS is basically funded by an increase in fuel price at the pump. Other funding options are to either have the government fund the whole system (as is done in Japan) or have it funded jointly by industry through national standards (as is done in the U.K.)

Capacity - staff

Staff capacity must be taken into account when establishing an FQMS. This capacity will very much depend on the size of the country and the complexity of the system.

For example, despite the complex U.S. fuel quality programs, it relies on a relatively small staff of about 35 to conduct enforcement activities; most of which are EPA contractors. Additionally there are small number of additional EPA staff that oversees the implementation and monitoring requirements of specific fuel programs. The Agency also relies on the civil and criminal enforcement tools to compel compliance as well. The monitoring tools, coupled with the enforcement tools, work well to ensure industry at all levels of the distribution chain are in compliance. The low number of permanent staff needed for the monitoring is supported by the system the Agency has established, as it also relies on self monitoring and reporting by industry

In Belgium Fapetro employs 10 people full time for the fuel quality monitoring program. In addition to these people, there are other experts involved in some aspects of the monitoring process, but not employed full time.

Capacity - Equipment

The monitoring and sampling equipment needed for establishing a comprehensive FQMS depends on the regulated fuel specifications and the properties that are to be monitored. Many industry groups have existing accredited methods, which list certified equipment, specific test methods, allowable variations in results for both in lab and round robin lab testing (repeatability and reproducibility), as well as other approved provisions. Both the refining and automotive industries have organizations or groups that are well established and work closely with the government to provide the best possible methods, machinery and testing apparatus, as well as guidance to support quality controls on their products. The American Society of Testing Methods (ASTM) is but one example.

While some test methods are simple and can be relatively inexpensive, more quality specific test methods, especially for verification of quality standards for parameters that are very stringent and have acceptable test ranges very narrow in scope, may require expensive, sophisticated equipment. In developing a FQMS, costs and capabilities should be closely considered. Setting stringent standards without consideration of full capabilities to effectively monitor and enforce these provisions may not be prudent if full resources are not committed including equipment needs.

To give an example of the type of equipment usually needed by an accredited laboratory, lets look at a specific laboratory established in Belgium to test European, US and Asian fuel quality. BfB Oil Research is an ISO 17025 accredited, independent laboratory in Belgium. It employs 4 chemists and 1 motorist full time for analytical services and has a capacity of taking and analyzing 8,000 samples per year, which can be extended. It tests. 5,000 samples per year for Fapetro. This contract is valid until 2006. Following is a list of equipment available at the BfB Laboratory for fuel tests:

- 4 * Automatics distillators Herzog
- 1 * Grabner vapour pressure
- 1 * Agilent HPLC with refractive index detector, degasser, thermostatic column with back flush, auto sampler, printer, PC
- 1 * Agilent GC-OFID with AC methaniser, auto sampler, auto sampler, auto injection, cryostat, printer, PC
- 1 * specific gravity U tube Mettler
- 1 * Micron Conradson Tanaka
- ! * double position CFPP apparatus Scavini, cryostat, printer
- 1 * gum apparatus Scavini 6 positions
- 1 * FT-IR Perkin Elmer
- 1 * UB-VIS Hitachi
- 1 * oxidation for gasoline (Scavini) 6 positions 6 bombs, with PC, printer, automatic pressure drop recorder link to PC
- 2 * oxidation for gasoil (Scavini) 6 positions and 8 positions
- 1 * XRF-dispersive in wavelength – Bruker S4 model, with printer, pC, automatic sampler (48)
- 1 * auto flash point Scavini Pensky Martens
- 1 * Atomic absorption, flame, auto sampler Perkin Elmer, internal PC + printer
- 1 * Viscosity bath 4 positions Schott CT1450 + AVS350, Ubbelhode capillaries
- 1 * FIA columns equipment, UV detecftor, 12 columns
- 1 * sediment extraction Sartorius, Vacuum pump
- 1 * CFR engine (double speed) fro RON MON tests
- 1 * HFRR apparatus with climatic chamber, microscope, PC, printer
- 1 * thermostat for Copper corrosion 24 position
- 1 * Karl Fisher titrator Mettler
- 1 * Oven Heraus

Sampling

The fuel monitoring and enforcement framework relies on sampling. In fact, a good sampling program is essential for a well functioning FQMS and thus a successful fuel quality strategy. As indicated previously most countries have some level of industry sampling complemented by regular and/or random government sampling.

The number of samples that need to be taken varies from country to country due to a variety of factors:

- Variations in petroleum product distribution;
- Geographical factors such as size, and ensuring a representative ratio of samples.
- Seasonal variations
- Total sales as well as the geographic distribution of gasoline and diesel must be analyzed so that in areas where more fuel is sold more frequent testing is practiced.

For example, in New Zealand sampling is carried out geographically thus reflecting the volume released from each terminal throughout the year. If a terminal accounts for one-third of the volume of fuel, then one-third of all samples are taken from that terminal. Hence the number of samples taken can vary from two samples per month to as little as five samples per year. A sampling plan is created every year based on this sampling scheme. These plans provide for effective nationwide coverage taking into account previous performance, market shares and regional consumption. The reasoning behind designing and operating a statistically based sampling scheme in this manner is that New Zealand's distribution system is divided between four companies that all share the same system: BP, Caltex, Mobil and Shell. Gull Petroleum, a minor supplier, has a separate and smaller distribution network. The scheme is believed to give a 95% confidence level of detecting a 3% level of non-compliance

Another key issue impacting the extent of sampling undertaken is sample location variations. It is recommended that samples be taken from a variety of locations including from service stations, refineries, pipelines and during transport. In most cases industry verify product quality at their own refineries and in their pipelines, governments tend to sample service stations and transports companies for monitoring and enforcement purposes. Random testing of tank lorries is key whether or not these are operated by independent owners or by the oil companies /refineries themselves is extremely important to verify compliance. Studies carried out across the globe on fuel contamination and adulteration have all reached the same conclusion that in most cases contamination occurs after the fuel has left the refinery gate either during transport or at the pump. In both cases contamination can either be wilful thus considered adulteration or accidental due to mixing with other fuels previously transported or stored.

The South Korean FQMS required the Korean Petroleum Quality Inspection Institute (KPQII) to take about 60,000 samples in 2002. Most of these samples were taken from gasoline (around 40,000 samples), diesel (around 20,000 samples) and kerosene (2,000 samples) and the rest from heating oil and others, which include fuel oil, by-product fuel, asphalt and solvents. During that year, the budget for the fuel quality sampling was Won 13.47 billion, approximately US $1.2 million. Refineries are required to pay the government a fee per volume of petroleum product sold. This money is re-invested in the fuel quality sampling programme. In 2002 the fee was Won 0.145 / L (about 1.3 US cent/100 L) for automotive fuels and W on 0.027 /L (about 0.2 US cent/100L) for LPG of the total production.

Further examples of sampling costs are given below:

Table 5.3. Example for Sampling Costs in Belgium.

Tests	Price in € per sample	Price in US$ per sample
Aromatic /olefin	70	81
Aromatic hydrocarbon	121	140
Cetane rating	242,5	281

Distillation	35	41
Fuel density at 15°C	15	17
Lead	50	58
Oxygen content in gasoline	195	226
RON	160	186
Sulphur	150	174
Viscosity	25	29

Source: BFB Oil Research SA, Belgium, 2003.

The table below sets out some approximate costs for sampling under the Australian program including costs per sample for the inspectors who take the samples, equipment, courier costs and testing at the laboratory. Exact costs depend on a number of variables, the most significant of which is the State or Territory in which the sample is being taken.

Table 5.3. Example for Sampling Costs in Belgium.

Item	Cost per sample in A$	Cost per sample in US$
Lab Testing covers: Gasoline - Oxygen, MTBE, DIPE, TBA, Sulphur and RON. Diesel, Sulphur, Cetane, Density, Distillation and Viscosity. Costs are approx:	A$400.00	US$275
Equipment needed per sample, each sample consists of three, 1 litre samples		
3 by1 litre micro drums, $1.55 ea	A$4.65	US$3.19
3 by police A4 audit bag, $3.25 ea	A$9.75	US$6.69
3 by harcor secure pull seal, $0.33 ea	A$0.99	US$0.68
3 by fuel sample label, $0.50 ea	A$1.50	US$1.03
Courier costs for transport from capital cites to the labs in either Melbourne or Sydney	A$49.00	US$33.64
Total cost for equipment and analysis of samples	A$465.89 per sample	US$319.85 per sample
Cost of inspectors to take samples vary according to Jurisdiction	A$200.00 to A$600.00	US$137 to US$412

Source: Australian Government; Department of the Environment and Heritage, 2003..

Sanctions in place for non-compliance

An FQMS can only be as effective as its sampling and enforcement mechanisms. A sanctioning and penalty scheme must be legally binding and established early on to act as a deterrent. Penalties can include monetary fines, business permit revocations, operation restrictions or business closures. Some countries also take into consideration if non-compliance has occurred due to malpractice or carelessness. In the latter case the sanctions are not as severe, and only a warning may be issued at first. However, if non-compliance persists, tougher measures are taken. That said, proving wilful versus accidental non-compliance is not always easy. However, one simple, cost effective tool to deter companies from breaking the law, is to use a “name-and-shame” policy e.g. the government publicly releases non-compliance data and those companies not in accordance with the law. This has an immediate impact on consumer acceptability and confidence

While having a full slate of sanction options available is valuable, these options will be rendered useless if a government does not have the authority to use them. Again, a coordinated effort amongst different authorities is vital to affectively leverage sanctions as a deterrent for violators. In Belgium, each fuel sample taken must be analyzed in the next 24 hours. If the sample is off spec then the government official in charge of the sampling orders a control analysis that must be carried out in the next 48 hours. If the sample is still not on spec, then the fuelling station owner has 24 hours to rectify the situation and get rid of the off-spec product. If the product is still non-compliant after 24 hours, then the station is closed down for as long as necessary.

The problem with this approach is that quite often if a second sample is not taken immediately after non compliance has been first detected , the fuel which must be re-sampled has either been sold or has otherwise disappeared.

Due to this issue, the Belgian government has instituted a new system, which attempts to catch repeated non compliance offenders. Annex 3 B of the Belgium Ministerial Act of 18 February 1997 stipulates that all petroleum products sold and consumed in Belgium must correspond to the following key characteristics. These characteristics are split into three categories after consultation with petroleum experts: Categories 1 and 2 include characteristics that must be systematically monitored. Whereas the characteristics under Categories 3 must only be monitored if an abnormality is found while testing Categories 1 and 2.

To establish a list of sites out of compliance with the characteristics identified under Categories 1-3, a bonus/malus system is maintained by the Belgian Government. The system works as such: each point of sale starts with a neutral position of 0 malus (minus) points. If however, during the monitoring of a point of sale, one or several abnormalities are detected, that point of sale will receive malus (minus) points that are calculated accordingly. The aim under this system is that all points of sale which have received malus points will be monitored sufficiently so as to allow them to come back to a neutral position of 0 malus points in a reasonable time frame.

3. How do I report on my fuel quality and use my FQMS as a tool?

As indicated throughout this module an FQMS is the core implementation tool for any fuel quality strategy. Without monitoring it is impossible to know whether fuel quality specifications are being met.

Therefore, reporting of all monitoring results and enforcement data on an annual basis is essential. This also entails carrying out a detailed analysis of the annual findings to assess non compliance trends and whether certain fuel quality parameters should be strengthened or whether the FQMS itself and or the enforcement mechanisms need re-vamping.

In the EU for example, Article 8 of Directive 98/70/EC on the Quality of Petrol and Diesel Fuels, establishes reporting requirements, obliging the Member States to monitor their compliance with the fuel quality specifications set out in Annex I-IV of the Directive. The EU regulating body, the European Commission plays a central role. By no later than June 30 of each year the Member States must submit a summary of the fuel quality monitoring data collected during the period January to December of the previous calendar year.

The following information should at least be included in the report, as published by the European Commission on February 18, 2002 in the Decision on a common format for the submission of summaries of national fuel quality data:

- Compilation of the samples taken and an analysis of the results
- Detail about quantities of each grade of gasoline and diesel sold in the country
- A description of the national fuel quality monitoring system

The above mentioned factors help to explain the apparent success factors in the fuel quality monitoring programs from a compliance perspective. These factors are also addressed in some detail in the following case study. Most important, however, is that monitoring and enforcement systems must be tailored to the country concerned and take into account geography, human and financial resources and socio-economic factors.

The publication of this information is applicable to all countries and should be studied as a good example of reporting on monitoring and enforcement.

4. How do I establish an FQMS?

There is a variety of information available on the establishment of an FQMS and several different models to choose from. Once again each model has been tailor made to suit a countries particular needs and socio economic, geographic, legislative, and penal system. However, in most cases as can be seen in the case studies below the core issues discussed throughout this module have been taken into account.

When studying the fuel quality monitoring systems described below, and contemplating the establishment of your own FQMS, it is worth noting the following :

- Countries with little of no experience in setting up and running an FQMS should seek advice from organisations with specialist knowledge.
- At the present time, fuel additives are not mandated, but the situation could change within the next few years. Hence, it is essential to ensure new laboratory equipment is capable of analysing all emerging quality features such as additive type, composition.
- To trace source of origins of non-compliance it is essential to start with service station ‘housekeeping’ to search for contaminants and then progressively move back to distribution or blending depots, refinery, or import sources and border controls,
- If a potential fraud exists or is prevalent, it is essential to involve the Customs and Excise Department.

Case Study 11. Comparison of the fuel quality monitoring systems in various countries

This case study will be issue oriented and focus on different FQMS. Similarities and differences between these regional approaches such as the voluntary nature of the Singaporean system, and the compliance driven US approach are highlighted.

Issue Focus - The Belgian, South Korean and US programs have a number of factors and influences in common that are important for a successful fuel quality monitoring system from a compliance perspective. For example, each country: 1) designed, developed and implemented their own programs; 2) foster industry cooperation in running their programs; 3) focus on random sampling; 4) will not hesitate to issue severe penalties, including fines, business permit revocations, or business closure; 5) have devoted significant financial resources to their fuel quality monitoring programs.

Furthermore, the apparent lack of statistical reliability and traceability regarding non-compliance in the other countries (see table 5.4. below) seems to demonstrate that a fuel quality monitoring program founded on at least the five factors listed above is more successful and reliable in tracking actual implementation and compliance.

U.S. – One difference between the above mentioned three countries is that in the US the legislative/regulatory framework put in place by the U.S. Congress and the US Environmental Protection Agency puts most of the costs of compliance on industry in terms of complying with various requirements under the fuel programs such as registration, record keeping, attests, and so forth.

The threat of liability/penalty in U.S. the is so high that coupled with the random inspections/sampling compliance is compelled on its own. In this regard the U.S. system is similar to New Zealand’s and Australia’s fuel quality monitoring program. Therefore, Industry involvement is an extremely important factor in ensuring the success of fuel quality monitoring, but not just from the refining and retail industries. The importance of the global auto industry in facilitating compliance cannot be understated. In the U. S., annual fuel surveys conducted by the industry’s trade association have evolved into part of the fuel quality monitoring scheme. It has also been used by the auto industry to press for the government to issue stricter fuel specifications. (The oil industry does its own surveys and internal fuel quality monitoring to ensure compliance.) Fuel quality is critical to the operation of the vehicle, of course, but is also crucial in supporting new vehicle compliance with emission certification standards. If vehicles are not complying, the government can issue penalties to automakers.

EU and Belgium - The European Fuel Quality Monitoring (FQM) System for diesel and gasoline serves mainly as a guideline since the Member States have voted against any mandatory monitoring. The Member States can continue to use their own systems as long as equivalent fuel quality results are guaranteed. In addition, there will be no enforcement scheme under the program; control over enforcement will be left to the Member States.

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Overall, fuel quality in Northern Europe is rarely non-compliant, because refiners are not only solely responsible or working closely with government officials on fuel quality monitoring but are also made liable for fuel quality from the refinery to the pump at the refuelling station. Fuel quality compliance reports from most of the Southern European countries recently sent to the European Commission seem to indicate a high level of compliance as well, but that said it is not clear the exact nature of fuel quality monitoring and enforcement programs in place.

Some European countries prefer to use their own existing fuel quality monitoring schemes rather than apply the impending CEN standards. For example **Belgium** has transposed the Directive into national law and has its own unique fuel quality monitoring programs. Actual fuel quality is well under the limits prescribed in the Directive, according to reports Member States are required to submit on an annual basis under the Directive.

Belgium has one of the most extensive fuel quality monitoring programs in Europe, relying mostly on a sampling program as a monitoring method. In 2001, the government took nearly 12,000 samples of super leaded, Eurosuper 95, Super plus 98 and diesel fuel from stations all over the country and found a non-compliance rate of 6.23%. Of this percentage, 10% of those samples represented fuel sold at non-branded pumps.

The Belgian government, through the Ministry of Economic Affairs, supplements the sampling program with enforcement action where necessary. Enforcement mechanisms include civil actions, such as infringement proceedings. Where an infringement of the law is found, the fuelling station receives a warning, noting that a case will be opened against it. If further infringements are detected, a second warning is sent, and the government can shut the station down until the fuel complies with the law. In 2001, 612 infringement warnings were sent. Over the last seven years, the government has shut down more than 20 refuelling stations, generally for a short period of time.

The oil industry is very cooperative with the government, especially since the late 1990s, when it threatened to publicly “name and blame” all companies that sold off-spec fuel in a monthly report. A Petroleum Analysis Fund (Fapetro) was established through a tax on both the consumer and the oil industry to fund its compliance program, run under the auspices of the Ministry of Economy. A managing committee runs Fapetro and includes representatives of the government and industry (distributors, oil companies and refuelling stations).

Asia and Australasia - Generally speaking fuel specifications are not as developed in most Asian countries as compared to the U.S. or Europe. Therefore, it is no surprise that FQM legislation is lacking in most Asian countries. However, formal legislated or regulatory fuel quality monitoring programs are also lacking in countries with more advanced fuel specifications, such as Hong Kong.

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As a small, enclosed region Hong Kong is completely reliant on imported fuel by large international oil companies. The Hong Kong government requires oil companies to assure that fuel is compliant, and it collects samples from fuelling stations to ensure fuel is meeting specifications. Singapore also relies on voluntary sampling through cooperation between the oil industry, and the government's National Environment Authority (NEA). The oil industry is required to submit some test results to NEA for reference purposes, and it also samples from its fuelling stations. The government reports no cases of fuel quality non-compliance.

India has recently enforced future fuel specifications, but is still struggling to ensure that fuel is meeting those specifications through its fuel quality monitoring program. There are two legislative acts and two guidelines that cover fuel quality monitoring and adulteration, and they conflict, particularly as to which one is legally binding and must be followed. There is the Essential Commodities Act of 1955; the Order from the Ministry of the Petroleum and Natural Gas (MoPNG) under the Act; an industry quality control manual; and, sampling guidelines from the Society for Petroleum Laboratory. There is also confusion among the documents as to actual sampling procedures. Samples are taken at the refinery gate, point of transport, and retail outlets. Oil companies must test fuel at the refinery and issue fuel quality certificates to their customers and transporters assuring compliance with specifications.

Fuel adulteration is a serious problem in India, and the Anti-Adulteration Cell (AAC) of the Ministry of Petroleum and Natural Gas (MoPNG) reports a loss of about US$20.7 million a year, not including other costs such as damage to vehicles and engines, and other environmental costs. The oil industry has also put together Industry Guidelines on Transportation Disciplines for transporters, ensuring that transporters, not the industry, are liable for the quality of the fuel after it leaves the refinery. Under the guidelines, if transporters are found to have off-spec fuel, they can be suspended from conducting business for up to two years. Transporters and the oil industry have also signed good faith agreements to further ensure the quality of fuel.

Indian states are responsible for enforcing the Essential Commodities Act to prevent adulteration. The Act provides the framework for enforcement, provides for imprisonment of up to one year and fines for those not in compliance with the Act. Further, the right to do business may be forfeited for a minimum of six months if the offence is repeated. MoPNG has issued Marketing Discipline Guidelines that also provide for enforcement – however, they are not legally binding and have been criticized by the Centre for Science and the Environment (CSE) as not providing a strong enough incentive to stop adulteration.

Even if low or no non-compliances rates are reported by the government, this does not necessarily mean that this is the case as can be seen from the situation in India where corruption is fairly common. A non-compliance rate of only up to 2.4% is officially reported by various government agencies in India, on the other hand research by the CSE (a non-governmental organization) suggest much higher non-compliance rates (over 8%).

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Similar doubts are raised about certain countries in Western and Eastern Europe who claim very low non-compliance rate but for whom car manufacturers who have measured actual fuel quality at the pump and have collected extensive data and argue non-compliance is much more prevalent than reported.

In South Korea the Petroleum Business Act (PBA) regulates fuel quality monitoring, and the Ministry of Commerce (MOC), Industry and Energy and the Korean Petroleum Quality Inspection Institute (KPQII) are responsible for carrying out sampling and inspections under the Act. Refineries, importers, sellers, by-product sellers, fuel tanks and terminal sites are all subject to regular inspections. Refineries and terminals are sampled at least once a month, tanks sites at least once every four months. Samples can be taken at fuelling stations at anytime. Inspections are targeted at refineries and importers and at retailers. Out of a total of 65,356 samples taken in 2001, the non-compliance rate was 0.62%.

Enforcement actions can be taken against violators, but penalties depend on the severity of the non-compliance. For example, the government can suspend fuel sellers in the supply chain from doing business for three-six months, and can even revoke a business permit. As in the case of Belgium and Germany, South Korea bases such a penalty on whether the offence is careless or intentional. Warnings are given for the first unintentional offence; second and third unintentional offences can result in business suspension for three and six months, respectively. Penalties ranging from US$24,000-160,000 can be levied against refiners, importers and distributors in lieu of suspension.

To promote environmental competition among the country's refineries, the Environmental Protection Agency (EPA) began its own fuel quality sampling and warned it would publish results in newspapers beginning in April 2002. This may not turn out to be effective since refineries could produce the cleanest fuels when it knew the EPA was scheduled to take its samples. However, as indicated above similar "name and blame" tactics in Belgium have served as a deterrent.

Australia's fuel quality monitoring program is similar to many of the other countries' mentioned above. Firstly, the country relies on sampling as a primary fuel quality monitoring method, similar to just about every country reviewed in the study. The government of Australia, similar to Belgium, India, U.S. and South Korea runs the fuel quality monitoring program. Secondly, Australia relies on a number of other mechanisms in its fuel quality monitoring program, such as record keeping and reporting and can levy penalties for non-compliance with these provisions. It also carries out thorough inspections and is similar to the U.S.'s in these two respects.

Australia, like the U.S., EU, UK, Hong Kong, Japan, Singapore and Taiwan, also relies on some kind of industry self-reporting and monitoring. In Australia, however, this is required by law as opposed to the U.S. where voluntary industry surveys are carried out that over the years have served as another monitoring tool.

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Most of the countries reviewed in this study couple fuel quality monitoring program with enforcement actions that can be taken to compel compliance with fuel quality standards. Enforcement actions include civil, criminal and administrative actions, injunctions, penalties, warnings and closure of non-compliant businesses. Australia, the U.S. and South Korea can levy severe penalties, more than any of the other countries reviewed. In Australia fines can be US$327,000 and businesses that sell non-compliant fuel may be shut down through injunctions granted by the Federal Court. Australia also has the ability to criminally prosecute offenders.

Moreover, Australia's program is somewhat unique for a number of reasons. Firstly, Australia specifically lays out the rights and responsibilities for both inspectors and the owners of the premises they visit. Inspectors can enter a premises at any time to seek permission to take a sample. If permission is denied then they can apply for a monitoring warrant. Enforcement warrants are required to search a premises if a breach has been detected. The Act appears to safeguard the rights of owners to conduct business and provide for minimal intrusion by the inspector to ensure the owner is meeting the requirements of the Act, both for fuel quality and other provisions. Inspectors may be prosecuted themselves for violating the identity card provisions in the Act. Another interesting feature of the Act is that it encourages cooperation and information sharing with groups that typically receive consumer complaints on fuel quality.

Lessons learned - It is difficult to draw conclusions that correlate compliance rates to specific fuel quality monitoring/enforcement provisions or programs. All countries named above report few compliance issues. Moreover, there is no "best program" or "right approach" to fuel quality monitoring programs. Countries have taken voluntary and mandatory approaches with seeming success. On the other hand, countries like India have implemented a fuel quality monitoring/enforcement program that includes sampling and stringent enforcement measures that include imprisonment, yet the country still struggles against adulteration at retail outlets and downstream.

This is due to overlapping and conflicting authority under FQM legislation and guidelines. Also, Indian states may not be enforcing against non-complying retail outlets under the Essential Commodities Act. And, MoPNG's guidelines against adulteration are not legally binding. India's situation suggests that a few key elements to an effective fuel quality monitoring program are needed: the fuel quality monitoring and enforcement scheme must be clear to the regulated community and the threat of enforcement through some kind of penalty (fine, shutting down of business, etc.) must serve to incentives compliance. Because of the distinct differences in approach, this study demonstrates that although most countries do draw upon the same elements, the regulatory and legislative requirements for implementation of fuel quality standards in this area and the subsequent monitoring and enforcement schemes are extremely different in the various countries and regions. In addition, it concludes that most countries have all struggled with the development of a monitoring program that provides the best balance between compliance achievement and cost. Some countries such as Belgium and the U.S. believe they have reached this balance.

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The Australian fuel quality monitoring program can be considered one of the top international programs. Recent efforts by Environment Australia to establish a far more strategic approach to sampling based on potential risk areas i.e. a more risk management approach versus sampling according to the percentage of the market; and to tighten up processes to ensure security of the chain of evidence in relation to samples, shows that Australia continues to work towards reaching the right balance between compliance achievement and cost.

Table 5.4. summarizes the fuel quality monitoring systems in the above mentioned countries.

Table 5.4. Comparison of Fuel Quality Monitoring Program/Enforcement Schemes of Study Countries

Country	FQMP Type	Enforcement Scheme	Overall Non-Compliance Rates/# Samples[1]
US	**By law**: Sampling/testing; recordkeeping/reporting; auditing; certification; registration; surveys; attest; labelling; Voluntary: Industry surveys.	**Yes**, state and federal: Civil, criminal, administrative prosecution and penalties; injunctions.	Very few instances of non-compliance generally **RFG**: 4 cases per year **Gasoline volatility**: 1% for seasonal transition/N/A **Diesel**: 5% for fleets only/N/A
EU	**By law**: report fuel quality data annually; Voluntary: sampling through CEN.	**No**: Delegated to the Member States.	Member states responsible but non-compliance rates generally low.
Australia	**By law**: Sampling program; record keeping/reporting; industry self-monitoring; information sharing with consumer and other groups; certification.	**Yes**: Severe fines may be levied for off-spec/non-compliant fuel; injunctions.	Approximately 3% / 640 (2002)
India	**By law**: Sampling program.	**Yes**: Government can close a non-compliant business, levy penalties and imprison violators for up to one year.	Hard to tell based on conflicting data, MoPNG reports 2.4%/618 (2001)
New Zealand	**By law**: Sampling program.	**Yes**: Penalties can be assessed against parties for non-compliance.	Unknown/277 (2001-2002), but government reports only very few cases of non-compliance.
Singapore	**Voluntary**: Industry samples every batch of fuel and reports to the government.	**No**.	Unknown but the government reports no cases of non-compliance.
South Korea	**By law**: Sampling program at refineries, terminal and fuelling stations.	**Yes**: warnings, business permit revocations, suspension of business, severe fines.	0.62%/65,356 (2001) 0.74%/31,730 (January to June 2002)

Notes: 1) As reported by the government

Source: International Fuel Quality Center (IFQC), 2003.

B. Classroom Material

It is important that fuel quality produced and marketed is monitored on a regular basis to ensure compliance with the standards legislated. The objective of this exercise is to discuss what the arrangements are for fuel quality monitoring in your country and what possible improvements in monitoring could consist of current incentives and subsidies.

1. Current Monitoring capacity

Please try to complete the following chart as much as possible

Responsible agency	
Capacity – staff:	
Capacity equipment, include what parameters can be tested:	
Operating budget	
Number of tests carried out on average per week/month/year:	
Sanctions in place for non compliance	
Process to apply sanctions	
How many companies have been sanctioned last year?	
Reporting on Fuel Quality Monitoring	

2. Future Fuel Quality Monitoring

Please describe the changes that are required with respect to the items listed below

Legal mandate for monitoring:	
Capacity – staff:	
Capacity equipment, include what parameters can be tested:	
Operating budget	
Sanctions in place for non compliance	

Process to apply sanctions	
Reporting on Fuel Quality Monitoring	

Select your reporter and good luck!!!

C. For Further Reading

Description	URL
Fuel Monitoring and Control Systems	http://www.p-net.dk/download/conf2/conf92.pdf
Procedures Manual for Approvals - Fuel Quality Standards Act 2000	http://www.deh.gov.au/atmosphere/transport/fuel/approvalsmanual/
EU Fuel Quality Monitoring - 2001 Final Summary Report; produced by AEAT Consultants for DG Environment	

VI. Module 5 - How Do You Finalize Fuel Quality Strategy and Gather Support for Its Implementation?

This final Module of the Manual focuses on the final steps of putting a fuel quality strategy together. It summarizes the main components of a fuel quality strategy and discusses how to organize the stakeholder process to obtain buy-in for the strategy itself and for its implementation. It also discusses the different steps of translating the strategy into legislation.

A. Explanatory Section

1. Core aspects of a fuel quality strategy

Table 6.1. below summarises the building blocks of a fuel quality strategy into three main categories: (1) context analysis, (2) process, (3) implementation.

Assessment of the different building blocks in these three main categories will guide those responsible for the drafting of a fuel quality strategy towards the development of a detailed approach to formulate comprehensive fuel quality strategy.

This table can also serve as a checklist so that each government official working on the strategy can tabulate progress made and actions still to be taken.

Table 6.1. Checklist

Information	Remarks	Evaluation +++/--- "Home-work?"
CONTEXT		
Information on linkage on fuel quality – vehicle emissions- air quality-health	Preferably information specific for your city or country if not from elsewhere in Asia or Europe/USA	
Priority fuel parameters that need attention	Based on assessment of air quality/ source apportionment, vehicle fleet composition, fuel mix, and current standards, what are the parameters for diesel and gasoline that need attention most urgently	
Current characteristics of refiners producing your fuel	This can be in your country or elsewhere if you import fuel	
Plans of refiners producing your fuel	This includes assessment of capacity of the refiners to produce cleaner fuels	
Information on tax and other incentives to influence refiners to speed up refinery modification	This applies to the current instruments in place in your country/city that can be applied	
Energy Security	What is importance attached by key stakeholders to having in-country refining?	

Information	Remarks	Evaluation +++/--- “Home-work?”
Fuel improvements as part of different policy agenda’s	What are other policy drivers that can be mobilized to introduce cleaner fuels, such as climate change policy or energy policy	
PROCESS		
Knowledge of who the key stakeholders are with respect to fuel quality standards	Important is to know who are credible spokespersons and organizations.	
Current committees responsible for fuel standards	Is the current organizational set-up sufficient or is there a need for setting up of (additional) bodies to develop and adopt cleaner fuel standards	
Options/scenarios of what fuel improvements are required/proposed	Has thinking on fuel quality improvements sufficiently advanced to be able to present clear options or scenario’s to stakeholders for discussion.	
Economic and Financial assessment of fuel improvement options	Ideally this is based on modeling for the local situation. Second best solution is making use of information from other (comparable) locations. Regulator to carry out its own assessments independent of assessments carried out by refiners.	
Synergy or conflict with other fuel related policies	In case of ongoing efforts to deregulate fuel sector, how do plans to impose cleaner fuel standards fit in with deregulation efforts?	
Voluntary Strategies to encourage early introduction of cleaner fuels	In anticipation of legal enforcement of cleaner fuel standards, have voluntary measures been identified to encourage early introduction of cleaner fuels, including instruments to ensure this	
Legal instruments for changing fuel quality	What are the procedures, at what level, by whom and how can new fuel standards be promulgated. What are the specific policies, laws, standards that need to be refined	
IMPLEMENTATION		
Milestones for introduction of cleaner fuels	Lead-time for introduction of cleaner fuels can be 6-8 years. What are the milestones that have been identified so that stakeholders can track progress during the lead period	
Monitoring of fuel quality	Is monitoring capacity in place to ensure compliance with fuel quality standards. If not does strategy include activities to ensure availability	

Information	Remarks	Evaluation +++/--- "Home-work?"
Capacity building	Are capacity building measures part of the strategy to ensure that all key stakeholders are capable to play their roles properly	
Impact assessment of cleaner fuels	Are steps being taken to ensure that adequate impact assessment will be carried out of impact of cleaner fuel on vehicle emissions, air quality and ultimately health	

2. Setting up an Effective Stakeholder Process

The importance of designing and implementing a strong stakeholder consultation process in support of the formulation of a fuel quality strategy cannot be overestimated. Without the active buy-in of main stakeholders, both the formulation and the implementation of the fuel quality strategy is put at risk.

The first step in setting up a stakeholder consultation process is the identification of the stakeholders. There are different categories of stakeholders and their involvement in the fuel sector varies.

The first, category encompasses fuel quality "drivers". This includes regulators, as well as, lobby groups trying to promote cleaner fuels. The second category encompasses stakeholders affected by fuel quality regulations. This predominantly refers to the fuels industry, and the automotive sector. Finally, there is a third category of stakeholders of great importance in the data gathering and the formulation of fuel quality strategies. This includes private and public organisations, as well as consultants/ experts.

Stakeholders can represent the public or private sector as well as civil society, they can be single representatives or group representatives, and can be formal groups/associations or be part of and informal alliances of organizations or of influential individuals.

Typically, the following stakeholders are included under the categories identified above:

Drivers

Department of Energy
Department of Environment
Department of Transport
Department of Health
Local governments
Legislators
Environmental NGOs
Media

Affected Groups

- Oil companies with in-country refining capacity
- Oil companies trading imported fuels
- Petrol station owners and operators
- Vehicle industry

Cooperating/facilitating groups

- Bilateral and multilateral development agencies
- Financing organizations
- Department of Finance
- Consulting firms specializing in refining business

This is a list of typical stakeholders, however, it is not necessarily exhaustive. It is important to analyze based on the specific institutional context in which the fuel quality strategy is being formulated whether there are any additional stakeholders, which need to be included.

Once the right stakeholders have been identified, the next step is to analyze the significance as well as the interests of these different groups and individuals. Stakeholders can support the formulation of a fuel quality strategy, leading to the introduction of cleaner fuels, but they can also strongly oppose it. A careful upfront analysis of the expected positions of the different stakeholders can help to avoid substantial delays in the ultimate approval of the fuel quality strategy.

Stakeholder Consultation Process: Phase I:

After having identified the stakeholders and analyzed their interests, the next step is to set-up the actual stakeholder consultation process. In doing so, it is important, first of all to see whether there are established forums that can be used for this purpose. If this is the case, it is strongly recommended to make use of such rather than setting up a new forum. In proceeding with the stakeholder consultation, it is important that there is a clear communication infrastructure and strategy. Again, if use can be made of existing, relevant, websites and/or newsletters, this is to be preferred. In all cases, it is essential that it is clear who is responsible for the stakeholder consultation process. Also, it is important that the stakeholder consultation process is adequately financed and that funds are available for stakeholder consultation meetings. However, considering that stakeholders are invited to take part in the stakeholder consultation based on the interest they have in the outcome of the process they should not be paid to take part in the process.

In starting a stakeholder consultation process, it is important to differentiate different phases. The first phase typically commences when the regulators have taken the decision to formulate a fuel quality strategy and if the first draft of the strategy is available containing the basic outlines of the strategy proposed by the regulator. It is not recommended to start a formal consultation process without having an initial first draft of this strategy. In this first phase it is important however that regulators are willing to make considerable changes in the draft strategy. If this is not the case, the chances for conflict increase and stakeholders might have the perception that the government has entered in the process with little willingness to listen to their views and work constructively towards the finalization and the implementation of the fuel quality strategy. In order to achieve the widest possible buy-in to the fuel quality strategy, it is important that a wide range of stakeholders can recognize their concerns in the first draft of the strategy. This means that both environment and health as well as technical considerations are given. With respect to the latter, as outlined in earlier chapters of this manual, a fuel quality strategy needs to be medium to long-term in character (8 to 15 years), in order to give the industry the necessary lead time for investment and planning and the government enough time to properly implement the strategy.

This first phase of the consultation process will also be important in the identification of possible difficulties and constraints perceived by stakeholders regarding implementation.

Stakeholder Consultation Process: Phase II:

The issues identified during the first phase of the consultation process are essential for the proper development of a detailed implementation strategy in the second draft of the fuel quality strategy. At this stage, an incentive program will also be included to facilitate the introduction and implementation of the cleaner fuel specifications/standards under the fuel quality strategy. In discussing and designing an incentive program in support of the implementation of a fuel quality strategy it is essential to consider the financing of such incentives. This will require close coordination with the Department of Finance to ensure the availability of funding and or agreement on potential revenue loss from tax incentives.

The first, more open, phase of the consultation process needs to be followed by a second draft of the fuel quality strategy, which is more definite in its structure and contents. This is the more or less draft final version of the document. While commenting in the first phase was on whether a fuel quality strategy was needed, etc., the design of the consultation process should be such that in the second phase the emphasis is on the "how" of the implementation of the proposed strategy.

It is important at this phase in the consultation process to create a public event where the different stakeholders commit themselves to the objectives and associated time frames. This is of importance in the subsequent legislative process in which the fuel quality strategy is transformed into legislation.

It is suggested that in this phase the regulator also launches detailed discussions with refiners and/or technology suppliers as to whether they are interested in acting as a "frontrunner," that is that they would introduce the cleaner fuels specified in the strategy ahead of schedule. As seen under Module 3 this would mean that certain incentives will have to be provided to motivate industry "frontrunners". Proposed incentives should therefore be included in the draft fuel quality strategy.

It is important to realize that a stakeholder consultation process can be a mix of a transparent process, open to all the stakeholders, as well as a closed process in which bilateral discussions are conducted between the regulator and individual companies. It is important, however, that the regulator does not make commitments to individual companies, which would compromise the content of the strategy nor that commitments are made to certain companies and not others.

Fuel quality regulators in Asia have a variety of resources available for launching their stakeholder process. First, as indicated throughout this manual, there are a variety of available publications on successful stakeholder processes in the area of fuel quality. In addition, regulators or experts who participated in these processes are usually willing to give their expert advice. The Australian and EU stakeholder processes are given below as examples.

Second, Asian governments can appeal to bilateral or multilateral development agencies for support in the establishment of a fuel quality strategy quoting the developmental impact of cleaner fuels and air quality.

Case study 12. Development of Australia's First National Fuel Quality Standards

Background - In Australia, fuel standards are set under the Fuel Quality Standards Act 2000. In general, Australia's starting point for developing fuel standards is harmonisation with international standards, especially where those standards are technology enabling, while taking into account Australian conditions and requirements.

Before 2002, while there were some legislated state standards and voluntary industry standards, Australia had no national fuel quality standards for petrol and diesel. As the first stage in the development of fuel quality standards a technical review of the fuel quality requirements for Australian transport was commissioned. This review considered the impacts of tighter fuel standards on vehicle emissions, the refining industry in Australia, and the economy. The review provided an invaluable scientific and technical base to inform decisions and consultation relating to the introduction of new fuel standards.

Using the information gained from the technical review, three initial public discussion papers were prepared. These papers were made available to all stakeholders and used to inform discussion on the issue.

The comments received in response to the proposals outlined in the discussion papers were consolidated and used to revise the initial position. There was a second limited consultation process on the revised position. A cost benefit analysis showed that the proposed standards would result in substantial health benefits with a small increase in the price of fuel. At this stage most of the parameters that would make up the diesel and petrol standards were agreed, however there were some parameters that were problematic for key stakeholders.

The approach taken was to take a decision on agreed parameters but defer decisions on the more problematic parameters until more information was available. This resulted in the first set of fuel quality standards for petrol and diesel being agreed and coming into effect from 1 January 2002. This timing was critical as it mirrored the previously agreed timing on the introduction of more stringent vehicle technologies. The full set of petrol and diesel standards, with all identified parameters, will come into full effect by 2006. Australia is now considering the need to further revise the fuel quality standards to enable more advanced vehicle emission technologies.

Issue Focus - Australia's first fuel standards were the result of robust and transparent consultation with a wide group of stakeholders.

In spite of high levels of cooperation and general agreement on the majority of parameters, some issues emerged as problematic for some stakeholders. In particular proposed limits of ethanol, olefins, benzene and MTBE in petrol raised concerns in some quarters. These concerns risked delaying the entire fuel quality standard setting process with implications for the implementation of the agreed vehicle standards.

In relation to the fuel additive MTBE, independent importers of fuel approached the Government and stated that the proposal to ban MTBE would prevent them from obtaining an ongoing supply of fuel on overseas markets and would result in fuel shortages and price rises. It was also noted that a ban on MTBE would be inconsistent with the approach being taken in Europe.

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On the other hand, there were concerns held by various stakeholder groups about the potential risks of groundwater contamination from MTBE given Australia's very high dependence on groundwater. Major oil companies in Australia that voluntarily do not use MTBE, those states which have banned its use, and the mineral water industry argued strongly for a ban.

These issues were raised fairly late in the process. In retrospect, including the assessment of octane enhancers in the technical review and discussion papers would have given both industry and government more time to fully consider the issues associated with the use of additives to meet octane need.

When the Government made its decision on the original petrol and diesel standards it deferred a decision on the MTBE limit in petrol. This was to allow further assessment of the availability of MTBE-free petrol in the region, to address environmental risks and to ensure that fuel importers continued to have fair access to Australian markets.

After several months the Government announced a 1% MTBE limit, which would take effect from 1 January 2004. It was determined that the 2 year delay in the implementation of these standards would provide a reasonable timeframe for importers to source supplies of petrol that meet this standard.

In coming to this decision the Government considered the concerns expressed about the potential risk that MTBE poses to Australia's water resources and the implication of the effective ban on MTBE on independent operators importing petrol into Australia.

Lessons Learned - The Australian fuel standards development process illustrated the need for a sound scientific basis, comprehensive economic evaluation, independent expert advice, detailed consultation with stakeholders, an adequate consultation timeframe and an open and well defined process.

The domestic refining industry (BP, Shell, Caltex, and Mobil) and our major importer (Trafigura) as well as the Federal Chamber of Automotive Industries worked very closely with the Department of Environment and the Industry and Transport Departments in the review process and in developing the standards. They provided valuable assistance in understanding the technical issues involved and were generous with their expertise and time.

In particular it was important to understand the context and implications (including the environmental and health benefits, the economic costs, and the politics) of the proposed fuel standards and the closely related vehicle standards. Australia was able to set fuel quality standards based on a sound technical basis by mastering the technicalities and being able to seek independent advice on a range of issues (such as availability of MTBE free fuel in Asia).

A flexible approach allowed the first set of standards to come into effect on 1 January 2002, while giving Government time to further investigate the impacts of some proposed parameters and providing the fuel refining and importing industries with a reasonable lead time on all parameters.

Case study 13. EU Stakeholder Processes and Issues of Relevance

Use EU auto oil program as case study of data sharing responsibilities and issues, which arise regarding cost inflation in particular from industry most likely to lose out e.g. refining. Suggest how governments can double check data through third party. Also discuss how political, or single industry issues can take over discussions and how to properly manage e.g. Auto Oil II hijacked by sulphur issue.

Background - The EU Auto-Oil Programme (AOP1) was the first programme of its kind at the EU policy level to bring together the resources and expertise of the two major industry stakeholders the automobile sector through the European Association of Automobile Manufacturers (ACEA) and the oil refiners through the European Petroleum Industry Association (EUROPIA) in collaboration with the services of the European Commission. The Programme itself was launched in 1992 and built upon an:

- Air quality modelling study,
- A technical research programme "European Programme on Engines, Fuels and Emissions" (EPEFE)
- A cost effectiveness modelling study.

The EPEFE programme, which was funded by both industries', would be the technical foundation for the final legislative proposals forwarded by the European Commission to the European Parliament and the Council of Ministers in 1996.

The rationale of the AOP was to quantify both the cost and the emission reduction potential of a variety of different measures, which could contribute to reducing vehicles emissions and the attainment of air quality targets. The measures which were included in the analysis were supposed to focus not only on advances in vehicle technology and fuel quality but also on the benefit of improvements to the regular inspection and maintenance procedures as well as the potential contribution of non technical measures such as road pricing, improved public transport and scrappage schemes. It must be said however, that the non-technical measures in the end were barely touched upon and thus not a part of the legislative proposals.

The final AOP legislative proposals were forwarded to the European Parliament and Council of Ministers in winter 1997. The legislative text proposed EURO III-IV passenger vehicle, LDV and HDV emission requirements as well as mandatory fuel quality specifications for 2000 with suggested (not mandated) further reductions in sulphur and aromatic levels in 2005.

The debate within the European Parliament and Council would last another 2 years and would result in significant changes to the final text as demonstrated in this Chapter.

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Issue Focus -. The European Commission estimated that as a result of its AOP package of legislative proposals industry would incur the following costs by the year 2000:

Passenger car producers:	ECU* 3,094 million per annum
Van/light duty vehicle producers:	ECU 373 million per annum
Heavy Duty vehicle producers:	ECU 675 million per annum
Refining Industry:	ECU 765 million per annum
National governments associated with improved inspection and maintenance:	ECU 555 million per annum

Measures proposed for vehicles for 2005 were evaluated to cost:

Passenger car/light commercial vehicle producers	ECU 2,500 million per annum
Heavy duty vehicle producers	ECU 500 million per annum

Cost to the consumer for measures which become effective from 2000:
Fuel
Additional cost per litre/1 000 l

Gasoline:	ECU 0.002 per litre ECU 2 per 1 000l
Diesel:	ECU 0.0018 per litre ECU 1.8 per 1 000l

Additional calculated cost on the fuel bill of the average motorist:

Gasoline car:	ECU 2.3 (assuming 12,600 per year and 8.61 l/100km)
Diesel car:	ECU1.7 (assuming 12,600 per year and 7.61 l/100km)

*The European Currency Unit the ECU was replaced by the Euro in January 2002

As can be seen from the above cost estimates, the industry most likely to pay the highest bill for the AOP proposals would be the car industry. In total, the additional costs per litre came to a total of ECU 765 million/annually versus an automotive technology bill of ECU 3 billion/annually. Needless to say the car industry was not pleased with the final proposal and felt it had to shoulder most of the burden in meeting the new air quality requirements in comparison with the oil industry. ACEA was convinced that the Commission's minimal fuel quality changes were a result of oil industry cost inflation in the cost effectiveness modelling undertaken by Bechtel consultants. It voiced its concerns publicly, and then promptly stepped down from the AOP and its tri-partite relationship in disappointment and anger in 1997. The car industry then proceeded to heavily lobby the European Parliament and the EU Member States and succeeded in equalising the costs between the two industries due to more stringent fuel quality demands for 2005. The final proposal from the Council and Parliament barely resembled the original Commission proposal and thus the efficacy of the AOP in deriving accurate cost effectiveness data was questioned.

Analysis - Lessons Learned - In retrospect, if the Commission officials in charge of running the AOP, and the consultants in charge of the cost modelling had had better knowledge of actual oil industry costs and new refining technology, the final legislative proposal would have been more balanced. This of course cannot be expected of government officials but should have been the case for the consultants. Critics also claim that the Commission proposal would have been more balanced if rather than a cost effectiveness study, a cost benefit analysis had been undertaken taking account health costs from air pollution and subsequent benefits from cleaner fuels.

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In addition, the Commission should have allowed for more checks and balances through EU Member State experts, and concerned health and environment non-governmental groups (NGO's) in its discussions or in the EPEFE programme. This would have created a second layer of advisors and expertise.

Other issues, which made sound data evaluation difficult was the lack of recent fuel quality data. CONCAWE, the research arm of the oil industry had published annual data on market quality but interestingly enough stopped doing so prior to the start of the AOP. When the auto industry launched its own EU-wide market fuel quality analysis, it discovered that the actual fuel quality on the market in 1997 on average already met the fuel quality specifications being proposed in 2000 as a result of the AOP.

In 1997 the second Auto Oil Programme (AO2) was launched. Due to the un-balanced final results of the AO1 and the heavy criticism from the auto industry (ACEA refused to participate in another AOP unless things were changed), certain Member State governments and environmental and health NGO's, the AO2 programme was run in a very different manner by the European Commission. To facilitate greater participation and data gathering, the programme was based on the input of 7 working groups and was open to all stakeholders including Member State governments, NGO's and the European Parliament.

Although at the end of the day the scope of the AO2 programme was criticised due to its focus on sulphur (the other 2005 parameters were supposed to be addressed under AO2), the programme itself was seen as more balanced by the auto industry and Northern Member States especially Germany. This time it was the oil industry most positioned to lose, but as the refining sector especially in Northern Europe was already investing in lower and zero sulphur fuels, and it had had its fingers burned for its non-transparent positioning under AOI, the outcome from AO2 was much less controversial and seen as more balanced then its predecessor.

3. The Final Step: From Fuel Quality Strategy to Fuel Quality Legislation

In parallel to the finalization of a fuel quality strategy, it is important to consider how the objectives in terms of cleaner fuel specifications and associated time frames as well as possible incentive programs are embodied in legislation. There are too many examples of fuel quality strategies or action plans formulated, which have never made it to the legislative phase and, which as a consequence were only partially or not implemented at all. To successfully translate a fuel quality strategy into legislation the first step is to identify whether a legislative framework is already in place that needs which can simply be amended or whether a new dedicated fuel quality legislative text must be drafted. In most cases in Asia, legislation already exists.

The second step is to consider is whether a basic law needs to be revised or whether it is sufficient to make changes to the administrative rules and regulations under an existing piece of legislation that covers fuel quality. The advantage of the latter is a larger amount of flexibility for the regulator to make changes when and as needed. However, the disadvantage of this approach is that it offers opponents of fuel quality improvements also the same flexibility and possibilities to delay the introduction of cleaner fuels.

As indicated under Module 1, when drafting a legislative text on fuel quality there are a series key elements, which must be incorporated, these are:

1) The authority/agency responsible for overseeing the implementation and monitoring of the standards, including monitoring.
2) A series of definitions should be given regarding the products concerned e.g. conventional gasoline and diesel fuels,
3) Reference to economic instruments and allowance to use tax incentives (if agreed by relevant Ministry or department)
4) Mandated list of fuel quality properties and limits (usually in table form)
5) Mandated timeline for adoption of new fuel quality specifications,
6) Monitoring and reporting requirements including methodology
7) Enforcement Measures e.g. penalties, fines and sanctions
8) Review procedures so that the legislation can be reviewed due to technology changes, priority changes etc.

In many cases, there are established technical committees in place, responsible for reviewing and/or drafting fuel quality legislation. Use can be made of such technical committees but it is important to assess whether capacity building measures are required to strengthen these committees.

B. Classroom Material

This is the last exercise of the course. The objective is to see what the best way will be to follow up in country by you after the end of the course. This exercise is also intended to identify any possible external assistance you will require in the completion and introduction of the strategy.

To encourage you in the completion and the follow up all countries included in the course will be invited to the Better Air Quality 2003 workshop, which will take place 17-19 December to report on the progress in the follow-up after the course.

1. What needs to be done still?

Please consider the following table and based on the conditions in your country complete or alter the table.

Setting medium term air quality targets			
What	**How**	**Who**	**Assistance from**
Setting medium term vehicle emission standards			
What	**How**	**Who**	**Assistance from**
Develop consensus on fuel requirements for medium term			
What	**How**	**Who**	**Assistance from**
Assessment of current refining capacity			
What	**How**	**Who**	**Assistance from**
Incentive schemes			
What	**Who**	**How**	**Assistance from**
Monitoring			
What	**Who**	**How**	**Assistance from**

2. Time Path

Please include what the critical milestones will be in the development of your fuel quality strategy and when you believe that it will be in place. Please consider in your time path all the legal requirements that apply in your country for stakeholder consultation, interdepartmental consultations, and requirements to have standards formally adopted.

Good luck!!!

C. For Further Reading

Description	**URL**
European Auto-Oil II Programme	http://europa.eu.int/comm/environment/autooil/

VII. Glossary

AAM – Alliance of Automobile Manufacturers, www.autoalliance.org

AAQ – Ambient Air Quality

ACEA -- Association of International Automobile Manufacturers, www.acea.be

Air toxics – also Hazardous Air Pollutants – hazardous, either for environment or health.

API – American Petroleum Institute

ASTM -- American Society for Testing and Material, www.astm.org

AQIRP -- US "Air Quality Improvement Research Program".

BIS – Bureau of Indian Standards

Bpd -- Barrels per day

CAFÉ – Corporate Average fuel Economy

Categories of Sources -- Sources to emit one or more of the 189 hazardous air pollutants identified and regulated by the EPA under the 1990 Clean Air Act. Categories could be petrol service stations, electrical repair shops, coal-burning power plants, chemical plants, etc. The air toxics producers are to be identified as major (large) or area (small) sources.

CFPP -- Cold Filter Plugging Point

CI – Cetane Index

CI – Compression Ignition

CN – Cetane Number

CNG – Compressed Natural Gas

CO -- Carbon monoxide

CO2 -- Carbon Dioxide

Combustion products -- chemicals that are produced when a substance (petrol for example) is burned.

CONCAWE – Conservation of Clean Air and Water in Europe, www.concawe.be

Control technology; control measures -- equipment, processes or actions used to reduce air pollution.

CP -- Cloud Point

CRC – Coordinating Research Council (USA)

Criteria air pollutant -- Key air pollutants.

Detergent -- Additive present in gasoline to prevent build-up of engine deposits, keep engines working smoothly and burning fuel clean.

De-NOx -- NOx reduction

DHDS – Diesel Hydro De-Sulfurisation

DI – Distillation Index or also refereed to as Driveability Index

DI – Direct Injection

DIN – Deutsches Institut fur Normung, German Institute of Standardisation

DME – Di-Methyl Ether

DOC – Diesel Oxidation Catalyst

EC – European Commission

E70, E100, etc -- % gasoline evaporated at 70°C, 100°C, etc.

EMA – Engine Manufacturers Association, www.enginemanufacturers.org

Emission -- release of pollutants into the air from a source.

EPA – Environment Protection Agency

EPEFE – European Program on Emissions Fuels and Fuels Technologies

ETBE – Ethyl Tertiary Butyl Ether

EU – European Union

EUDC – Extra Urban Driving Cycle

FBP – Final Boiling Point

FCC – Fluid Catalytic Cracker

Hazardous air pollutants (HAPs) -- see Air toxics -- Air pollutants listed under the EPA as causing serious health and environmental hazards.

HC – Hydrocarbons

HD – Heavy duty

HFRR – High Frequency Reciprocating Rig (determines wear scar diameter)

I&M – Inspection and maintenance

IC – International Combustion

IDI – Indirect Injection

IPCC – International Panel for Climate Change

JAMA – Japan Automobile Manufacturers Association, www.japanauto.com

JARI – Japan Automobile Research Institute

JCAP – Japanese Clean Air Program

Lead (Pb) -- an Air Pollutants from leaded petrol, paint, smelters (metal refineries); manufacture of lead storage batteries.

LDO – Light Diesel Oil

LEV – Low Emission Vehicle

Light Cycle Oil (LCO) -- the distillate stream produced from fluid catalytic cracking.

LPG – Light Petroleum Gas

LSD – Light Sulfur Diesel

MECA – Manufacturers of Emission Controls Association, www.meca.org

MMT – Methylcyclopentadienyl Manganese Tricarbonyl

MMT – Million Metric Tonnes

Mobile sources -- moving objects that release pollution; mobile sources include cars, trucks, buses, planes, trains, motorcycles and petrol-powered lawn mowers. Mobile sources are divided into two groups: road vehicles, which include cars, trucks and buses, and non-road vehicles, which includes trains, planes and lawn mowers.

MON – Motor Octane Number

MTBE – Methyl Tertiary Butyl Ether

NAAQS – National Ambient Air Quality Standards

NGO – Non Government Organisation

NMHC -- Non-Methane Hydrocarbon

NOx – Oxides of Nitrogen

NO2 – Nitrogen dioxide

OBD – On-Board Diagnostic

Octane -- a measure of a gasoline's tendency to cause engine knock during combustion.

OEM – Original Equipment Manufacturers.

Olefin -- a class of hydrocarbons containing an unsaturated carbon, i.e. chemical bonds are shared rather than being fully linked with hydrogen or other atoms. These are a generally more reactive species.

OTAQ – Office of Transportation and Air Quality (USA)

Oxygenate – a gasoline component containing oxygen, i.e. alcohols or ethers.

Oxygenated fuel (oxyfuel) – special formulated gasoline blend with additional oxygenates, which burns more completely than regular petrol in cold start conditions; more complete burning results in reduced production of CO, a criteria air pollutant.

Ozone (O3) – High concentrations of ozone gas are found in a layer of the atmosphere -- the stratosphere -- high above the Earth. Stratospheric ozone shields the Earth against harmful rays from the sun, particularly ultraviolet B. Smog's main component is ozone; this ground-level ozone is a product of reactions among chemicals produced by burning coal, petrol and other fuels, and chemicals found in products including solvents, paints, hairsprays, etc.

Ozone hole – thin place in the ozone layer located in the stratosphere high above the Earth. Stratospheric ozone thinning has been linked to destruction of stratospheric ozone by CFCs and related chemicals.

PAH – Polyaromatic Hydrocarbons

Particulate; particulate matter (PM-10) – particulate matter includes dust, soot and other tiny bits of solid materials that are released into and move around in the air. Particulates are produced by many sources, including burning of diesel fuels by trucks and buses, incineration of garbage, mixing and application of fertilizers and pesticides, road construction, industrial processes such as steel making, mining operations, agricultural burning (field and slash burning), and operation of fireplaces and woodstoves.

Pb – lead

PCV – Positive Crankcase Ventilation

Petroleum Coke -- the hard carbon residue that is the product of cracking reactions. In refining, it is the byproduct of coking operations. It is also an undesirable reaction product in other processes that usually lies down on and deactivates catalysts.

PM – particulate matters

PM10 – particulate matter below 10 micron size

PM 2.5 – particulate matters below 2.5 micron size

Pollutants (pollution) – unwanted chemicals or other materials found in the air. Pollutants can harm health, the environment and property. Many air pollutants occur as gases or vapors, but some are very tiny solid particles: dust, smoke or soot.

Polymerization – refining process that combines light olefins to produce a high-octane gasoline stream.

ppm – parts per million

Primary standard – pollution limit based on health effects. Primary standards are set for criteria air pollutants.

PSI – Pounds per square inch. A measure of pressure.

Reformulated gasoline – specially refined petrol with low levels of smog-forming volatile organic compounds (VOCs) and low levels of hazardous air pollutants. The 1990 Clean Air Act requires sale of reformulated petrol in the nine smoggiest areas. Reformulated petrols were sold in several smoggy areas even before the 1990 Clean Air Act was passed.

RON – Research Octane Number

RVP – Reid Vapour Pressure

Saturate -- addition of hydrogen to unsaturated molecules, providing atoms for all the chemical bonds and resulting in a saturated molecule.

Saturated Molecule -- a molecule that has all the bonds of the atoms connected to another atom.

SCR – Selective Catalytic Reduction

Secondary standard -- pollution limit based on environmental effects such as damage to property, plants, visibility, etc. Secondary standards are set for criteria air pollutants.

SI – Spark Ignition

SIP – State Implementation Program (USA)

Smog – a mixture of pollutants, principally ground-level ozone, produced by chemical reactions in the air involving smog-forming chemicals. A major portion of smog-formers comes from burning of petroleum-based fuels such as petrol. Other smog-formers, volatile organic compounds, are found in products such as paints and solvents. Smog can harm health, damage the environment and cause poor visibility. Major smog occurrences are often linked to heavy motor vehicle traffic, sunshine, high temperatures and calm winds or temperature inversion (weather condition in which warm air is trapped close to the ground instead of rising). Smog is often worse away from the source of the smog-forming chemicals, since the chemical reactions that result in smog occur in the sky while the reacting chemicals are being blown away from their sources by winds. Weather and geography determine where smog goes and how bad it is. When temperature inversions occur (warm air stays near the ground instead of rising) and winds are calm, smog may stay in place for days at a time. As traffic and other sources add more pollutants to the air the smog gets worse.

Source – any place or object from which pollutants are released. A source can be a power plant, factory, dry cleaning business, gas station or farm. Cars, trucks and other motor vehicles are sources, and consumer products and machines used in industry can be sources too. Sources that stay in one place are referred to as stationary sources; sources that move around, such as cars or planes, are called mobile sources.

Stationary source – a place or object from which pollutants are released and which does not move around. Stationary sources include power plants, gas stations, incinerators, houses etc.

Sterically Hindered – attribute of a class of molecules that renders them difficult for certain chemical reactions. This term is used to describe complex molecules in distillates that because of their structure make it difficult for the sulfur in the molecule to react on the catalyst surface to assist in sulfur removal.

Stratosphere – part of the atmosphere, the gases that encircle the Earth. The stratosphere is a layer of the atmosphere 9-31 miles above the Earth. Ozone in the stratosphere filters out harmful sunrays, including a type of sunlight called ultraviolet B, which has been linked to health and environmental damage.

Sulfur – a yellowish element widely used in fertilizer and chemical industries. It is a natural constituent of crude oil that is undesirable in refining operations or final petroleum products.

Straight Run – products produced directly from crude distillation with no subsequent chemical processing.

Sulphur dioxide (SO2) – sulphur dioxide is a gas produced by burning coal, most notably in power plants. Some industrial processes, such as production of paper and smelting of metals, produce sulphur dioxide. Sulphur dioxide is closely related to sulphuric acid, a strong acid. Sulphur dioxide plays an important role in the production of acid rain.

TAME – Tertiary Amyl Methyl Ether

Temperature inversion – one of the weather conditions that are often associated with serious smog episodes in some portions of the country. In a temperature inversion, air doesn't rise because it is trapped near the ground by a layer of warmer air above it. Pollutants, especially smog and smog-forming chemicals, including volatile organic compounds, are trapped close to the ground. As people continue driving, and sources other than motor vehicles continue to release smog-forming pollutants into the air, the smog level keeps getting worse.

T10, T50, T90, T95 – temperature at which 10%, 50%, 90% or 95vol% has evaporated.

THC – Total Hydrocarbons

ULEV – Ultra Low Emission Vehicle

UNEP – United Nations Environment Program

Unsaturated Molecule – a molecule that does not have all of the chemical bonds of at least one atom connected to another atom. In these cases two atoms “share” a chemical bond. Unsaturated molecules are usually more reactive than saturated molecules because of thin chemical bond configuration.

Ultraviolet B (UVB) – a type of sunlight. The ozone in the stratosphere, high above the Earth, filters out ultraviolet B rays and keeps them from reaching the Earth. Ultraviolet B exposure has been associated with skin cancer, eye cataracts and damage to the environment. Thinning of the ozone layer in the stratosphere results in increased amounts of ultraviolet B reaching the Earth.

Vapour – gases escaping from liquid petrol in a process called vaporization or evaporation. When you put gas in your car, you can often see wavy lines in the air at the pump nozzle and you can smell petrol; that tells you petrol vapors are in the air.

Vapour recovery nozzles – special gas pump nozzles that will reduce release of petrol vapor into the air when people put gas in their cars. There are several types of vapor recovery nozzles, so nozzles may look different at different gas stations. The 1990 Clean Air Act requires installation of vapor recovery nozzles at gas stations in smoggy areas.

VLI – Vapour Lock Index (VLI = 10xRVP kpa) + 7xE70)

Volatile organic compounds (VOCs) – smog-forming chemicals found in petrol and many consumer products, from hair spray to charcoal starter fluid to plastic popcorn packaging.

WBCSD – World Business Council for Sustainable Development

WHO – World Health Organisation

WTO – World Trade Organisation

WWFT – World Wide Fuel Charter, www.acea.be