Phasing Lead out of Gasoline :

An Examination of Policy Approaches in Different Countries

OECD
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Preface for Publication on Lead Policies

"There are geod examples of industry and governments working together to solve environmental problems. Removing lead from gasoline is one of them"

Klaus Töpfer, Executive Director, United Nations Environment Programme

There is a firm consensus among government representatives, the lead industry, and health experts that gasoline should not contain lead. This consensus began to build in the 1970's when the first health effects from exposure to airborne lead were suspected.

Since that time, additional studies have confirmed that any absorption of lead into the body has detrimental effects, particularly on the early development of nervous systems in children and fetuses. Further, a previous report by several UN agencies, *Global Opportunities for Reducing the Use of Leaded Gasoline,* states that "no safe level of exposure to lead has been found".

With the knowledge of potential health effects, some governments established programmes to completely phase-out the use of lead gasoline. In Austria, Canada, Denmark, Germany, Japan, Slovakia, Sweden, and the United States, for example, lead is no longer a gasoline additive. Many other countries have substantially reduced the lead content of gasoline.

The removal of lead from gasoline became a worldwide issue in the mid 1990's when UNEP's Governing Council and environment ministers from OECD countries urged Governments to phase-out lead as quickly as possible. At its June 1997 special session, the UN General Assembly endorsed additional measures to support Agenda 21 actions that specifically included phasing out the use of leaded gasoline.

In 1999, unleaded gasoline accounted for 80 percent of total worldwide sales. In a significant portion of the remaining 20 percent, the lead content has been reduced, generally at low cost - less than two US cents per litre for most countries. The benefits, however, have been substantial. According to the World Bank, countries can save five to ten times the cost of converting to unleaded gasoline in health and economic savings. These facts should encourage policy-makers that lead can be removed from gasoline *without* harm and *with* net economic benefits.

Although there has been significant progress, millions of people in Asian, Latin American and African countries are still exposed to unacceptable levels of airborne lead. The health effects from this exposure can also exacerbate health effects from other forms of water and air pollution.

Removing lead from gasoline in countries where it is still used, however, is not without significant challenges. What policies, for example, produce the greatest environmental and human health returns at the least cost? Would a national policy of placing an extra heavy tax on leaded gasoline, as happened in Hong Kong, for example (sales of unleaded gasoline surpassed 50 percent in just one month), work, elsewhere? Is it better to have a mixed unleaded/leaded vehicle fleet or maintain the existing flect and reduce the amount of lead? What are the implications for refiners and automakers?

These questions are the basis for this publication: *Phasing Lead out of Gasoline: An Examination of Policy Approaches in Different Countries.* The publication builds on the information provided in two previous publications: the UNEP/ UNICEF/UNITAR *Global Opportunities for Reducing the Use of Leadad Gasoline* and the UNEP UNICEF publication *Childhood Leud Poisoning.*

The information in this publication can help accelerate efforts by governments and industry to remove lead from gasoline. The combination of successful programmes in some countries with the coordinated actions of the lead industry should give policy makers confidence that the reduction of airborne lead from leaded gasoline can be accelerated.

Please, read this report, consider the recommendations carefully and *act* to remove lead in gasoline. Your children - and their children - will thank you.

Jacqueline Aloisi de Larderel
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Acknowledgements

In December 1996 UNEP and the Organisation for Economic Co-operation and Development (OECD) convened in Paris a consultative meeting on lead in gasoline. One result was a decision to commission two issue papers - the first concerning problems arising from the use of older vehicles in developing countries and the second on policy options for phasing out the use of lead in gasoline. In late 1997, the International Lead Management Center (ILMC) generously offered to provide funding for the preparation of the studies. A Steering Committee was created to oversee the process.

Draft copies of the papers were distributed to the Steering Committee for their review in mid1998. Extensive and very helpful comments were received from several members, especially from the Ford Motor Company, Octel, the Natural Resources Defense Council, OECD and ILMC. Comments were also solicited from other organisations, including the Danish Environmental Protection Agency, Hampshire Research, UNICEF, CONCAWE, the Manufacturers of Emissions Controls Association, the US Environmental Protection Agency, and the International Petroleum Industry Environmental Conservation Association (IPIECA).

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Mr. Jack Short, Deputy Secretary General
Mr. Richard Sigman, Principal Administrator
Mr. Peter Wiederkehr, Administrator

Executive Summary

1. Background and Introduction

Until approximately 1970 almost all gasoline used around the world contained lead, in many cases at concentrations above 0.4 grams per liter. Since the early 1970s, however, there has been a steady movement away from leaded fuel, driven by concerns about the health effects of lead and because the catalytic converters used in modern vehicles to reduce carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxide (NO_x) emissions are rendered inoperable by lead. Many countries around the world have completely eliminated the use of leaded gasoline at this time. In others, where leaded gasoline continues to be sold, the amount of lead has been reduced significantly.

Health Concerns Associated With Lead in Gasoline

Over the past century, a range of clinical, epidemiological and toxicological studies have defined the nature of lead toxicity, identified young children as a critically susceptible population, and investigated mechanisms of lead toxicity. According to the 1995 **Environmental Health Criteria Document for Lead,** published by the International Programme on Chemical Safety (IPCS), lead affects many organs and organ systems in the human body, with subcellular changes and neurodevelopmental effects evident. The most substantial evidence from cross sectional and prospective studies of populations with blood lead levels below 25 µg/deciliter relates to decreases in intelligence quotient (IQ).

A global consensus has emerged to phase out the use of lead in gasoline:

- In December 1994, at the Summit of the Americas, Heads of State from a number of countries pledged to develop national action plans for the phase out of leaded gasoline in the Western Hemisphere.
- In May 1996, the Worid Bank called for a global phase out of leaded gasoline, and offered to help countries design feasible phase out schedules and create incentive frameworks.
- A recommendation of the Third "Environment for Europe" Ministerial Conference, held in Sofia, Bulgaria in October 1995, called for the reduction and ultimate phase out of lead in gasoline.
- In June 1996, the second United Nations Conference on Human Settlements, Habitat II, included the elimination of lead from gasoline as a goal in its agenda.
- In 1996, OECD Environment Ministers adopted a Declaration on Risk Reduction for Lead in which they declared they wouid give highest priority to actions such as a progressive phase-down of the use of lead in gasoline.
- Environmental ministers from the Group of Seven plus Russia endorsed the phase out of leaded gasoline in their 1997 *Declaration of Environmental Leaders of the Eight on Children's Environmental Health.*
- In May 1999, the European Council of Ministers of Transport endorsed a resolution which calls on ECMT Member countries to phase out the use of leaded petrol as rapidly as possible.

Need For Unleaded Gasoline To Control Other Important Vehicle Pollutants

Vehicle emissions of carbon monoxide, hydrocarbons and nitrogen oxides result in a variety of adverse effects on health and the environment.

Focusing solely on the health consequences, the World Health Organization (WHO) has published air quality guidelines, summarized below.

Summary of WHO Recommended Guidelines

Compound	Guideline Value	Averaging Time
Ozone	120 µg/m³ (0.06 ppm)	8 hours
Nitrogen Dioxide	200 µg/m³ (0.11 ppm)	1 hour
Nitrogen Dioxide	40-50 µg/m³ (0.021-0.026 ppm)	Annual
Carbon Monoxide	100 mg/m³ (87 ppm)	15 minutes
Carbon Monoxide	60 mg/m³	30 minutes
Carbon Monoxide	30 mg/m³	1 hour
Carbon Monoxide	10 mg/m³	8 hours

Many if not most urban areas around the world have experienced air quality levels in excess of the WHO guidelines. In most of these cities, vehicle emissions are a major if not the dominant contributor. The state-of-the art technology for reducing CO, HC and NO_x emissions from vehicles is the catalytic converter, which converts large portions of the pollutants to carbon dioxide, water vapor, oxygen and nitrogen. Approximately 86 per cent of all new gasoline fueled cars manufactured in the world during 1995 contained a catalytic converter. This technology cannot be used with leaded gasoline, however, since lead poisons the catalyst, rendering it ineffective.

2. Options To Produce Lead Free Gasoline

Lead is added to gasoline because it is a low cost octane enhancer. If lead is not added to gasoline, it is necessary to 1) modify the refinery process to raise the octane level of the unleaded gasoline pool, 2) add alternative octane enhancing additives, or 3) reduce vehicle octane requirements. In most countries, a mixture of the first two approaches is used.

Refinery Modifications

To replace the octane formerly contributed by lead additives, refiners have adopted a number of techniques. Catalytic cracking and reforming are used to increase the concentrations of high-octane hydrocarbons such as benzene, toluene, xylene, and other aromatic species, and olefins. Alkylation and isomerization are also used to convert straight-chain or low molecular weight paraffins (which have relatively low octane value) to higher octane branched paraffins. Increased quantities of light hydrocarbons such as butane are also blended.

Modern conversion refineries can substitute for lead at a considerably lower cost than less advanced skimming refineries. Typically the cost of phasing out leaded gasoline is in the range of US$ 0.01-0.02 per liter, which includes the annualized refinery investment costs amortized over the life of the investment, the incremental operating costs of producing gasoline without lead, and/or the cost of alternative gasoline additives. Even in technologically less-developed skimming refineries the cost is estimated to be less than $0.03 per liter. Refinery modernization investments necessary to reduce the lead content of gasoline often improve productivity and refining efficiency, and can increase revenues.

Use of Blending Components

Many small skimming refineries constructed to serve smaller markets in developing countries, however, cannot achieve sufficient economies of scale to justify capital intensive conversion and upgrading investments. It may be more economical to close these refineries and import unleaded gasoline or high octane gasoline blending components.

Use of high octane oxygenated blending agents such as ethanol, methanol (with cosolvent alcohols), and especially methyl tertiary-butyl ether (MTBE) has increased greatly in recent years. In addition, the antiknock additive methylcyclopentadienyl manganese tricarbonyl (MMT) is used in some countries although the environment agencies in both the U.S. and Canada have argued against its use.[1]

Lower Octane Approaches

In an effort to stimulate the introduction of unleaded gasoline, in 1970 the General Motors Corporation announced that its new cars would be designed to use unleaded gasoline and operate on 91 RON fuel rather than 94 RON. This enabled unleaded gasoline to be introduced without any refinery modifications; lead was just not added to the so called unleaded pool.

1/The Canadian government has recently reversed its ban on the use of MMT in unleaded petrol in the face of a legal challenge by the Ethyl Corporation.

Impact of Alternatives on Emissions

Some of these solutions have created or aggravated environmental problems of their own. Most lead substitutes are not of serious concern if the switch to lead free gasoline is combined with the introduction of catalytic converters as the catalysts break down many of the more reactive or toxic hydrocarbons. In order to maximize the health benefits of unleaded gasoline use in vehicles without catalysts, and to minimize any health risks associated with evaporative emissions, it is prudent to ensure that acceptable alternatives are used.

Policy Approaches

Once a country decides to convert to unleaded fuel, two major issues must be resolved:

- What policy instrument or combination of instruments are most effective in bringing about the switch? and
- How quickly should the conversion take place?

In phasing out the use of leaded fuel, different countries have used a variety of policy tools. It has now been conclusively demonstrated that taxation policies that keep unleaded gasoline less expensive than leaded gasoline are very effective in promoting rapid conversion to unleaded fuel as well as minimizing the deliberate use of leaded gasoline in catalyst equipped cars. **In no case shouid leaded gasoline be priced lower than unleaded fuel if rapid progress is desired.**

Once a decision is made by a country to phase out the use of leaded gasoline, a firm date for its elimination should also be set.

The schedule for completely phasing lend out of gasoline should be based on a careful balancing of several important factors - the need to reduce the direct health risks from lead, the requirement for unleaded gasoline to protect catalytic converters and the speed with which any necessary refinery modifications can be carried out.

While each country has to weigh these factors carefully, considering its own specific circumstances, the global tendency has been for countries to move quickly. China aims to eliminate leaded fuel in less than three years throughout the entire country, and more quickly in its most polluted cities.

While a very important step, the elimination of lead from fuel is not the only element in a comprehensive fuels strategy. No increase in the toxicity of the fuel should be tolerated when shifting from leaded to unleaded fuels. If the aromatics and benzene content of the fuel increase due to the greater use of high octane, high aromatic gasoline blending components, this should be seen as a short term, transitory phase. Other fuels improvements such as lowering volatility and sulfur levels should also be considered as a means of achieving air quality goals.

Contents

1. Background and Introduction

Lead is a harmful pollutant and human exposure to all sources should be minimized. Phasing lead out of gasoline makes a very important contribution. Until approximately 1970, almost all gasoline used around the world contained lead and in many cases at concentrations above 0.4 grams per liter. Since the early 1970's, there has been a steady movement away from leaded fuel, driven in part by concerns regarding the health effects of lead and in part by the need for lead free fuel to allow the use of catalytic converters to reduce carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxide (NO_x) emissions. Many countries around the world have, in fact, completely eliminated the use of leaded gasoline at this time including those listed below. In many countries where leaded gasoline continues to be sold, the amount of lead been reduced significantly.

Country	Year of Leaded Gasoline Phase Out
Austria	1993
Germany	1996
Denmark	1995
Slovakia	1994
Japan	1980
Canada	1993
Sweden	1995
United States	1996

The move away from lead in gasoline is motivated by several factors, as summarized below.

1.1 - Health Concerns Associated with Lead in Gasoline

Over the past century, a range of clinical, epidemiological and toxicological studies have continued to define the nature of lead toxicity, to identify young children as a critically susceptible population, and to investigate mechanisms of action of lead toxicity. A full discussion of lead toxicity, clinical manifestations and mechanisms of action can be found in the 1995 **Environmental Health Criteria Document for Lead**, published by the International Program on Chemical Safety (IPCS). In summary, lead affects many organs and organ systems in the human body with subcellular changes and neurodevelopmental effects appearing to be the most sensitive. The most substantial evidence from cross sectional and prospective studies of populations with lead levels generally below 25 µg/deciliter of blood relates to decrements in intelligence quotient (IQ).

As noted by the IPCS, existing epidemiological studies do not provide definitive evidence of a threshold. Below the range of about 10 - 15 µg/deciliter of blood, the effects of confounding variables and limits in the precision in analytical and psychometric measurements increase the uncertainty attached to any estimate of effect. However, there is some evidence of an association below this range. Animal studies provide support for a causal relationship between lead and nervous system effects, reporting deficits in cognitive functions at lead levels as low as 11-15 µg/deciliter of blood which can persist well beyond the termination of lead exposure. Other effects which may occur include:

- impaired sensory motor function
- impaired renal function
- a small increase in blood pressure has been associated with lead exposure
- some but not all epidemiological studies show a dose dependent association of pre-term delivery and some indices of fetal growth and maturation at blood lead levels of 15 µg/deciliter or more.

Lead and its compounds may enter the environment at any point during mining, smelting, processing, use, recycling or disposal. In many older homes, lead based paint can make a significant contribution. Lead pipes can also be a significant source of lead in drinking water. When addressing health risks associated with lead,therefore all potential sources of exposure should be investigated. In countries where leaded gasoline is still used, however, the major air emission is generally from mobile and stationary combustion of gasoline. Areas in the vicinity of lead mines and smelters are also usually subject to high levels of air emissions.

Airborne lead can be deposited on soil and water, thus reaching humans through the food chain and in drinking water. Atmospheric lead is also a major source of lead in household dust in homes which are close to heavily trafficked roads.

Because of the concerns highlighted above, a global consensus has emerged to phase out the use of lead in gasoline:[1]

- In December 1994, at the Summit of the Americas, Heads of State from a number of countries pledged to develop national action plans for the phase out of leaded gasoline in the Western Hemisphere.

- In May 1996, the World Bank called for a global phase out of leaded gasoline, and offered to help countries design feasible phase out schedules and create incentive frameworks.

1/US Environmental Protection Agency (US EPA) (1986) Ambient Air Quality Criteria Document for Lead. Research Triangle Park NC: EPA ORD; US Centers for Disease Control (CDC) (1991) Preventing Lead Poisoning in Young children. Atlanta: US DHHS, October 1991; Howson C and Hernandez Avila M (1996) Lead in the Americas. Washington: NAS Press; International Program on Chemical Safety (IPCS) (1995) Environmental Health Criteria Document: Lead. Geneva: IPCS, WHO; National Research Council (NRC) (1993). Measuring Lead exposures in Infants, Children and Other Sensitive Populations. Washington: NAS Press.

- A recommendation of the Third "Environment for Europe" Ministerial Conference, held in Sofia, Bulgaria in October 1995, called for the reduction and ultimate phase out of lead in gasoline.

- In June 1996, the second United Nations Conference on Human Settlements, Habitat II, included the elimination of lead from gasoline as a goal in its agenda.

- In 1996, OECD Environment Ministers adopted a *Declaration on Risk Reduction for Lead* in which they declared they would give highest priority to actions such as a phasing-down the use of lead in gasoline.

- Environmental ministers from the Group of Seven plus Russia endorsed the phase out of leaded gasoline in their 1997 *Declaration of Environmental Leaders of the Eight on Children's Environmental Health*.

In May 1999, the European Council of Ministers of Transport endorsed a Resolution which calls on ECMT Member countries to phase out the use of leaded petrol as rapidly as possible."

1.2 - Need For Unleaded Gasoline to Control Other Important Vehicle Pollutants

a) Other Important Pollutants From Gasoline Vehicles

Vehicle emissions of carbon monoxide, hydrocarbons and nitrogen oxides result in a variety of adverse effects on health and the environment.[2]

Carbon Monoxide (CO)
Carbon monoxide (CO) is a tasteless, odorless, and colorless gas produced though the incomplete combustion of carbon-based fuels. CO enters the bloodstream through the lungs and reduces the delivery of oxygen to the body's organs and tissues. The health threat from CO is most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Healthy individuals also are affected, but only at higher levels. Exposure to elevated CO levels is associated with impairment of visual perception, work capacity, manual dexterity, learning ability and performance of complex tasks.

Nitrogen Oxides (NO_x)
NO_x emissions produce a wide variety of health and welfare effects. Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection (such as influenza). NO_x emissions are an important precursor to acid rain and may affect both terrestrial and aquatic ecosystems. Atmospheric deposition of nitrogen leads to excess nutrient enrichment problems ("eutrophication") which can produce multiple adverse effects on water quality and the aquatic environment, including increased nuisance and toxic algal blooms, excessive phytoplankton growth, low or no dissolved oxygen in bottom waters, and reduced sunlight causing losses in submerged aquatic vegetation critical for healthy ecosystems.[3] Nitrogen dioxide and airborne nitrate also contribute to pollutant haze, which impairs visibility and can reduce residential property values and revenues from tourism.

Photochemical Oxidants (Ozone)
Ground-level ozone is the prime ingredient of smog, the pollution that blankets many areas during the summer.[4] Short-term exposures (1-3 hours) to high ambient ozone concentrations have been linked to increased hospital admissions and emergency room visits for respiratory problems. Repeated exposures to ozone can exacerbate symptoms and the frequency of episodes for people with respiratory diseases such as asthma. Other health effects attributed to short term exposures include significant decreases in lung function and increased respiratory symptoms such as chest pain and cough. These effects are generally associated with moderate or heavy exercise or exertion. Those most at risk include children who are active outdoors during the summer, outdoor workers, and people with pre-existing respiratory diseases like asthma. In addition, long-term exposures to ozone may cause irreversible changes in the lungs which can lead to chronic aging of the lungs or chronic respiratory disease.

Ambient ozone also affects crop yield, forest growth, and the durability of materials. Because ground-level ozone interferes with the ability of a plant to produce and store food, plants become more susceptible to disease, insect attack, harsh weather and other environmental stresses. Ozone chemically attacks elastomers (natural rubber and certain synthetic polymers), textile fibers and dyes, and, to a lesser extent, paints. For example, elastomers become brittle and crack, and dyes fade after exposure to ozone.

Ozone is also an effective greenhouse gas, both in the stratosphere and the troposphere.[5] That is, ozone absorbs infrared radiation emitting from the earth, captures it before it escapes into space, and re-emits a portion of it back toward the earth's surface. The specific role of ozone in climate change

2/ Derived from WHO, 1987. Air Quality Guidelines for Europe, Regional Office for Europe.
WHO, 1992. Air quality guidelines in the European region, EUR/ICP/CEH 079/A
WHO, 1994. Updating and Revision of the Air Quality Guidelines for Europe - Inorganic air pollutants, EUR/ICP/EHAZ 94 05/MT04
WHO 1995a. Updating and Revision of the Air Quality Guidelines for Europe - «Classical» air pollutants, EUR/ICP/EHAZ 94 05/PB01
WHO, 1995b. Updating and Revision of the Air Quality Guidelines for Europe -PCBs, PCDDs, PCDFs, EUR/ICP/EHAZ 94 05/MT10
WHO, 1995c. Updating and Revision of the Air Quality Guidelines for Europe - Ecotoxic effects, EUR/ICP/CEH230/B
WHO,1996. Updating and Revision of the Air Quality Guidelines for Europe - Volatile organic compounds, EUR/ICP/EHAZ 94 05/MT12
US EPA National Ambient Air Quality Standards

3/Of course, the main sources of nitrogen in aquatic ecosystems are usually nitrogenous waste runoff from heavily fertilized agricultural land.
4/Ozone occurs naturally in the stratosphere and provides a protective layer to ultraviolet radiation.
5/Intergovernmental Panel on Climate Change (IPCC), Working Group I, "Climate Change 1992 - The Supplementary Report to the IPCC Scientific Assessment", supplement to:
Intergovernmental Panel on Climate Change (IPCC), Working Group I, "Policymakers Summary of the Scientific Assessment of Climate Change", Fourth Draft, 25 May 1990.

is very complex and not yet well understood. Ozone concentrations in the atmosphere vary spatially, both regionally and vertically, and are most significant in urban areas where precursor gases are abundant. This variability makes assessment of global, long-term trends difficult.

Ozone is not emitted directly into the atmosphere, but is formed by a reaction of VOC and NO_x in the presence of heat and sunlight. Ground-level ozone forms readily in the atmosphere, usually during hot summer weather. VOCs are emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and other industrial sources. VOCs are also emitted by natural sources such as vegetation. NO_x is emitted from motor vehicles, power plants and other sources of combustion. Changing weather patterns contribute to yearly differences in ozone concentrations and differences from city to city. Ozone can also be transported into an area from pollution sources found hundreds of miles upwind.

In the US, EPA recently tightened the air quality standard from 0.12 parts per million of ozone measured over one hour to 0.08 parts per million measured over eight hours, with the average fourth highest concentration over a three-year period determining whether an area is out of compliance. The updated standard recognizes the current scientific view that exposure to ozone levels at and below the current standard causes significant adverse health effects in children and in healthy adults engaged in outdoor activities.

Recommendations of the World Health Organization
Focusing solely on the health consequences of CO, NO_2 and Ozone (which results from HC and NO_x), the World Health Organization (WHO) recently published revised air quality guidelines for Europe; these are summarized in the Table below.

b) Technology for Controlling CO, HC and NO_x Emissions

Many if not most urban areas around the world have experience air quality levels in excess of the WHO guidelines. In most of these cities, vehicle emissions are a major if not the dominant contributor. The state of the art technology for reducing CO, HC and NO_x emissions from vehicles relies

Summary of WHO Recommended Guidelines

Compound	Guideline Value	Averaging Time
Ozone	120 $\mu g/m^3$ (0.06 ppm)	8 hours
Nitrogen Dioxide	200 $\mu g/m^3$ (0.11 ppm)	1 hour
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Carbon Monoxide	100 mg/m^3 (87 ppm)	15 minutes
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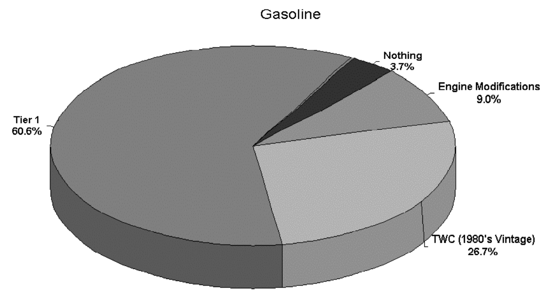
Carbon Monoxide	30 mg/m^3	1 hour
Carbon Monoxide	10 mg/m^3	8 hours

Figure 1: Pollution Controls On Light Duty Vehicles - 1998



on the catalytic converter, which converts large portions of the emissions to carbon dioxide, water vapor, oxygen and nitrogen; in fact approximately 86% of all new gasoline fueled cars manufactured in the world during 1998 contained a catalyst (see Figure 1).[6]

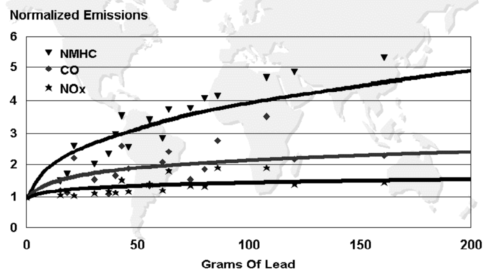
This technology cannot be used with leaded gasoline, however, since lead poisons the catalyst.

The impact of leaded gasoline on catalyst performance was studied by the US Environmental Protection Agency in 1984.[7] Twenty-nine in use automobiles with three-way catalyst emission control systems were misfueled with leaded gasoline in order to quantify the emissions effects. The vehicles used between four and twelve tanks of leaded gasoline with an average lead content of 1.0 grams Pb per gallon. Four different test programs were conducted with different misfueling intensities (rates) and mileage accumulation schedules. The US Federal Test Procedure (FTP) and several short tests were conducted at various stages. The results of the program indicated that vehicle emissions were mainly affected by the amount of lead passing through the engine and secondarily by the rate of misfueling.

Based on the data collected, it was possible to develop quantitative relationships between lead consumption and HC, CO and NO_x emissions.[8] Emission levels for each of the 29 vehicles involved in the EPA program were normalized to the levels which existed prior to any lead contamination[9] and then plotted as a function of the total amount of lead consumed. Normalization made it possible to eliminate the influence of different emissions standards. Regression

6/While catalysts have been installed on new cars in Japan and the United States for over 20 years and in Europe for more than five years, the use of this technology is no longer limited to these highly industrialized countries. For example, Thailand, Taiwan, Hong Kong, Brazil and Chile have also required catalysts on all new cars for several years.
7/"Misfueling Emissions of Three-Way Catalyst Vehicles", R. Bruce Michael, U.S. Environmental Protection Agency, presented at the Society of Automotive Engineers, Fuels and Lubricants Meeting, October 8-11, 1984, SAE Paper #841354.
8/It is important to emphasize that lead in gasoline does not increase emissions from the engine itself but rather poisons the catalytic converter which would otherwise clean up the pollution.
9/(Emissions)/(Emissions with no lead)

Figure 2: Impact of Lead On Emissions From Catalyst Equipped Cars



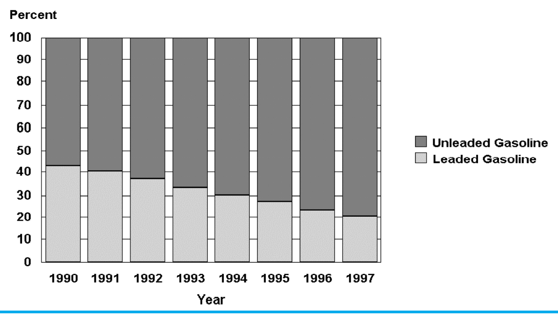
equations were then derived relating HC, CO and NO_x emissions respectively to the grams of lead consumed by each vehicle.

As Figure 2 indicates, FTP emissions of HC, CO and NO_x generally increase steadily with continuous misfueling. HC emissions increase the most rapidly on a percentage basis, followed by CO and, to a lesser extent, NO_x. Reasonably good correlations exist for the relationship between total lead consumed and emissions increases of each pollutant, especially for HC, the pollutant most affected. In the case of this latter pollutant, approximately 90% of the variability in emissions can be explained by the lead exposure.

1.3 - Global Trend to Unleaded Gasoline

Driven in some cases by the direct adverse health effects noted above and in others by the need to introduce catalysts to address other air pollution concerns, (and in still other cases by a combination of the two), many countries around the world have introduced unleaded gasoline over the last few decades; as noted earlier, an increasing number of countries have now banned leaded gasoline entirely.[10] As illustrated in Figure 3, approximately 80% of gasoline sold worldwide in 1996 was unleaded. Further, in many countries that sell leaded fuel the lead content has been reduced significantly. Throughout the EU, for example, the maximum amount of lead which can be added to fuel is 0.15 grams per liter compared to 0.4 grams per liter less than a decade ago.

Figure 3:Worldwide Use of Gasoline



10/*Agenda 21 also made reference to the removal of lead from gasoline.*

However, there are many countries and some large geographical areas, such as Africa, where only leaded gasoline is sold.

Unleaded gasoline has been required to be available throughout the European Union since 1989. Unleaded fuel is also widely available in Poland, Hungary and the Czech Republic. As noted earlier, a number of European countries have already completely banned the sale of leaded gasoline, including Austria, Germany, Sweden, Denmark and Slovakia. This ban will soon be extended throughout the European Union as Parliament and Council of Ministers have agreed that the sale of leaded gasoline should be prohibited by the year 2000.[11]

Vehicles equipped with catalytic converters *require* unleaded gasoline to prevent the catalyst being poisoned by lead deposits. Vehicles without catalytic converters can use unleaded gasoline but do not *require* it. Reducing or eliminating gasoline lead is desirable for public health reasons, however. Therefore, one transition strategy, which could be used while catalyst technology is being phased in, is to continue to market leaded fuel with minimal lead content (0.15 grams/liter or less).

The octane boost due to lead does not increase linearly with lead concentration. The first 0.1 g/liter of lead additive gives the largest octane boost, with subsequent increases in lead concentration giving progressively smaller returns. This means that supplying two units of low-lead gasoline will result in lower lead emissions than one unit of high-lead and one unit of unleaded gasoline having the same octane value. If octane capacity is limited, the quickest and most economical way to reduce lead emissions may thus be to reduce the lead content of existing leaded gasoline grades as much as possible, rather than by encouraging non-catalyst cars to use unleaded fuel. This also helps to reserve supplies of unleaded gasoline (which may be feasible to produce and distribute only in limited quantities) for those catalyst-equipped vehicles that truly require it. Reducing the allowable lead content will also reduce the refining cost difference between leaded and unleaded gasoline. If this is reflected in retail prices, it will reduce the temptation for owners of catalyst-equipped vehicles to misfuel with leaded gasoline. In the United States between 1985 and 1995, the leaded content of leaded petrol was limited to 0.1 grams per gallon.

However, the primary purpose of this paper is not to debate the merits of low lead or unleaded gasoline but to review the relative merits and demerits of different policy approaches which could be used to phase out its use.

11/*Derogations from this ban are permitted to member states up to 2005. In addition, a very limited quantity of leaded fuel, not to exceed ˚ of 1% will be allowed in perpetuity for use in classic cars.*

2. Options to Produce Lead Free Gasoline

Lead is added to gasoline because it is a low cost octane enhancer. If lead is not added to gasoline, therefore, it is necessary to either modify the refinery process to raise the octane level of the unleaded gasoline pool or to add alternative octane enhancing additives or to reduce the vehicle octane requirement. In most countries, a mixture of the first two approaches is applied.

2.1 - Refinery Modifications

Most refineries can be classified into two major groups: skimming and conversion refineries.[1] To replace the octane[2] formerly contributed by lead additives, refiners use a number of techniques. Increased catalytic cracking and reforming increase the concentrations of high-octane hydrocarbons such as benzene, toluene, xylene, and other aromatic species, and olefins. Alkylation and isomerization convert straight-chain or low molecular weight paraffins (which have relatively low octane) to higher-octane branched paraffins. Increased quantities of light hydrocarbons such as butane are also added.

Blending these components into an acceptable gasoline requires a careful matching of different characteristics. For example, Reformate provides very good octane but too much can increase aromatics and benzene levels. FCC Light provides good octane levels but can raise the vapor pressure. Alkylate is very attractive on all counts.

Modern conversion refineries can substitute for lead at a considerably lower cost than less advanced skimming refineries. Typically the cost of phasing out leaded gasoline - including the annualized refinery investment coasts amortized over the life of the investment, the incremental operating costs of producing gasoline without lead, and/or the cost of alternative gasoline additives - has been estimated to be in the range of US$ 0.01-0.02 per liter. Even in technologically less developed skimming refineries, the cost is estimated to be less than $0.03 per liter.[3] Further, refinery modernization investments necessary to reduce the lead content of gasoline often improve productivity and refining efficiency, and can increase revenues.

2.2 - Importation of Blending Components or Refined Product

As noted by the World Bank, however, many small skimming refineries constructed to serve smaller markets in developing countries cannot achieve sufficient economies of scale to support and accommodate investments in capital intensive, modern conversion and upgrading units. It may be more economical to close some of these refineries and import unleaded gasoline or high octane gasoline blending components.

Use of high octane oxygenated blending agents such as ethanol, methanol (with cosolvent alcohols), and especially methyl tertiary-butyl ether (MTBE) has increased greatly. In addition, the antiknock additive methylcyclopentadienyl manganese tricarbonyl (MMT) is used in some countries although the Environment agencies in both the U.S. and Canada have argued against its use.[4] Car makers also oppose its use because of its potential as a catalyst poison.

The choice of refinery investment or importation of gasoline blending components, (or even importing blended unleaded gasolines), is uttimately an important local economic/political decision.

2.3 - Lower Octane Approaches

In 1970, General Motors Corporation, in an effort to stimulate the introduction of unleaded gasoline, announced that all new cars starting with the 1971 Model Year would be designed to use unleaded gasoline and to operate on 91 RON fuel rather than 94 RON. This enabled unleaded gasoline to be introduced without any refinery modifications; lead was just not added to the so called unleaded pool.

2.4 - Impact of Alternatives on Emissions

Some of these solutions have created or aggravated environmental problems of their own. For example, the increased use of benzene and other aromatics (which tend to increase benzene emissions in the exhaust) has led to concern over human exposure to benzene. The US EPA recently concluded that the weight-of-evidence indicates that benzene is a human carcinogen.[5] (While there is an increased health risk if benzene levels increase with unleaded fuel, the risk is less than from lead. However, from a public health perspective, it is clearly better to keep benzene levels as low as possible.)[6]

The xylenes, other alkyl aromatics, and olefins are also much more reactive in producing ozone than most other hydrocarbons. Increased use of light hydrocarbons in gasoline produces a higher Reid vapor pressure (RVP), and increased evaporative emissions. MMT or its combustion by-products may cause adverse health effects as well; the auto industry

1/"Phasing Out Lead From Gasoline: World-Wide Experience and Policy Implications", Magda Lovei, The World Bank, August 1996.
2/Octane is a measure of the ability of a fuel to resist self detonation in the combustion chamber. In 1929, the octane scale was established in which two hydrocarbons were selected as references: one that tended to knock in an engine under almost all conditions (n-heptane) and the other having a much higher knock resistence than any known gasoline component at that time (iso-octane).
3/Ibid.

4/The Canadian government has recently reversed its ban on the use of MMT in unleaded petrol in the face of a legal challenge by the Ethyl Corporation.
5/"The Motor Vehicle Related Air Toxics Study", US EPA, March 1994.
6/"Phasing Out Lead From Gasoline: World-Wide Experience and Policy Implications", Magda Lovei, The World Bank, August 1996.

Example Properties of Process Streams Blended to Gasoline

	Olefins %	Aromatics %	Benzene %	Research Octane	Motor Octane	Vapor Pressure	Sulfur PPM	ASTM D 86 Distillation, deg. F		
								10%	50%	90%
Reformate	0	70	3	99	89	5	0	165	280	340
FCC Light	40	15	1.5	91	79	12	600	90	140	220
FCC Heavy	20	40	0	89	81	3	2000	220	275	340
Alkylate	0	0	0	94	92	7	0	135	230	245
Butane	0	0	0	94	90	60	0	31	31	31
Lt. St. Run	0	3	2	75	73	12	500	125	160	190
Hydrocracked Light	0	1	1	81	78	13	0	115	150	180
Isomerate	0	0	0	85	83	15	0	125	170	180
Polymer Gasoline	99	0	0	97	81	9	0	150	170	330
Coker Light	35	1	1	78	71	12	1800	95	110	160

believes that it may damage emissions control systems and thereby increase CO, HC or NO_x emissions from vehicles.

Most of these lead substitutes are not a serious concern if the switch to lead free gasoline is combined with the introduction of catalysts as catalysts tend to be especially effective with many of the more reactive or toxic hydrocarbons. However, in order to maximize the health benefits of unleaded gasoline use in vehicles without catalysts, and to minimize any health risks associated with evaporative emissions, it is prudent to assure that acceptable alternatives are used.

Once a country decides to make the switch to unleaded rather than leaded fuel, there are two major issues that must be resolved:

- What policy instrument or combination of instruments are most effective in bringing about the switch, and
- How quickly should the conversion take place?

These are the subject of the next two sections.

5/"The Motor Vehicle Related Air Toxics Study", US EPA, March 1994.
6/"Phasing Out Lead From Gasoline: World-Wide Experience and Policy Implications", Magda Lovei, The World Bank, August 1996.

Policy Tools for Switching from Leaded to Unleaded Gasoline

3.1 - Fuel Distribution Approaches

a) Mandatory Phase Out by a Date Certain

Mandating the complete phase out of leaded fuel provides the greatest certainty that it will actually occur. Where a country imports the fuel or has only a small number of refineries this is frequently just a straightforward economic and political question - is the country willing to increase the price of fuel (since the alternatives to lead tend to be more expensive) to reap the greater health and economic benefits of unleaded fuel?

However, in countries where there are a number of different refineries with different capabilities or large numbers of older vehicles whose owners have concerns regarding potential valve seat recession, government officials will take on the burden of responding to these concerns if they follow this path.

b) Unleaded Fuel Dispenser Nozzles

To assure that only unleaded gasoline would be used in cars equipped with catalytic converters, the US EPA required that unleaded gasoline nozzles should be of smaller diameter than leaded gasoline nozzles. Further, fuel filler inlet restrictors were required to be installed on the catalyst equipped vehicles to prevent the leaded gasoline nozzles from fitting. This very effectively eliminated the **inadvertent misfueling** of catalyst equipped cars with leaded fuel.

c) Fuel Taxes

As noted above, the most expeditious policy for eliminating lead in gasoline is to ban it outright. However, as an interim measure prior to taking that final step, many countries have chosen to adopt a tax policy that assures that the price of unleaded gasoline is lower than leaded; in this way a market pull can stimulate the rapid increase in unleaded sales.

Price Per Liter (US$)

	1990				1995			
Country	Leaded	Unleaded	Diff.	% Diff	Leaded	Unleaded	Diff.	% Diff.
Austria Belgium	.906 .912	.871 .856	.035 .056	-4.0 -6.5	- 1.151	1.121 1.036	- .114	- -.7
Czech Rep.	.690	.691	-.001	0.2	0.761	0.727	.034	-4.75
Denmark	1.016	0.946	0.069	-7.3	1.086	1.081	.005	-0.5
Finland	1.092	1.007	0.084	-8.4	-	1.112	-	-
France	0.981	0.958	0.023	-2.4	1.175	1.126	.048	-4.3
Germany	0.793	0.731	0.061	-8.4	1.180	1.082	.098	-9.1
Greece	0.727	0.686	0.041	-6.0	0.882	0.822	.060	-7.3
Hungary	0.791	-	-	-	0.804	0.773	.031	-4.0
Ireland	1.041	1.005	0.036	-3.6	0.971	0.902	.069	-7.6
Italy	1.230	1.215	0.016	-1.3	1.124	1.057	.067	-6.3
Luxembourg	0.685	0.652	0.032	-5.0	0.950	0.841	.109	-13.0
Netherlands	0.989	0.946	0.043	-4.5	1.284	1.178	.106	-9.0
Norway	1.027	0.950	0.077	-8.1	1.384	1.279	.105	-8.2
Poland	0.293	-	-	-	0.505	0.485	.021	-4.3
Portugal Spain	0.961 0.812	0.921 -	0.040 -	-4.4 -	1.039 0.905	1.026 0.857	.013 .048	-1.3 -5.6
Sweden	1.093	NA			1.106	1.052	.054	-5.1
Switzerland	0.792	0.734	0.058	-7.8	1.041	0.966	.074	-7.7
UK	0.798	0.746	0.052	-6.9	0.942	0.849	.093	-11.0

In Hong Kong, for example, in an effort to stimulate unleaded gasoline sales, a tax policy was adopted that resulted in unleaded gasoline being 1$HK cheaper per liter than leaded gasoline. Within one month, sales of unleaded fuel surpassed 50%.

Unleaded petrol was introduced in Singapore in 1991. Its use is encouraged through a differential tax system making unleaded petrol about 10 cents per liter cheaper than leaded petrol. At the end of 1997, the sale of unleaded petrol constituted about 75% of the total petrol sales. Availability of unleaded petrol has enabled Singapore to adopt more stringent exhaust emission standards for petrol-driven vehicles that require the use of catalytic converters. The oil companies voluntarily agreed to phase out leaded petrol by July 1998.

A number of European countries have also used this approach. In Germany, for example, leaded gasoline has been completely eliminated through tax incentives even though a formal ban awaits final EU action.

Summarized below is the experience throughout Europe in stimulating unleaded gasoline sales through tax incentives.

As these data indicate, the differential between leaded and unleaded has grown throughout the 1990s in many European countries.

A concern with the use of tax incentives to stimulate unleaded gasoline sales is that it might lower overall government revenue. However, tax systems can be designed in such a way as to be effectively revenue neutral or even slightly increase overall government revenue, as illustrated in the Table below.

Year	1997	2005	2005	2005	2005
Fuel Consumption (Million Tons)	10.00	11.49	11.49	11.49	11.49
Fuel Consumption (million Liters)	13,327.0	15,309	15,309	15,309	15,309
Percent Leaded Leaded Liters (millions)	95% 12,661	95% 14,543	95% 14,543	25% 3,827	0% 0
Ex Refinery Price	$0.50	$0.50	$0.50	$0.50	$0.50
Normal Taxes ($/liter)	$0.75	$0.75	$0.75	$0.75	$0.75
Lead Tax ($/gram) Avg. Lead Content (g/Liter)	0 0.32	0 0.32	0.25 0.32	0.25 0.32	0.25 0.32
Lead Tax ($/liter)	0	0	0.08	0.08	0.08
Leaded Retail Price ($/Liter)	1.25	1.275	1.355	1.355	1.355
Leaded Tax Revenues	$9,495.49	$10,907.33	$12,070.78	$3,176.52	$0.00
Unleaded Liters (millions)	666	765	765	11,481	15,309
Unleaded Production Cost Penalty (%)	0.02	0.02	0.02	0.02	0.02
Ex Refinery Price	0.51	0.51	0.51	0.51	0.51
Normal Taxes ($/liter)	0.765	0.765	0.765	0.765	0.765
Unleaded Retail Price ($/liter)	1.275	1.275	1.275	1.275	1.275
Unleaded Tax Revenues	$509.76	$585.55	$585.55	$8,783.27	$11,711.03
Total Tax Revenue	$10,005.25	$11,492.88	$12,656.33	$11,959.79	$11,711.03
Leaded/unleaded Differential	-2.0%	0.0%	5.9%	5.9%	5.9%

In this hypothetical case, total government tax revenue from gasoline sales is calculated assuming no tax differential as well as a tax differential designed to maintain the retail price of leaded gasoline at least 6% higher than unleaded gasoline. This table shows that overall tax revenue can be slightly higher than in the base case even if leaded gasoline sales decline substantially.

d) Mandating Unleaded Pumps

To assure that unleaded gasoline is widely available, one approach is to require that all service stations above a certain volume be required to provide unleaded fuel. In countries that allow the sale of both leaded and unleaded fuel but also require catalysts on new cars, such a policy seems necessary to assure that unleaded fuel is widely available for protecting the catalysts. For example, in India, new light duty vehicles sold in the four Metros (Delhi, Mumbai, Calcutta and Chennai) have been required to be fitted with catalytic converters and to meet standards 50% more stringent than the national norms since April 1, 1995. As of June 1, 1998, this catalyst requirement was be expanded to all major cities of the country. However, unleaded gasoline has only been available until recently withing the 4 metros. As a result there is a great deal of concern that many of the catalyst equipped cars have been poisoned by lead.

3.2 - Vehicle Manufacturer Approaches

a) Mandate Vehicles Designed for Lead Free Gasoline

To assure that at some point all vehicles will be able to operate with no difficulties using unleaded fuel and/or to assure that the market for unleaded gasoline will gradually grow, countries can require that all new cars be designed to operate on unleaded fuel. This requirement can also apply to cars imported after a certain date.

b) Fuel Filler Inlet Restrictors

As noted earlier, in the US fuel filler inlet restrictors were required on all new cars as part of the overall lead phase out strategy. This was intended to assure that the catalytic converter on these cars would not be inadvertently poisoned by lead, as well as to gradually increase demand for unleaded fuel.

3.3 - Conclusions Regarding Policy Alternatives to Eliminate Leaded Gasoline

Mandating the complete phase out of leaded fuel provides the greatest certainty that it will actually occur.

If a country imports fuel or has only a small number of refineries the issue of lead is frequently just an economic question - is the country willing to increase the price of fuel (since the alternatives to lead tend to be more expensive) to reap the greater health and economic benefits?

However, where there are a number of different refineries with different capabilities or large numbers of older vehicles whose owners (rightly or wrongly) have concerns regarding potential valve seat recession, government officials will take on the burden of responding to these concerns if they mandate lead phase out.

The use of economic instruments that keep leaded gasoline more expensive to the consumer leave many of these issues to the marketplace. If the car owner is concerned regarding valve seat recession, then he can choose to pay more for leaded fuel. If a refinery is particularly disadvantaged with regard to providing unleaded fuel with satisfactory octane, it can continue to offer leaded fuel in the marketplace, perhaps with a smaller profit margin.

Under this approach, however, leaded fuel can continue to be used indefinitely with the result that children and others will remain at some increased risk.

The optimal solution must of course be country specific, taking account of the local conditions, but it would seem that some principles stand out:

- Tax policy can be used to stimulate a more rapid shift to unleaded fuel by many vehicle owners.
- Allowing unleaded fuel to be more expensive than leaded fuel is counterproductive to programs designed for lead phase out.
- There should be some certain date by which the complete lead phase out is to occur.

How Rapidly Should the Phaseout Occur

The schedule for completely phasing lead out of gasoline should be based on a careful balancing of several important questions - the need to reduce the direct health risks from lead, the need for unleaded gasoline to protect catalytic converters and the speed with which any necessary refinery modifications can be carried out. Each of these issues is reviewed briefly below.

4.1 - Health

As summarized above, in section 1a, lead emitted from vehicle exhaust as a result of lead in gasoline can cause a variety of adverse health effects at very low levels, especially in children. Therefore, considering lead health concerns alone, lead in gasoline should be phased out as quickly as possible. If lead is eliminated from gasoline, lead emissions from vehicles will also be eliminated.

Phaseout strategies must also recognize that various approaches to the reformulation of fuels can result in automotive emissions with undesirable toxicity characteristics unless vehicles are equipped with catalytic converters. The relative need for the introduction of catalytic converter equipped cars will thus impact upon the speed with which phaseouts are implemented.

4.2 - Catalyst Protection

As summarized above, in Section 1d, lead in gasoline poisons catalytic converters, the primary component of emissions control systems designed to significantly reduce CO, HC and NO_x. In order to protect these systems, unleaded gasoline must be introduced no slower than fuel demands dictated by the penetration of these vehicles into the car fleet. Further, it unleaded fuel must be widely distributed so these vehicles have access to the fuel wherever they drive. Beyond these considerations, there always remains a risk of deliberate or inadvertent misfueling of catalyst cars with leaded gasoline as long as leaded gasoline is present. Deliberate misfueling should be minimized by maintaining a sufficient price advantage for unleaded gasoline relative to leaded gasoline but doing so will likely increase the use of unleaded fuel in non catalyst cars, thereby necessitating increased production of unleaded gasoline.

4.3 - Refinery Modifications

An important factor in national phaseout strategies is the time needed to make necessary refinery improvements. As summarized in Section 2a, in many countries that have their own refining industry substantial refinery improvements are necessary to provide completely unleaded gasoline of sufficient octane to satisfy the vehicle fleet. This will have to be done in parallel with other improvements such as lowering the sulfur content of diesel fuel, lowering benzene and sulfur in gasoline, and so on.

5. A Tale of Two Countries

The phase out of leaded gasoline in the US took approximately 25 years whereas in China it will take approximately three. It seems useful therefore to compare the lessons of each.

5.1 - The US Experience

In the 1970 Clean Air Act, two separate but parallel programs were created for reducing lead in gasoline. One was the unleaded gasoline availability requirement, which mandated that refineries produce unleaded gasoline in suf ficient quality to be used with the catalytic converter -equipped vehicles that were to be introduced in the 1975 model year .

A second program called the lead phase down, was directed at reducing the health risks associated with lead. Lead phase down was based on a judgement that the rate of lead removal if the US relied solely on the replacement of non-catalyst leaded vehicles with catalyst-equipped unleaded vehicles, equipped would be too slow to satisfy public health concerns. The rate of lead phase down came to a head when after publicly raising the question of whether the program should be scrapped, EP A concluded in 1985 that the cost of using leaded gasoline was greater than the benefit of using leaded gasoline. Taking lead out of gasoline could be done at zero or even negative cost to the economy after considering not only increased vehicle maintenance but also health ef fects. A decision was made to lower the lead content of leaded gasoline to 0.1 grams/gallon. In the 1990 Clean Air Act Amendments, Congress made the decision to ban lead in gasoline entirely by 1996.

As one of the first countries to mandate the use of unleaded gasoline, the US did not take steps to control the price differential between leaded and unleaded fuel. One result was that for many years leaded fuel was marketed as the "price leader" which encourage individuals including those who drove catalyst equipped cars to purchase this lower cost fuel.[1] As a result many catalytic converters were damaged or destroyed, undermining the huge national investment in this advanced pollution control technology; the lead phase down proceeded much more slowly than EP A originally anticipated.

Further, because a dual fuel program was in ef fect for many years, refiners and fuel distributors were required to put in place a dual distribution system with separate tanks for leaded and unleaded fuel. To police this ef fort, EPA had a sustained effort over many years to ensure that unleaded gasoline was not being contaminated with leaded gasoline.

The net effect was that while the US succeeded in eliminating lead in gasoline, it was an expensive twenty-five year ef fort with many bumps along the way .

1/In 1985 on average leaded gasoline cost 7 cents less per gallon than unleaded and 16% of the cars that required unleaded were using leaded fuel.

5.2 - China's Plans

During the period from March 3 to 7, 1997, a symposium devoted to the elimination of lead in gasoline in China was held in Shanghai. Sponsorship was provided by the China National Environmental Protection Agency (NEP A), the US EPA, the World Bank, the W orld Health Organization, General Motors, V olkswagen, Engelhard and Degussa.

The objective of the symposium was to discuss and debate whether and if so how to eliminate lead from gasoline in China. Participants included representatives of the above organizations, the municipalities of Beijing, Shanghai, Guangzhou, and a broad spectrum of Ministries and organizations involved in the issue of lead free gasoline.

At the conclusion of the symposium, it was decided that China would convert to 100% unleaded gasoline by 2000. This was reinforced when at the conclusion of the symposium, representatives from the Ministry of Finance, MMI, the Ministry of Public Security, the State Planning Commission and SSTC all endorsed the plan and of fered their strong support. Most importantly , Sinopac, which produces about 80% of the gasoline in China, announced that they were prepared to invest 15 billion RMB (US$2 billion) to eliminate 70 MON gasoline and all leaded gasoline by 2000.

The major plans of Sinopac included:

- Completely phasing out the use of straight run gasoline by the end of 1998
- Completely phasing out the sale of leaded gasoline in eight major cities by 1998
- Completely phasing out the sale of leaded gasoline across the entire country by 2000

In order to do this, Sinopac committed to a massive revamping and rebuilding program designed to raise the unleaded gasoline octane pool to 91 RON by 2000. T otal investment will be approximately 15 billion RAB ($2 Billion) by 2000. This will change the composition of gasoline feedstocks as illustrated below:

Sinopac Production Plans (Million Tons)

Fuel	Octane	1995	2000	Portion For Gasoline
FCC	88-92	45	68	27
Catalytic Reformate	94-100	7	15	4.5
Alkylate	94	1.2	1.2	1
MTBE	107-117	0.375	0.525	0.005

China is well on track to carrying out this strategy with leaded gasoline banned from Beijing in July 1997, and in Shanghai, Guangzhou and other large cities in October of that same year.

After considering the US and other experiences, China concluded that the wisest course would be to adopt a fast phaseout schedule. By eliminating leaded gasoline prior to the introduction of catalytic converters on new cars, China believes that it will not only minimize the health risks associated with lead exposure but will also assure that the large national investments in catalysts expected to begin around the turn of the century will yield the maximum benefit.

	Gasoline Type	1996	Percent	2000	Percent
Total		30.51		40.07	
Other		6.28	20.6%	6.07	
Sinopac		24.23	79.4%	34	
	70 MON	8.13	33.6%	0	
	'Leaded	2		0	
	'Unleaded	6.13		0	
	90 RON	13.85	57.2%	25.5	
	'Leaded	7.39		0	
	'Unleaded	6.46		25.5	
	93 RON	1.76	7.3%	7	
	'Leaded	0.23		0	
	'Unleaded	1.53		7	
	95 RON	0.12	0.5%	0	
	'Leaded	0.01		0	
	'Unleaded	0.11		0	
	97 RON	0.29	1.2%	1.5	
	'Leaded	0.27		0	
	'Unleaded	0.02		1.5	
	Other	0.08		0	
	Leaded Total	9.98	41.2%	0	0.0%
	Unleaded Total	14.25	58.8%	34	100.0%

6. Conclusions and Recommendations

Both to reduce the public health risks from lead exposure, especially to children, and to allow the widespread use of catalytic converters to reduce CO, HC and NO_x emissions, **a global consensus to phase out the use of leaded gasoline has emerged.** As a result, approximately 80% of all gasoline sold in the world last year was unleaded, and this fraction increases daily.

In phasing out the use of leaded fuel, many different policy tools have been used. It has now been conclusively demonstrated in a variety of countries, that **taxation policies that ensure that unleaded gasoline is cheaper than leaded gasoline can be very effective in accelerating the rapid introduction of unleaded fuel** as well as minimizing the deliberate use of leaded gasoline in catalyst equipped cars. **In no case should leaded gasoline be allowed to be priced lower than unleaded** if rapid progress is desired.

Once a decision is made by a country to phase out the use of leaded gasoline, a date for its elimination should also be set.

The schedule for completely phasing lead out of gasoline should be based on a careful balancing of several important criteria - the need to reduce the direct health risks from lead; the seriousness of other air pollution problems which will require the use of catalytic converters and the need for unleaded gasoline to protect catalytic converters; and the speed with which any necessary refinery modifications can be carried out, to cite just a few.

While each country has to weigh these factors carefully, considering its own specific circumstances, the global tendency recently has been for countries phasing out lead to move quickly rather than slowly. China appears to be eliminating lead in less than three years across the entire country, and in an even shorter period in its most polluted cities.

While a very important step, the elimination of lead is not the only important element in a comprehensive fuels strategy. First of all, no increase in the toxicity of the fuel should be tolerated when shifting from leaded to unleaded. If aromatics and benzene content of the fuel increase due to the greater use of high octane, high aromatic gasoline blending components, this should be a short term, transitory phase which is eliminated as quickly as feasible. Other fuels improvements such as lowering volatility and sulfur levels should also be considered.

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ABOUT THE UNEP DIVISION OF TECHNOLOGY, INDUSTRY AND ECONOMICS

The mission of the UNEP Division of Technology, Industry and Economics is to help decision-makers in government, local authorities, and industry develop and adopt policies and practices that:

- ❑ are cleaner and safer;
- ❑ make efficient use of natural resources;
- ❑ ensure adequate management of chemicals;
- ❑ incorporate environmental costs;
- ❑ reduce pollution and risks for humans and the environment.

The UNEP Division of Technology, Industry and Economics (UNEP TIE) located in Paris, is **composed of one centre and four units**:

✔ **The International Environmental Technology Centre (Osaka)**, which promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins, in developing countries and countries in transition.

✔ **Production and Consumption (Paris)**, which fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.

✔ **Chemicals (Geneva)**, which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety world-wide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO)

✔ **Energy and OzonAction (Paris)**, which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/ Collaborating Centre on Energy and Environment supports the work of the Unit.

✔ **Economics and Trade (Geneva)**, which promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

UNEP TIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology cooperation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

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ABOUT THE OECD'S ENVIRONMENTAL HEALTH AND SAFETY PROGRAMME

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation consisting of 29 democratic countries with industrialised market economies in Europe, Asia, North America and the Pacific. Founded in 1960, the OECD promotes: economic growth, employment and social welfare in OECD countries; free trade between OECD countries, as well as with non-members; and sound economic growth in non-member countries. The OECD has programmes of work in the following areas: General economic policy; Statistics; International trade; Development co-operation; Science, technology and industry; Financial, fiscal and enterprise affairs; Energy; Food, agriculture and fisheries; Education, employment, labour and social affairs; Territorial development; Public management; Transport; and Environment. The later includes the OECD Environmental Health and Safety Programme.

What is OECD's Environmental Health and Safety Programme? Following concern over widespread contamination and accompanying adverse effects, coupled with the need for international co-operation, the OECD established this Programme in 1971 to undertake work on the safety of chemicals. Today, the 29 Member countries and the OECD Secretariat work together to develop and co-ordinate environmental health and safety activities on an international basis. Such activities include harmonising chemical testing and hazard assessment procedures; harmonization of classification and labelling; developing principles for Good Laboratory Practice; co-operating on the investigation of existing chemicals (high production volume chemicals); work on Pollutant Release and Transfer Registers (PRTRs), as well as sharing and exploring possible co-operative activities on risk management from chemicals. In addition, the EHS Programme also conducts work on pesticides, chemical accidents, waste management, biotechnology and food safety.

The principal objectives of the Environmental Health and Safety Programme are to: assist OECD Member countries' efforts to protect human health and the environment through improving chemical, biotechnology, and pesticide safety; making policies more transparent and efficient; and preventing unnecessary distortions in the trade of these products.

The major products of the EHS Programme are: test guidelines, Good Laboratory Practice, the system of mutual acceptance of industrial chemical testing data, hazard/risk assessment methods, initial assessment reports on high production volume chemicals, risk management monographs, consensus documents on products derived through modern biotechnology, guidance documents on preventing chemical accidents; material to facilitate the exchange of pesticide assessment reports; and a system to effectively control the transfrontier movement of hazardous wastes.

Much of this information is available free of charge to the public through the EHS web site:
http://www.oecd.org/ehs/

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