# CLEAN FUELS & VEHICLES REGULATORY TOOLKIT

## Full Report


UNEP

Partnership for Clean Fuels and Vehicles

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# CLEAN FUELS AND VEHICLES TOOLKIT

# I. BACKGROUND

The transport sector is a major source of air pollution and CO2 emissions. These emissions are set to increase sharply as the global vehicle fleet is projected to grow to between 2 and 3 billon vehicles by 2050 – with almost all of this growth taking place in developing and transitional countries. The sector remains the main source of urban air pollution in many developing and transitional countries, contributing over 50% of urban air pollution in many cities. The key pollutant is fine particulate matter (PM) causing an estimated 3.2 million premature deaths annually (World Health Organization, April 2014), with the transport sector being a major contributor. One component of PM, black carbon, is an important climate pollutant. In addition, the sector contributes nearly one quarter of global CO2 emissions. This share is set to rise to at least one third by 2050 unless significant steps are taken.

Developed countries have made major investments to introduce cleaner and more efficient modes of transport and vehicles emissions have been reduced sharply. Similar approaches to promote the use of cleaner fuels and vehicles need to be adopted by developing and transitional countries, where the bulk of vehicle growth is now taking place.

The Partnership for Clean Fuels and Vehicles (PCFV), the leading global public-private partnership to promote cleaner fuels and vehicles, has been working with developing and transitional countries to reduce vehicular air pollution through the promotion of cleaner fuels and vehicles. Today, the PCFV with its Secretariat hosted at UNEP's Transport Unit, within the Division of Technology, Industry and Economics has a global reach of 73 partners. These partners are drawn from the private sector (oil and vehicle industry), government (developing and developed), international organizations and the civil society.

In the coming years, the PCFV will focus on the following two major campaigns, as agreed by partners at an Extraordinary PCFV Partners meeting that was held in London in October 2012, ten years following the launch of the PCFV;

- A campaign aimed at gasoline[1] fueled vehicles to complete the phase out of leaded gasoline and to support countries to adopt measures to ensure that only catalyst equipped vehicles will be added to their fleets.

- For consistency, gasoline is used throughout even though many countries refer to this fuel as petrol.

1 For consistency, gasoline is used throughout even though many countries refer to this fuel as petrol.

- A campaign to promote the introduction of low sulfur fuels of 50 ppm or less hand in hand with the support for the development and adoption of vehicles emissions standards.

Reducing sulfur levels in diesel fuels is especially important in reducing the smallest particulates and black carbon and can reduce vehicle emissions in two ways, by reducing direct emissions of both sulfur dioxide and sulfate particulate matter from all vehicles - old and new, and by improving the effectiveness of vehicle emission control technologies such as diesel particle traps resulting in decreased vehicle emissions of particulate matter (PM), carbon monoxide (CO), hydrocarbon (HC) and black carbon (BC).

These two campaigns introduce a systems approach to the PCFV work. This regulatory toolkit is meant to introduce the need for a systems approach to vehicle emission reduction in developing and transitional countries. Developed countries have used different tools to move to stricter fuel quality and vehicle emission standards. However, it is important to note that in spite of these differences, these countries have had a clear and concise road map – a systems approach that matches fuels and vehicle improvements - to move towards tighter vehicle emissions regulations. A similar approach is missing in most developing and transitional countries.

Through PCFV support, many developing and transitional countries have adopted targets and roadmaps to introduce lower sulfur fuels, after completing the phase-out of leaded gasoline. For optimal environmental and mechanical performance, fuels and vehicle standards are best developed and introduced in a "systems approach" where vehicle standards are developed and implemented in coordination with the appropriate fuel standards. Unfortunately, the adoption of cleaner fuels and vehicle emission standards in most developing countries is not coordinated, and lacks a clear long term strategy. As a result the potential emissions reductions expected from moving to cleaner fuels are not fully achieved. A systems approach to fuels and vehicles regulations will thus ensure that countries apply a long term strategy and outlook to their roadmap towards cleaner fuels and vehicles regulation and link the phased introduction of cleaner fuels with those of cleaner vehicles.

This toolkit will assist developing and transitional countries to establish a systems approach to clean fuels and vehicles regulations. The toolkit will support countries to introduce 50 ppm and lower sulfur fuels, import lower emitting and more efficient vehicle technologies, establish vehicle emissions control roadmaps and ultimately improve air quality and human health in these countries. The toolkit will also contain specific case examples for developing and transitional countries to integrate cleaner fuels and vehicles emission standards.

The main focus of the toolkit will be on light duty vehicles regulations, which is also the focus area of the PCFV. However, a heavy duty vehicles component may also be included. The regulatory toolkit is available online, as an interactive toolkit on the PCFV website - http://www.unep.org/Transport/new/PCFV/, and the executive summary is also available in hard copy for distribution in developing and transitional countries.

# 2. INTRODUCTION

Over approximately the last twenty-five years, extensive studies have been carried out to better establish the linkages between fuels and vehicles and vehicle emissions. One major study, the Auto/Oil Air Quality Improvement Research Program (AQIRP) was established in 1989 in the US and involved 14 oil companies, three domestic automakers and four associate members.[2] Likewise, in June 1993, a contract was signed by the auto and petroleum industries to undertake a common test program, called the European Program on Emissions, Fuels and Engine Technologies (EPEFE). In Asia, The Japan Clean Air Program (JCAP) was conducted by Petroleum Energy Center as a joint research program of the automobile industry (as fuel users) and the petroleum industry (as fuel producers), supported by the Ministry of Economy, Trade and Industry.[3] The second phase of the JCAP program focused on future automobile and fuel technologies aimed at realizing Zero Emissions while at the same time improving fuel consumption, with a special focus on studies of fine particles in exhaust emissions.

The most important lesson learned and reinforced from these studies is that with regards to vehicle emissions, vehicles and fuels are a system and need to be treated as such. A clear historical example of this reality is the close linkage between the requirement for lead-free gasoline as a precondition for the introduction of catalytic converter technology to reduce the CO, HC and nitrogen oxides (NOX) which would otherwise be emitted in large quantities from gasoline-fueled vehicles. The more current example is the necessity of lowering levels of sulfur in gasoline and diesel fuel to enable the use of certain advanced pollution control technologies; in fact it is now understood that sulfur levels must be reduced to near zero if the maximum benefits are to be achieved by the most advanced technologies used with combustion engines today.

2 "Auto/Oil Air Quality Improvement Research Program, Final Report", January 1997.

3 The program consisted of two stages: the first stage called JCAP I commenced in FY 1997 and terminated in FY 2001; the second called JCAP II commenced in FY 2002 and continued until 2007 to provide a further development of the research activities of JCAP I.

GOAL AND STRUCTURE OF THE TOOLKIT:

*Relying heavily on each of studies establishing the linkages between fuels and vehicles and vehicle emissions, as well as other recent work, this toolkit will provide information to policy makers in developing countries that will assist in enabling the development of a regulatory framework to address vehicle emissions and fuel quality, including technical and policy background and case studies of existing regulatory approaches.*

*The toolkit first summarizes what is known about the impact of fuel sulfur content on vehicle emissions and assesses the implications for the phase-in of tighter new vehicle standards. The second section summarizes the impact of sulfur in gasoline and diesel fuel on vehicle emissions within the context of the emissions standards that the affected vehicles are designed to meet. The last section summarizes the approaches including regulatory governance taken by various countries to require or stimulate lower sulfur fuels and more stringent vehicle standards.*

# Gasoline Vehicles and Fuels

## General Description of gasoline fuel parameters

Gasoline is a complex mixture of volatile hydrocarbons used as a fuel in internal combustion engines. The emissions of greatest concern from gasoline-fuelled vehicles are CO, HC, NOX, PM[4] and certain toxic hydrocarbons such as benzene, formaldehyde, acetaldehyde, and 1,3-butadiene. Each of these can be influenced by the composition of the gasoline used by the vehicle. The most important characteristics of gasoline with regard to its impact on emissions are sulfur concentration, volatility, aromatics, olefins, oxygenates, and benzene level.

## Impact of Gasoline Composition on Vehicle Emissions

The following table summarizes the impacts of various gasoline fuel qualities on emissions from light duty gasoline vehicles as a function of European[5] emissions standards.

4 Traditionally gasoline fueled vehicles have not been a significant source of PM but newly emerging gasoline direct injection technologies can emit much higher levels of particulate.

5 Other than Japan, the United States and Canada, most countries follow the European fuels and vehicles

## Table A: Impact of Gasoline Composition on Emissions from Light Duty Vehicles[6]

| Gasoline | No Catalyst | Euro 1 | Euro 2 | Euro 3 | Euro 4 | Euro 5/6 | Other Coniderations |
|---|---|---|---|---|---|---|---|
| Lead | Pb, HC | CO, HC, NOX all increase dramatically as catalyst destroyed | | | | | Lead is now virtually banned worldwide with only 5/6 countries still using |
| Sulfur (50 to 450 ppm) | SO2 | CO, HC, NOX all increase ~15-20% SO2 and SO3 increase | | | | | Onboard Diagnostic light may come on incorrectly |
| Olefins | Increased 1,3 butadiene, increased HC reactivity, NOX, small increases in HC for Euro 3 and cleaner | | | | | | Potential deposit buildup |
| Aromatics | Increased benzene in exhaust | | | | | | |
| | Potential increases in HC, NOX | HC, NOX, CO HC, NOX, CO | | | | | Deposits on intake valves and combustion chamber tend to increase. Some recent studies indicate that PM emissions could also increase [7] |
| Benzene | Increased benzene exhaust and evaporative emissions | | | | | | |
| Ethanol up to 3.5% O2 | Lower CO, HC, slight NOX in crease (when above 2% oxygen content), Higher aldehydes | Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems | | | | | Increased evaporative emissions unless RVP adjusted, potential effects on fuel system components, potential deposit issues, small fuel economy penalty |
| MTBE ↑ up to 2.7% O2 | Lower CO, HC, higher aldehydes | Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems | | | | | Concerns over water contamination |
| Distillation characteristics T50, T90 | Probably HC | HC | | | | | |
| RVP | Increased evaporative HC Emissions | | | | | | Most critical parameter for Asian countries because of high ambient Temperatures |
| Deposit control additives | | Potential HC, NOX emissions benefits | | | | | Help to reduce deposits on fuel injectors, carburetors, intake valves, combustion chamber |

roadmap. A summary of European Light Duty Vehicle Emissions Standards is contained in Appendix A.

6 For the purposes of qualitative sulfur impacts, vehicles meeting US Tier 1 standards would have impacts similar to Euro 3 vehicles while Tier 2 and 3 vehicles would have impacts similar to Euro 5/6 vehicles.

7 "Development of a Predictive Model for Gasoline Vehicle Particulate Matter Emissions," SAE Int. J. Fuels Lubr. 3(2):610-622, 2010, doi: 10.4271/2010-01-2115. Author(s): Koichiro Aikawa - Honda R&D Co Ltd, Takayuki Sakurai - Honda R&D Co Ltd, Jeff J. Jetter - Honda R&D Americas Inc.

*Notes: CO = carbon monoxide; HC = hydrocarbon; Pb = lead; RVP = Reid vapor pressure; MTBE = methyl tert-butyl ether; NOX = oxides of nitrogen; O2 = oxygen; SO2 = sulfur dioxide; T50 = temperature at which 50% of the gasoline distils; T90 = temperature at which 90% of the gasoline distils*

## Two and Three Wheeled Vehicles

Some rapidly developing countries such as China and India have a much larger population of two and three wheeled vehicles than anywhere else in the world. While emissions from these vehicles are expected to be influenced by fuel characteristics, this topic has had little study. However, based on the limited available data and the combustion similarities between these and other internal combustion engines, these impacts are estimated to be as shown in the table below.

### Table B: Impact of Gasoline Composition on Emissions from Motorcycles

| Gasoline | No Catalyst | India 2005 | Euro 3 | India 2008 | China Stage 3 | Other Considerations |
|---|---|---|---|---|---|---|
| Lead | Pb, HC | CO, HC, NOX all increase dramatically as catalyst destroyed | | | | |
| Sulfur (50 to 450 ppm) | SO2 | CO, HC, NOX all increase SO2 and SO3 increase | | | | |
| Olefins | Increased 1,3 butadiene, HC reactivity and NOX | | | | | Potential deposit buildup |
| Aromatics | Increased benzene in exhaust | | | | | |
| Benzene | Increased benzene exhaust and evaporative emissions | | | | | |
| Ethanol up to 3.5% O2 | Lower CO, HC, slight NOX increase | Minimal effect with oxygen sensor equipped vehicles | | | | Increased evaporative emissions unless RVP adjusted, potential effects on fuel system components, potential deposit issues, small fuel economy penalty |
| MTBE up to 2.7% O2 | Lower CO, HC | Minimal effect with O2 sensor equipped vehicles | | | | Concerns over Water Contamination small fuel economy penalty |
| Distillation characteristics T50, T90 | Probably HC | HC | | | | Not as quantifiable as in passenger cars |
| RVP | Increased evaporative HC Emissions | | | | | |
| Deposit control additives | | potential emissions benefits | | | | Help to reduce deposits on fuel injectors, carburetors |

*Notes: CO = carbon monoxide; HC = hydrocarbon; Pb = lead; RVP = Reid vapor pressure; MTBE = methyl tert-butyl ether; NOX = oxides of nitrogen; O2 = oxygen; SO2 = sulfur dioxide; T50 = temperature at which 50% of the gasoline distils; T90 = temperature at which 90% of the gasoline distils*

Most two- and three-wheeled vehicles currently used around the world are not equipped with catalytic converters to control emissions. Therefore it would seem that the impact of the various fuels parameters will be similar to those from pre Euro I cars. Where Euro 3 limits have been introduced however, vehicles are impacted by sulfur and lead in a manner similar to Euro I and 2 gasoline fueled cars. For two- and three-wheeled vehicles equipped with 2-stroke engines, the amount and quality of the lubricating oil is probably more important for emissions than fuel quality but this technology is rapidly being phased out in most countries. This is fortunate as 2-stroke engines have very high PM emissions relative to 4-stroke engines.

## Diesel Vehicles and Fuels

### General Description of Diesel Fuel Parameters

Diesel fuel is a complex mixture of hydrocarbons with the main groups being paraffins, napthenes and aromatics. Organic sulfur is also naturally present. Additives are generally used to influence properties such as the flow, storage and combustion characteristics of diesel fuel. The actual properties of commercial automotive diesel depend on the refining practices employed and the nature of the crude oils from which the fuel is produced. The quality and composition of diesel fuel can significantly influence emissions from diesel engines.

Diesels emit high levels of oxides of nitrogen and particulates. Modest to significant NOX control can be achieved by delaying fuel injection timing and adding exhaust gas recirculation (EGR). Very high pressure, computer controlled fuel injection can also be timed to reduce PM emissions. Modifying engine parameters to simultaneously reduce both NOX and PM is difficult and limited since the optimal settings for one pollutant frequently increases emissions of the other and vice-versa. Achieving very low levels of NOX and PM therefore require exhaust treatment. Lean NOX catalysts, selective catalytic reduction (SCR), NOX storage traps with periodic reduction, filter traps with periodic burn-off, and oxidation catalysts with continuous burn-off are evolving technologies that are being phased in at differing rates in various parts of the world.

Reformulated diesel fuels can effectively reduce oxides of nitrogen and particulate emissions from all diesel vehicles. These fuels have reduced sulfur, reduced aromatics, and increased Cetane Number. To reduce PM and NOX emissions from a diesel engine, the most important fuel characteristic is sulfur because sulfur contributes directly to PM emissions and high sulfur levels preclude the use of or impair the performance of the most effective PM and NOX control technologies.

# Impact of Diesel Fuel Composition on Vehicle Emissions

The following tables (C and D) summarize the impacts of various diesel fuel qualities on emissions from light and heavy duty diesel vehicles, respectively.

## Table C: Impact of Fuels on Light Duty Diesel Vehicles[8]

| Diesel Fuel Characteristic | Pre-Euro | Euro 1 | Euro 2 | Euro 3 | Euro 4 | Euro 5/6 | Other Coniderations |
|---|---|---|---|---|---|---|---|
| Sulfur | SO2, PM | | If oxidation catalyst is used, SO3, SO2, PM | | If catalyzed filter, 50 ppm maximum, 10-15 ppm better | | If NOX adsorber used requires near zero sulfur (<10 ppm) with low S, use lubricity additives |
| Cetane | Lower CO, HC, benzene, 1,3 butadiene, formaldehyde & acetaldehyde | | | | | | Higher white smoke with low cetane fuels |
| Density | PM, HC, CO, formaldehyde, acetaldehyde & benzene, NOX | | | | | | |
| Volatility (T95 from 370 to 325 C) | NOX, HC increase, PM, CO decrease | | | | | | |
| Polyaromatics↑ | NOX, PM, formaldehyde & acetaldehyde but HC, benzene & CO | | | | | | some studies show that total aromatics are important for emissions in a manner similar to polyaromatics |

*Notes: CO = carbon monoxide; HC = hydrocarbon; NOX = oxides of nitrogen, PM = particulate matter; ppm = parts per million; SO2 = sulfur dioxide; SO3 or sulfur trioxide is an intermediate compound.*

8 For the purposes of qualitative sulfur impacts, vehicles meeting US Tier 1 standards would have impacts similar to Euro 3 vehicles while Tier 2 and 3 vehicles would have impacts similar to Euro 5/6 vehicles.

9 Euro 5 emissions standards for light duty diesel vehicles have been adopted by the EU for implementation in 2010; Euro 6 limits were also adopted for 2015 implementation. Both Euro 5 and Euro 6 standards are expected to mandate the use of PM filters on all light duty diesel vehicles.

## Table D: Impact of Fuels on Heavy Duty Diesel Vehicles [10]

| Diesel | Pre-Euro | Euro 1 | Euro 2 | Euro 3 | Euro 4 | Euro 5/6 | Comments |
|---|---|---|---|---|---|---|---|
| Sulfur | SO2, PM | | If oxidation catalyst is used, SO3, SO2, PM | | If catalyzed filter, 50 ppm maximum, 10-15 ppm better | | If NOX adsorber used requires near zero sulfur (<10 ppm) with low S, use lubricity additives |
| Cetane | Lower CO, HC, benzene, 1,3 butadiene, formaldehyde & acetaldehyde | | | | | | Higher white smoke with low cetane fuels |
| Density | HC, CO, NOX | | | | | | |
| Volatility (T95 from 370 to 325 C) | Slightly lower NOX but increased HC | | | | | | Too large a fraction of fuel that does not volatilize at 370 C increases smoke and PM |
| Polyaromatics | NOX, PM, HC | | | | | | Some studies show that total aromatics are important |

*Notes: CO = carbon monoxide; HC = hydrocarbon; NOX = oxides of nitrogen, PM = particulate matter; ppm = parts per million; S = sulfur; SO2 = sulfur dioxide; SO3 or sulfur trioxide is an intermediate compound*

10 For the purposes of qualitative sulfur impacts, vehicles meeting US 1992 MY standards would have impacts similar to Euro 1 vehicles while US 1996 MY standards are similar to Euro 2 effects, MY 2001 similar to Euro 3, MY 2004 similar to Euro 4, MY 2007 similar to Euro 5 and Euro 6.

11 The EU Commission has adopted Euro 6 emissions standards for heavy duty engines, likely mandating the use of PM filters on all heavy duty diesel vehicles from 2014.

# 3. WHY THE WORLD IS MOVING TOWARD NEAR ZERO[12] SULFUR LEVELS IN FUELS

## Background

Both gasoline and diesel fuels are produced from crude oil, which varies from oilfield to oilfield in color and composition. Crude oils range in consistency from water to tar-like solids, and in color from clear to black. An "average" crude oil contains about 84% carbon, 14% hydrogen, 1%-3% sulfur, and less than 1% each of nitrogen, oxygen, metals, and salts[13]. However, crude oil is of little use in its raw state; its value lies in what is created from it when distilled – fuels, lubricating oils, waxes, asphalt, and petrochemicals.

Sulfur, a non-metallic element, is widely found in nature and occurs naturally in crude oil. The amount of sulfur in crude oil can range anywhere from 100 to 33,000 parts per million (ppm) . If a crude oil contains little or no sulfur it is called "sweet crude" (up to approximately 7,000 ppm)[14], if it contains some sulfur it is called "Medium Sour (between 7,000 and 10,000 ppm) and if it contains considerable quantities of sulfur it is called "sour crude" (from 10,000 ppm up to 33,000 ppm or higher). Sulfur may be present in crude oil as hydrogen sulfide (H2S), as compounds (e.g. mercaptans, sulfides, disulfides, thiophenes, etc.) or as elemental sulfur. When crude oil is processed into gasoline and diesel fuel in the refinery, some sulfur finds its way into the fuel. The higher the density of the crude oil, the more difficult it is to remove the sulfur. Depending on the crude oil used and the refinery configuration, sulfur levels in gasoline can be anywhere from 10 to as high as 1000 ppm or more, and in diesel fuel it can be from 10 or lower to more than 10,000 ppm.[15]

## Concerns About Sulfur

There are four main reasons to be concerned about the sulfur content of fuels:

1. Health Impacts
2. Environmental Impacts
3. Potential Damage to Engines, and
4. Degradation of Technologies Needed to Reduce Vehicle Emissions

12 Generally in the range of 10 parts per million maximum.

13 http://www.osha-slc.gov/dts/osta/otm/otm_iv/otm_iv_2.html

14 Part Per Million - is normally used as measure for the sulfur content in fuels. It can be roughly translated in percentages: 10,000 ppm would mean the fuel would contain 1% sulfur.

15 Ultimately, the sulfur content in the retail marketplace will depend on the regulatory requirements.

# 1) Health Impacts

Motor vehicles can emit large quantities of CO, HC, $NO_X$ and such toxic substances as benzene, formaldehyde, acetaldehyde, 1,3,butadiene and PM. Depending on fuel composition, they can also emit significant amounts of sulfur oxides ($SO_X$) and lead. Each of these, along with secondary by-products such as ozone ($O^3$), can cause serious adverse effects on health and the environment. Greenhouse gases (GHGs) responsible for climate change are also increasingly emitted by the transportation sector. Vehicle emissions most closely identified with this sector include carbon dioxide ($CO_2$), nitrous oxide ($N^2O$) and methane ($CH_4$). However, it is important to note that other vehicle-related pollutants also contribute to global warming; this is especially true of BC which has recently received a great deal of attention as the scientific understanding of its role in climate change has increased.

Exposure to levels of air pollutants have been associated with a variety of adverse health effects. Based on available information, the World Health Organization (WHO) sets and periodically updates air quality guidelines. The following summary is based on the guidelines adopted by the World Health Organization (WHO)[16] and standards adopted by the United States Environmental Protection Agency (USEPA).

## *a. Particulate matter*

Particulate matter (PM) represents a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size. $PM_{10}$ refers to particles generally less than or equal to 10 micrometers (µm). Inhalable (or "thoracic") coarse particles refer to those particles generally larger than 2.5 µm but less than or equal to 10 µm in diameter. $PM_{2.5}$ refers to fine particles, those particles generally less than or equal to 2.5 µm in diameter. Ultrafine PM refers to particles less than 0.1 µm in diameter. Larger particles tend to be removed by the respiratory clearance mechanisms (e.g. coughing), whereas smaller particles are deposited deeper in the lungs, or even absorbed into the blood through the lungs.

Fine particles are produced primarily by combustion processes but also through transformations of gaseous emissions (e.g., SOX, NOX and Volatile Organic Compounds - VOCs) in the atmosphere. Thus, $PM_{2.5}$ includes a complex mixture of different pollutants including sulfates, nitrates, organic compounds, elemental carbon and metal (including toxic heavy metal) compounds. These particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometers.

16 "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global update 2005, Summary of risk assessment

The range of effects of PM is broad, affecting the respiratory and cardiovascular systems and extending to children and adults and to a number of large, susceptible groups within the general population. Risk increases with exposure and there is little evidence to suggest a threshold below which no adverse health effects would be anticipated.

The WHO Air Quality Guidelines for PM are:

**$PM_{2.5}$: 10 µg/$m^3$ annual mean, 25 µg/$m^3$ 24-hour mean**

**$PM_{10}$: 20 µg/$m^3$ annual mean, 50 µg/$m^3$ 24-hour mean**

Health effects associated with short-term exposures (hours to days) to ambient PM include premature mortality, increased hospital admissions, heart and lung diseases, increased cough, adverse lower- respiratory symptoms, decrements in lung function and changes in heart rate rhythm and other cardiac effects. Studies examining populations exposed to different levels of air pollution over a number of years show associations between long-term exposure to ambient $PM_{2.5}$ and both total and cardiovascular and respiratory mortality[17] [18], In addition, a reanalysis of the American Cancer Society Study shows an association between fine particle and sulfate concentrations and lung cancer mortality [19]

The health effects of $PM_{2.5}$ have been further documented in local impact studies which have focused on health effects due to $PM_{2.5}$ exposures measured on or near roadways. Taking account of all air pollution sources, including both spark-ignition (gasoline) and diesel-powered vehicles, these latter studies indicate that exposure to $PM_{2.5}$ emissions near roadways, dominated by mobile sources, are associated with potentially serious health effects. For instance, a recent study found associations between concentrations of cardiac risk factors in the blood of healthy young police officers and $PM_{2.5}$ concentrations measured inside vehicles[20]. Also, a number of studies have shown associations between residential or school outdoor concentrations of some

17 Pope CA, III; Thun, MJ; Namboodiri, MM; Docery, DW; Evans, JS; Speizer, FE; Heath, CW. 1995. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. Am J Respir Crit Care Med 151:669–674.

18 Dockery, DW; Pope, CA III: Xu, X; et al. 1993. An association between air pollution and mortality in six U.S. cities. N Engl J Med 329:1753–1759.

19 Krewski D. et al. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. Health Effects Institute Special Report, July 2000.

20 Riekider, M.; Cascio, W.E.; Griggs, T.R.; Herbst, M.C.; Bromberg, P.A.; Neas, L.; Williams, R.W.; Devlin, R.B. (2003) Particulate Matter Exposures in Cars is Associated with Cardiovascular Effects in Healthy Young Men. Am. J. Respir. Crit. Care Med. 169: 934–940.

constituents of fine particles found in motor vehicle exhaust and adverse respiratory outcomes, including asthma prevalence in children who live near major roadways.[21 22 23] In addition to $PM_{2.5}$ and $PM_{10,}$ ultra-fine particles (UF) have recently attracted significant scientific and medical attention. These are particles smaller than 0.1 micrometer and are measured as number concentration. While there is considerable toxicological evidence of potential detrimental effects of UF particles on human health, the existing body of epidemiological evidence is insufficient in the view of WHO to reach a conclusion on the exposure/response relationship to UF particles. Therefore no recommendations have yet been provided by the WHO as to guideline concentrations of UF particles at this point.

The Global Burden of Disease Study 2010 (GBD 2010) is the largest-ever systematic effort to describe the global distribution and causes of a wide array of major diseases, injuries, and health risk factors.[24] The results show that outdoor air pollution, primarily $PM_{2.5}$ is responsible for over 3.2 million premature deaths each year. It is clear that air pollution is an extremely serious and widespread problem which requires strong action.

### *b. Ozone*

Ground-level ozone pollution is formed by the reaction of VOCs and NOx in the atmosphere in the presence of heat and sunlight.

The health and welfare effects of ozone are well documented[25], [26] Ozone can irritate the respiratory system, causing coughing, throat irritation, and/or uncomfortable sensation in the chest. It can reduce lung function and make it more difficult to breathe deeply, and breathing may become more rapid and shallow than normal, thereby limiting a person's activity. Ozone can also aggravate asthma, leading to more asthma attacks that require a doctor's attention and/or the use of additional medication. Animal toxicological evidence indicates that with repeated exposure, ozone can inflame and damage the lining of the lungs, which may lead to permanent changes in lung tissue and irreversible reductions in lung function. People who are more susceptible to

21 Van Vliet, P.; Knape, M.; de Hartog, J.; Janssen, N.; Harssema, H.; Brunekreef, B. (1997). Motor vehicle exhaust and chronic respiratory symptoms in children living near freeways. Env. Research 74: 122–132.

22 Brunekreef, B., Janssen, N.A.H.; de Hartog, J.; Harssema, H.; Knape, M.; van Vliet, P. (1997). Air pollution from truck traffic and lung function in children living near roadways. Epidemiology 8:298–303.

23 Kim, J.J.; Smorodinsky, S.; Lipsett, M.; Singer, B.C.; Hodgson, A.T.; Ostro, B (2004). Traffic-related air pollution near busy roads: The East Bay children's respiratory health study. Am. J. Respir. Crit. Care Med. 170: 520–526.

24 Global Burden of Disease Study 2010, The Lancet, Dec 13, 2012

25 U.S. EPA Air Quality Criteria for Ozone and Related Photochemical Oxidants (Final). U.S. Environmental Protection Agency, Washington, D.C., EPA 600/R–05/004aF–cF, 2006.

26 U.S. EPA (2006) Review of the National Ambient Air Quality Standards for Ozone, Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper Second Draft. EPA– 452/D–05–002.

effects associated with exposure to ozone include children, the elderly, and individuals with respiratory disease such as asthma. Those with greater exposures to ozone, for instance due to time spent outdoors (e.g., children and outdoor workers), are also of concern, even with short-term exposure under current ground-level ozone levels.[27] Current research suggests that the actual ozone concentration threshold for mortality may be lower than current public health standards, and research on this topic is ongoing. In light of variation of response of different individuals to ambient ozone levels, the WHO recommends that air quality guidelines be set at the level of:

**Ozone: 100 µg/m$^3$ for daily maximum 8-hour mean**

It should be noted that background concentrations of ground-level ozone vary in time and space but can reach average levels of around 80 µg/m3. These arise from both anthropogenic and biogenic emissions of ozone precursors and downward intrusion of stratospheric ozone into lower levels of the atmosphere, and as a result, the proposed WHO guideline value may occasionally be exceeded due to natural causes.

### *c. Nitrogen dioxide*

Evidence from animal toxicological studies indicates that long-term exposure to $NO_2$ at concentrations above current ambient concentrations has adverse effects. In population studies $NO_2$ has been associated with adverse health effects even when the annual average $NO_2$ concentration complied with the WHO-2000 annual guideline value of 40 µg/m$^3$. Also some indoor studies suggest effects on respiratory symptoms among infants at concentrations below 40 µg/m$^{3.}$ Together these results support a lowering of the annual $NO_2$ guideline value. However, $NO_2$ is an important constituent of combustion-generated air pollution and is highly correlated with other primary and secondary combustion products; it is unclear to what extent the health effects observed in epidemiological studies are attributable to $NO_2$ itself or to other correlated pollutants. The current scientific literature, therefore, has not accumulated sufficient evidence to change the WHO 2000 guideline value of 40 µg/m$^3$ for annual mean $NO_2$ concentrations.

Short-term experimental human toxicology studies show acute health effects at levels higher than 500 µg/m$^3$, and one meta-analysis has indicated effects at levels exceeding 200 µg/m$^3$. The current scientific literature has not accumulated evidence to change from the WHO 2000 guideline value of 200 µg/m$^3$ for 1-hour NO2 concentration.

In conclusion, the WHO guideline values remain unchanged at the following levels:

27 "Estimating Mortality Risk Reduction and Economic Benefits from Controlling Ozone Air Pollution", National Academies Press, National Research Council, Division on Earth and Life Studies, Board on Environmental Studies and Toxicology, Committee on Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure, John C. Bailar III (chair), Professor Emeritus, Department of Health Studies University of Chicago

**$NO_2$ concentration: 40 µg/$m^3$ for annual mean;**

**$NO_2$ concentration: 200 µg/$m^3$ for 1-hour mean.**

The California Air Resources Board approved staff recommendations to lowering the existing 1-hour-average standard for $NO_2$ of 0.25 ppm to 0.18 ppm, not to be exceeded, and established an annual-average standard of 0.030 ppm, not to be exceeded.

Evidence from recent studies is "sufficient to infer a likely causal relationship" between short-term exposure to $NO_2$ and adverse effects on the respiratory system. According to a draft Environmental Protection Agency risk assessment, a 30-minute exposure to $NO_2$ concentrations between 0.2 ppm and 0.3 ppm has been shown to irritate airways in asthmatics. Children, whose lung function continues to develop into adolescence, and those over the age of 65 are also particularly susceptible to $NO_2$ exposure. The risk assessment also identified as an at-risk group those whose jobs require significant periods of driving. Mean $NO_2$ levels inside vehicles are often two to three times the outdoor concentrations.

### *d. Sulfur dioxide*

Controlled short-term exposure studies with exercising asthmatics indicate that some individuals experience changes in pulmonary function and respiratory symptoms after periods of exposure as short as 10 minutes. Based on this evidence, it is recommended by WHO that a value of 500 µg/$m^3$ should not be exceeded over averaging periods of 10 minutes. Because exposure to sharp peaks depends on the nature of local sources and meteorological conditions, no single factor can be applied to this value in order to estimate corresponding guideline values over somewhat longer periods, such as an hour.

For longer-term exposure, there is still considerable uncertainty as to whether sulfur dioxide is the pollutant responsible for the observed adverse effects or, rather, a surrogate for ultra-fine particles or some other correlated substance. For example, in Germany[28] and the Netherlands[29] a strong reduction of $SO_2$ concentrations occurred over a decade. Although mortality also decreased with time, the association of $SO_2$ and mortality was judged to not be causal and was attributed to a similar time trend of a different pollutant (PM). In consideration of: (1) the uncertainty of $SO_2$ in causality; (2) the practical difficulty of reaching levels that are certain to be associated with no effects; and (3) the need to provide greater degrees of protection than those provided

28 Wichmann, H.E. et al. Daily mortality and fine and ultrafine particles in Erfurt, Germany part 1: Role of particle number and particle mass. Research Report 98. Cambridge, MA: Health Effects Institute (2000)

29 Buringh E, Fischer P, Hoek G. 2000. Is SO2 a causative factor for the PM-associated mortality risks in the Netherlands? Inhalation Toxicol 12 (Suppl):55–60.

by the guidelines published in 2000, and assuming that reduction in exposure to a causal and correlated substance is achieved by reducing sulfur dioxide concentrations, then there is a basis for revising the 24 hour guideline downward for sulfur dioxide, and the following guideline is recommended by WHO as a prudent precautionary level:

**Sulfur dioxide: 20 μg/m³ for 24-hour mean.**
**500 μg/m³ for 10-minute mean (unchanged)**

The WHO has determined that an annual guideline is not needed, since compliance with the 24-hour level will assure low levels for the annual average.

### e. *Carbon Monoxide*

Carbon monoxide, CO-- an odorless, invisible gas created when fuels containing carbon are burned incompletely – also poses a serious threat to human health. Fetuses and persons afflicted with heart disease are especially at risk. Numerous studies in humans and animals have demonstrated that individuals with weak hearts are placed under additional strain by the presence of excess CO in the blood. In particular, clinical health studies have shown a decrease in time to onset of angina pain in those individuals suffering from angina pectoris and exposed to elevated levels of ambient CO[30]. Some epidemiologic studies have found relationships between increased CO levels and increases in mortality and morbidity.[31]

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.

### *f. Air Toxics*

People experience elevated risk of cancer and other noncancerous health effects from exposure to air toxics[32]. Mobile sources have historically been a major source of this exposure. According to the US National Air Toxic Assessment (NATA) for 1999, mobile sources were responsible for 44 percent of outdoor toxic emissions and almost 50 percent of the cancer risk among the 133 pollutants quantitatively assessed. Benzene is the largest contributor to cancer risk of all the assessed pollutants and mobile sources were responsible for about 68 percent of all benzene emissions in 1999.

30 "Effect of Carbon Monoxide on Exercise Performance in Chronic Obstructive pulmonary Disease", Aronow, et. al., Am. J. Med., 1977, "Health Effects of Exposure To Low Levels of Regulated Air Pollutants, A Critical Review", Ferris, Journal of The Air Pollution Control Association, May 1978

31 Environmental Protection Agency, Air Quality Criteria for Carbon Monoxide, Office of Research and Development, Washington, D.C., June 2000b

32 Air toxics are pollutants known for, or suspected of, causing cancer or other serious health problems, such as asthma or birth defects.

According to the 1999 NATA, nearly the entire U.S. population was exposed to an average level of air toxics that has the potential for adverse respiratory noncancerous health effects.[33] Mobile sources were responsible for 74 percent of the potential noncancerous hazard from outdoor air toxics. It is important to note that NATA estimates of noncancerous hazard do not include the adverse health effects associated with particulate matter.

On March 11, 2011, the Environmental Protection Agency (EPA) released the fourth version of the National Air Toxics Assessmen t (NATA), which concluded that much progress has been made in reducing air toxics emissions in the U.S. Between 1990 and 2005, air toxics emissions declined by approximately 42 percent from all sources. EPA continues to implement the Clean Air Act to achieve further reductions in air toxics.

## 2) Environmental Impacts

There are a number of public welfare effects associated with the presence of ozone and $PM_{2.5}$ in the ambient air including the impact of $PM_{2.5}$ on visibility and materials and the impact of ozone on plants, including trees, agronomic crops and urban ornamentals.

### *a. Visibility*

Visibility can be defined as the degree to which the atmosphere is transparent to visible light. Visibility impairment manifests in two principal ways: as local visibility impairment and as regional haze[34]. Local visibility impairment may take the form of a localized plume, a band or layer of discoloration appearing well above the terrain as a result of complex local meteorological conditions. Alternatively, local visibility impairment may manifest as an urban haze.' This urban haze is largely caused by emissions from multiple sources in the urban areas and is not typically attributable to only one nearby source or to long-range transport. The second type of visibility impairment, regional haze,

33 To express chronic noncancerous hazards, US EPA uses the RfC as part of a calculation called the hazard quotient (HQ), which is the ratio between the concentration to which a person is exposed and the RfC. (RfC is defined by EPA as, "an estimate of a continuous inhalation exposure to the human population, including sensitive subgroups, with uncertainty spanning perhaps an order of magnitude, that is likely to be without appreciable risks of deleterious noncancerous effects during a lifetime.") A value of the HQ less than one indicates that the exposure is lower than the RfC and that no adverse health effects would be expected. Combined noncancerous hazards were calculated using the hazard index (HI), defined as the sum of hazard quotients for individual air toxic compounds that affect the same target organ or system. As with the hazard quotient, a value of the HI at or below 1.0 will likely not result in adverse effects over a lifetime of exposure. However, a value of the HI greater than 1.0 does not necessarily suggest a likelihood of adverse effects. Furthermore, the HI cannot be translated into a probability that adverse effects will occur and is not likely to be proportional to risk.

34 See discussion in U.S. EPA, National Ambient Air Quality Standards for Particulate Matter; Proposed Rule; January 17, 2006, Vol71 p 2676.

usually results from multiple pollution sources spread over a large geographic region. Regional haze can impair visibility in large regions and across states.[35] [36].

### *b. Acid Deposition*

Acid deposition, or acid rain as it is commonly known, occurs when NOx and SO2 react in the atmosphere with water, oxygen and oxidants to form various acidic compounds that later fall to earth in the form of precipitation or dry deposition of acidic particles. It contributes to damage of trees at high elevations and in extreme cases may cause lakes and streams to become so acidic that they cannot support aquatic life. In addition, acid deposition accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of a nation's cultural heritage.

Nitrogen oxides have also been found to contribute to ocean acidification, thereby amplifying one of the many deleterious impacts of climate change.[37] Approximately one third of all nitrogen oxide emissions end up in the oceans. The impact of these emissions on acidification is intensely felt in specific, vulnerable areas; in some areas it can be as high as 10 to 50 percent of the impact of carbon dioxide. The hardest hit areas are likely to be those directly around the release site, so these emissions are especially significant in and around coastal waters.

### *c. Eutrophication and Nitrification*

Nitrogen oxides emitted by vehicles and other sources into the air can deposit to water bodies and contribute to eutrophication and nitrification. Eutrophication is the accelerated production of organic matter, particularly algae, in a water body. Nitrogen deposition contributes to eutrophication of watersheds, particularly in aquatic systems where atmospheric deposition of nitrogen represents a significant portion of total nitrogen loadings. This increased growth can cause numerous adverse ecological effects and economic impacts, including nuisance algal blooms, dieback of underwater plants due to reduced light penetration, and toxic plankton blooms.  Algal and plankton blooms can also reduce the level of dissolved oxygen, which can adversely affect fish and shellfish populations. In recent decades, human activities have greatly accelerated nutrient impacts, such as nitrogen and phosphorus, causing excessive growth of algae

35 U.S. EPA (2004) Air Quality Criteria for Particulate Matter (Oct 2004), Volume I Document No. EPA600/P–99/002aF and Volume II Document No. EPA600/P–99/002bF.

36 U.S. EPA (2005) Review of the National Ambient Air Quality Standard for Particulate Matter: Policy Assessment of Scientific and Technical Information, OAQPS Staff Paper. EPA– 452/R–05–005.

37 Doney, Scott C., et al., Impact of Anthropogenic Atmospheric Nitrogen and Sulfur Deposition on Ocean Acidification and the Inorganic Carbon System, (2007), PNAS Vol. 104:14580-14585, at 14580.

and leading to degraded water quality and associated impairment of freshwater and estuarine resources for human uses. [38]

Severe and persistent eutrophication often directly impacts human activities. For example, losses in a nation's fishery resources may be directly caused by fish kills associated with low dissolved oxygen and toxic blooms. Declines in tourism occur when low dissolved oxygen causes noxious smells and floating mats of algal blooms create unfavorable aesthetic conditions. Risks to human health increase when the toxins from algal blooms accumulate in edible fish and shellfish, and when toxins become airborne, causing respiratory problems due to inhalation.

### *d. Global Concerns: Climate Change*

There is no longer any scientific dispute that human production of greenhouse gases, including carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$), are responsible for the unprecedented rate of warming observed over the past century. According to the Intergovernmental Panel on Climate Change ("IPCC"), "[w]arming of the climate system is unequivocal, as is now evident from observations of increases in global air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."[39] Moreover, "[m]ost of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." Thus, the world's leading scientific body on the subject has now concluded, with greater than 90 percent certainty, that emissions of greenhouse gases are responsible for climate change. In addition to these three mentioned greenhouse gases, black carbon, a fraction of PM, is a significant climate forcing pollutant.

A product of inefficient combustion, black carbon, also known as soot, consists of microscopic solid particles of incompletely burned organic matter.[40] Black carbon is a potent warmer, exerting effects on the global climate both while suspended in the atmosphere and when deposited on snow and ice. In fact, one study estimates that a given mass of black carbon will warm the air between 360,000 and 840,000 times more than an equal mass of carbon dioxide.[41] While the quantification is quite variable, a large number of recent studies have raised serious concerns regarding the climate

38 Deposition of Air Pollutants to the Great Waters, Third Report to Congress, June 2000, EPA– 453/R–00–005.

39 IPCC, Summary For Policymakers: Climate Change 2007: The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Feb. 2007) at 5 [hereinafter Working Group I Summary].

40 See W. Chameides and M. Bergin, Soot Takes Center Stage, 297 SCIENCE 2214 (Sept. 27, 2002), (explaining that "BC is produced through incomplete combustion of biomass, coal, and diesel fuel").

41 Mark Z. Jacobson, Control of Fossil-Fuel Particulate Black Carbon and Organic Matter, Possibly the Most Effective Method of Slowing Global Warming, 107 Journal Of Geophysical Research 4410 (2002) at 10.

impacts of black carbon.[42] The most pernicious characteristic of black carbon from a climatic perspective is its dark color and correspondingly low albedo, or reflectivity. Because of this dark coloring, black carbon absorbs heat from sunlight.

A very recent study[43] finds that soot is warming the climate about twice as fast as scientists had estimated.[44] The new, deeper view puts soot second behind the dominant agent forcing warming, carbon dioxide, which accounts for 1.66 W/m2. Soot's contribution to the warming is roughly twice as large as estimated in the 2007 assessment made by the Intergovernmental Panel on Climate Change.

## 3) Potential Damage to Engines

While sulfur contributes to adverse effects on both health and the environment in a number of ways, the most important concern with regard to vehicle emissions is the impact on pollution control technology. The primary reason for introducing lower sulfur vehicle fuels, therefore, is to enable the introduction of emissions control devices that can significantly reduce vehicle emissions and to allow them to achieve their full emissions reduction potential. These technologies are already in place in some countries and are continuously being improved to further reduce vehicle emissions.

42 Bond TC, Sun H. 2005. Can Reducing Black Carbon Emissions Counteract Global Warming? Environ. Sci. Technol. 39(16):5921-5926, Delucchi MA. 2003. Appendix D: CO2 Equivalency Factors. . An Appendix to the Report, "A Lifecycle Emissions Model (LEM): Lifecycle Emissions from Transportation Fuels, Motor Vehicles, Transportation Modes, Electricity Use, Heating and Cooking Fuels, and Materials. Davis, California: Institute of Transportation Studies, Forster P, Ramaswamy V, Artaxo P, Berntsen TK, Betts R, Fahey DW, Haywood J, Lean J, Lowe DC, Myrhe G and others. 2007. Changes in Atmospheric Constituents and in Radiative Forcing In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. Climate Change 2007: The Physical Sciences Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA, Fuglestvedt JS, Berntsen TK, Godal O, Sausen R, Shine KP, Skodvin T. 2003. Metrics of Climate Change: Assessing Radiative Forcing and Emission Indices. Climatic Change 58(3):267-331, Hansen J, Sato M, Kharecha P, Russell G, Lea DW, Siddall M. 2007. Climate change and trace gases. Philosophical Transactions of the Royal Society A 365:1925-1954, Hansen J, Sato M, Ruedy R, Lacis A, Oinas V. 2000. Global Warming in the 21st Century: An alternative Scenario. Proceedings of the National Academy of Sciences 97(18):9875-9880, Jacobson MZ. 2007. Testimony for the Hearing on Black Carbon and Global Warming. House Committee on Oversight and Government Reform. 110th Congress, First Session ed. Washington, DC, Jacobson MZ. 2002. Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming. J Geoph Res 107(D19):16:1-16:22, Ramanathan V. 2007. Role of Black Carbon on Global and Regional Climate Change. House Committee on Oversight and Government Reform, 110th Congress, 1st Session. Washington, DC.

43 Science 25 January 2013: Vol. 339 no. 6118 p. 382, DOI: 10.1126/science.339.6118.382

44 "Bounding the role of black carbon in the climate system: A scientific assessment" T. C. Bond, S. J. Doherty, D. W. Fahey, P. M. Forster, T. Berntsen, B. J. DeAngelo, M. G. Flanner, S. Ghan, B. Kärcher, D. Koch, S. Kinne, Y. Kondo, P. K. Quinn, M. C. Sarofim, M. G. Schultz, M. Schulz, C. Venkataraman, H. Zhang, S. Zhang, N. Bellouin, S. K. Guttikunda, P. K. Hopke, M. Z. Jacobson, J. W. Kaiser, Z. Klimont, U. Lohmann, J. P. Schwarz, D. Shindell, T.Storelvmo, S. G. Warren, C. S. Zender, DOI: 10.1002/jgrd.50171

However, these technologies generally require specific fuel qualities, often including low sulfur levels.

### a. *Sulfur in Gasoline*

Sulfur occurs naturally in crude oil. Its level in refined gasoline depends upon the source of the crude oil used and the extent to which the sulfur is removed during the refining process.

Modern gasoline engines use computer controlled intake port fuel injection and increasingly direct injection (so called GDI) with feedback control based on an oxygen sensor to meter precisely the quantity and timing of fuel delivered to the engine. Control of in-cylinder mixing and use of high-energy ignition promote nearly complete combustion. The three-way catalytic converter provides greater than 90% reduction of carbon monoxide, hydrocarbons, and oxides of nitrogen. Designs for rapid warm-up minimize cold-start emissions. On-board diagnostic (OBD) systems monitor emissions systems performance and identify component failures. Durability in excess of 160,000 km, with minimal maintenance, is now common.

Three-way catalytic converters were introduced on cars in the United States and Japan well before the impact of sulfur on catalyst performance was fully understood. We now know that sulfur in gasoline reduces the efficiency of catalysts and adversely affects heated exhaust gas oxygen sensors. Higher sulfur gasoline (above 10 ppm) is a barrier to the introduction of new lean burn technologies using De-NOX catalysts, while low sulfur gasoline will enable new and future conventional vehicle technologies to realize their full benefits. If sulfur levels are lowered, existing vehicles equipped with catalysts will generally have improved emissions.

Laboratory testing of catalysts has demonstrated reductions in efficiency resulting from higher sulfur levels across a full range of air/fuel ratios. The effect is greater in percentage for low-emission vehicles than for traditional vehicles. Studies have also shown that sulfur adversely affects heated exhaust gas oxygen sensors; slows the lean-to-rich transition, thereby introducing an unintended rich bias into the emission calibration; and may affect the durability of advanced OBD systems.

The EPEFE study demonstrated the relationship between reduced gasoline sulfur levels and reductions in vehicle emissions. It found that reducing sulfur in fuel reduced exhaust emissions of HC, CO and NOX (the effects were generally linear at around 8-10% reductions as fuel sulfur was reduced from 382 ppm to 18 ppm)[45] . The study results confirmed that fuel sulfur affects catalyst efficiency with the greatest effect being in the warmed-up mode. In the case of air toxins, benzene and C3-12 alkanes

45 The study found that the effects tended to be larger over higher speed driving than in low speed driving

were in line with overall hydrocarbon reductions, with larger reductions (around 18%) for methane and ethane.

For gasoline-fueled vehicles with no catalytic converters, reducing sulfur will have no effect on the pollutants of greatest concern, CO, HC or NOX. While the amount of $SO_2$ emitted is in direct proportion to the amount of sulfur in the fuel, gasoline vehicles are not usually a significant source of $SO_2$. Since $SO_2$ can be converted in the atmosphere to sulfates, however, these emissions will also contribute to ambient levels of particulate matter ($PM_{10}$ and $PM_{2.5}$) which is an increasingly serious concern in cities especially Chinese cities, [46] so air quality benefits are expected with lower sulfur fuel even when used in vehicles without catalytic converters.

The percentage benefits of reducing sulfur levels in fuels increase as vehicles are designed to meet stricter standards. Increasingly strict emissions standards require extremely efficient catalysts with a long lifetime. Recent regulations in Europe and the U.S. require warmed-up catalysts to have over 98% HC control, even towards the end of the vehicle's lifetime (100,000 km in Europe and over 100,000 miles in the U.S.).

Based on the experience with advanced gasoline fueled vehicle emissions controls, it is concluded that most gasoline vehicles (other than lean Direct Injection) meeting both Euro 5 and Euro 6 emissions standards should perform satisfactorily with gasoline having a maximum sulfur content of 50 ppm. However this will depend on how much 'margin' there is between the actual emissions performance and the emission standards, and the higher levels of sulfur may impact on the ability to meet the limit values at full durability of 160 000 km. If and when they shift to 10 ppm maximum sulfur fuels, their performance will improve.

The United States and California have recently adopted even more stringent emissions requirements, the so called Tier 3 or LEV III standards. To ensure that the full range of light duty vehicles can comply with these requirements over the regulatory full useful life, ultra low sulfur gasoline (10 ppm sulfur average) is required.

### *b. Sulfur in Diesel Fuel*

The contribution of the sulfur content of diesel fuel to exhaust particulate emissions has been well established with a general linear relationship between fuel sulfur levels and the sulfate fraction of particulate emissions. Shown below (Figure 1) is one estimate of this relationship calculated from data provided by the US EPA. (This figure shows only the sulfur-related PM and not the total PM emitted from a diesel engine without any aftertreatment PM controls.) An indirect relationship also exists as some

46 US EPA models predict that over 12% of the SO2 emitted in urban areas is converted in the atmosphere to sulfate PM.

emissions of sulfur dioxide will eventually be converted in the atmosphere to sulfate PM[47].

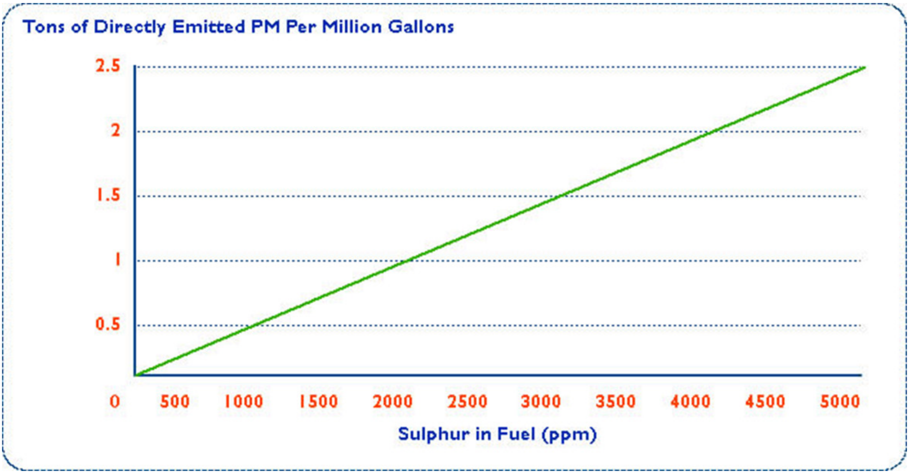



*Figure 1: Tons of Directly Emitted Sulfate PM from Diesel Fuels Sulfur*
*Notes: Only particulate matter (PM) related to sulfur and not the total PM emitted from a diesel engine are reflected in this figure.*
*Source: Calculated from data provided by the United States Environmental Protection Agency (US EPA)*

For diesel vehicles with no controls, the amount of sulfur in the fuel are directly related to $SO_2$ and PM emissions. Figure 2 illustrates the linkage between sulfur levels in the fuel and the mass of particulate; sulfur sits on the surface of the carbonaceous core in direct proportion to the amount of sulfur in the fuel.

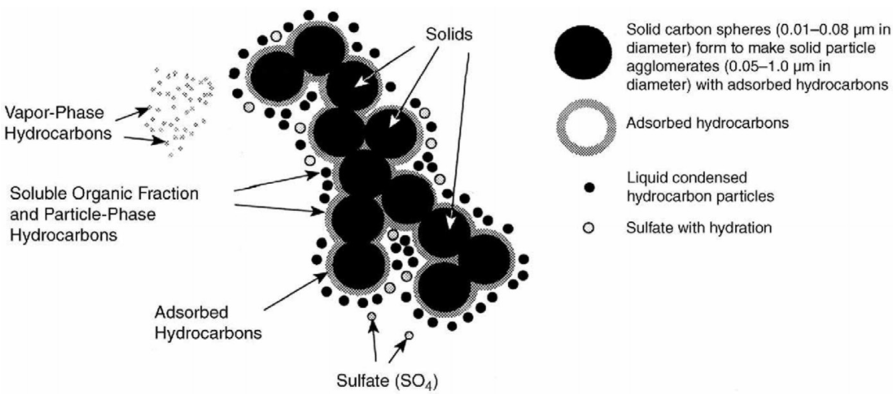



*Figure 2: Schematic Illustration of a Typical Diesel Particle*
*Source: Health Effects Institute (HEI)*

47 Similar to the secondary transformation of NOX to nitrate.

The amount of $SO_3$ emissions is also directly proportional to the amount of sulfur contained in the fuel. In the oxygen-rich exhaust of diesel vehicles several percent of the $SO_2$ formed during combustion is oxidized to $SO_3$, which dissolves in the water vapor present to form sulfuric acid ($H_2SO_4$) vapor. $H_2SO_4$ forms very small (so called ultrafine) particles in diesel exhaust which are considered especially hazardous because of their ability to penetrate deeply into the lungs. Even though sulfate particles account for only a small fraction of particle volume or mass, they account for a large fraction of particle numbers.

According to the US EPA, approximately 2% of the sulfur in the diesel fuel is converted to direct PM emissions. In addition, $SO_2$ emissions can lead to secondary particle formation—particles that form in the ambient air. US EPA models predict that over 12% of the $SO_2$ emitted in urban areas is converted in the atmosphere to sulfate PM. Urban areas would benefit most from reductions in $SO_2$ emissions, as polluted urban air has higher concentrations of the constituents that catalyze the $SO_2$-to-sulfate reaction. Even with vehicles without advanced pollution controls, reductions of fuel sulfur levels would likely have a significant impact on primary and secondary PM concentrations in urban areas.

## 4) Degradation of Technologies Needed to Reduce Vehicle Emissions

### *a. Impact of Sulfur on Diesel Oxidation Catalysts*

Light duty diesel engines (<3.5 tons gross vehicle weight (GVW)) generally require diesel oxidation catalysts (DOCs) to comply with Euro 2 or more stringent vehicle emission standards. Oxidation catalysts lower HCs, CO and PM emissions, typically removing around 30% of total particle mass emissions through oxidation of a large proportion of the soluble organic fraction. The conversion of sulfur on the catalyst from $SO_2$ to $SO_3$ reduces the availability of active sites on the catalyst surface and therefore reduces catalyst effectiveness.

The effectiveness of DOCs is dramatically reduced by sulfur in diesel fuel, and therefore they should be used only in areas which have fuel sulfur levels of 500 ppm or below.

### *b. Impact of Sulfur on Diesel Particulate Filters*

Diesel particulate filters (DPFs) reliably demonstrate over 95% efficiency in removing PM from diesel exhaust with near-zero (less than 10 parts per million) sulfur fuel use. DPFs are also capable of reducing the total number of particles emitted to levels similar to or even slightly lower than those of gasoline engines. Filters however need to be cleaned, ideally without human intervention, before reaching capacity in order to maintain vehicle performance and fuel and filter efficiency.

The Continuously Regenerating Diesel Particulate Filter (CR-DPF) and the Catalyzed Diesel Particulate Filter (CDPF) are two examples of PM control with passive regeneration, not requiring human intervention. The CR-DPF and CDPF devices were found to achieve 95% efficiency for control of PM emissions with 3 ppm sulfur fuel.[48] Efficiency dropped to zero with 150 ppm sulfur fuel and PM emissions more than double over the baseline with 350 ppm sulfur fuel. The increase in PM mass comes mostly from water bound to sulfuric acid. Soot emissions also increase with higher sulfur fuel but even with the 350 ppm sulfur fuel DPFs maintain around 50% efficiency for non-sulfate PM. With 50 ppm sulfur fuel, advanced PM filters can work satisfactorily – more than 75% reduction of $PM_{2.5}$ and smaller particles - although not as well as with 10 ppm sulfur. The systems recover to original PM control efficiency, over 95% with a shift to use of near-zero sulfur fuels, but recovery takes time due to sulfate storage on the catalyst.

As noted by The Energy and Resources Institute (TERI) in a study of PM filters and low-sulfur fuel in Mumbai, "Continuously Regenerating Technology (CRT™) proved to be highly effective in reducing PM emissions from Ultra Low Sulfur Diesel (ULSD)-powered BS-II (approximately Euro II) buses. [49] It is, however, important to highlight that CRT is very sensitive to the sulfur content in diesel. According to Johnson Matthey, the manufacturer, a CRT can work effectively only if it is used in a modern diesel bus running on diesel with sulfur content of no more than 50 ppm:"

Sulfur also increases the required temperature for regeneration of the filter, meaning that more fuel is required in order to regenerate the filter. In moving from 3 to 30 ppm sulfur fuel, the exhaust temperatures required for regeneration increase by roughly 25°C.

### c. *Impact of Sulfur on Selective Catalyst Reduction (SCR) Technology and NOx Adsorbers*

SCR has emerged as the leading $NO_X$ reduction technology for diesel engines. SCR uses a reducing agent, injected into the exhaust gas before the catalyst, to achieve high rates of $NO_X$ conversion in the oxygen-rich exhaust.[50] Sulfur does not reduce

48 US Department of Energy 1999, Diesel Emission Control—Sulfur Effects (DECSE) Program US Department of Energy: Washington, DC. Available URL: http://www.ott.doe.gov/decse/

49 Workstream 1: Evaluation of alternative fuels and technologies for buses in Mumbai, Final report, TERI, 2004, New Delhi: The Energy and Resources Institute. 82 pp. [TERI Project Report No. 2001UT41]

50 SCR systems are completely ineffective if the urea reagent is not added and thus requires great attention to in use enforcement and monitoring when this technology is used. European regulators have taken steps to require fail safe systems that will significantly degrade vehicle performance if the urea tank is not filled.

conversion efficiency in SCR systems as directly as in other advanced control technologies, but emissions are impacted. Fuel sulfur will increase the PM emissions from the downstream oxidation catalyst, and sulfur reactions in urea-based SCR systems can also form ammonium bi-sulfate, a respiratory irritant.

$NO_x$ adsorbers are also known as $NO_x$ storage catalysts or lean $NO_x$ traps. $NO_x$ adsorber systems have now entered the marketplace and have demonstrated 95% efficiency in conversion of $NO_x$ to $N_2$. However, SOx takes up active sites that should store NOx and that SOx is more difficult to remove; hence efficiency (for NOx removal) is reduced. There is a need for periodic de-SOx with a resulting fuel penalty of 1.5%. However, long-term durability remains an issue. Also, without significant technological breakthroughs, it is generally recognized that this system can only operate with near zero sulfur fuels.

### *d. Impact of Sulfur on Engine Durability*

Sulfur content is also known to have effects on engine wear and deposits, but appears to vary considerably in importance, depending largely on operating conditions. High sulfur content becomes a problem in diesel engines operating at low temperatures or intermittently. Under these conditions there is more moisture condensation, which combines with sulfur compounds to form acids and results in corrosion and excessive engine wear. Generally, the lower the sulfur levels the less the engines wear out.

Diesel fuel has natural lubricity properties from compounds including the heavier hydrocarbons and organo-sulfur. Diesel fuel pumps (especially rotary injection pumps in light duty vehicles), without an external lubrication system, rely on the lubricating properties of the fuel to ensure proper operation. Refining processes to remove sulfur and aromatics from diesel fuel tend to also reduce the components that provide natural lubricity. In addition to excessive pump wear and, in some cases, engine failure, certain modes of deterioration in the injection system could also affect the combustion process, and hence emissions. Additives are available to improve lubricity with very low sulfur fuels and should be used with any fuels with 50 ppm sulfur or less.

In conclusion, most light- and heavy- duty vehicles meeting both Euro 5 and Euro 6 emissions standards can perform satisfactorily with fuels having a maximum sulfur content of 50 ppm. The notable exceptions are gasoline direct injection or diesels which use NOx adsorbers to control NOx emissions. If and when they shift to 10 ppm maximum sulfur fuels, their performance will improve. Alternatively, it will not be feasible to adopt Euro 5 or Euro 6 equivalent standards until the maximum sulfur levels in fuels are limited to 50 PPM or less.

## Concluding Remarks on Vehicles and Fuels

One of the most important lessons learned in the approximately 50-year history of vehicle pollution control worldwide is that vehicles and fuels must be treated as a system. Improvements in vehicles and fuels must proceed in parallel if significant improvements in vehicle related air pollution are to occur. A program that focuses on vehicle standards or fuel quality alone will be less effective than a program designed to improve both in a coordinated fashion.

A second important lesson is that a program that focuses on cleaning up vehicles and fuels as a system can be successful. Many countries are following the EU system for cleaning up vehicles and fuels and this system has laid out a clear roadmap which carefully links vehicle emissions standards and the associated technologies with appropriate fuel parameters and specifications needed to optimize emissions performance.

A third important lesson is that most vehicles new and used available for import into developing nations have some form of pollution control technology and without the lower sulfur fuels to enable the efficient operation of these technologies, the vehicles end up having the technologies removed removing any potential clean air gains that could have been available.

# 4. THE TOOLS

There are many tools compiled in this toolkit that can be used to move towards cleaner fuels and vehicles and this chapter will review a cross section of the tools which have been used in many countries over the years.

## Mandatory Standards

Mandatory standards are the most direct method for adopting cleaner fuels and cleaner vehicles.[51] In most cases, countries model their requirements on the standards already adopted by either Europe, as transposed into United Nations Economic Commission for Europe (UNECE) Regulations, or the United States.[52] Very often countries will make slight variations to suit local conditions or select a different mix of requirements. For example, with regard to vehicle emissions standards:

- When Brazil first put in place its PROCONVE program during the mid-1980's, it took account of the widespread use of alcohol in its gasoline and added an aldehyde standard to what were otherwise similar to the US light duty vehicle requirements.

- Early this century, Hong Kong realized that the first few generations of European standards provided weaker requirements for diesel cars than for gasoline cars for NOx and PM; since these were the most serious air pollution challenges in the region, Hong Kong adopted European requirements for gasoline cars but California's much more stringent requirements for diesels.

- As evaporative emissions become a larger fraction of light duty gasoline vehicle total hydrocarbon emissions, countries such as China are considering adding the US evaporative standards and even the Onboard Refueling Vapor Recovery requirements to their China 6 limits. Beijing will likely introduce these requirements earlier than the national government.

51 Historically, emissions standards have been based on emissions measured over fixed, defined driving cycles. Over time, regulators have realized that emission in actual use can vary quite widely depending on the actual driving conditions and therefore additional focus has been placed on addressing real in use driving. This can take the form of adding multiple tests to the type approval process, or requiring emissions in use as measured using portable emissions monitors to comply with standards.

52 Japan is the only other country which has truly unique vehicle emissions regulations and no other country follows their specific requirements.

- Similarly with regard to fuels, most countries tended to follow the US or European roadmaps for lead and sulfur levels but varied some of the other parameters depending on local conditions. For example:

- China's clean fuels roadmap for gasoline varies olefin limits from those in Europe in recognition of the differing refinery configurations in China.

- Volatility requirements expressed as Reid Vapor Pressure (RVP) can and should vary widely based on the ambient temperature conditions in a given country or region within the country or season. Therefore this parameter will often vary from those adopted by Europe or the US.

Adopting fixed standards for vehicles and fuels and a time schedule for their implementation has the advantage of removing uncertainty for all the stakeholders involved. Vehicle and fuel providers know what will be required of them and can plan and if necessary invest accordingly. Similarly, their customers can anticipate the types of products that will be available to them and when, and environmental and health officials can estimate the future trajectory of vehicle emissions and possible consequences.

In adopting and implementing standards for fuels and new vehicles sufficient resources are needed for a strong and effective compliance program. Details of the fuels and vehicles compliance program in the US are provided later in this document.

## Import Restrictions

Many countries import some or all of their vehicles and those imported vehicles can be either new or used. Placing restrictions on the types and quality of imports can be a very important tool and can take many forms:

### New Vehicle Standards

As noted above, such standards are a very effective tool for reducing vehicle emissions.

### Used Vehicle Standards

Many countries import large numbers of used vehicles each year and these vehicles can be relatively clean or very highly polluting. For example, many vehicles imported into Mexico from the United States are old and poorly maintained, inexpensive vehicles which are highly polluting. These so called Chocolates are a major concern to Mexico's environmental authorities. Under consideration is some kind of inspection scheme that could weed out the highest polluting vehicles and prevent them from entering the country. New Zealand has instituted such an approach where all imported cars are given a simple inspection test to assure that at a minimum the catalytic converter is functioning.

Another approach assumes that as a vehicle ages its pollution control technology will generally deteriorate. Therefore some countries will limit imports to vehicles that are less than a certain age – 10 years or 5 years or even 3 years. For example, Kenya has adopted a restriction that prohibits imported vehicles that are over 8 years old.

## Economic Incentives

Economic incentives such as tax variations or price variations can also play a very important role in shaping the phase in of cleaner vehicles and fuels and these have been used very creatively in the past. Many examples exist including:

- When Hong Kong was experiencing issues associated with the introduction of lead free gasoline, one challenge in particular stood out: many fueling stations were quite small and were unable to have two pumps, one with leaded gasoline and one with unleaded. Since some customers still wanted leaded gas, Hong Kong authorities felt that it would be difficult and even perhaps inappropriate to mandate a complete switch overnight. Their solution was to adopt a tax policy that while allowing both fuels to be sold made clear that unleaded fuel would be less expensive than leaded. Within only a few months of adopting this policy, the vast majority of Hong Kong's consumers had opted for the unleaded fuel and it rapidly dominated the market. As demand for the more expensive leaded fuel gradually disappeared Hong Kong was able to make lead free mandatory.

- Thailand faced a similar challenge in that different customers wanted different fuels. Recognizing the routine fluctuations in the price of crude oil in the global marketplace and the impact of this on the price of gasoline, Thai officials came up with an ingenious plan. As the price of crude oil rose, they allowed the retail prices of leaded and unleaded gasoline to rise accordingly. However, when the market price of crude oil went down, they only allowed the price of unleaded gasoline to decline, locking in the high price of the leaded fuel. As the gap between leaded and unleaded widened, the market shifted almost entirely to unleaded and demand for leaded fuel almost disappeared. Thai officials were then able to ban leaded gasoline with almost no public backlash.

- As described in more detail below (see Section 5), several European countries adopted creative tax policies to incentivize cleaner vehicles with catalytic converters (and in later years particulate filters) and unleaded and lower sulfur fuels as key elements moving toward mandatory requirements.

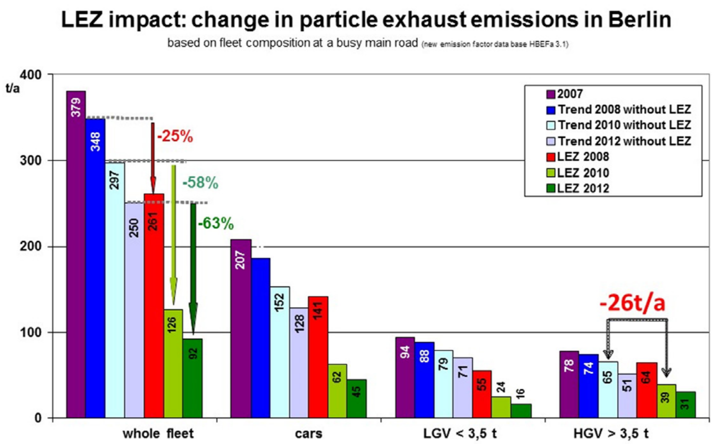
## Use Restrictions

Another approach used mainly by cities to incentivize the switch to cleaner vehicles was clean vehicle zones or low emissions zones (LEZs). A wide variety of cities and towns across Europe operate or are preparing LEZs, to help meet the EU health-based air quality limit values, where the most polluting vehicles are regulated. This means that vehicles may be banned or in some cases pay a fee if they enter the LEZ when their emissions are over a set level.

Different vehicles are regulated, depending on the local conditions. All LEZs affect heavy duty vehicles, some also affect diesel vans, others also affect diesel and gasoline cars; in Italy, motor cycles and three-wheelers are also included.

One of the most famous LEZs is in London which has several elements and is constantly evolving. In London, if you drive an electric car, you can drive in and out of the city's central zone without paying the steep $15.50 (£10) daily congestion charge. Since 2008, certain diesel-powered trucks, buses and large vans are "deterred" from driving in the city. The LEZ emissions standards are based on European emission standards relating to particulate matter (PM), which are emitted by vehicles, which have an effect on health. The following vehicles are not charged:

- Larger vans and minibuses that meet the Euro 3
- Lorries, buses, and coaches that meet Euro IV.
- Cars and motorcycles



The Mayor of London has indicated that he is planning to turn the entire downtown core into an "Ultra-Low Emission Zone," admitting only battery electrics and unspecified "low-emission vehicles" by 2020. This would include more than 1,600 hybrid buses for London by 2016 and all of the city's new black taxis to be zero emission by 2020.

Another very successful program is in Berlin. The program started in 2008 and at that time, only diesel vehicles that met Euro 2 standards or better were allowed into the center of the city. Euro 1 diesel vehicles could also be admitted but only if they were retrofitted to reduce PM emissions. Gasoline vehicles had to be Euro 1 or cleaner. On January 1, 2010, the program was further tightened with only diesel vehicles meeting Euro 4 or Euro 3 with a particulate filter being allowed. As illustrated above, initial indications indicate that the program has been a great success.

Beijing has a similar program in place which has expanded over time. Initially dirtier (so called yellow label vehicles) were banned from the central part of the city bounded by the second Ring Road over the normal work day (7 AM to 7 PM). Most recently these vehicles are banned from entering the area bounded by the 5th Ring Road.

## Special Exemptions for advanced technologies

There have been many steps taken by countries and cities around the world to stimulate the development and purchase of advanced technology vehicles. For example, as noted above, London provides an exemption from its congestion charge scheme for electric vehicles. A few other examples include:

### Exemptions from Episodic Restrictions

When Berlin adopted a high pollution episode scheme several years ago, it provided that only vehicles meeting the more stringent emissions regulations would be allowed to drive in the city when pollution levels exceeded certain hazardous limits. As a result, the city had one of the cleanest car fleets in Germany.

### Car Pool Lane Privileges

In the United States, the State of Virginia exempted hybrid electric cars from its car pool lane restrictions. As a result Virginians had a much higher sales fraction of hybrids than other parts of the country.

### Sales Restriction Exemptions

Beijing, China has adopted a monthly limit on the number of new vehicles that can be sold and selects eligible purchasers using a lottery system. Purchases of electric vehicles are exempted from the system and can be purchased with no limitation.

## Voluntary Incentive Programs

The SmartWay Program is a public-private initiative between the US EPA, large and small trucking companies, rail carriers, logistics companies, commercial manufacturers, retailers, and other federal and state agencies. Its purpose is to improve fuel efficiency and the environmental performance (reduction of both greenhouse gas emissions and air pollution) of goods movement supply chains.

Launched in 2004, SmartWay is an EPA program that reduces transportation-related emissions by creating incentives to improve freight supply chain energy and environmental efficiency. It aims to accelerate the availability, adoption and market penetration of advanced fuel efficient technologies and operational practices in the freight supply chain, while helping companies save fuel, lower costs and reduce adverse environmental impacts. EPA helps SmartWay Partners move more goods, more miles with lower emissions and less energy.

SmartWay is comprised of four components:

- SmartWay Transport Partnership: A partnership in which freight carriers and shippers commit to benchmark operations, track fuel consumption and improve performance annually.

- SmartWay Technology Program: A testing, verification, and designation program to help freight companies identify equipment, technologies and strategies that save fuel and lower emissions.

- SmartWay Vehicles: A program that ranks light-duty cars and small trucks and identifies superior environmental performers with the SmartWay logo.

- SmartWay International Interests: Guidance and resources for countries seeking to develop freight sustainability programs modeled after SmartWay.

SmartWay Transport is comprised of partnerships, policy and technical solutions, and research and evaluation projects that find new ways to optimize the transportation networks in a company's supply chain. Supported by major freight industry associations, environmental groups, states, companies, and trade publications, SmartWay Transport attempts to lead the way to greater fuel efficiency and lower emissions from the freight sector, while presenting a model of government and industry cooperation for public and private benefits.

SmartWay partners demonstrate to customers, clients, and investors that they are taking responsibility for the emissions associated with goods movement, are committed to corporate social responsibility and sustainable business practices, and are reducing their carbon footprint. To date, the partnership includes nearly 2,900 companies and associations committed to improving fuel efficiency.

SmartWay Tractors and Trailers meet voluntary equipment specifications that can reduce fuel consumption by 10 to 20 percent for 2007 long-haul tractors and trailers. Each qualified tractor/trailer combination can save between 2,000 to 4,000 gallons of diesel per year. Models that meet these equipment specifications save operators money and reduce greenhouse-gas emissions and air pollutants.

EPA Technology Verification for SmartWay designation is a testing and verification program designed to quantify emissions reductions and fuel savings from various available technologies, such as tractor and trailer aerodynamics, auxiliary power units, and wide-based tires. As a result, companies can compare the fuel efficiency and environmental performance of various technologies and make more informed purchases.

In its first decade, the program is estimated by EPA to have achieved significant benefits including:

- SmartWay partners have saved 120.7 million barrels of oil, saving $16.8 billion dollars to date.

- SmartWay's clean air achievements are estimated at 51.6 MMT $CO_2$, 738,000 tons NOx, and 37,000 tons PM reduced so far, helping protect the health and well-being of citizens, especially in low-income communities near ports, truck stops, and borders.

- The United Nations, the World Bank, the Commission for Environmental Cooperation, as well as the governments of China, Mexico and Canada, have projects and programs that rely upon SmartWay's technical assistance, methods and tools.

- US ports rely on SmartWay's Port Drayage Truck program to help reduce pollution and address environmental justice concerns in and around major US ports.

Similar efforts are underway in other parts of the world, building on this experience. A good example is the Green Freight China Program organized by Clean Air Asia with support from China Sustainable Energy Program (Energy Foundation) and partners (Ministry of Transport, US EPA and others). Its premise is that city level and regional level projects for the freight sector will be successful and sustained only if an integrated policy package is in place nationally, due to the freight being carried across regional boundaries. A Green Freight China Program is being designed that focuses on energy efficiency and reduced GHG and air pollutants, that:

- Fills gaps in national policies and institutions that aim to reduce fuel use and emissions from the freight sector, and fill gaps the Guangdong GEF project that is restricted to the Guangdong Province.

- Provides a basis for nation-wide efforts to reduce fuel use and emissions from the freight sector. The program design will build on existing programs in other countries as well as the Green Trucks Pilot Project in Guangzhou; and

- Could also be used as a model for other countries establishing such programs, especially developing countries.

The idea stems from the involvement of the Clean Air Initiative for Asian Cities (CAI-Asia) in the World Bank Guangzhou Green Trucks Pilot Project (Dec 2008 – Feb 2010) and preparation of a GEF[53] Guangdong Green Freight Demonstration Project (launch planned in September 2011), as well as the success of the SmartWay Transport program in the US and steps towards a similar program in Europe.

Measures to reduce fuel use and emissions from trucks include:

- Vehicle activity and driving pattern improvement
- Enhanced maintenance
- Tire and wheel technologies and equipment
- Aerodynamics technologies and equipment
- Idling control through technologies and behavior
- Fuel, oil and lubricant improvement
- Oil by-pass filtration system
- Emissions control technologies

53 The Global Environment Facility is a partnership for international cooperation where 183 countries work together with international institutions, civil society organizations and the private sector, to address global environmental issues

- Fleet and engine modernization

## Mandatory Vehicle Scrappage Programs

To the extent that older high polluting vehicles can be taken off the road and destroyed and replaced by cleaner vehicles, pollution levels can be greatly reduced. China is attempting to bring this about and has mandated that all yellow label vehicles across the country be destroyed by the end of 2017; in the three main regions[54], all these vehicles are to be scrapped by the end of 2015. All gasoline vehicles that were produced without a catalyst (so called Pre-Euro or pre 2000 Model Year) and all pre Euro 3 diesel vehicles receive a yellow registration label.

## Court Actions

In some countries, citizens have gone to court to challenge governments to do more to provide them with clean, healthy air and this can be the basis for accelerating the move to clean fuels and vehicles. Examples include:

**Experience in Europe:** The binding character of the limit values also emerges from the individual right of every EU citizen living in a non-attainment area, that the air quality (AQ) management authority undertakes all proportionate efforts to bring air pollution below the limit value or at least to reduce the excess of the limit value to the extent possible. That an individual right for action emerges from the excess of the AQ limit values was confirmed by the European Court of Justice, ruling on request of the German Superior Administrative Court, which in turn confirmed the claim of a citizen living along a heavily polluted arterial road in Munich, that the administration had not brought forward appropriate measures to reduce air pollution in the neighborhood and that more ambitious measures needed to be implemented to minimize the excess of the limit values and to meet them as soon as possible. As a result, the city of Munich had to revise its AQ plan by adding new measures. Forced by the court ruling, Munich eventually introduced a low emission zone where vehicles not meeting certain emission standards were banned. Only recently, the European Court of Justice clarified, again on request of the German Superior Court, that NGOs also have the right to file an action against insufficient local air quality planning.

**Experience in India:** Fuel specifications based on environmental consideration were for the first time notified in the country by the Ministry of Environment & Forests in April 1996 for achievement by 2000. These norms mandating lead free gasoline were incorporated in the Bureau of Indian Standards (BIS) 2000 standards. Further, based on the Supreme Court order of April 1999, Ministry of Surface Transport (MoST)

54 Jing-Jin-Ji composed of Beijing, Tianjin and Hebei Province, the Yangtze River Delta(YRD) and the Pearl River Delta (PRD)

notified Bharat Stage-I (BIS 2000) and Bharat Stage-II vehicle emission norms broadly equivalent to Euro I and Euro II for introduction in entire India and NCR respectively.

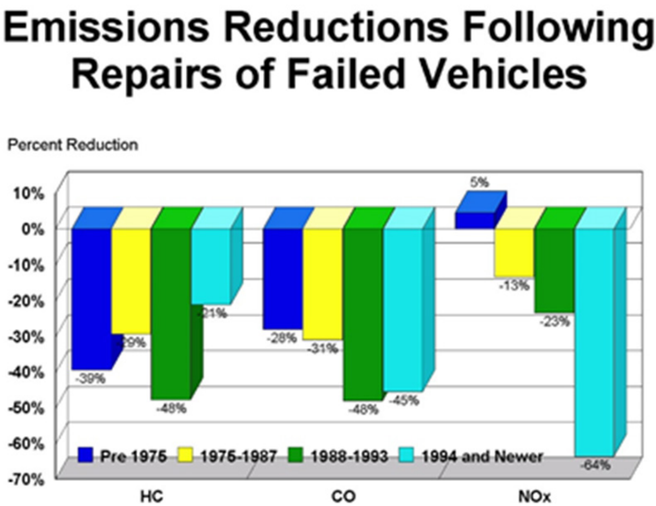
In further response to the Supreme Court, the Ministry of Petroleum & Natural Gas (MoP&NG), Government of India constituted an Expert Committee, under the Chairmanship of Dr. R.A. Mashelkar, then Director General, Council of Scientific & Industrial Research (CSIR) on 13th September 2001 to recommend an Auto Fuel Policy for the country including major cities; to devise a road map for its implementation; to recommend suitable auto fuels and their specifications considering the availability and logistics of fuel supplies, the processing economics of automotive fuels, and the possibilities of multi-fuel use in different categories of vehicles; to recommend attributes of automobile technologies, fiscal measures for ensuring minimization of social cost of meeting a given level of environmental quality and institutional mechanisms for certification of vehicles and fuels, as also the monitoring and enforcement measures. The Expert Committee submitted their report to the Government of India in August 2002, which included their recommendations for achieving the desired objectives. Based on these recommendations, MoP&NG released the "Auto Fuel Policy" as approved by the Government in October 2003, which contained the recommendations for implementation, along-with the time frame, wherever applicable.

The Auto Fuel Policy (2003) addressed measures to cover various areas in which action was required viz. vehicular emission norms, fuel quality and the standard of CNG/LPG kits, measures to reduce emissions from in-use vehicles, vehicle technology, air quality data and Research & Development. It also covered air quality data and health effects of air pollution.

## Inspection and Maintenance (I/M)

Vehicles that are properly tuned and adjusted tend to be cleaner than vehicles out of tune. Modern vehicles equipped with advanced pollution controls are even more dependent on properly functioning components to keep pollution levels low. Minor malfunctions in the air/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 vehicle inspection programs based on periodically subjecting vehicles to a short test can identify these problem cars and, by requiring a retest after necessary maintenance assure their repair. The combination of inspection (I) and remedial maintenance (M) has become known as I/M.

It has been well established that properly designed and operated I/M programs are capable of significantly reducing emissions. For example in one evaluation of the long term benefits of the province of British Columbia in Canada's AirCareI/M program, it was determined that over the first 8 years of the program, HC emissions were reduced by 34.3%, CO by 38.4% and NOx by 10.3%. [55]




In an effort to determine the mass emissions reductions from the program, a sample of 957 vehicles was tested in the laboratory before and after normal repairs with the results summarized in the figure above. Substantial decreases in average emissions are evident in all cases but one. An increase in average NOx emissions of 4.5% was observed among the oldest vehicles. The newest vehicles on the other hand tended to show the percent reduction in NOx.

In addition to the emissions reductions, the audit program found that fuel economy for the failed vehicles improved by approximately 5.5% following repairs.

The audit program also demonstrated that the centralized program was resulting in a very high quality test program. For example, after reviewing over 2 million tests, the auditor concluded that in only 1.1% were incorrect emissions standards applied. Not one instance was found where a vehicle was given a conditional pass or waiver inappropriately. [56] About 1% of the failed vehicles were found to be receiving waivers

55 "Results and Observations Relating to the First Eight Years of Operation (1992-2000)", by Stewart, Gourley and Wong, December 2001.

56 If the vehicle is taken to an authorized technician and spends at least $200 on repairs, it can receive a conditional pass or waiver even if it does not meet the emissions standards.

even though their emissions were excessive, i.e., they exceed either 10% CO, 2,000 ppm HC or 4,000 ppm NOx. If the cost limits were increased such that these percentages were halved, the auditor concluded that HC and CO reductions from the program would each increase by about 5%.

Available data also indicated that many vehicles are repaired sufficiently that they remain low emitting. For example, almost 53,000 vehicles that failed the test the first year were repaired well enough to pass the following year.

Overall these data confirm that I/M programs when properly performed in a centralized facility using a loaded mode test can and do achieve a substantial reduction in emissions. According to the auditor, improvements to the program such as including evaporative testing, reducing or eliminating cost waivers, adding the IM240 test or tightening the standards could all increase the overall benefits significantly. [57]

AirCare regularly conducted detailed scientific reviews to assess overall program effectiveness and report on total reductions in vehicle emissions attributed to the program. The British Columbia AirCare program is considered by many to have the most in depth technical reviews in the inspection and maintenance industry. These reviews follow established scientific methodology and are fair appraisals of the program's strengths and weaknesses.

Since its introduction in 1992, the AirCare program has been an important part of this region's air quality management plan. The Lower Fraser Valley region has seen significant improvements in the ambient concentrations of most common air contaminants over the last two decades, despite a significant population growth over the same time period. Metro Vancouver has recognized the historical importance of AirCare as a control measure in its overall strategy to provide healthy, clean and clear air for current and future generations.

Targeted I/M programs can contribute substantially to reduce the pollution caused by such vehicles. But there are also many challenges involved with implementing an effective I/M program and policymakers should make a decision to launch (or strengthen) an I/M program only if fully cognizant of the challenges involved. Some of these challenges are described in a report by the US Agency for International Development.[58] If a country decides to introduce I/M programs, certain overriding principles should be followed to help ensure successful programs:

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57 Effective January 1, 2001, the AirCare program was enhanced in several significant ways including: IM240 Testing for most 1992 and newer vehicles and biennial inspections for these vehicles

58 USAID. 2004. Vehicle Inspection and Maintenance Programs: International Experience and best practices, http://pdf.usaid.gov/pdf_docs/PNADB317.pdf

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

- Tightening of new vehicle emission standards should be followed by a concomitant tightening of in-use standards for those newer model vehicles. Policymakers must assure that appropriate in use standards are set for vehicles, which account for the technology advances which result from tighter new vehicle standards.

- In addition, policymakers must assure that the in use standards applied in the I/M programs appropriately reflect the differences between each group. In addition, policymakers must assess whether the I/M test procedures may also need to be different for vehicles with different pollution control technologies.

- Further, the pollutants of concern will differ between diesel-fuelled vehicles (PM, smoke and NOx) and gasoline (petrol) fuelled vehicles (CO, HC and NOx). Policymakers should account for these differences in designing their I/M programs.

- When an I/M program is initiated, if standards are set too stringently, most vehicles could fail placing a great strain on the service sector as well as being politically unacceptable. Policymakers should adopt initial standards that only fail the worst 15% to 20% of the vehicle fleet and then gradually tighten the standards as the service industry and maintenance practices improve.

## Structure of the Program

The first decision that is usually made regarding an I/M system is the fundamental structure of the program and this is often the key determinant of the overall success or failure of the effort. Several key principles should guide policymakers in deciding on the I/M program structure:

- Experience indicates that centralized I/M systems (sometimes called test only systems) where the inspection function is separated from the maintenance function have produced the best result. Decentralized systems where inspections and repairs are combined are very difficult to supervise and audit and have been found to be subject to corruption and poor quality control. Policymakers should be especially cognizant of the international experience in this regard and resist the adoption of programs that combine testing with repair and that are very unlikely to achieve significant emissions reductions.

• In defining the structure of the I/M system, policymakers should assure that there is a careful and thorough dialogue among all relevant stakeholders. These include providers, regulators, enforcers/police, vehicle manufacturers, the driving public and the media.

• Experience from across the world has demonstrated that while governments should regulate I/M programs the actual implementation of I/M programs can best be carried out by the private sector. Policymakers should assure that a carefully designed and well thought out bidding document is prepared in an open and transparent manner and that all potential bidders are given a fair opportunity to compete for the final contract.

• Governments contemplating the establishment of an I/M system or expanding the scope of an I/M system need to consider

• whether they have adopted the appropriate in use vehicle emissions standards and test procedures on which to base I/M,

• If there is the institutional capacity and willingness to enforce an I/M program, and

• Whether the repair sector has been trained sufficiently to be able to carry out the repairs on cars which fail the tests. If any of these aspects are found to be deficient, policymakers should take all appropriate steps to rectify the situation.

• With regard to the repair sector, the vehicle manufacturers can play an important role in providing training and policymakers should take steps to involve them in the development of an overall strategy to upgrade the repair industry.

## Institutional Administrative Set up

The single most important determining factor for success of I/M is support by senior decision makers and the institutional capacity to manage and regulate the system. Where such institutional capacity is insufficient a weak regulatory framework results. Inadequate funding and enforcement could lead to a system that is plagued by corruption and poor quality control. Policymakers should adhere to the following principles, therefore, in setting up the I/M system:

- Policymakers must assure that an adequate fee structure is developed in which the affected vehicle owners pay the full costs of the I/M program including the costs of auditing and overseeing the program by government or private auditors. This follows the principle of the polluter pays.

- Within countries that have a combined roadworthiness and emission-testing program, the responsibility is often shared between the Departments of Transport and Environment. Poor coordination between these two departments can hamper efforts to strengthen I/M. Policymakers should assure that there is a full dialogue with all appropriate ministries or departments at the early stages of program design and that full agreement is worked out regarding specific roles and responsibilities.

- In those countries where responsibility is shared between national and local government organizations coordination problems can also occur in the implementation of existing I/M programs as well as in the strengthening of the I/M system. Again policymakers should assure that there is a full dialogue with all appropriate ministries or departments at the early stages of program design and that full agreement is worked out regarding specific roles and responsibilities.

- Any I/M system needs to account for new vehicle emissions standards, which in most cases are issued by national governments. Policymakers should strive to develop I/M systems within a national framework.

- Overall success in an I/M program depends in part on assuring that all vehicles that are intended to participate in the program are actually inspected and repaired if necessary. Experience has demonstrated that the most effective I/M programs are those that are linked to registration of vehicles, i.e., failure to present proof of passing an inspection leads to denial of registration. Policymakers should therefore carefully develop and implement a registration based enforcement system for all affected vehicles.

- A well-functioning I/M system will include a data management system that ensures that all test data are transmitted on a regular basis to a central database. This will be easier if I/M stations are linked by computers that automatically transmit information on a real time basis. This is much easier in a centralized system with a limited number of contractors than in the case of a decentralized system with a large number of independent workshops. In designing the program, policymakers should assure that a good data management system is included and assure that sufficient funds are included in the fee structure to manage and operate the system.

- Policymakers should also be aware that increased reliance on data management centres will make it necessary to strengthen the quality of the overall database on vehicles in actual use.

## Technical Issues

Many I/M systems, often those operated by the government, lack the commitment of resources or the requirement to assure that hardware is maintained and upgraded as appropriate. Also funds for calibration of equipment are often inadequate. Often, limited attention is paid to assure adequate training of staff that carries out the inspections.

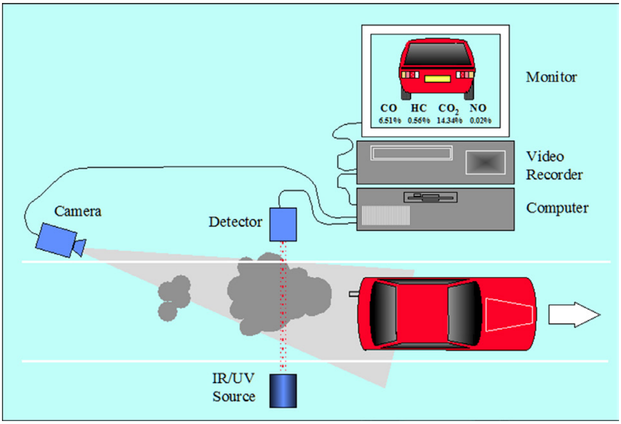
- One remedy noted earlier which policymakers should carefully consider is privatising such programs and adopting a fee structure which provides adequate funds.

- The shift towards more stringent emission standards for new vehicles should be followed by tighter in-use standards for the newer models. The test procedure should be shifted to a "loaded test" rather than "idle test" when new vehicle standards result in the introduction of catalyst technology on vehicles. This will require new, additional test equipment including chassis dynamometers. The costs of such equipment will make it difficult for small-scale workshops to take part in the implementation of an I/M program, which is another reason for considering a centralized system.

- Since the I/M test procedure is fundamentally different from the type approval test procedure it is difficult to directly link the I/M standards that should apply to the type approval standards. A good approach to setting standards would be to initiate the program with fairly modest standards that would allow most vehicles to pass initially. After going through a full cycle, standards should be adjusted to fail the worst ~15 to 20% of the vehicles. Over time as the overall fleet quality improves, standards should be adjusted. Also the gasoline vehicles should be further subdivided between those with catalysts and those without.

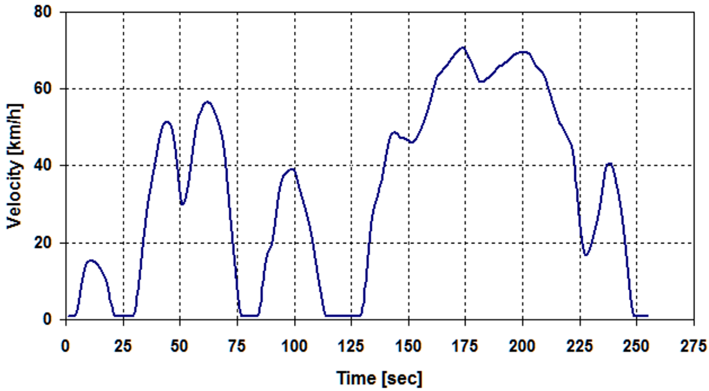
- Since most developing countries have adopted EU standards for new vehicles, it may be more appropriate to adopt a European short test rather than the US derived IM240. An example of such a test is shown in the figure 3 below.

• A potentially serious problem, especially where most vehicles still are equipped with simple carburettor technology, is the "Clean for a Day" syndrome, in which vehicles are tuned to pass the test and then immediately readjusted to a high pollution condition afterwards. To deal with this problem, policymakers must give attention to complementary in use test programs such as roadside screening or remote sensing (see Figure 4 below for a typical remote sensing set-up.).




• There are certain countries or cities which are leading the way with respect to testing of certain types of vehicles such as the Smoky Vehicle Control Program in Hong Kong which involves dynamometer smoke testing for light and heavy duty diesel vehicles. Policymakers should consult with the technical leaders in the region as they develop their programs.

• Emphasis in I/M should be on identification of gross polluters within each technology category. Remote sensing (RSD) is evolving and may play an important role in identifying the gross polluting vehicles, especially where most vehicles are low tech. It might be less suitable for more advanced technologies unless further improvements are made. Currently, most experience with RSD has been with clean screening as a means to reduce the testing load although dirty screening programs are also in effect or being developed.




- In designing programs, policymakers should assure that frequency of inspections varies for vehicles with differing mileage accumulation rates and with more or less durable emission control systems. For example, taxicabs typically accumulate far more mileage in a given period than do private cars and therefore they should be subject to more frequent inspections.

## Public participation

Public perceptions regarding the effectiveness and transparency of I/M systems will heavily influence the willingness of the general public to cooperate with I/M regimes imposed by the government. To ensure a positive public perception it is important that the public understand the public health need for the program and believe that it is fair and effective. The US EPA has developed a toolkit for public participation. [59]

Experience indicates that the driving public is on average more interested in roadworthiness and safety of vehicles than in emission levels because the linkage between vehicle roadworthiness and the safety of drivers, passengers and pedestrians is more apparent. To ensure the required public acceptance of I/M programs and their willing participation in maintenance and inspection of vehicles I/M programs will have to considerably strengthen the public awareness-raising component of their programs. Particular emphasis should be placed on the health benefits that can result from a successful program.

Environmental NGOs lack resources and often have limited understanding of vehicle emission standards and I/M issues. This limits the effectiveness of these groups in encouraging government officials to assure that good quality I/M programs are put in place.

59 US EPA, Public Participation Guide, http://www2.epa.gov/international-cooperation/public-participation-guide

- Considering the above, policymakers should develop a strong and ongoing public awareness component to the program that routinely informs the public regarding the need for the program, the benefits which it is having and the overall performance. A special focus of the public awareness campaign should be on environmental NGOs who need to have their understanding and capacity upgraded. Again, policymakers must assure that sufficient funds for this effort are included in the inspection fee structure.

- Policymakers should develop performance standards for I/M stations that will guarantee fast and reliable testing for the public; poorly performing stations must be penalized as well. Performance measures could include typical waiting times as well as pass/fail rates.

- Policymakers also need to think about methods to be employed to get a better cooperation from the public in I/M programs. Consideration should be given to tax incentives, lower registration fees for cleaner vehicles, or linkage to vehicle insurance rates.

## Quality Assurance – Audit

I/M programs have often been associated with fraud and corruption. Failure to address these issues will seriously compromise the credibility of effectiveness of I/M systems.

Governments often experience difficulties in setting up effective quality assurance and audit mechanisms of the I/M systems in their countries. Yet, a well-functioning audit and quality assurance system is crucial for the acceptance and success of any I/M system. Audits can be implemented by a special unit in the responsible government department or can be outsourced to a private sector firm provided it is not operating a part of the I/M system. These private sector providers should also not provide training or consultancy services to the I/M provider.

- Policymakers should assure that such auditing functions are fully built into the overall program design and accounted for in the fee structure. Further, in designing such auditing systems, as a general rule, it can be stated that the less reliance there is on human judgment or manual actions, the more reliable the result.

- Policymakers should also assure that test fees are set at a reasonable level that will allow private sector operators to make a sufficient profit to maintain, replace and upgrade equipment as required.

- The duties of the regulatory agency are often not well defined and the agency is usually not well staffed. Policymakers should define the duties of the regulatory agency to include design of the I/M system, setting appropriate test procedures and standards, assuring proper operation of the I/M program and careful auditing. Where audits identify problems, policymakers should insure that the regulatory agency is authorized to and has the capacity to enforce the requirements, including the removal of the license to carry out the inspection by offending operators.

- A key element of a successful I/M program that is frequently neglected in the program design is how to enforce the case against corrupt entities, especially inspectors. Policymakers must give careful attention and thought to what are appropriate sanctions so as to assure that a workable system is in place.

## Roadside testing programs

Roadside testing can complement a more comprehensive Motor Vehicle Inspection System but not replace it. Policymakers should insure that roadside testing is designed as a complement to but not an alternative to testing in fixed stations. The roadside testing should primarily have the function of identification of gross polluting vehicles.

- Apart from the privatisation of the inspection centres, policymakers should also consider whether to outsource roadside apprehension to the private sector. They should insure that the inspection fee fully provides for the costs of an adequate roadside apprehension program.

- Certain countries have tried to strengthen enforcement by allowing enforcers to retain a part of the fines collected from apprehended vehicles. The effectiveness of this approach needs to be studied by policymakers to be sure that this doesn't increase the likelihood of corrupting the overall system.

## The "M" in I/M

While a great deal of attention is being paid to the I in I/M, it is the M that actually reduces emissions. Very often, the quality of repairs is weak and needs special attention. Therefore, in designing I/M programs policymakers need to include a particular focus on this issue. This is especially true in countries or regions where the service sector is very informal and lacks good training or equipment.

- The service industry should have sufficient equipment to properly repair vehicles. In addition, adequate training must be made available so that the mechanics and technicians are sufficiently skilled to repair the failed vehicles that come to their shops.

- In tightening the I/M requirements, policymakers should pay careful attention to assuring that the service industry has sufficient lead-time to equip itself to repair failing vehicles. A one year transition from the time testing is initiated until mandatory repairs are required is a reasonable phase in.

- Policymakers should also insure that good lines of communication exist between the repair industry and the I/M managers so that problem vehicles can be resolved. Routine meetings should be arranged to discuss problems.

- One mechanism for resolving disputes or difficulties with individual vehicles is the introduction of referee stations, where owners can get a second opinion and advice about appropriate repairs. Policymakers should carefully consider provision of one or more referee stations in the overall design of the program.

- Policy makers should also address quality assurance for spare parts. One approach that should be considered is requiring parts suppliers to warranty the performance of their parts and to label the details of the warranty on the packaging.

## Motorcycles

There has been limited international experience with I/M programs for motorcycles and much of it has been of poor quality. However, the same principles regarding program structure, institutional arrangements, and quality assurance apply. Perhaps the most successful motorcycle I/M program is in Taipei, Taiwan. Motorcycles are tested in private garages on a loaded dynamometer with the data being transmitted real time to a centralized data center including a video showing simultaneous images of the vehicle license plate and instrument readings.

# 5. AUTOMOBILE EMISSIONS IN THE UNITED STATES AND EUROPE

## Background

During the 1950s, motor-vehicle-related air pollution began to emerge as a serious issue in both the United States and Europe. Much of that decade and the next were directed toward fact-finding and initial studies. Emphasis was placed on defining the problem, establishing the motor vehicle role, developing test procedures and emissions measurement techniques, as well as assessing public health and environmental damages. In addition, some initial but modest control efforts were initiated. But by the end of the 1960s and into the early 1970s, it became clear that the approaches of the United States and Europe would fundamentally diverge.

Many factors contributed to this difference. The different internal political structures of the United States and Europe played one role. In the United States, the Congress enacted the Clean Air Act (CAA) of 1970 and subsequent amendments, which established federal authority over motor vehicle regulation and delegated power to the U.S. Environmental Protection Agency (EPA) to set national standards. Moreover, the state of California received a special opportunity in the CAA, one not granted to any other state, to set its own more aggressive standards on motor vehicle emissions; other states could opt to follow them, provided EPA granted California's request, which it typically did. By contrast, Europe functioned, at least with respect to motor vehicle standards, as a multination coalition of independent states that varied substantially in economic development, industrial structure, and public opinion. When the European Community was established to foster free trade, initial efforts to set motor vehicle emissions standards by Member States such as Germany and France were seen by some other Member States as potential impediments to free trade—and strong emissions standards were therefore resisted.

Another important factor was a difference in public concerns. The emergence of the environmental movement in the United States, culminating in the first Earth Day in 1970, became closely linked to public health concerns. The year 1970 was also the one in which Senator Edmund Muskie spearheaded adoption of the landmark 1970 Clean Air Act Amendments. Simultaneously, in an effort to politically neutralize the environmental issue, President Nixon created the Environmental Protection Agency. In Europe, air pollution control was also gaining advocates, but with a stronger emphasis on ecological impacts such as forest degradation (and later, climate change); less emphasis was placed on local public health and epidemiologic evidence. (Other differences included the amount of driving, or vehicle kilometers traveled, in the United

States versus in Europe, and the use of alternative transportation modes such as public transportation.)

## Development of the U.S. Program

In 1960, California adopted legislation that called for the installation of pollution control devices as soon as three workable control devices were developed [60]. In 1964, the state was able to certify that three independent manufacturers of emission control equipment had successfully developed such devices, which triggered the legal requirement that new automobiles must comply with California's standards beginning with the 1966 model year. Soon afterward, the major U.S. domestic vehicle manufacturers announced that they too could and would clean up their cars with technology they had developed in house, thus eliminating the need for the independently developed devices.

Subsequent to California's pioneering efforts, and as a result of recognition of the national nature of the automobile pollution problem, in 1964 Congress initiated federal motor vehicle pollution control legislation. As a result of the 1965 Clean Air Act Amendments, the 1966 California auto emissions standards were applied nationally in 1968.

In December 1970, the Clean Air Act was amended by Congress "to protect and enhance the quality of the nation's air resources." Congress took particular notice of the significant role of the automobile in the nation's effort to reduce ambient pollution levels by requiring a 90% reduction in emissions from the level previously prescribed in emissions standards first for 1970 models for carbon monoxide (CO) and hydrocarbons (HC), and then for 1971 models for nitrogen oxides (NOx). Congress clearly intended to aid the cause of clean air by mandating levels of automotive emissions that it hoped would essentially remove the automobile from the pollution picture.

In many ways, the serious effort to control motor vehicle pollution can be considered to have begun with the passage of the landmark 1970 law. By including the stringent "technology forcing" requirements in the law and providing only very limited flexibility to EPA in relaxing these requirements, it forced the manufacturers to work aggressively toward compliance, because only Congress itself could provide relief. In addition, the law provided EPA with broad authority to implement the requirements, including provisions to mandate a recall of vehicles whenever "a substantial number of properly maintained and used" vehicles failed to meet standards in use over their useful lives, and to modify fuel quality—including the level of lead (Pb) in gasoline—if necessary to enable compliance. This latter authority was especially critical, because the principal

60 Krier, James E., and Edmund Ursin. 1977. Pollution and Policy: A Case Essay on California and Federal Experience with Motor Vehicle Air Pollution, 1940–1975. Berkeley: University of California Press.

technology that emerged to enable compliance with the emissions standards was the catalytic converter—a technology that could not withstand lead additives. (Lead had been added to gasoline since the 1920s to "improve" combustion.)

Finally, the 1970 law grandfathered in the California motor vehicle pollution control program and left that state with the unique authority (subject to EPA approval) to set its own standards and regulations for vehicle emissions. This proved critical over the years that followed, as California—suffering from the most serious vehicle-related air pollution problem in the country—consistently pushed the technology envelope over the next four decades, something it continues to do to this day.

In 1977, the CAA was "fine-tuned" by Congress, which delayed and slightly relaxed the auto standards under pressure from the vehicle industry. In doing so, though, Congress authorized the states to adopt either the federal EPA motor vehicle emissions standards or the California standards (thereby yielding two car designs that the manufacturers would have to produce), but Congress prohibited the states from setting any other standards that would require the creation of a so-called "third car." The 1977 amendments also expanded the law by imposing similarly stringent emissions requirements on heavy-duty trucks. More recently, Congress passed the 1990 Clean Air Act Amendments, further expanding EPA's authority to regulate off-road vehicles and fuels. Also, EPA has issued a series of increasingly stringent regulations under the broad authority granted to it under the clean air law.

As a result of these requirements, substantial and rapid improvements in vehicle emissions have occurred over the past 40 years.

Shortly after the 1970 law went into effect, a gradual phase-out of the use of lead in gasoline was initiated, which allowed auto manufacturers to introduce lead-intolerant catalysts on most 1975 model-year cars. Further tightening of the NOx standards, first in California and then across the country in the early 1980s, accelerated the introduction of advanced electronic controls, which also enabled improvements in fuel economy during this same period. By the mid-1980s, stringent particulate matter (PM) standards were also introduced for diesel cars. Following the 1990 Clean Air Act Amendments, a further reduction in all of the pollutants was phased in throughout the 1990s.

While Congress was in the late stages of the debate regarding what became the 1990 Clean Air Act Amendments, two significant events occurred:

In September 1990, California adopted the Low Emissions Vehicle (LEV) Program, which was distinctive in several important respects:

- It provided flexibility to manufacturers by allowing them to certify vehicles meeting several distinct categories or sets of emissions standards (called "bins") as long as their fleet sales on average complied with an overall standard for non-methane organic gases (NMOGs), which declined year by year throughout the 1990s.

- It created a new category of vehicles, zero-emitting vehicles (ZEVs), in an effort to force the vehicle industry to devote significant resources to developing and introducing into the marketplace vehicles that effectively did not rely on the internal combustion engine. This arguably resulted in the introduction first of electric cars, then of hybrid electric cars, and is soon leading to commercially available fuel-cell-powered vehicles.

- It provided special credits for vehicles with near zero exhaust and evaporative emissions, PZEVs.

- It also specifically linked vehicles and fuels, and it forced the introduction of "reformulated" gasoline with reduced sulfur levels, lower volatility, and other changes in composition.

Just as California was adopting the LEV program, New York became the first state that used Section 177 of the 1977 Clean Air Act Amendments to adopt California's vehicle emissions standards. Subsequently, a number of other states have also adopted the California requirements.

As a backdrop to all these developments, air quality issues in the United States, although improved, remained widespread and serious. A growing body of public health studies—especially epidemiologic evidence of thousands of fatalities per year in areas with higher air pollution levels—impelled EPA to tighten health-based air quality requirements for both ozone (or photochemical smog) and PM.

Thus the broader authority provided to EPA under the 1990 Clean Air Act Amendments, the surge in California to push the air pollution technology envelope even further, and the healthy cooperation and occasional competition between EPA and California to mandate clean vehicles and fuels have all combined to bring several additional important elements into the U.S. program. These include the following:

- An unanticipated a new class of vehicles called sport utility vehicles (SUVs) emerged, soon representing almost half the U.S. light-duty vehicle market. SUVs were legally classified as light trucks, which were traditionally covered by more lenient emissions standards. Today's latest emissions standards now require light trucks to meet the same requirements as cars.

• Recognizing the growing importance of evaporative hydrocarbons, EPA has substantially broadened and tightened evaporative emissions requirements including the addition of onboard refueling vapor recovery systems that capture the emissions from the vehicles fuel tank during refueling.

• Light-duty diesel vehicles had been allowed to meet a more lenient NOx standard than their gasoline counterparts; both California and EPA now require diesel and gasoline vehicles to meet the same standards.

• The close linkage between vehicle emissions requirements and fuel quality is now recognized and established, with the result that very low levels of sulfur in both gasoline and diesel fuel are being mandated not only in California, but across the entire country.

• Heavy-duty trucks, which traditionally had more lenient emissions requirements, have been forced to introduce very advanced after-treatment technologies by 2010.

• Nonroad vehicles, especially diesel-fueled farm and construction equipment, as well as ships and locomotives, are required to meet stringent emissions standards similar to the limits covering on-road heavy-duty vehicles, with a lag of only a few years after on road vehicles.

• Tier I standards adopted in 1991 were tightened by Tier II standards adopted in 2004. Most recently, on March 3rd, 2014, the U.S. Environmental Protection Agency (EPA) finalized a further tightening of emission standards for vehicles and gasoline, reducing standards for smog-forming volatile organic compounds and nitrogen oxides by an additional 80 percent, establishing a 70 percent tighter particulate matter standard and virtually eliminating fuel vapor emissions.[61] The final fuel standards will reduce gasoline sulfur levels by more than 60 percent – down from 30 to 10 parts per million (ppm) in 2017. EPA found that reducing sulfur in gasoline will provide significant and immediate health benefits because every gas-powered vehicle on the road built prior to these standards will run cleaner – cutting smog-forming NOx emissions by 260,000 tons in 2018.A more detailed summary of this program is contained in Appendix B.

61 These so called Tier 3 standards closely mirror the LEV III standards adopted earlier by California.

# Development of the European Program

Automobile emissions regulations in Europe have been developed in least three arenas: the individual Member States, the European Community (now the EU), and the United Nations Economic Commission for Europe (UNECE).

As noted earlier, during the 1950s and 1960s, efforts were under way in Europe as well as in the United States to deal with motor vehicle air pollution. France and Germany were especially active during this period, working independently toward emissions test procedures and emissions standards. The French organization Union Technique de l'Automobile du Motocycle et du Cycle (UTAC) was, for example, working on a driving cycle based on city driving in Paris. Similarly, the German Auto Manufacturers Association, Verband der Automobilindustrie (VDA), requested that Professor Luther at the University of Clausthal be given a research assignment to develop a driving cycle for emissions testing.

One of the primary purposes of the European Economic Community (EEC), since the Treaty of Rome in 1957, was the elimination of trade barriers among the Member States. For many years, Directorate General III of the European Commission was responsible for harmonization within the internal market. It could develop directives on motor vehicle standards and, with the unanimous agreement of the other Directorates General, could send them forward to the Council of Ministers and the Parliament for approval. Once a directive was adopted and transposed into the national laws of each Member State, a Member State was obliged to accept an approved vehicle from another Member State and must issue a harmonized certificate for that vehicle.

The UNECE deals with economic issues as well as transportation and traffic questions, pursuant to the 1958 Geneva Agreement concerning the adoption of uniform conditions of approval and reciprocal recognition of approval for motor vehicle equipment and parts (335 United Nations Treaty Series 211, as amended). Transportation matters are handled by the Inland Transportation Committee, with Subcommittee One dealing with road traffic. Under this subcommittee, the Working Party on Pollution and Energy (previously known as Working Party 29) is responsible for motor vehicle regulations, with the Groupe des Rapporteurs pour la Pollution et l'Energie (GRPE) responsible for the development and evolution of all emissions control legislation and related subjects.

As France and Germany developed their motor vehicle standards, officials at the European level recognized the potential for individual countries proceeding unilaterally to create a patchwork of regulations that would act as a barrier to trade. In late 1965, WP 29 of the UNECE began an effort to define a European driving cycle. To lead that and other efforts in this emerging field, WP 29 created an expert working group on automobile pollution, GRPA (subsequently renamed GRPE). After investigations and negotiations, especially among the French, Germans, and British, in January 1967 the

European Driving Cycle was accepted by the GRPA, and it was sent forward to WP 29 in March of that year.

While discussions continued in Geneva (UNECE) and Brussels (EEC), pressure was building in the Member States to take action. A German draft regulation announced on January 1, 1968, called for idle CO controls and crankcase controls in 1969 and emissions controls under driving conditions in 1970. Other countries became increasingly concerned regarding the potential for these regulations to effectively become barriers to trade within Europe. Other factors confounded this concern. Some European manufacturers were active in the U.S. market, but those that were not expected that having to adopt U.S. procedures or standards could place them at a competitive disadvantage. And European manufacturers and markets were quite diverse, with some focused almost exclusively on small cars and others only on large cars; the form of the standard could have differential effects by size of car.

A race against time ensued because of the German plans. If a UNECE regulation on vehicle emissions were adopted and an EEC directive based on it were subsequently issued before the German requirements went into effect, the German regulators agreed that their requirements would be made moot. If not, the German regulation would become national law, and each country would be free to develop its own requirements. In fact, with less than two months to spare, UNECE Regulation 15, or ECE R 15, was published[62] . It went into effect on August 1, 1970, following the adoption of the EEC Directive on March 20, 1970, Directive 70/220/EEC. Thus the German regulation, which would have become effective on October 1, 1970, was superseded.

Following the initial development of the ECE R 15 requirements, a series of gradual steps to lower emissions was introduced. The second step, calling for a 20% reduction in CO and a 15% reduction in HC, entered into force on October 1, 1975 (ECE R 15, series 1). Next, restrictions were imposed for the first time on nitrogen oxides on October 1, 1977 (ECE R 15, series 2). A further modest step went into effect on October 1, 1979, when ECE R 15, series 3, called for a 12% to 19% reduction.

This trail of events set the process in place that effectively constrained the pace and stringency of European motor vehicle emissions regulation for the next 20 years. Two critically important features characterized the development of European regulations during this period. First, for the "Common Market" countries of the EEC, the development of emissions directives focused much more on ensuring that barriers to free trade did not occur than it did on protecting the environment and public health.

62 ECE (United Nations Economic Commission for Europe). 1970. Uniform Provisions Concerning the Approval of Vehicles Equipped with a Positive-ignition Engine with Regard to the Emission of Gaseous Pollutants by the Engine, Annexed to the Agreement of March 20, 1958, Concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts. 740 United Nations Treaty Series 364, as Revised/Consolidated in 1078 United Nations Treaty Series 351. August 1.

Second, because unanimous agreement was required by all Member States of the EEC, the pace of regulation was in effect set by the least aggressive Member State rather than by the limits of technological feasibility or environmental need.

## a) The Important Role Played by Lead in Gasoline

To illustrate these transatlantic institutional differences, consider the issue of lead (Pb) in gasoline. In the United States in early 1971, it was already apparent that catalytic converters requiring lead-free gasoline were likely to be the dominant technology of choice to comply with the 1975 emissions standards. EPA initiated steps to phase out the use of leaded gasoline and to ensure that lead-free fuel would be widely available before 1975 model-year cars entered the marketplace. Several European (including German) vehicle manufacturers that were active in the U.S. market were also working on catalyst technology. In 1971, Germany adopted its "Lead in Gasoline Law," which reduced the lead content to 0.4 grams/liter (g/l) from January 1, 1972, and to 0.15 g/l from January 1, 1976. Because of concerns that Germany would mandate lead-free fuel and create a barrier to trade, the EEC then issued a Directive that prohibited any member of the European Common Market from mandating fuel with less than 0.15 grams of lead per liter. In other words, the result in Europe was no lead-free fuel, and hence no catalytic converters were allowed. This prohibition on lead-free fuel clearly delayed progress in Europe for at least another decade. By contrast, the United States phased out lead in gasoline during the 1970s and 1980s—a more precautionary approach against the risks posed by lead exposure such as cognitive impairment in children[63].

## b) Breaking the European Logjam

Public concern about motor vehicle air pollution in Europe continued to build throughout the 1980s, and individual Member States began to consider ways to get around the restrictions and weak standards of the EEC and ECE. Several European manufacturers were producing much cleaner vehicles for the U.S. market than for their home market, and the European public began demanding these cleaner technologies. The issues came to a head with the growing evidence showing serious damage to the Black Forest in Germany and Austria and other signs of ecological deterioration[64]. As knowledge of these technological improvements in cars spread, and as the adverse effects of motor vehicle pollution became more widely recognized, more and more people across Europe began demanding the use of these systems in their countries. During the mid-1980s, Austria, the Netherlands, and the Federal Republic of Germany adopted innovative economic incentive approaches to encourage purchase of low-pollution vehicles. Sweden and Switzerland—not members of the Common Market at

63 Walsh, Michael P. 1999. Phasing Lead out of Gasoline: An Examination of Policy Approaches in Different Countries, United Nations Environment Programme/Organization for Economic Co-Operation and Development.

64 Of course, there was also growing concern with the adverse health effects of lead, especially in children.

that time and therefore not legally constrained by its Directives—decided to adopt mandatory requirements based on the use of lead-free fuel and catalytic converters.

A key breakthrough occurred on May 16, 1984, when the European Commission proposed that Member States be allowed to mandate the availability of unleaded gasoline by January 1986; it also mandated that unleaded gasoline must be available in every Member State by 1989. Thus widespread availability of unleaded fuel; mandatory requirements for U.S.-type emissions standards in some countries outside the Common Market such as Austria, Sweden, and Switzerland; and economic incentives encouraging U.S.-type control technology in Germany and the Netherlands resulted in large numbers of catalyst-equipped cars emerging across Europe as the decade came to a close.

In 1990, the European Council of Environmental Ministers, in what became known as the Consolidated Directive, reached unanimous agreement to require all new models of light-duty vehicles by 1992/1993 to meet emissions standards roughly equivalent to U.S. 1987 levels. Specifically, the ministers decided to do the following:

- Require all light-duty vehicles to meet emissions standards of 2.72 grams per kilometer (g/km) CO, 0.97 g/km of HC plus NOx, 0.14 g/km of particulates for type approval, and 3.16 g/km CO, 1.13 g/km for HC plus NOx, and 0.18 g/km particulates for conformity of production;

- Require the Commission to develop a proposal before December 31, 1992, that, taking account of technical progress, required a further reduction in limit values;

- Have the Council decide before December 31, 1993, on the standards proposed by the Commission; and

- Allow Member States, prior to 1996, to encourage introduction of vehicles meeting the proposed requirements through "tax systems" that include pollutants and other substances in the basis for calculating motor vehicle circulation taxes[65] .

Since the adoption of the consolidated Directive, Europe has moved quickly and aggressively to further tighten its requirements for clean vehicles and fuels. The first Auto-Oil program started in the early 1990s led to the adoption, in 1998, of the Euro

65 European Commission. 1990. Commission of the European Communities, COM (89) 662, Proposal for a Council Directive Amending Directive 70/220/EEC on the Approximation of the Laws of the Member States Relating to Measures to Be Taken against Air Pollution by Emissions from Motor Vehicles, Brussels, February 2.

3 emission standards for new passenger cars and light commercial vehicles; these standards have been mandatory since January 2000.

The European Commission intended to use the second Auto-Oil program to investigate and confirm the Euro 4 emission standards, taking into account the likely improvements in emission control technology between 1998 and 2005, when Euro 4 was intended to become mandatory for new vehicles. However, the European Parliament and the Council decided to fix the Euro 4 emission standards at the same time as Euro 3 with the result that the second Auto-Oil program effectively focused on a range of additional measures that Member States might wish to apply where air quality problems due to road transport persisted.

In addition, Euro 3 introduced new requirements covering:

- A cold start emission test carried out at –7 Celsius with specific limits for hydrocarbons and carbon monoxide;

- In-use compliance checking to ensure that vehicles continue to achieve their type-approved emissions performance up to 100,000 km in the case of Euro 4;

- A revised test procedure for evaporative emissions to better reflect a 24-hour daily temperature profile;

- Requirements for on-board diagnostic systems, and

- Inclusion of start-up emissions in the test – previously the first 40 seconds was not sampled.

The use of tax incentives by some of the Member States stimulated manufacturers to provide Euro 4 cars earlier than the mandatory date of 2005; similarly tax incentives were used by some member states to stimulate the early introduction of lower sulfur fuels[66].

Some Member States continued to put pressure on the Commission to come forward with new emission standards that were more stringent than Euro 4 to deal with their continuing air quality concerns, especially regarding diesel cars. It became clear that future emission standards for road vehicles must form an important part of the overall Clean Air for Europe (CAFE) strategy that was being developed to help achieve future EU air quality. For cars, the Environment Council of 18-19 December 2000 reported its conclusions on the second Auto-Oil program and noted the following:

66 For example, from 1st of June 1999 a tax incentive was introduced in Denmark in order to promote auto diesel with low sulfur content (defined as sulfur below 50 ppm). The incentive was 0.18 DKK per liter. As a result all auto diesel sold on the Danish market from that date met the low sulfur spec.

"The Council supports the opinion put forward in the Commission communication concerning the need for further action on particulate matter, nitrogen oxides and tropospheric ozone."

The Council invited the Commission to:

- Encourage the progressive and harmonized introduction of fuels whose characteristics allow for the optimization of new technologies for the post-treatment of emissions and of new engine types;

- Make continued efforts to significantly reduce nano-particle emissions;

- Bring the provisions on limit values for diesel engines – for example, on emissions of nitrogen oxides (NOx) – closer to the provisions for gasoline engines;

- Start technical work and the necessary studies to assess the feasibility of a new phase in the reduction of limit values for emissions which could come into force by 2010;

- Review the latest developments of the new propulsion technologies, and to submit a report to the Council as soon as possible.

In short the Council asked the Commission to continue the work of further reducing emission from motor vehicles, in particular NOx and nano-particle emissions.

The European Parliament and the Council had decided to set the Euro 4 emission standards back in 1998. The political aim of Euro 4 had been to require the use of particulate filters on new diesel cars. However, engine controls improved, and high pressure common rail diesel systems became commonplace with the result that the Euro 4 emission limits were able to be met without the use of a particulate filter. Such vehicles would also qualify for tax incentives in those Member States offering such incentives.

Some manufacturers chose to take a "green line" and equip at least their larger diesel cars with particulate filters of one type or another.

The issue of fuel quality remained important and the EU mandated near zero-sulfur gasoline and diesel (less than 10 ppm sulfur) from 2009 to allow the technology necessary to achieve lower pollutant emissions and improvements in CO2, which was becoming a high priority in Europe. Such fuels were also to be widely available by 2005 to allow the use of advanced aftertreatment technologies such as catalyzed diesel particulate filters and NOx adsorbers (especially for GDI) by some vehicles meeting Euro 4 requirements.

As a result of this effort, Euro 6 limits and requirements are being phased in across Europe at this time with all road fuels meeting a 10 ppm sulfur limit.

In 2009 the European Parliament adopted amendments to its Fuel Quality Directive that ordered an assessment of health and environmental risks from the use of metallic additives in fuel (Directive 2009/30/EC). The results of that assessment are to be based on a test methodology developed specifically for that purpose. The European Commission has put in place a comprehensive process for assessing the risk associated with use of metallic additives in transportation fuels. It requires an applicant seeking permission to sell metallic additives for use in Europe to undertake an extensive series of studies to assess the emissions associated with the additive's use, the level of hazard associated with the additive, and the exposure under various conditions (including high exposure levels under accident scenarios and the exposure of sensitive subgroups), allowing for an ultimate characterization of the risk associated with these additives. The process attempts to capture the subtle changes in pollutant formation, emissions and exposures, which can be particularly important for evaluating chronic health effects, especially among sensitive subpopulations. The extensive testing required by the proposed protocol, testing that covers concerns related to health and environmental impacts, as well as the impacts on vehicles in which the additives are used is to be funded by the supplier of the additives in question.

Directive 2009/30 requires: fuel labeling for gasoline containing metallic additives and set a final limit of 2 mg/L manganese which went into effect on 1 January 2014. One company brought a lawsuit against the European Parliament and the United Kingdom challenging the new labeling requirements and limits on manganese in gasoline. Parties who argued in defense of the rules included the German government, the Council of the European Union, the European Parliament, and the European Commission.

On 8 July 2010, the High Court of Justice of England and Wales, Queen's Bench Division ruled in Afton Chemical Limited vs. Secretary of State for Transport (Case C-343/09) that new limits and labeling requirements on metallic additives are valid and may proceed. Among its findings, the court ruled that these requirements comply with the precautionary principle, stating the following:

> *"A correct application of the precautionary principle presupposes, first, identification of the potentially negative consequences for health of the proposed use of MMT and, secondly, a comprehensive assessment of the risk to health based on the most reliable scientific data available and the most recent results of international research. Where it proves to be impossible to*

*determine with certainty the existence or extent of the alleged risk because of the insufficiency, inconclusiveness, or imprecision of the results of the studies conducted, but the likelihood of real harm to public health persists should the risk materialize, the precautionary principle justifies the adoption of restrictive measures, provided they are non-discriminatory and objective. In those circumstances it must be acknowledged that the European Union legislature may, under the precautionary principle, take protective measures without having to wait for the reality and the seriousness of those risks to be fully demonstrated. (Emphasis added)*

Below is a table summarizing the timeline and close linkages between the vehicles emissions standards and fuel quality standards in Europe.

### Summary of Euro Stages and Fuel Quality Standards in Europe - Timelines[67]

| Vehicle Emissions Standards | | | Fuel Quality | |
|---|---|---|---|---|
| Year | Light Duty | Heavy Duty | Year | Main Change in Properties |
| 1980-90 | Pre-Euro 1 | | 1976-80 | Sulfur and lead gradually reduced |
| 1988 | | Euro 0 | 1989 | Benzene (5%) and octane start to be regulated |
| 1992 | | Euro I | | |
| 1993 | Euro 1 | | 1994 | Further Sulfur reduction |
| 1995 | | Euro II | 1996 | |
| 1996 | Euro 2 | | | |
| 2000 | Euro 3 | Euro III | 2000 | Directive 98/70/EC<br>No Lead in gasoline<br>Sulfur in gasoline 150 ppm, in diesel 350 ppm<br>Aromatics, Octane, oxygen, olefins, benzene limits |
| 2005 | Euro 4 | Euro IV | 2005 | Sulfur in gasoline and diesel 50 ppm (availability of 10 ppm must be ensured)<br>Aromatics lowered |
| 2008 | | Euro V | | |
| 2009 | Euro 5 | | 2009 | 10 ppm gasoline and diesel |
| 2011 | | | 2011 | E10 introduced |
| 2013 | | Euro VI | | |
| 2014 | Euro 6 | | | |

67 Derived from IFQC.

## Where We Stand Today

The dominant regulatory programs for motor vehicle emissions around the world today are those of the United States (including California) and the EU. Emissions regulations in every other country of the world, except Japan, are derivatives of one of these two programs, especially the EU program. The United States and EU are each currently in the process of phasing in tighter standards applicable to both light- and heavy-duty vehicles. [68] In recent years, as noted above, EPA, led by the California Air Resources Board, has moved toward progressively more stringent emissions standards for all categories of vehicles, while plugging loopholes such as the weaker requirements for SUVs.

While the EU has tightened its overall standards substantially, its standards for diesel cars currently remain weaker than those for gasoline cars especially with regards to real world in use performance. Efforts are currently underway to address this problem and an additional step to address real driving emissions is expected to be phased by 2017.

*In both the US and EU programs, the close linkage between vehicle emissions standards and fuel quality, the systems approach, has been established as an overarching principle.*

Over the course of the past 50 years, substantial progress has been made in both Europe and the United States in reducing emissions from vehicles. The United States—often led by California, but nationally as well—has been the clear leader in pushing the development and commercialization of technologies for reducing emissions of lead (Pb), CO, HC, NOx, and PM from both gasoline and diesel fueled vehicles, and thereby the leader in proactively reducing serious risks to public health. For a variety of reasons, including its apparent inability to mandate lead-free gasoline until 1989, Europe has lagged the U.S. control program by as much as almost 20 years. Since the 1990s, however, Europe has moved aggressively toward clean vehicles and fuels and has narrowed the gap considerably.

An area where Europe has clearly lagged behind the U.S. is in the area of evaporative emissions control. The evaporative standards in place in Euro 3, 4, and 5 result in control technology packages equivalent to those applied to US vehicles ending in the mid-1990s and are providing only 35% reductions of combined diurnal parking, running

68 In one very important area, the European regulations are more stringent, particle number. For both light and heavy duty vehicles, the EU regulations require meeting a limit on the number of small ultrafine particles as well as the mass of particles. There is a growing body of evidence indicating that the ultrafine particles may be the most important component leading to serious adverse health impacts due to their ability to penetrate deeply into the lung and enter into the circulatory system.

loss, refueling, permeation, and hot soak emissions from uncontrolled levels. Beginning with enhanced evaporative requirements (1996) and onboard refueling vapor recovery (ORVR)(1998) and ending with Tier 3, the US EPA has implemented strong measures to reduce the levels of short and extended term parking emissions, improve off-cycle canister purge, and cut running loss and permeation. These measures reduce VOC emissions by over 10 kg/vehicle•year and are bringing these emissions to near-zero levels. While both Europe and the US have installed Stage II vapor recovery at gas stations to reduce refueling emissions, the US also requires vehicle-based ORVR systems. ORVR provides 98% control of refueling emissions and is more cost-effective than Stage II in the US. ORVR's success is now resulting in the phaseout of Stage II, which provides only 70% control, in most states in the US. Overall, a tremendous gap in measuring and controlling evaporative emissions exists in Europe.

Regarding fuel quality, Europe has been the world leader in moving to low levels of sulfur. Using tax incentives, Sweden actually shifted most of its diesel fuel to near zero levels in the early 1990's. Europe has also been in the forefront of mandating a particle number standard for both diesel and gasoline fueled vehicles.

## In Use Compliance

One of the biggest challenges for motor vehicle pollution control is assuring that vehicles actually meet the intended emissions levels in actual use during normal driving and over their actual lifetimes. As noted earlier, Europe has had ongoing challenges for several years controlling actual in use diesel vehicle emissions of NOx. The US has had similar challenges in the past with heavy duty diesel trucks and most recently China has found similar issues as well. As noted in a recent study,

> *"This program included a sub-task for measuring on-road emission profiles of hundreds of HDDVs using portable emission measurement systems (PEMS). The major finding is that neither the on-road distance-specific (g km−1) nor brake-specific (g kWh−1) NOx emission factors for diesel buses and heavy-duty diesel trucks improved in most cases as emission standards became more stringent. For example, the average NOx emission factors for Euro II, Euro III and Euro IV buses are 11.3 ± 3.3 g km−1, 12.5 ± 1.3 g km−1, and 11.8 ± 2.0 g km−1, respectively. No statistically significant difference in NOx emission factors was observed between Euro II and III buses. Even for Euro IV buses equipped with SCR systems, the NOx emission factors are similar to Euro III buses. The data regarding real-time engine performance of Euro IV buses suggest the engine certification cycles did not reflect their real-world operating conditions. These new on-road test results indicate that*

*previous estimates of total NOx emissions for HDDV fleet may be significantly underestimated. The new estimate in total NOx emissions for the Beijing HDDV fleet in 2009 is 37.0 Gg, an increase of 45% compared to the previous study. Further, we estimate that the total NOx emissions for the national HDDV fleet in 2009 are approximately 4.0 Tg, higher by 1.0 Tg (equivalent to 18% of total NOx emissions for vehicle fleet in 2009) than that estimated in the official report. This would also result in 4% increase in estimation of national anthropogenic NOx emissions."* [69]

It may be useful to highlight some of the challenges faced in the US compliance program in recent years and the steps taken to address them.

Vehicle manufacturers are required to design and build their vehicles to meet emission standards for the useful life of the vehicle specified by law. Under Section 207 of the Clean Air Act, if EPA determines that a substantial number of vehicles in a class or category do not meet emission standards in actual use, even though they are properly maintained and used, EPA can require the manufacturer to recall and fix the affected vehicles. An emission recall is a repair, adjustment, or modification program conducted by a manufacturer to remedy an emission-related defect for which vehicle owners have been notified.

EPA has the authority to order a manufacturer to recall and fix noncomplying vehicles. However, most recalls are initiated voluntarily by manufacturers once a potential noncompliance is discovered. These voluntary actions could be influenced by the potential for EPA action. Some voluntary recalls are directly influenced via EPA in discussion with manufacturers. In a recent typical year, more than 2.5 million cars and light trucks were affected by some type of voluntary emission-related recall. These recalls included several preceding model years.

The range of problems for which vehicles can be recalled varies widely. For example, recalls performed in a recent year were performed for:

- Problems detected by the OBD system because of faulty components (e.g., oxygen sensor) and causing the malfunction indicator light (MIL) to illuminate
- Defects of the OBD system itself, such as software update issues
- Possible emissions problems—defects that could cause emissions to increase

69 Wu, Y., Zhang, S., Li, M., Ge, Y., Shu, J., Zhou, Y., Xu, Y., Hu, J., Liu, H., Fu, L., He, K., Hao, J., 2012a. "The challenge to NOx emission control for heavy-duty diesel vehicles in China". Atmos. Chem. Phys. 12, 9365e9379.

- Safety-related problems—emissions-related defects that could also cause safety problems

- Label problems—incorrect Vehicle Emission Control Information labels

Some important enforcement related actions are summarized in the next sections.

## Using Defeat Devices Costs Diesel Engine Industry $1 Billion for Clean Air Violations

Announcing a total settlement that comprises the largest Clean Air Act enforcement action in history, the Justice Department and the Environmental Protection Agency said that seven manufacturers of heavy duty diesel engines will spend more than one billion dollars to settle charges that they illegally poured millions of tons of pollution into the air, including an $83.4 million civil penalty, the largest in environmental enforcement history.

The settlement resolved charges that the companies violated the Clean Air Act by installing devices that defeat emission controls. The defeat devices allowed engines to meet EPA emission standards during standardized testing but disable the emission control system during normal highway driving. The Clean Air Act prohibits any manufacturer from selling any new motor vehicle engine equipped with any device designed to defeat the engine's emission control system. The engines meet the emission limits when they run on the EPA's Federal Test Procedure, but when the engines are running on the highway, up to three times the limit of NOx emissions resulted.

The companies were alleged to have sold an estimated 1.3 million of the affected engines, which range from the type used in tractor trailers to large pick-up trucks.

The emission problems were discovered when EPA tested one of the company's engines. EPA and DOJ then began an extensive investigation.

EPA now routinely tests in-use heavy-duty highway and non-road engines using portable emissions measurement systems (PEMS). These systems can measure emissions in real time, under the same conditions that vehicles or equipment might experience in actual service. PEMS testing allows EPA to characterize emissions levels without having to remove the engine from a large vehicle and test it in a laboratory under simulated conditions.

Using PEMS devices, EPA has introduced highway heavy-duty "not-to exceed" (NTE) NOx standards. The NTE standard represents a maximum value for the entire in-use test. It is calculated by averaging second-by-second NOx measurements into 30-second sets.

## EPA Stops Illegal Import of Vehicles That Fail to Meet Pollution Standards

In another important recent case, a Chinese power sports company and its related U.S. distributor have agreed to recall and replace fuel tanks that will better control gasoline vapors in approximately 1,000 vehicles and take other steps to control pollution stemming from the illegal import of over 12,000 recreational vehicles and highway motorcycles. These motor vehicles were manufactured in China and imported without the required certification indicating that emissions would meet federal standards.

The companies involved paid a combined civil penalty of $725,000.

In the settlement, EPA alleges that over 12,000 highway motorcycles and recreational vehicles imported by the companies between 2007 and 2013 were not certified by EPA, as required by the Clean Air Act (CAA), to meet applicable federal emission standards. Of these, EPA found that 993 vehicles had fuel tanks that did not operate properly to control evaporative emissions, or gasoline vapors, and that approximately 1,400 vehicles were imported without proper emission control information labels.

In addition to the penalty, the companies instituted a Recall and Fuel Tank Replacement Program to replace all uncertified fuel tanks with certified ones to prevent any excess gasoline vapors. The companies also corrected the emission control information labels for those vehicles that were still within the control of the companies.

EPA discovered the alleged violations through joint inspections conducted with the U.S. Bureau of Customs and Border Protection and through a review of importation documents and other information provided by the companies.

The CAA prohibits any vehicle or engine from being imported and sold in the United States unless it is covered by an EPA-issued certificate of conformity indicating that the vehicle or engine meets required emission standards.

## Updating Test Procedures as Conditions Change

Revisions to EPA's vehicle certification test updated the test for increased exhaust emissions due to certain driving conditions. EPA said the 20-plus year old test used to certify vehicles for compliance with the Clean Air Act emission standards doesn't realistically account for the emissions effect of aggressive driving behavior, high acceleration rates or air conditioners' operation. These behavior patterns contribute significantly to vehicle emissions. For example, the maximum speed on the FTP test cycle is only 57 miles per hour (mph) and the acceleration rates are very mild. The revisions to the test cycle will provide control of emissions during aggressive accelerations and at speeds of up to 80 mph to reflect real world driving.

The Agency also found that nitrogen oxide (NOx) emissions double with the use of air conditioners. The revised rule will cut these excess emissions in half, which is important as air conditioners are most often used on sunny, hot days which pose the greatest potential for high ozone levels.

The 1990 Clean Air Act requires EPA to "review and revise as necessary" the regulations for the Federal Test Procedure (FTP) to "insure that vehicles are tested under circumstances which reflect the actual current driving conditions." The final rule is based on five years of extensive data collection and detailed analysis of urban driving behavior gathered by EPA, the California Air Resources Board and auto manufacturers.

## Other Testing Improvements

EPA has also been implementing the new "5-cycle" fuel economy labeling requirements, which require manufacturers to measure fuel economy over five test cycles: city, highway, US06, SC03, and cold CO, compared to just the city and highway test cycles used in the past. These additional test cycles cover a broad range of vehicle operation, such as high speeds, aggressive accelerations, air-conditioning, and cold temperature. These conditions were not captured over the original two test cycles.

The emissions tests that EPA requires for light-duty vehicles are listed below. These tests are used to measure compliance with emission standards, Department of Transportation corporate average fuel economy (CAFE) standards, and consumer fuel economy labeling requirements. There are two components to car and light truck certification testing. The first component is initial testing that manufacturers conduct to support their application for a certificate of conformity. Manufacturers must conduct this testing for all test groups they wish to certify and must report the results to EPA as part of the certification application.

The second component is confirmatory testing, which occurs after an application has been submitted. Confirmatory tests are performed by either the manufacturer or by EPA and serve to validate the manufacturer's initial emissions or fuel economy test results. EPA does not confirmatory-test all test groups but rather uses random and targeted methods to select vehicles for confirmatory testing. The confirmatory test rate in a recent year was 15 percent of all test groups. Tests include the following:

- Federal Test Procedure (FTP)
- Highway Fuel Economy Test
- US06 (High Speed/Acceleration Cycle)
- SC03 (Air Conditioning Test Cycle)

- Cold CO (FTP conducted at 20° F)
- Evaporative Emissions (3-day test), (2-day test)
- Onboard Vehicle Vapor Recovery (ORVR)
- Running Loss Emissions Test

EPA has also implemented new durability procedures for cars and light trucks. These procedures introduced new durability test cycles for aging vehicles and components. Each manufacturer must supply information to EPA on in-use performance. If the results are acceptable, EPA approves the manufacturer's durability process for that model year. Each manufacturer's durability process must be approved each year.

EPA also implemented evaporative permeation requirements for motorcycles and all-terrain vehicles (ATVs). These requirements reduce the amount of hydrocarbon vapor that permeates through plastic fuel tanks and rubber fuel lines.

## Aftermarket Tampering Devices

EPA participated in a landmark enforcement settlement involving the illegal sale of an aftermarket tampering device – so called oxygen sensor simulators - that interferes with a vehicle's OBD catalyst monitoring system. When installed, they trick the OBD catalyst monitor into sensing a properly functioning catalyst even when the catalyst is missing or faulty. EPA considers oxygen sensor simulators to be illegal defeat devices under the CAA. EPA and the Department of Justice investigated, tested, and evaluated these devices, which were marketed by Casper's Electronics. In a settlement, Casper's was required to pay civil penalties, recall the devices, and stop selling them. Publicity about the settlement helped stop other marketers of these devices from selling them as well.

Europe has also been moving to address the serious in use problems related to vehicles. There has clearly been a major shift in focus in Euro 6/VI from Type Approval to real world emissions performance. Key elements of the new regulations include:

- New driving cycle (WHDC including Cold Start)
- Longer useful life of vehicles
- Off-cycle and In-service testing (PEMS)
- OBD requirements

- Anti- tampering requirements for NOx –control
- PN-limit and new measurement procedure

A major effort is still underway to develop Real Driving Emissions (RDE) regulations to go into effect in Model Year 2017 light duty vehicle standards.

Finally both Europe and the US have established programs to assure reasonable performance and durability of replacement aftermarket catalytic converters for light duty vehicles.

The Table F below summarizes and compares the major elements of the US/California program with the European program.

### Table F: A Comparison of the US/California Program and the EU Program

| Regulatory Program | U.S. EPA/California | European Union |
|---|---|---|
| Fuels | 15 ppm sulfur limit for diesel; moving to 10 ppm sulfur average for gasoline | 10 ppm sulfur limits for both gasoline and diesel |
| Light-duty Vehicles | Very stringent limits for HC, CO, NOx (Full useful life out to 240K km) | Stringent standards for HC, CO, NOx (Full useful life out to 160K km) |
| | Fuel neutral standards started with EPA NLEV, Tier 2 and CARB LEV I | Different standards for gasoline and diesel vehicles (less stringent for diesel vehicles) |
| | Same emission limits for light-duty vehicles through 4545 kg GVW with fleet average compliance flexibility | Different emission limits for different weight classes of light-duty vehicles; no fleet averaging |
| | Stringent mass-based standards for particle emissions (CA LEV III has most stringent PM limits) | Very stringent number-based standards for particles (diesel with Euro 5 and GDI with Euro 6c) |
| | Very stringent evaporative emission standards and limits captures all sources of VOC losses including refueling losses (ORVR), running losses, multiple day parking events, and permeation plus minimize short-term parking emissions | Evaporative standards only capture short term diurnal VOC losses |
| | Multiple test cycles designed to capture real vehicle driving | Current test cycle not effective at capturing real world driving emissions; adding real world focus to Euro 6c; eventually moving to WLTP cycle |

| | | |
|---|---|---|
| | Long history/experience with compliance programs to ensure emission reductions are delivered for in-use vehicles; recall authority to resolve chronic emission problems | No structured compliance effort; no recall authority; real world driving includes in-service compliance component |
| | GHG limits based on vehicle footprint | GHG limits based on vehicle mass |
| Heavy-duty Vehicles | Stringent limits for HC, CO, NOx | Stringent limits for HC, CO, NOx |
| | Stringent mass-based standards for particle emissions | Very stringent number-based standard for particles (Euro VI diesel) |
| | Transient cycle includes cold and hot-starts; NTE limits | Moved to WHTC transient cycle with cold and hot starts with Euro VI; NTE limits |
| | In-use compliance program using PEMS started with 2007 limits; focused on NTE events – with engine map carve outs; recall authority | In-use compliance program using PEMS started with Euro VI; focused on WHTC work-based window – no engine map carve outs; no recall authority |
| | GHG limits introduced for 2014 | No GHG standards; will begin monitoring program |
| Motorcycles | Large differences between motorcycle and car emission limits; includes diurnal evaporative emission limit | Stringent future standards in place that close the gap between motorcycle and car emission limits; future standards include diurnal evaporative emission limit |
| Off-road Diesel Engines | Largely harmonized limits for HC, CO, NOx, and PM but covers wider range of engine power ratings | Largely harmonized limits for HC,CO, NOx, and PM but no limits for small and very large diesel engines |
| | Transient and steady-state test cycles (harmonized) | Transient and steady-state test cycles (harmonized) |
| | No activity currently focused on developing a Tier V proposal but continued harmonization in this sector could cause movement toward the Euro Stage V proposal | Stage V proposal released that includes PN limit for 19-560 kW engines, railcar engines, and inland marine engines 300 kW and larger; Stage V proposal also includes emission limit on small and large nonroad engines |
| | No in-use testing currently required, EPA surveillance testing with recall authority is available in this sector | Stage V proposal includes an undefined, in-use emissions testing requirement |

# 6. CANADA'S PROGRESS IN ADDRESSING CLEAN FUELS AND VEHICLES

The Canadian Environmental Protection Act (CEPA) gives Environment Canada (EC) broad authority to regulate both vehicles and fuels and EC has used this authority to put a very strong program in place. The CEPA is similar to the US Clean Air Act. The Canadian vehicle industry is closely integrated with the US industry and many vehicles are manufactured in Canada for the US market. Because of this close integration, the Canadian vehicle industry is strongly supportive of vehicle and fuels regulations that are closely harmonized with the US and that, in fact, has generally occurred. In addition to close consultations with stakeholders in the development of environmental regulations, Environment Canada coordinates closely with its main trading partner, the US.

Environment Canada was created in 1971. Since then the Canadian federal government has adopted increasingly stringent standards for smog-forming emissions from motor vehicles. Several key initiatives helped to develop the Canadian regulatory fuels and vehicles program. There have been considerable efforts by the federal government and industry directed towards providing cleaner gasoline and diesel fuels for Canadians. Fuel related initiatives include the removal of lead in gasoline, the reductions of summer vapor pressure, and lowering benzene in gasoline and lowering sulfur levels in both gasoline and diesel fuels. Many of the federal initiatives were developed on the recommendations from a special committee called the Canadian Council of Ministers of the Environment (CCME) Task Force on Cleaner Vehicles and Fuels (October 1995) with representation from both federal and provincial governments. Part of the process of the CCME was to determine an appropriate level of sulfur in gasoline and diesel.

On February 19, 2001, the Minister of the Environment announced that the Government would make significant investments in new measures to accelerate action on clean air and published the Federal Agenda on Cleaner Vehicles, Engines and Fuels. The Agenda set out a series of regulatory and non-regulatory measures to be developed and implemented over the next decade to further protect the health of Canadians and the environment by reducing emissions from vehicles, engines and fuels.

The federal Sulfur in Gasoline Regulations took effect July 2002 and required an average gasoline sulfur concentration of 150 mg/kg as of July 2002 and 30 mg/kg as of January 2005.

More recently, Canada has proposed a further tightening of sulfur levels in gasoline. The proposed Regulations Amending the Sulfur in Gasoline Regulations (the proposed SiGR Amendments) would introduce lower limits on the sulfur content of gasoline in alignment with the United States Environmental Protection Agency (U.S. EPA) Tier 3 fuel standards. The proposed SiGR Amendments are published with the proposed Regulations Amending the On-Road Vehicle and Engine Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999 (the proposed ORVEER Amendments). The proposed ORVEER Amendments would introduce stricter limits on air pollutant emissions from new passenger cars, light-duty trucks and certain heavy-duty vehicles beginning with the 2017 model year in alignment with the United States Environmental Protection Agency (U.S. EPA) Tier 3 vehicle standards. These two regulatory initiatives would work in concert to reduce vehicle air pollutant emissions.

The Sulfur in Diesel Fuel Regulations set maximum limits for sulfur in diesel fuel for use on-road, off-road, in rail (locomotive), vessels, and stationary engines. The goal of the Sulfur in Diesel Fuel Regulations is to ensure that the level of sulfur in diesel fuel used in Canada will not impede the effective operation of advanced emission control technologies installed on vehicles and engines.

The current and upcoming maximum sulfur limits and effective dates for production, import and sales of diesel fuel in Canada are summarized in the table below:

### Maximum sulfur limits for categories of diesel fuel

| Diesel fuel for use in: | Regulated Activity | Sulfur Limit (mg/kg) | Effective Date |
|---|---|---|---|
| Large Vessels (Marine Diesel) | Production, import or sales | 1000 | June 1, 2014 |
| Large Stationary Engines | Production, import or sales | 1000 | June 1, 2014 |
| Non-large Vessels | Production or import | 15 | June 1, 2012 |
| Non-large Vessels | Sales | 500 | October 1, 2007 |
| Non-large Vessels | Sales | 15 | June 1, 2014 |
| Small Stationary Engines | Production, import or sales | 15 | June 1, 2014 |
| Rail (locomotive) | Production or import | 15 | June 1, 2012 |
| Rail (locomotive) | Sales | 500 | October 1, 2007 |
| Off-road Engines | Production, import or sales | 15 | Since 2010 |
| On-road Vehicles | Production, import or sales | 15 | Since 2006 |

## Case study for the regulatory process in Canada

The Sulfur in Diesel Fuel Regulations can be used here to illustrate how a regulation is developed, designed, implemented and then enforced in Canada. The full development of these regulations took place incrementally over 20 years. Specific parts of the diesel pool were addressed in tandem with the vehicles and engines that use that part of the pool. The above table shows that on-road diesel was address first and then followed by other parts of the pool.

The first step was to develop the policy for how to address sulfur in diesel fuel. In the mid 1990s, the Canadian government set up a multi-stakeholder process, called the Task Force on Cleaner Vehicles and Fuels, which brought together provincial/territorial governments, vehicle and engine manufacturers, fuel producers and importers, fuel users, and environment and health non-governmental organizations. This inclusive process identified issues and advised the Federal government on priorities for action. The inclusion of all relevant stakeholders ensured broad acceptance of the final recommendations of the Task Force. It also insured that all relevant information was gathered and analyzed. By participating on this task force, staff in the Federal government (engineers, economists, lawyers, health and environmental scientists) gained valuable expertize on fuel related matters, and were able to make internal recommendations to the Minister of the Environment and other relevant members of the Cabinet.

In regards to sulfur in diesel fuel, the Federal government accepted the Task Force recommendation that the level in sulfur in diesel fuel should be lowered through regulation by the Federal government. Prior to this, voluntary and regional approaches had been used. This led to a number of issues: specifically, fuel producers that were voluntarily meeting a lower sulfur level were being undercut in the market by those who were not participating in the voluntary program, and fuel producers preferentially sent batches of low-sulfur diesel to provinces with regulations and sent other (high-sulfur) batches to provinces without regulations which became a "dumping ground" for poor-quality diesel fuel. Other nations would be able to learn from the experience and policy decisions taken nations that have already reduced the sulfur in their diesel fuel, and so much of the background information is already available and need not be independently developed.

Once the policy was approved by Cabinet, regulations were developed. These regulations were legally authorized by the Canadian Environmental Protection Act. The first step was to design how the regulations would work. This was done primarily by engineers with the assistance of lawyers. On vehicle and fuel issues, Canada generally aligns with regulatory actions in the U.S., however it often takes a simpler approach to achieve the same regulatory levels (e.g., through fewer regulatory flexibilities and exemptions). At the same time and building upon the analysis of the task force, the costs and benefits of the regulation were determined (primarily by economists with the assistance of engineers and scientists). Stakeholders, especially fuel producers and importers, were consulted upon the details of the regulatory text and on the costs and benefits of the regulations. This process took several years, but ended in a regulation that met the policy requirements to reduce sulfur in diesel fuel and yet was understood and achievable by the affected fuel producers.

Sufficient time was given before the regulations came into force to allow for the design, construction approval, purchasing, installing and testing of the necessary equipment at the refineries (i.e., about 3 to 4 years). This delay may not be needed if a country only imports diesel fuel and there are already numerous sources of low-sulfur diesel fuel available for the source of imports. Once the regulations were in force, it was essential to the environment, to the engines and to the fuel industry itself that the regulated requirements were complied with. Parties seeking financial advantage by supplying non-complying, less-expensive, high-sulfur diesel fuel have to be identified and prosecuted to ensure environmental goals are met, the engines are not damaged and other fuel suppliers are not undercut in the market.

The first step was to ensure that the regulatees (the fuel producers and importers) understand the regulations and their obligations. Various types of guidance documents were developed, including a very detailed and technical question and answer document, and all inquiries from regulatees were responded to (primarily by the engineers that designed the regulations). In addition, the regulation required fuel producers and importers to provide information on the sulfur level in their diesel fuel on a quarterly and then later an annual basis. Government staff (engineers and administrative staff who administered the regulations) examined this data and compared it to other information to identify if there were issues and flag any such issues to those responsible for enforcing the regulations. This data also forms the basis for annual reports to the public on the level of sulfur in diesel fuel. Fuel producers, vehicle manufactures, fuel users, environment and health groups and provincial governments all find this data to be of considerable use.

It was also necessary to train the enforcement officers who will be enforcing the regulations to ensure that they understood the significance and effect of the regulations and how the regulations worked. To this end, relevant guidance and training material was developed by the engineers that designed the regulations, and an internal working group of staff from policy, compliance promotion, regions and enforcement was set up and it continues to ensure that any developing issues regarding the regulations are identified and addressed.

After the regulations regarding sulfur in on-road diesel fuel were underway, the regulatory process started again for reducing sulfur in off-road diesel, and then again for the other diesel pools. This incremental approach allowed time for the on-road technology to be adapted for use in the off-road and other pools, and for the spreading out of the costs of sulfur reduction.

A summary of Canada's fuel regulations are provided below:

- Fuels Information Regulations, No. 1 (1977)

- Requires annual reporting on sulfur levels in fuels.
- Gasoline Regulations (1990, last amended July 2010)
- Limits the concentration of lead in gasoline.
- Contaminated Fuel Regulations (1991)
- Prohibits the import and export of contaminated fuel.
- Benzene in Gasoline Regulations (1997, last amended March 2011)
- Limits the amount of benzene in gasoline.
- Sulfur in Gasoline Regulations (1999, last amended April 2009)
- Limits the amount of sulfur in gasoline
- Gasoline and Gasoline Blend Dispensing Flow Rate (2000)
- Limits the nozzle flow rate of fuel thereby reducing the release of benzene and volatile organic compounds into the air at the pump.
- Sulfur in Diesel Fuel Regulations (2002, last amended July 2012)
- Set maximum limits for sulfur in diesel fuel for use on-road, off-road, in rail (locomotive), vessels, and stationary engines.
- Regulations Prescribing Circumstances for Granting Waivers Pursuant to Section 147 of Act (2010)
- Allows the Minister of the Environment to grant temporary waivers under certain circumstances.
- Renewable Fuels (2010, last amended November 2013)
- Aims to reduce GHG emissions by requiring an average 5% renewable fuel content in gasoline and 2% renewable content in diesel fuel.

The regulations limiting sulfur and lead enabled the introduction of cleaner vehicle and engine regulations.

# 7. INDIA'S PROGRESS IN ADDRESSING CLEAN FUELS AND VEHICLES

## Background

Vehicular emission norms in India were first introduced in 1991 and tightened in 1996, when most vehicle manufacturers had to incorporate technologies such as catalytic converters to reduce exhaust emissions in the National Capital Region (NCR) and other major cities. This necessitated the use of lead free and lower sulfur fuels. Initially, refineries supplied lead free gasoline only to the cities where catalysts were required; because unleaded fuel was only available in limited areas for some time, many catalytic converters were destroyed by lead poisoning as vehicles drove out of those areas and were misfueled.

In India, automotive fuels are produced in accordance with Bureau of Indian Standards (BIS) standards. These standards are amended from time to time to meet environmental as well as other quality aspects and are mandatory. Fuel specifications based on environmental consideration were requested for the first time by the Ministry of Environment & Forests in April 1996 for achievement by 2000. These standards mandating lead free gasoline were incorporated in the BIS 2000 standards. Further, based on the Supreme Court order of April 1999, the Ministry of Surface Transport (MoST) notified Bharat Stage-I (BIS 2000) and Bharat Stage-II vehicle emission norms broadly equivalent to Euro I and Euro II, respectively, for introduction in entire India and NCR respectively.

## Auto Fuel Policy 2003

In response to the Supreme Court, the Ministry of Petroleum & Natural Gas created an Expert Committee, under the Chairmanship of Dr. R.A. Mashelkar, then Director General, Council of Scientific & Industrial Research (CSIR) on 13th September 2001 to recommend an Auto Fuel Policy for the country including the major cities. The Expert Committee submitted their report to the Government of India in August 2002 and based on its recommendations, MoP&NG released the "Auto Fuel Policy" in October 2003. In accordance with this policy, starting from 2005, fuel conforming to BS III norms (maximum sulfur content for gasoline of 150 PPM and diesel of 350 PPM) was introduced in 13 major cities, while BS II fuel (maximum sulfur content of 500 PPM) was made available elsewhere in the country. From April 2010, BS IV fuel (maximum sulfur content of 50 PPM for both gasoline and diesel) was implemented in 13 major cities and BS III fuel made available in the rest of the country from September 2010.

For light duty vehicles and trucks, Bharat Stage-II emission norms were mandated across the entire country from April I, 2005 to be upgraded to Euro III equivalent emission norms on April 1, 2010. In the major cities Euro III equivalent emission norms were mandated from April 1, 2005 and Euro IV equivalent from April 1, 2010.

For new 2 and 3 wheelers, Bharat Stage-II emission norms went into effect from April 1, 2005.Euro III equivalent emission norms were encouraged from April 1, 2008 but mandatory not later than April 1, 2010.

## The New Expert Committee

The Auto Fuel Policy (2003) had envisaged that the Policy undergo periodic revisions. Technological and other changes which take place over time were to be incorporated in the policy framework. Unfortunately, this plan was ignored for many years until 2013 when environmental pressures built up sufficiently that it was finally felt necessary to initiate a process to develop an Auto Fuel Vision & Policy for the country which would lay a clear roadmap to the year 2025. Accordingly, the Ministry of Petroleum & Natural Gas on 19 December 2012 constituted a new Expert Committee under the Chairmanship of Shri Saumitra Chaudhuri, a Member of the Planning Commission, to prepare a "Draft Auto Fuel Vision & Policy 2025".

The terms of reference for the Expert Committee included:

1. Recommend a road-map for auto fuel quality up until 2025 for the country, taking into account the achievements under the last Auto Fuel Policy, the emission reductions of in-use vehicles, the growth of vehicles and the supply and availability of fuels, and
2. Recommend vehicular emission norms for various categories of vehicles and a roadmap for their implementation.

Earlier this year, the Expert Committee completed its work and recommended the following:

## Fuels Road Map

The production and sale of BS IV gasoline and diesel should continue to be gradually increased and become mandatory across the entire country by January 1, 2017. BS V gasoline and diesel fuel (maximum sulfur content of 10 ppm) should start to be introduced in 2017 and be mandated across the entire country by April 1, 2020. The committee further recommended that the retail price of BS III fuel should be the same as that for BS IV, thus eliminating the incentive to use BS III fuel when BS IV fuel is also available. The additional charge on BS III fuel should be in the form of a High Sulfur

Tax [70] which would accrue to Oil Industry Development Board (OIDB) to be utilized to finance the capital investment required for refineries to upgrade themselves to move to full BS V automotive fuels by 2020. In addition, the committee recommended the imposition of a special fuel upgrading tax of 75 paise[71] per liter on all gasoline and diesel sold in India that will accrue to the OIDB and be made available to the refineries to fund the investment needed for upgrading to BS IV and finally to full BS V automotive fuel production.

## Vehicle Emissions Road Map

For vehicles with four or more wheels, the Committee recommended a gradual expansion of the sale of BS IV vehicles as the sale of BS IV fuel expands and be mandatory nationwide by April 2017. BS V emission norms should apply to all new models of four or more wheeled vehicles from April 1, 2020 and for continuing models before April 1, 2021. No emission norms were recommended for BS VI by the Committee. However, conceptually the committee noted that the BS VI emission regime could become applicable with effect from 1 April 2024 for all classes of vehicles thus giving a gap of four years to the automobile manufacturers for upgrading and adjusting their technology, design and standards.

On July 4, 2014, India finalized the fourth stage of emission standards for motorized two wheeled vehicles. [72] The Bharat Stage (BS) IV standards will go into effect for type approval of new motorcycle models in April 2016, and for all motorcycle models in April 2017. The new standards tighten the HC+NOX emission limits compared with the existing BS III standards by 23%–60%, depending on motorcycle category. The other significant change to the regulation is the adoption of the Worldwide Harmonized Motorcycle Test Cycle (WMTC) as the mandatory test cycle. With this change, India has harmonized the testing cycle as well as the definition of motorcycle categories as per United Nations Economic Commission for Europe (UNECE) Global Technical Regulation 2 (GTR-2). In addition, the new regulation establishes the first evaporative emission standards for two-wheelers in India. Lastly, BS IV establishes that crankcase emissions form BS IV motorcycles are prohibited from release into the atmosphere.

The Committee recommends that BS V Emission norms for two wheelers I be applicable for new models from April 1, 2020 for new models and for continuing models within one year thereafter.

70 Called a cess in India

71 1 paise equals 1/100th of a Rupee

72 From ICCT Policy Update, August 2014, Two-Wheeler Bharat Stage IV Emission Standards, http://www.theicct.org/policy-update-bharat-stage-iv-emission-standards-two-wheelers-india

The committee also recommended a similar schedule for the implementation of BS IV and BS V standards for both gasoline/ CNG/Auto LPG and diesel fuelled three wheelers.

## Where We Stand Today

The Expert Committee has completed its report and submitted it to the newly elected Prime Minister for consideration by the new government. The matter is pending.

## Lessons Learned From Indian Experience

National policies regarding fuel quality are critically important.

A Vehicles and Fuels Roadmap laying out a long term strategy is in everyone's interest so investment schedules can be optimized.

Such a roadmap needs to be periodically reviewed and updated as new information becomes available and as circumstances change.

# 8. CHINA'S PROGRESS IN ADDRESSING CLEANER FUELS AND VEHICLES

## Background

The vehicle population in China has experienced significant growth over the past thirty years. The tremendous growth in the last decade has led China to become the largest vehicle producer and consumer in the world. Annual sales of on-road vehicles (excluding 2-wheelers and rural vehicles) have grown from roughly 250,000 in 1980 to nearly 22 million vehicles in 2013. Over that same time period, 2-wheeler (motorcycles and electric bikes) annual sales have grown from about 600,000 to a staggering 50+ million. Since 2000, the total stock of cars, trucks, and buses has more than quadrupled from 13.5 to over 60 million vehicles. Over this ten-year span, the total stock of motorcycles has roughly tripled from 68 to over 200 million.

Given the sheer magnitude of vehicle growth over the past decade, the task of curbing the negative impacts of vehicle emissions has taken on increased significance. Looking at the history of efforts to improve air quality, emission control legislation in China has evolved greatly since its inception in the early 1980s. Figure 5 highlights a few select milestones in China's mobile source emission control including the establishment and revisions of the Air Pollution Prevention and Control Law, the cornerstone of the air quality program. The first significant policies targeting vehicle emissions were phased in with the implementation of 'China I' standards[73] in Beijing and Shanghai in 1999.

73 Like many countries around the world, China has chosen to mirror its vehicle and fuels programs after those set forth by the European Commission.

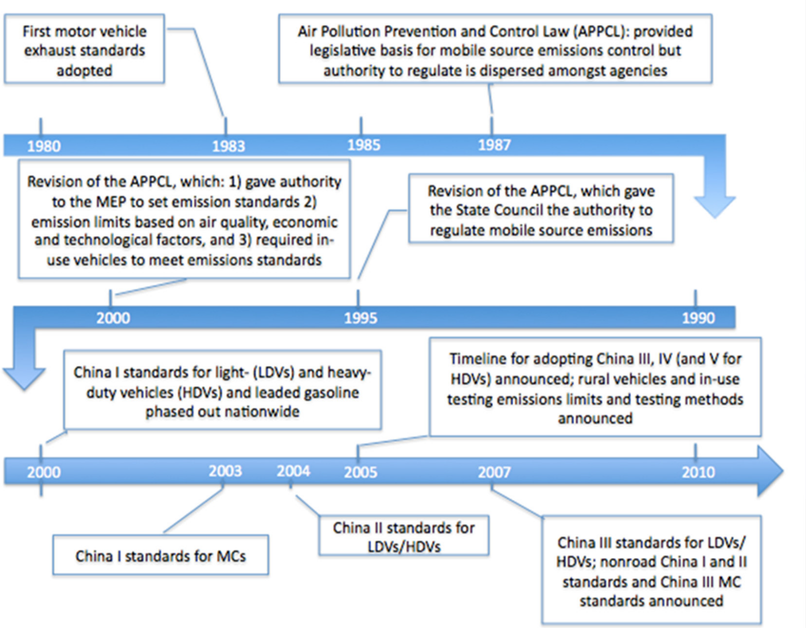



*Figure 5: Selected milestones in China's Vehicle Emission Control Program*

Despite the massive growth in vehicle stock and activity, China's vehicle emission control program has been effective in curbing criteria pollutant emissions. During the period from 2000 to 2010, China quickly moved from Euro I standards to Euro 4 for light duty vehicles. However, fuel quality did not keep pace because the Ministry of Environmental Protection (MEP) does not have the legal authority to regulate fuel quality. As a result, in 2010, China delayed the introduction of China 4 truck standards until 2012. In 2012, again because of poor fuel quality, the standards for trucks were delayed again until July 2013. Even then, press reports indicate that many trucks are still entering the marketplace which do not meet China 4 standards.

One result is that the air pollution problem in many parts of China has reached crisis levels. Just three of 74 major cities recorded met national air quality standards throughout last year according to Wu Xiaoqing, deputy minister for environmental protection. Only Haikou in Hainan, Lhasa in Tibet and Zhoushan in Zhejiang met the new air quality standards. Wu said the smog-plagued Beijing-Tianjin-Hebei area experienced air pollution on more than 60 per cent of days last year, the worst in the country. Annual average levels of $PM_{2.5}$ - tiny pollutant particles smaller than 2.5 microns that can penetrate deep into the lungs - reached 106 micrograms per cubic meter in the region, more than 10 times the World Health Organization's safety limit of 10. The area also has seven of China's 10 most polluted cities. Other built-up regions - city clusters in the Yangtze and Pearl River deltas - also registered chronic smog problems.

Wu said China was paying a "heavy, massive" environmental price for economic growth. "Our measures to curb air, water and other types of pollution may somewhat stall the growth of our gross domestic product, but this is what we have to do," he said.

In a report released May 21,2014 the Organization for Economic Cooperation and Development. said more than 3.5 million people die each year from cancer, heart disease and respiratory problems linked to outdoor air pollution, with deaths costing the OECD's 34 member countries—which include the world's advanced economies—$1.7 trillion yearly. Half of that cost is due to road transport, with diesel vehicles producing the most harmful emissions, it said. Outside the OECD, China loses some $1.4 trillion yearly the Paris-based organization said.

Air pollution-related deaths rose 4 percent worldwide from 2005 to 2010, including 5 percent in China, said the report, which calls for strict vehicle emissions standards and a "rethink" of regulatory and tax policies that favor diesel-powered vehicles.

China's Ministry of Environmental Protection said on January 26th 2014 that motor vehicle pollution is a major cause of pollution. The Ministry recently released the annual report of China's motor vehicle pollution's prevention in 2013 (hereinafter referred to as the annual report), and announced the 2012 national motor vehicle emissions status. The Annual Report shows that China has become the world's vehicle production and sales superpower for four consecutive years.

The Annual Report data shows that, in 2012, China's vehicle population continued to grow, and reach 223,828,000. Classified by emissions standards, cars that achieve the State IV standard and above account for only ten percent of the fleet. According to the environmental protection symbol classification, "green standard car" accounts for 86.6%, "yellow car"[74] of high emissions still accounts for 13.4%. Notably, the "yellow cars" have discharged 58.2% of NOx, 81.9% of PM, 52.5% CO and 56.8% of HC from motor vehicles.

China plans to take more than five million ageing yellow label vehicles off the roads this year in a bid to improve air quality, with 330,000 cars set to be decommissioned in Beijing alone, the government said in a new policy document. The State Council said that as many as 5.33 million "yellow label" vehicles that fail to meet Chinese fuel standards will be "eliminated" this year, the document said. As well as the 330,000 cars

74 In China, gasoline fueled vehicles receive a yellow label if they are pre-Euro, that is produced in 1999 or earlier without a catalytic converter. Diesel fueled vehicles receive a yellow label if they are pre- Euro 3 vehicles. Also Chinese reports refer to cars but include trucks and buses as cars in the statistics.

in Beijing, 660,000 will be withdrawn from the surrounding province of Hebei, home to seven of China's smoggiest cities in 2013.

Beijing plans to limit the total number of cars on the road to 5.6 million this year, with the number allowed to rise to 6 million by 2017. Last year it cut the number of new license plates by 37 percent to 150,000 a year and is also paying for another 200,000 ageing vehicles to be upgraded.

The State Council document did not say how the plan would be implemented, but Beijing's municipal government has previously offered subsidies of between 2,500-14,500 Yuan ($400-2,300) to drivers who voluntarily hand in their ageing vehicles to be scrapped.

Beijing currently forbids vehicles that do not meet required standards from entering the city, but officials have admitted that China currently lacks the monitoring and policing capability to ensure all cars make the grade, and drivers have also found ways to avoid detection.

## Chinese Legislature Tightens Environmental Law

The China's legislature has recently passed the biggest changes to its environmental protection laws in 25 years, The new requirements would punish polluters more severely as the government works to limit smog and tainted soil associated with three decades of economic growth. Amendments to the law "sets environmental protection as the country's basic policy," the official Xinhua News Agency reported on April 24th, 2014. Previous to this change, the rules hadn't been changed since the law was first enacted in 1989, just as China started consuming more energy as it turned into a global manufacturing hub.

The new law says that economic and social development should be coordinated with environmental protection and encourages studies on the impact environmental quality causes on public health, urging prevention and control of pollution-related diseases.

The amendment was adopted after four readings. It is rare in China for a law or amendment to go through three readings and not be passed, highlighting the importance of the legislation in the country's pursuit of sustainable development.

Lawmakers said during their panel discussion that the phenomena in which the cost for observing environmental legislation is higher than violating laws widely exist, causing environmental pollution. Xin Chunying, deputy director of the Legislative Affairs Commission of the NPC Standing Committee, gave an example during the deliberation of the law, saying that an electricity generator complex with production capacity of 100,000 kilowatt needs to pay between 500,000 and 600,000 Yuan in environmental protection fees to alleviate and control pollution. But if the factory shuts down its pollution processing equipment and does nothing to protect the environment, it may only face a 10,000 Yuan fine. Handing out heavier punishment for environmental wrongdoing is an important principle of the new legislation, and will deter violations.

It says that the country should establish and improve an environment and health monitoring, survey and risk assessment mechanism.

The law gives harsher punishments to environmental wrongdoing, and has specific articles and provisions on tackling smog, making citizens more aware of environmental protection and protecting whistleblowers. It says citizens should adopt a low-carbon and frugal lifestyle and perform environmental protection duties, and nominates June 5 as Environment Day.

The public is encouraged to observe environmental protection laws and make their own efforts in this regard, including sorting their garbage for recycling.

Now the world's biggest carbon emitter, China has moved to address the environmental damage that has been a byproduct of its breakneck economic growth and become a major cause of social unrest. Government reports and recent comments from top officials about pollution have revealed the extent of the damage to China's soil, water and air.

The amendments become effective January 1, 2015; the amendments give the public and government "powerful new tools" to cut pollution:

- The revised law will offer channels for whistle-blowers to make environment-related appeals. Non-government groups can also file lawsuits for environmental damage under certain conditions.

- Previously, polluters could often pay less in fines than the cost to install and operate pollution controls. New measures such as heavier fines, naming and shaming of companies and the demotion, sacking or criminal prosecution of local government officials who don't enforce regulation or manipulate data are expected to be more effective.

- Company officials can be detained for up to 15 days if they haven't completed an environmental impact assessment, ignore orders to stop construction, or continue to pollute after being asked to stop, the revised law says.

- The law also proposes that organizations in charge of environmental impact assessments and supervision would bear joint liabilities if they are found to have acted fraudulently.

- Local officials may be demoted or sacked, if they are guilty of misconduct, including covering up environment-related wrongdoing, falsifying data or asking others to falsify data, failing to publicize environmental information which should be made public according to law or failing to give closure orders to enterprises which illegally discharge pollutants.

- If offenders' behaviors constitute crimes, they will be held criminally responsible.

- If an enterprise illegally discharges pollutants and is fined and asked to correct its wrongdoing by authorities, but refuses to make corrections, the enterprise may face a fine which accumulates daily. In the past, enterprises received a one-off fine.

- The new law allows public litigation and expands the range of subjects of public interest litigation on environmental issues. According to the new law, the subjects could be social organizations which have registered with the civil affairs departments of governments at municipal level or above and have been engaged in public litigation on environmental issues for more than five years. By promoting public interest litigation, it is hoped that the public's appeal for a better environment can be addressed through rule of law, instead of resorting to protests. China has faced an increasing number of protests, or "mass incidents," over environmental issues in recent years. A few cities have seen residents take to the streets against paraxylene projects, which they believe are a major threat to the environment and public health. In most of the cases, the projects in question were later suspended.

- Courts should receive public litigation on environmental issues according to law, while social organizations should not seek to profit through such litigation, according to the new draft.

China has more than 30 environment-related laws and about 90 administrative regulations concerning environmental protection. After the adoption of the revised Environmental Protection Law, the country's fundamental environment law, other environmental laws may also face changes. According to the NPC Standing Committee's annual legislation plan, the air pollution prevention and control law will be revised this year. A draft amendment to the air pollution prevention law will be tabled for a first reading in December 2014.

Vice minister for the environment Pan Yue described the new environmental protection laws as powerful tools against pollution, but warned of challenges in implementation.

"Good environmental law only gets you halfway there. It needs to be implemented," Pan told Xinhua in an interview. Calling the new law "the most powerful legislation in the environmental category", the vice minister said it could still fail without ironclad enforcement.

## Beijing Makes Strong Case for Aggressive Local Air Pollution Action Plan

Beijing's 5.35 million vehicles consume about 7 million metric tons of fuel and emit about 900,000 metric tons of pollutants annually, according to a September 11th 2013 report from the state-run Xinhua news agency based on information provided by municipal environmental authorities. Vehicles contribute about 86 percent of carbon monoxide, 57 percent of nitrogen oxides, 38 percent of hydrocarbon, and 22 percent of small particulate matter (PM-2.5) emissions in the city, Li Kunsheng, an official with the municipal environmental authority, said in a report from Beijing News, a newspaper affiliated with the municipal government.

Beijing has already implemented the equivalent of Euro 5/ emissions standards for light duty vehicles and limits the sulfur content of both gasoline and diesel fuel to a maximum of 10 ppm.

As part of an action plan to reduce air pollution through 2017 that was released September 2nd, 2013 shortly before the National Action Plan (see summary below), Beijing will expand its roadside emissions monitoring network to 150 monitoring points, environmental protection bureau officials said. Information from the current 22 roadside monitoring points helped lead to fines for excessive emissions for operators of about 5,000 vehicles in the first half of 2013, according to Li. Penalties for excessive vehicle emissions could be increased from 500 Yuan ($82) to about 3,000 Yuan ($490) under proposed ordinances.

By the end of 2017, Beijing hopes to reduce fuel consumption by about 5 percent in the city, according to the action plan. More than 4 million metric tons of gasoline and over 2 million metric tons of diesel fuel are currently consumed in Beijing annually, with diesel vehicles, particularly the more than 300,000 heavy trucks, contributing substantially, Li said.

Beijing's air pollution action plan also targets emissions from coal-fired power plants and heavy industry.

As part of its plan, Beijing is aiming to hold the number of registered vehicles in the city to around 6 million by the end of 2017. It also aims to:

- Introduce more controls on vehicles, particularly on those from outside the city, including expanding restrictions on which ones can enter inside the sixth-ring road (which runs around the city about 10 to 12 miles from the center) on certain dates and times;

- Promote the use of alternative fuel vehicles to reduce air pollution;

- Upgrade vehicle emissions standards to the equivalent of Euro 6 or tighter [75]by 2016, add onboard refueling vapor recovery, and further tighten fuel quality standards; and

- Move to scrap about 1 million older vehicles that do not meet current tailpipe and fuel quality standards.

Other measures being considered include congestion fees and progressive parking pricing, though these are in a study phase and it is uncertain when or if they would be implemented by 2017.

Beijing's Air Pollution Action Plan outlines responsibilities of municipal departments and district governments through 2017. It is the first in a series of measures to restrict consumption of coal-generated energy, shutter the most polluting businesses, promote so-called new-energy vehicles, and increase fees for airborne emissions, the government said.

Beijing's municipal Environmental Protection Bureau called the plan a "declaration of war" against PM-2.5 and said it would "work relentlessly" to improve air quality.

Beijing will attempt to reach a goal of zero growth in the number of cars on its roads by the end of 2017. It plans to accomplish this, in part, by requiring the retirement of older vehicles that do not meet current exhaust and fuel standards and by limiting the number of license plates it issues each month. Starting next year, the city plans more restrictions on which vehicles can be used within the fifth-ring and sixth-ring roads, including cars registered both in Beijing and elsewhere.

By the end of 2014, all new heavy-duty diesel vehicles will be required to install devices to trap particulate matter and to meet Beijing V tailpipe emission standards. Beijing also will implement plans to encourage the use of new-energy and cleaner energy vehicles, including those using natural gas, with an aim of having 200,000 such vehicles—particularly for public transportation—in use by the end of 2017.

75 Since Euro 6 standards for gasoline cars are the same as Euro 5 standards, Beijing is looking to the California requirements and it seems likely that Beijing 6 will include several provisions that are more stringent than Euro 6 including ORVR, enhanced evaporative controls, longer in use durability requirements and perhaps even lower numerical limits and modified test procedures.

# China Issues Comprehensive National Air Pollution Plan; Targets Key Regions

China's State Council has approved 35 measures to combat air pollution through 2017, primarily focusing on three highly developed regions with large urban populations where citizens are increasingly complaining about poor air quality. In a September 12th 2013 statement, the State Council said that China's air pollution situation is "grim." It said it has developed the air pollution action plan to help achieve the "Chinese dream" of sustained and healthy economic development and to protect social harmony and stability. The measures include new efforts to strengthen management of motor vehicles, restructure heavy industry and reduce coal and energy consumption.

The three target areas are the state-level municipalities of Beijing and Tianjin and Hebei province; the Yangtze River delta region that includes Shanghai; and the Pearl River delta region in Guangdong province that includes several major cities and is next to Hong Kong. Environment Minister Zhou Shengxian said that the Ministry of Environmental Protection will work with the three target areas "to accelerate the introduction of implementation details," according to a statement posted on the ministry website.

The State Council plan aims to reduce concentrations of small particulate matter (PM-2.5) in major cities by 10 percent by 2017 compared to 2012 levels, with higher targets set for the three focus areas—a 25 percent reduction in the Beijing-Tianjin-Hebei area, a 20 percent reduction in the Yangtze River delta region, and a 15 percent reduction in the Pearl River delta area.

Beijing has adopted its own action plan (see above) that calls for reducing PM-2.5 pollution 25 percent to 30 percent from 2012 levels by 2017, depending on the district, with a targeted average daily intensity ranging from 50 micrograms to 60 micrograms per cubic meter.

The State Council statement said China is attempting to adopt "polluter pays" principles in its environmental regulations and use market mechanisms such as pricing, taxes and other policies to encourage emission reductions and investments in industries focused on air pollution control.

The plan calls for managing sources that emit multiple pollutants, upgrading smaller coal-fired boiler systems, increasing industries' use of desulfurization and denitrification technology, boosting building energy efficiency and heat metering requirements, managing urban dust and outdoor air pollution from food service industries, getting older vehicles off the roads, upgrading fuel quality, enhancing traffic management and promoting so-called new energy vehicles.

Under the plan, 60 percent of new public buses purchased for Beijing, Shanghai and Guangzhou will have to be powered by either new energy systems (electric, hybrid) or cleaner fuels (LNG or CNG).

By the end of 2015, all large cities in the three main air pollution control areas will be expected to have switched to China V gasoline and diesel fuel (the China equivalent to Euro V), which has a maximum sulfur content of 10 parts per million. China V gas is already being rolled out in several cities in those regions. China IV diesel fuel and gasoline with 50 PPM maximum sulfur content will be required nationwide by the end of 2014. China V diesel fuel and gasoline with 10 PPM maximum sulfur content will be required nationwide by the end of 2017.
Improving technology and supporting the growth of two of what the government calls "strategic industries"—the environmental protection and new energy industries—are also highlighted in the plan.

The three key regions will be required to conduct annual air pollution control assessments to better coordinate regional governance over airborne emissions.

Areas will be required to expand air pollution monitoring systems and establish emergency action plans for times of heavy air pollution, a program that is already being implemented in several places including Beijing and Guangdong province. The emergency air pollution action plans will be required throughout the three main areas by the end of 2014 and in all other large cities by the end of 2015.

The State Council has ordered only the country's most developed regions to reduce concentrations of $PM_{2.5}$ - potentially harmful particles in the air smaller than 2.5 microns in diameter - over the next five years. The Beijing-Tianjin-Hebei region must cut $PM_{2.5}$ by 25 per cent, the Yangtze River Delta by 20 per cent and the Pearl River Delta by 15 per cent. Other urban areas have been told only to cut levels of the larger $PM_{10}$ pollutants by 10 per cent.

## Where We Stand Today

### Vehicle emissions standards

The current emissions standards roadmap for China is summarized below. China 4 standards are currently in effect for cars, trucks and buses. China 5 standards are scheduled to go into effect in 2018 for light duty vehicles; no schedule for China 5 introduction for trucks has yet been announced. The national government has just announced its plan to develop China 6 regulations for all categories of vehicles in 2015 but has not yet indicated its plans for implementation timing.

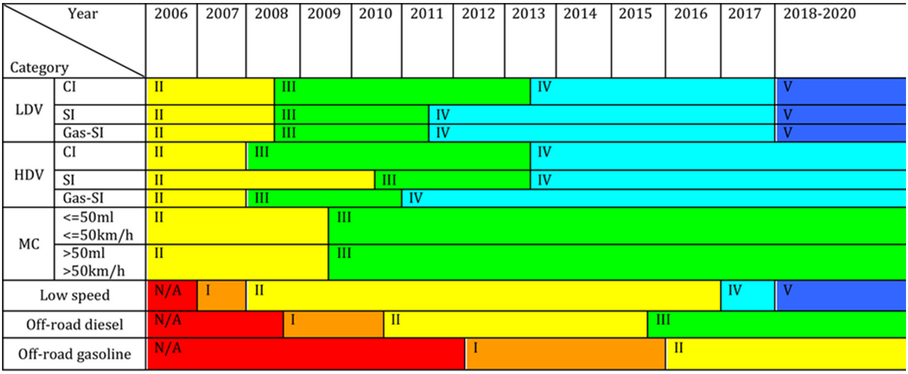



*Figure 6: Current Vehicle Emissions Standards in China*

Vehicle standards will be on a faster track in the three major regions but most heavy duty vehicles which are the major contributor to NOx and PM emissions tend to travel outside the regions and therefore will only be adequately controlled by national regulations.

## Fuel quality standards

Primarily following the European standards, the China fuel standards have been gradually tightened since the late 1990s. Unleaded gasoline was introduced in the late 1990s and mandated nationwide in 2000. The national limit on sulfur, the most important parameter affecting vehicle emissions after lead, has been lowered from 1,500-ppm in 1999 to the current level of 150-ppm for gasoline, and from up to 10,000-ppm to at most 2,000-ppm for diesel. A voluntary diesel sulfur limit of 500-ppm has been in effect and a mandatory limit of 350-ppm took effect in July 2011. (In many parts of the country, the 350 ppm limit was not enforced.) Major cities like Beijing and Shanghai have adopted fuel standards limiting sulfur content in gasoline and diesel to 50-ppm to enable early implementation of Euro 4 for passenger vehicles and Euro IV standards for medium- and heavy-duty vehicles.

Over the past decade, fuel standards in China, except for some major cities, have consistently lagged behind the fuel requirements corresponding to the vehicle emission standards. China III vehicle emission standards took effect for type approval certification nationwide for heavy-duty diesel vehicles (HDDVs) on Jan 1, 2007 and for light-duty vehicles (LDVs) on Jul 1, 2007, [76] but China III gasoline standard was implemented in Jan 2010, two-and-a-half years after China III LDV standards were implemented, and China III diesel standard was not mandated nationwide until July 2011, four -and-a-half years after the HDDV standard was tightened to China III. The

76 China III LDV standards were implemented on July 1, 2007, and China III diesel HDV standards were adopted on Jan 1, 2007. Both dates apply for new model type approval.

lagged implementation of fuel standards (particularly the high diesel sulfur limits) has become a major roadblock to ratcheting down vehicle emission standards.

As noted above, the nationwide fuels roadmap has now been defined with 50 PPM maximum fuels across the country by the end of 2014 and 10 PPM by the end of 2017.

## Barriers to progress in China

### Policy and political barriers

MEP lacks the authority to set fuel standards: While MEP is the lead agency for developing and enforcing vehicle emission standards and has proposed limits for toxics in fuels (e.g., benzene in gasoline), it does not have the clear authority to specify fuel quality parameters even if those parameters affect vehicle emissions. With MEP having no direct control of the stringency and implementation timeline of fuel quality standards, it has been unable to implement the systems approach and up until recently it has been unable to develop and implement a coherent vehicle emissions standards roadmap.

The technical committee that sets fuel standards is dominated by industry representatives: The development and management of fuel quality standards is led by the National Petroleum Products and Lubricants Standardization Committee (which is called TC280), a committee managed by the Standardization Administration of China (SAC), and a subcommittee under TC280 is dedicated to development of the fuel specifications. The secretariat organization of TC280, is the Research Institute of Petroleum Processing (RIPP), a research division of Sinopec, one of the largest oil companies in China. RIPP is responsible for staffing and managing TC280 and its subcommittee, as well as for drafting fuel specifications. Oil industry representatives and experts close to the industry dominate TC280 and its subcommittee—only three out of the 43 members in TC280 represent environmental and automobile interests and three out of the 30 members of the subcommittee are MEP or auto representatives. Such a small representation from the MEP and auto industry compromises the balance of the discussions on setting new standards due to the outsized influence of the oil industry's perspective.

### Financial barriers

Refineries may not recoup capital investment due to fuel price control: Retail prices of gasoline and diesel have always been set by the central government in China. Without a market pricing mechanism, it is difficult for the oil industry to recoup capital investments on refinery upgrades (such as adding desulfurization capacity at refineries) by passing on the higher production costs to consumers. Prior to its implementation, US EPA estimated the annual capital investment cost for meeting the ultra-low sulfur fuel requirements (15-ppm sulfur gasoline and diesel) would be USD 2.15 billion (15 billion RMB) in 2004 and USD 2.49 billion (17.5 billion RMB) in 2005. [77] US refineries were able to raise prices of ultra low sulfur gasoline and diesel to recover investments for the desulfurization units. [78] The incremental price was small compared to the variation in fuel price due to fluctuations in oil prices. To solicit industry's support for setting more stringent fuel standards, MEP needs to explore ways to provide financial support for refinery upgrades.

### Technical barriers

Limited technical expertise and data compared to the industry: There is a small team at MEP (including five staff in CRAES and two staff in VECC) working on fuels-related research and regulatory work and a laboratory in CRAES that performs fuel testing. But compared to the oil industry, MEP has far less expertise and technical capability, particularly on evaluating the emission implication of various fuel compositions, which is essential for recommending standard specifications. In addition, MEP has limited access data on refinery capacity and can only rely on the industry's analysis of the cost and technical implications when considering adopting more stringent standards.

## Lessons Learned from China's Experience

A comprehensive clean vehicles program requires close coordination between vehicles and fuel quality – vehicles and fuels are a system.

Strong and innovative local actions can pave the way for strong national actions.

77 EPA. 2000. Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Requirements, EPA420-R-00-026, Chapter IV, pp. IV-63–IV-64.

78 See some anecdotal examples in Washington States University Energy Extension Program. Ultra Low Sulfur Diesel. http://www.energy.wsu.edu/documents/renewables/Fuels.pdf (accessed April 29, 2010), and EPA. Retrofits and Cleaner Fuels. EPA website. http://www.epa.gov/ne/eco/diesel/retrofits.html (accessed April 29, 2010)

# 9. HOW TO IMPLEMENT A CLEAN FUELS AND VEHICLES PROGRAM

As countries or regions or cities consider a move to cleaner fuels and vehicles, they find themselves in many different circumstances - a strong or weak government agency with the power to mandate requirements, a domestic industry that produces vehicles and or fuels and that is an important source of jobs versus one that only imports these products or some hybrid of these, for example. But whatever the structural situation might be, a usual starting point involves raising public awareness of the health or environmental consequences of inaction.

## Educate the Public and Get Their Support

Without strong public support it is highly unlikely that it will be possible to move forward with a strong and effective clean vehicles and fuels program. First it will be important to pull together a good summary of available information. International information is easily available and is briefly summarized earlier in this document. Health information highlighting potential adverse impacts on children, the elderly and other sensitive groups is usually most important. Beyond health impacts, in some areas, other environmental effects may be considered very important by some influential groups. (In Europe, for example, dying forests and lakes due to acidification motivated action as much as health concerns.)

Where local data is available to supplement international data that should be gathered as well. This can be critically important.

Getting this information to the public and policy makers and policy shakers is then critical. Press events, press background briefings, public workshops and other activities of this type can be useful means to get the word out. Often, the NGO community can play a critical role in doing this.

The affected industries – at a minimum the oil industry and the vehicle industry – need to be involved in this process. At best, they will support what you are trying to do. But even if not, it is wise to know their concerns and to learn what their objections or disagreements might be.

At the end of the day, unless there is a perceived need for action by a cross section of the public, it will likely not occur.

## Determine Who Are the Decision-makers that Must Be Convinced to Act

As the above examples indicated, this can vary widely from country to country. For example, often there will not be one agency or organization blessed with this power to set both vehicle and fuel standards.

- In the US, the EPA has the power to set vehicle and fuel standards and works closely with stakeholders in their development.

- In Europe, there are different roles with the Commission in the lead initially to develop proposals but with the Member States and the Parliament playing critical roles and having the power to strengthen or weaken whatever the Commission proposed before it is finalized.

- In Canada, Environment Canada develops, implements and administers environmental fuel quality and most vehicle and engine emission regulations. These regulations play an important role in ensuring cleaner fuels to enable cleaner vehicles and engines. The Canadian government, industry and other interested parties work together to ensure that cleaner fuels and vehicles are available.

- In India, special expert committees have played a key role with the courts often applying important pressure.

- In China, multiple organizations are involved – certainly the Ministry of Environmental Protection (MEP) but also the State Council and others. Beyond the national government, local efforts such as those in Beijing and Shanghai can play a critical leadership role.

In a sense, each country is unique with its own political culture and power structure. This must be understood in order to be effective in bringing about real action.

## Find a Champion or Champions

Within the decision making structure or power structure, it is usually important to find a person or an organization that supports your objectives for clean vehicles and fuels and to do what you can to help that person.

## Determine the Most Appropriate Tool or Tools in Your Circumstance

Is a mandatory regulation the most likely initial step to bring about success or will tax incentives or disincentives work better in your country or region? Important considerations might include:

- Are all vehicles imported or are some vehicles manufactured or assembled in your country
- Is there a local refinery industry or is all your gasoline and diesel imported?
- If vehicles or fuels are imported, what is the status of controls in the country or countries from which you import?
- What are the potential jobs impacts in your country if you move forward toward cleaner vehicles and fuels?

## Develop a Strategy to Get Decision - makers to Act

It can be very helpful to determine who will be your allies and who will be you adversaries in this effort and what you need to do to bring them around to your point of view – to make it possible for the outcome to be positive after appropriate debate.

## Marshall the Facts

At the end of the day, policy makers will want to know and will need to know the facts:

- Why are clean vehicles and fuels needed?
- Is this possible technically? Politically? Economically?
- How much will it cost?
- Who will be affected?
- How much time is needed

# Enforcement

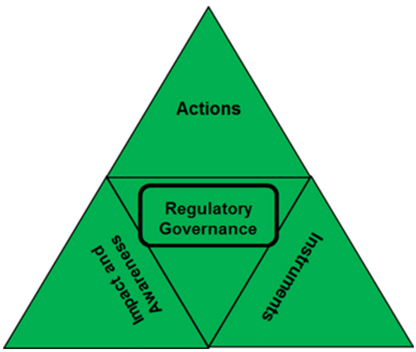
Experience has shown that regulations and standards have limited value unless that are enforced. The following section discusses the details of the enforcement and compliance programs for fuels and vehicles in the United States.

## Fuel inspection and compliance programs

A fuel compliance program is important to ensure that fuels sold at the retail stations meet all the mandated specifications. A fuel compliance program becomes more critical with the use of advanced emission control devices that can be damaged by impurities in fuel (e.g., high sulfur fuel). Identification of compliance points within the fuels distribution system (e.g. port of import, refinery gate) can ease enforcement.

## Governance

Although the focus of this section is regulatory governance, the principles can be applied to other initiatives. Regulatory governance connects the essential pillars of environmental change which include: impact awareness of the environmental issue, actions to address the environmental issue and the instruments to enable the action to address the environmental issue. Regulatory governance is generally enabled by a central government-led agency that writes the laws and regulations, administers and enforces the regulatory requirements.




For any program including regulatory there needs to be appropriate resources, financial and human to develop, implement and monitor the program. The range in complexity of a program can be correlated to the complexity of the industry and of the flexibilities provided within a program.

Each country or jurisdiction will have different ways of gathering resources to support an initiative such as a regulation. The lead agency will need to submit to the appropriate authorities the requirements for the new initiative. In this case the initiative would be the introduction of clean fuels to the market. Budgets will be needed for each phase of the regulatory process which includes regulatory development, implementation and administration. Once the regulations are implemented there would be the on-going regulatory administration, compliance promotion and enforcement. These units may be separate, but in all cases they should work closely together.

## The Regulatory Organization (people)

A responsible ministry, department or agency needs to be identified and to include the appropriate resources.

## Regulatory Development Team

There needs to be a Regulatory Team with the appropriate skillset. This team should include the following skill sets:

- Industry experts, fuel industry and vehicles industry (to determine what is feasible) and to work with industry to help support the development of the regulations,

- Legal (to draft legislation or regulations in accord with local laws),

- Economists and scientists to support the cost benefit analysis to determine to cost to implement the clean fuel program and the benefits from the cleaner air and associated health benefits,

- Trade experts (to evaluate trade impacts), and

- Communication experts to support the delivery of the regulatory initiative to the public

- These groups work under the specific law or enabling authority. This work could involve:

- Specific requirements enacted by a legislature or broader legislation which would enable specific requirements to be put into place by the government alone.

- Regulations can be a large number of specific requirements and these can be included in regulations: The standards themselves or reference to other e.g., U.S. or European standards; Test methods, timing of enactment, etc.

- Regulatory flexibility in general increases regulatory complexity and the administrative requirements under the regulations for both industry and the government.

The regulatory development team should follow the following steps:

- develop the policy on clean fuels:
- identify issues / advise on priorities
- gather appropriate information / become the experts
- consult with all stakeholders
- analyze all the inputs from stakeholders/ make internal recommendations
- develop instruments:
- design regulations
- develop compliance plans, input to Regulatory Impact Analysis

## Compliance Promotion

- Ongoing activity to promote the regulations and regulatory requirements to the regulate community. This can include the promotion of reporting templates and any updates to regulatory requirements

## Enforcement

- Enforcement of the regulations through trained enforcement officers on the requirements of the regulations with the support of regulatory experts. Depending on the complexity of the regulations, these can be as simple as spot checks on fuel quality and different points within the fuel distribution system with portable or lab based fuel quality analysis to confirm compliance with the regulated fuel quality parameter such as sulfur. For more complex regulations, this may require an audit capability skill to be able to look through a company records to confirm compliance with the regulated fuel quality standard.

• Enforcement offices can be specialized solely for the fuels regulations or can support other regulations including other environmental regulations.

• Enforcement offices can perform Regulator (Fuels) spot testing at the pump and / or refinery, terminal inspections.

• The regulated community such as the Fuel Suppliers' can have administrative requirements as prescribed in the regulations and enforced by the enforcement group within your lead organization. Enforcement and administration should work together for the administrative and report submission requirements under the regulations. Examples of some administrative provisions that can be required by the regulated community can include:

- Testing by refiners and importers on regulated fuel quality parameters
- Fuel sample retention and record keeping
- Reporting of test data
- Requirement for Independent Audit\

## Regulatory Administration and Operations

• Staff for this group can be some of the resources used from the regulatory development team. This group helps support both compliance promotion and enforcement of the regulations. If there are reporting requirements this group would review submitted reports, identify any issues, identify any regulatory adjustments and produce annual reports on the performance of the regulations.

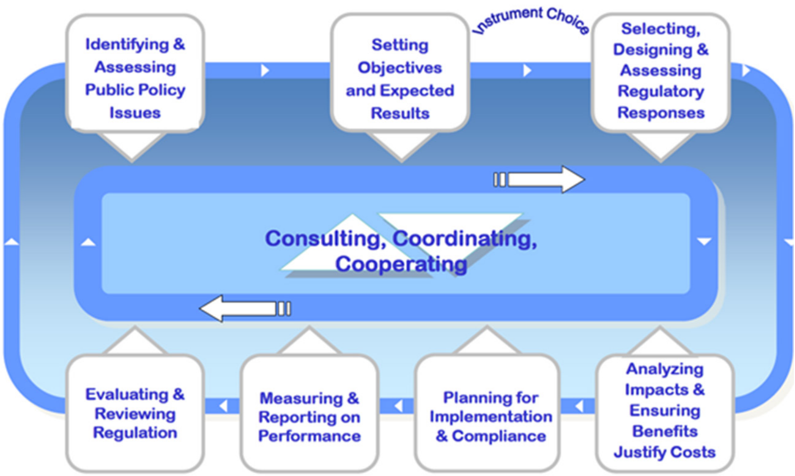
• Key elements for the implementation and administration of a regulatory program include:

- prepare and disseminate guidance material, promote compliance
- respond to stakeholder inquiries
- verify data
- analysis of reported data
- provide enforcement training
- provide advice on enforcement action
- issue public reports on fuel quality.

• Having reporting of fuel quality data under a regulation can help support the progress on implementation and provide data that can help model the impact of the regulations and future analysis. Data can be submitted by paper forms, email with attachments or an on-line regulatory submission system. In all cases the data should be submitted by a secure method if confidential data is involved.

The data can be stored in a secure database that can be used for compliance verification and analysis. .

Regulations have an ongoing cycle of review and evaluation to confirm compliance, performance and ongoing improvement in order to meet the environmental objectives.




Some lessons learned on regulatory governance and the development of regulations

- Consulting with industry and other government departments is key to the design of a successful regulation.

- Alignment with major trading partners enables a "level playing field" and smooth trade activity in regards to competition and market forces.

- The more complex a regulation or instrument, the tougher it is to enforce.

- But complex regulations/instruments allow for industry flexibility.

- Extensive training of administration/enforcement officers and education of the stakeholders/regulated community helps ensure compliance and a smooth application.

- Designing the regulation/instrument is the "tip of the iceberg" – much more follows. Implementation and administration can include:

    - Compliance promotion
    - Training
    - Data collection,

- Reporting
- Performance measurement
- Compliance verification
- Enforcement
- Amendments, etc.

## Overview of US EPA's fuel compliance program

This chapter reviews the experiences of US in enforcing motor fuel quality, and lessons learned from these two countries are used to inform recommendations for the establishment of an effective fuel quality enforcement program.

EPA manages a comprehensive fuel compliance program that combines fuel registration, extensive fuel inspections, a fuel quality testing and reporting system, and stiff noncompliance penalties. Most of the fuel inspection programs are funded by EPA; industry is required to fund one program that assures reformulated gasoline compliance for annual average standards. Another voluntary quality assurance survey program for diesel fuel sulfur compliance is also funded by industry consortium as an alternative defense that will be discussed in more detail later in this chapter. Section 211 of the Clean Air Act (CAA) gives EPA the authority to prohibit the manufacture or sales of fuel and fuel additives if they may reasonably be anticipated to endanger the public health or welfare or impairs emission control device or system. The 1990 CAA amendments added provisions to mandate that fuel combustion result in fewer emissions and expanded EPA's authority to include fuels used in non-road vehicles.

EPA's compliance program places the onus of proof largely on refiners, importers and other fuel handlers to demonstrate compliance through registration, fuel analysis and reporting. EPA assures the authenticity and probity of industry's proof of compliance by mandating independent lab sampling and testing, third party auditing of industry reports, and by conducting targeted and random audits at refineries, import facilities, truck loading terminals and retail stations. Key elements of the program are discussed in more details in the following sections.

## Regulated parties

The fuel compliance program targets all parties in the distribution system, including refiners, importers, distributors, carriers, oxygenate blenders, retailers, and wholesale-purchaser-consumers (fleet operators with their own dispensing pumps).

## Enforcement approach

EPA's compliance program was established to assure that fuel leaving the refinery gate or that is imported meets all requirements on a per-gallon and on an annual average basis. Table G below shows the per-gallon and average fuel requirements for gasoline and diesel fuel. Additional measures are established to assure that quality of fuel is maintained downstream of the refinery on a per-gallon basis. Each of the enforcement measures is briefly discussed in the following sections.

### Table G: Per gallon and average standards and performance requirements for gasoline and diesel Gasoline

| PROPERTY OR PERFORMANCE REQUIREMENT | REFORMULATED GASOLINE (RFG)[79] | | OTHER GASOLINE | |
|---|---|---|---|---|
| | PER GALLON | AVERAGE | PER GALLON | AVERAGE |
| Lead | Non-detectable | - | Non-detectable | - |
| Sulfur, ppm, max | 80 | 30 | 80 | 30 |
| Volatility (summer RVP) | Approximately 7.0 psi (48 kPa) | - | 7.8-9 psi | |
| (54-62 kPa) | - | | | |
| Aromatics | 25% | - | 25% | - |
| Benzene | 1.3 vol.% | 0.95 vol.% | - | - |
| Other heavy metals (e.g., manganese) | Non-detectable | - | - | - |
| RFG and anti-dumping[80] | Reduce VOCs and air toxics by 25-30% (compared with 1990 gasoline quality) | Reduce VOCs and air toxics by 25-30% (compared with 1990 gasoline quality) | | Fuel not dirtier than 1990 gasoline quality |
| Mobile Source Air Toxics (MSAT 1) | | Further reduces average toxics | | Further reduces average toxics |
| MSAT 2 | Benzene: 1.3 vol% | 0.62 vol.% on average | No cap but refinery/importer annual average cannot exceed 1.3 vol.% before use of credits | 0.62 vol.% average |

### Diesel (Motor vehicle, non-road)

79 RFG is a cleaner burning gasoline blend required in certain regions that do not meet air quality standards for ozone.

80 Sec. 211 of the Clean Air Act specifies a backstop limit on NOx, requiring that NOx emissions from a baseline vehicle using non-RFG shall not exceed the level from the baseline vehicle using the baseline gasoline in 1990. EPA no longer enforces the NOx standard, since compliance with the low sulfur levels in gasoline (30 ppm average and 80 ppm per-gallon cap) assures compliance with the old NOx standards. Starting 2011, EPA will begin to phase out the toxics standards as well. These will be replaced by a benzene standard (annual average of 0.62 volume percent).

| PROPERTY REQUIREMENT | PER GALLON |
|---|---|
| Sulfur | 15 ppm |
| Cetane index, min | 40 |
| Or Aromatics, max | 35% |

## Fuel and fuel additive registration

Refiners and importers are required to register with EPA any motor vehicle fuel and fuel additive prior to marketing in the US. Registration requires submission of the chemical description of the fuel or fuel additive as well as technical, marketing and health-related information, such as the in-use purpose of their product. EPA might also require testing for possible health effects for a product to maintain its registration or for a new product to be registered.

EPA uses the registration information to assess the likely combustion and evaporative emissions using the complex model[81] and identify products whose emissions might pose unreasonable risks to public health. EPA can deny new registration or repeal existing registration of any fuel or fuel additive that may endanger public health or impair emission control devices.

Detergent additives, which are required under the CAA to be added to all gasoline to reduce accumulation of deposits in engines and fuel supply system, have to be certified with EPA. The certification process includes:

1) Registration with EPA like other additives, and the registration should include the additive's composition and the minimum recommended additive concentration. The recommended concentration cannot be lowered without first notifying EPA.
2) Submitting a sample of the detergent additive to EPA
3) Submitting a certification letter for the detergent additive package. The letter must be signed by a person legally authorized to represent the certifying party.

After receiving the certification letter, EPA may review the certification data, analyze the submitted detergent additive sample, or subject the additive package to confirmatory testing, and may disqualify a certification where appropriate.

In addition, the detergent additive manufacturers are required to accurately communicate the minimum recommended concentration to each fuel manufacturer who purchases the detergents for compliance with EPA's requirement.

81 The complex model estimates NOx, toxics and VOC emission performance of fuels based on the following parameters: olefin, aromatics, sulfur, benzene, oxygen, distillations (E200 and E300) and RVP.

## Fuel testing and compliance reporting

EPA requires refiners and importers to analyze the properties of every batch[82] of fuel produced or imported for fuel properties associated with that kind of fuel. [83]Refiners and importers have to maintain all testing records and retain test samples. Fuel properties are reported to EPA on a quarterly or annual basis depending on the design of the particular compliance program [84]. In addition, annual reports are filed with EPA summarizing test results of every batch and the associated properties to show compliance with the per-gallon and average standards. EPA selectively audits the annual and quarterly reports, and lab records to check if they are internally consistent. EPA also audits the laboratories and the laboratory methods, quality assurance procedures, etc.

## Industry-paid independent lab testing

In addition to conducting self-testing of every batch of fuel, EPA requires refiners and importers to hire independent labs to sample and test reformulated gasoline and certain imported gasoline. Independent lab test reports are submitted to EPA for comparison with the reports submitted by the regulated parties. All laboratories reports have to be signed by senior management of the lab, and EPA could file criminal charges against the signatory if reports are found to be falsified.

## Industry-paid independent auditing of refinery reports and lab records

Refiners and importers are required to hire independent certified public accounting firms or certified internal auditors to audit all fuel test results, volume reports and other information of the refiners or importers.

## Presumptive liability and industry-funded field surveys

EPA rules place liability on refiners, importers, distributors, carriers, resellers, retail and wholesale purchase-consumers if they sell or use motor vehicle diesel fuel that does

82 In the diesel fuel program, by definition, a batch is a volume of fuel whose custody has been transferred to another party. A batch of gasoline is defined as a homogeneous mixture.

83 Sulfur content, aromatics and cetane number for diesel; sulfur, aromatics, benzene, lead, summer RVP distillation, olefin for gasoline, and other fuel properties that demonstrate compliance with the reformulated gasoline or conventional gasoline anti-dumping requirements.

84 For instance, refiners and importers are required to submit fuel quality reports for every batch of fuel produced or imported to show that all per-gallon requirements are met. To demonstrate compliance with the RFG and anti-dumping requirements, refiners or importers are required to submit reports every quarter and annually. Annual reports are required for demonstrating compliance with the benzene, VOCs and air toxics requirements, and the average and per-gallon maximum gasoline sulfur limits.

not meet the sulfur standards or if they sell or use gasoline that does not comply with the benzene, sulfur, volatility, toxics and lead contamination regulations. This means that when a violation is found, the party in possession of the non-conforming fuel, as well as all parties upstream in the fuel distribution system are presumed liable unless they establish an affirmative defense. Refiners and importers whose brands appear at retail outlets may implement downstream quality assurance program to ensure compliance and to establish one element of their defense against presumptive liability. Other elements must be established, including lack of causation.

As a means of meeting the sampling and testing defense element for ULSD, industry funds a fuel survey program. Under this program, industry-paid surveyors take statistically representative samples regularly from retail stations and test them against the diesel fuel sulfur requirements.

## EPA field audits and inspection

Besides auditing industry's self-reports and requiring industry to arrange for independent lab testing and independent auditing to verify the authenticity and probity of test results, EPA inspects refineries both randomly and also those that are suspected of producing non-conforming fuels. It also audits a small number of independent labs every year to ensure that close ties between the testing labs are maintaining appropriate independence and correctly reporting results.

## Non-compliance penalty

The CAA sets a maximum civil penalty of USD 37,500[85] per day per occurrence plus the amount of economic benefit or savings resulted from such violation. The actual penalties are determined by EPA based on various considerations including economic benefits, business size, and the gravity of violation (whether it results in significant increases in emissions). While the maximum fines are seldom assessed, EPA has levied heavy fines for severe violation. For instance, in 1985, EPA imposed fines of USD 266,000 against Decker Coal Co. for using leaded gasoline in 37 vehicles marked for unleaded fuel only. [86] In 2008, EPA assessed a penalty of USD 1.25 million against Biofriendly Corporation for failing to register an additive.[87] In addition, EPA can file criminal charges against refiners, importers and independent labs should they be found to have falsified or assisted in falsifying test results. [88]

85 The civil penalties are adjusted for inflation from the $25,000 cap on civil penalties when the CAA was enacted.

86 Associated Press. 1985. Fuel violation fines sought. Spokane Chronicle.

87 EPA. 2008. Biofriendly Corporation Clean Air Settlement. EPA website. http://www.epa.gov/compliance/resources/cases/civil/caa/biofriendlycorp.html

88 For instance, in 1998, Saybolt Inc., which performed testing and inspection services for refiners and importers, was fined a total of USD 4.9 million for submitting false statements to EPA about results of lab testing performed for

## Results and costs of the enforcement program

EPA's enforcement program has been successful: Less than 1% of facilities audited are found in violation with fuel quality requirements every year. Below are the major factors contributing to the success of the program:

***Non-compliance penalty:*** As mentioned previously, the fuel compliance program has aggressively pursued violators, including refineries, importers or testing laboratories. Substantial fines (millions of dollars) were imposed on big companies or when severe violations were found, and criminal charges have been filed against laboratories found to have falsified test results. Therefore, even though the maximum civil penalty of USD 37,500 per day per occurrence is seldom assessed, the possibility of being subjected to a hefty fine creates a deterrent effect forcing fuel producers, importers and handlers to more diligently ensure compliance.

***Presumptive liability:*** The presumptive liability provisions encourage all parties along the distribution chain to undertake efforts to assure quality of fuel they received, and deter dropping of illegal fuel during fuel distribution. The industry-paid surveys for verifying retail fuel quality help to assure compliance along the chain and lessen the regulatory burden on EPA.

***Independent testing and auditing:*** The EPA requirements of independent lab testing of every batch of fuels and independent auditing of in-house and lab test results make it difficult for refineries or importers to cheat by submitting falsified data to EPA.

## Vehicle compliance and enforcement program

New vehicle emission standards can only serve to protect air quality if vehicular emissions are actually reduced when the vehicles are in normal use. To fully deliver the promise of environmental and health benefits from new vehicle standards, an effective vehicle compliance and enforcement program has to be in place to ensure emissions of new and in-use vehicles are effectively controlled.

This chapter summarizes the key elements of the vehicle compliance and enforcement program in the US. When the US Clean Air Act was passed in 1970, the US vehicle compliance program only covered new vehicle certification. Over the years, the program has grown and evolved from one that focused mainly on ensuring prototype and new production vehicles comply with standards, to the current program that places strong emphasis on in-use testing to ensure compliance with emissions standards over the vehicle useful life.

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refiners and importers.

EPA was able to shift more resources to in-use vehicle testing programs because of the strong enforcement presence established in early years through its vigorous certification program and the Selective Enforcement Audit (SEA) program. These two programs deterred fraudulent reporting of certification results and compelled manufacturers to extensively test new vehicles at their own costs to ensure production conformity. This allowed EPA to shift its resources to in-use testing to ensure engines and emission control devices are durable and emissions are effectively controlled over the useful life of vehicles. The development of the portable emissions measurement system (PEMS), a recent breakthrough of instrumentation for on-road in-use emission measurement, makes in-use emission testing over a wide range of actual driving conditions feasible, particularly for heavy-duty vehicles and non-road engines.

The following sections review the compliance program for light-duty vehicles. A section is devoted to a summary of inspection and maintenance programs and best practices. Results and costs of the US compliance and enforcement program are also presented.

The new vehicle compliance and enforcement program for LDVs consists of: 1) Pre-production certification, 2) Confirmatory testing, 3) Selective enforcement audit (SEA), 4) In-use surveillance performed by EPA, 5) In-use verification testing performed by the vehicle manufacturer, 6) Recall, and 7) Warranties and defect reporting. How these elements are implemented over a vehicle's life is illustrated in Figure 7.

## Pre-production certification testing:

Under CAA Section 206, all engines and vehicles sold in the US are required to be covered by a certificate of conformity before they can enter the market. The certification demonstrates that the engine or vehicle conforms to all applicable emissions and fuel economy requirements. A deterioration factor is applied to the test results before comparing to the emission standards and determining pass and fail.

Pre-production certification testing is conducted by manufacturers to support their applications for a certificate of conformity and is usually performed before a certificate is issued. [89] A manufacturer can establish its own testing facility to conduct the test or contract the services of independent laboratories. Test results,

89 Certification testing in the US comprises the following test procedures: federal test procedure (FTP), highway fuel economy test, US06 (high speed/acceleration cycle), SC03 (air conditioning test cycle), cold CO (FTP conducted at 20 deg F), evaporative emissions, Onboard Refueling Vapor Recovery (ORVR), and running loss emissions test.

adjusted with deterioration factors, must be recorded in the certification applications to demonstrate compliance. Manufacturers must perform certification testing for all the "test groups" that they choose to certify.

A test group or engine family is a basic classification unit used for demonstrating compliance with vehicle emissions requirements. It is a group of vehicles or engines having similar design and emission characteristics. For light- and heavy-duty vehicles, these characteristics include engine displacement, cylinder number, arrangement of cylinders and combustion chambers (in-line vs. v-shaped), and subject to the same type of emission standards. The manufacturer should select the vehicle configuration within the test group that is expected to generate the highest level of emission and emission deterioration as the test vehicle (the worst-case configuration). The selected configuration is called the emission data vehicle in the US.

Manufacturers submit certification applications through EPA's computer system called VERIFY, which automatically validate all applications. Manual auditing is performed for some applications. EPA issued over 3,500 certificates for conformity to vehicle and engine manufacturers in 2007.

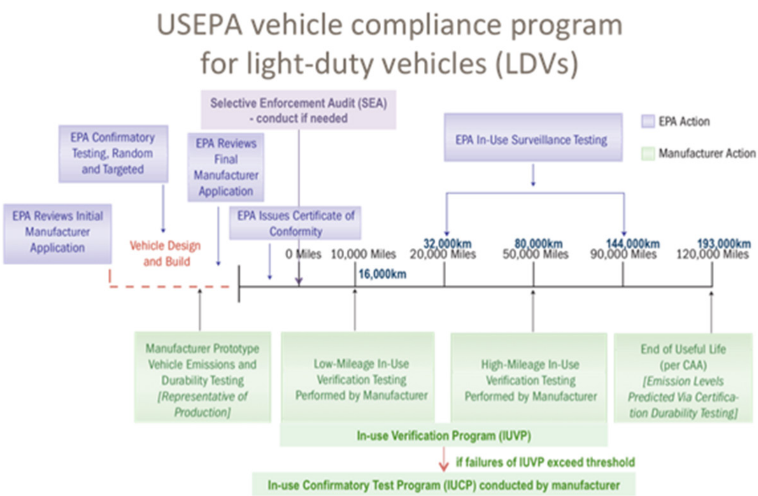


*Figure 7: US EPA Vehicle Compliance program for light-duty vehicles*

## Confirmatory testing:

Confirmatory tests are targeted and random tests performed by EPA to validate the emission and fuel economy testing results reported in certification testing. In recent years, EPA selected about 15% of all test groups for confirmatory test; two-third of the selected test groups (10% of all test groups) are randomly selected and the remaining one-third (5% of all test groups) are targeted testing. All LDV confirmatory tests are conducted at EPA's Ann Arbor laboratory.

The majority of vehicles targeted for confirmatory testing are those models that use new technology or new designs. Others are targeted due to potential emission concerns, including models with certified emission levels very close to the standards (small emission margin).

Manufacturers are invited to observe how the tests are performed. Every test vehicle has two attempts to pass, if the vehicle failed the first test, the vehicle is tested a second time. The manufacturer can also choose to inspect the test vehicle after it failed the first test to determine what went wrong (e.g., if the failure is due to wrong parts, or disconnected hose). If the manufacturer can demonstrate that it was an invalid test, the vehicle can be retested. If a vehicle fails two valid tests, no certificate will be issued. The manufacturer can choose either not to pursue certification, or make changes (recalibration) and then resubmit a new application.

## Selective enforcement audit (SEA):

The SEA program came about in the mid-1970s when EPA found that manufacturers were occasionally producing classes of new vehicles that did not comply with standards, even though the certified prototypes meet the standards. The SEA is aimed at identifying cases where prototype vehicles supplied by manufacturers are not representative of production.

Through the SEA program, EPA can require manufacturers to test vehicles pulled off from the end of the assembly line, at the manufacturer's expense, without prior notice. SEA offers EPA an early opportunity to assess whether the vehicles produced under the certificate of conformity are actually built adhering to the specifications of the prototype, and if manufacturers allow sufficient compliance margins such that in mass production the engine and emissions control equipment function effectively to comply with standards after deterioration factors are applied.

The SEA was designed based on the premise that testing a fixed percentage of all assembly line vehicles is not necessary; rather, a program that focuses on potentially suspect classes could achieve the same information at lower cost to the industry. To pick the target test groups for the audits, EPA uses information from many different sources, including compliance history with a manufacturer, compliance margin, certification data, I/M data, technology reviews, and defect reports.

The SEA can be performed at the manufacturer facility following EPA's requirements, or at any testing lab EPA chooses. If a model fails SEA testing, EPA has the power to revoke or suspend certification, which will restrict sales of the model, until the manufacturer can demonstrate conformity with the standards.

Because the penalties of failing the audits, like halting the assembly line of a failed vehicle class, were disruptive to the manufacturers, many manufacturers began routinely testing their vehicles. Soon after the program started, manufacturers tested far more (100 times more) vehicles than the number of vehicles audited by EPA. By mid 1980s, failed LDV audits became rare, and even failed individual vehicles in the SEA were infrequent, and EPA decided to shift LDV SEA staff resources to heavy-duty SEA efforts and the in-use testing (recall) program.

EPA has not conducted any SEA for LDVs in the past many years but the agency reserves the authority to conduct SEA if a problem is suspected with routine production line testing, such as reporting fraud or improper testing procedures.

## In-use surveillance and recall testing program:

Performed by EPA, the in-use surveillance and recall testing program targets vehicle classes (usually test groups) that are suspected of having emission-related problems, or are simply populations that are chosen to be sampled for other reasons. Vehicle classes could be selected based on:

1) manufacturer defect reports;
2) information from state I/M programs;
3) manufacturer service bulletins;
4) certification test results (EPA more likely tests vehicle models that have had problems in certification),
5) newer technology or engine,
6) sales volume, or
7) any other reason EPA deems appropriate.

All selected vehicles are tested at the Ann Arbor laboratory (unless designated by EPA), following the same test procedures and fuels (standard fuels) used in certification. Manufacturers are contacted if their vehicles are picked for in-use testing, and they are invited to watch the tests being performed and maintenance being performed on the vehicles, so they have confidence of the quality of the tests.

At the surveillance phase, EPA typically recruits three to five vehicles that are two or three years old from Southeastern Michigan (in proximity to the Ann Arbor lab). EPA's contractor contacts vehicle owners of each of the test group selected by EPA for testing. The owners are given small monetary awards (about US$20 per day) and a loaner car (or US$50 per day in lieu of a loaner car). EPA ensures that the cars have been properly maintained and used, and if needed performs required maintenance before testing. The maintenance performed depends on program requirements. Participants are given a list of any parts that are replaced.

If a number of failures were identified in the surveillance testing, EPA will discuss these with the manufacturer to find out some acceptable resolutions, such as voluntary recall, field fix, or extended warranty. EPA uses forced recall as a last resort.

The testing enters the confirmatory phase if the surveillance results indicate that a substantial number of vehicles in the class may exceed emission standards within the useful life, and if the manufacturer declines to voluntarily remedy the problem at that time. This step could lead to an EPA-ordered recall if the testing confirms the likelihood of a substantial number of vehicles failing within the class. The manufacturer can voluntarily recall the vehicles at any time to avoid this process. EPA will work with manufacturers to agree on appropriate remedies to avoid an ordered recall. However, EPA has the authority under Section 207(c) of the Clean Air Act to order a recall if voluntary measures are not agreed upon.

Recruitment and testing in confirmatory testing are much more rigorous than in surveillance testing because vehicles must be shown to fail when properly maintained and used. Usually, ten randomly selected vehicles from within the class in question are tested, and the test vehicles must have been properly maintained and used. EPA will review the results of the confirmatory testing and make a determination whether the failure rate indicates a substantial number are failing. This will depend on the number of failures and the margins of failure. There is no set number of failures that can trigger the ordered recall process. Generally, if more than two of the vehicles in the sample fail, there is risk of further action. The manufacturer will have the opportunity to take voluntary action prior to EPA issuing an official finding.

In the New Compliance Assurance Program (CAP2000) adopted by EPA in 2000, the in-use conformity phase becomes the in-use confirmatory testing (IUCP) program discussed below.

### In-use verification testing program (IUVP):

Performed by manufacturers, the IUVP is designed to test emissions of low-mileage (10,000 miles or 16,000km) and high-mileage (50,000 miles or 80,000km) in-use vehicles. One to five vehicles per test group are tested, and about 2,000 tests industry-wide are performed in a typical year. If 50% of the tested vehicles of the test group sample at either the low or high mileage test point fail or the average emission levels are greater than 1.3 times the standard limits, manufacturer must automatically conduct an In-use confirmatory test program (IUCP). In the IUCP, test vehicles are selected and tested in a more rigorous manner (same as the confirmatory phases of in-use testing described above) and failure of the IUCP could lead to recall.

Manufacturers are required to report all IUVP data to EPA. The large sample of in-use data allow EPA to identify potential design issues for future mode years, particularly on deterioration of emissions control devices under real life driving conditions, and focus attention to potentially high emission vehicles. The IUVP data is also used to assess and update the manufacturers' deterioration factors and procedures used to determine deterioration factors.

## Recalls:

The CAA authorizes EPA to require a manufacturer to recall a group of vehicles or engine at its own cost if it has been determined that a substantial number of vehicles from that group do not meet the standards even if they have been properly maintained and used.

EPA could require a recall when a test group fails the confirmatory phase of the in-use surveillance test. EPA could also require a recall based on the IUCP data. Manufacturers typically prefer to launch voluntary recall when they are presented with the data. If a manufacturer refuses to recall, EPA can follow established regulatory procedures that could result in an ordered recall.

EPA also investigates emission-related defects to determine if manufactures should remedy them. EPA usually contacts manufacturers prior to initiating action, and manufacturers generally issue voluntary recalls as a result. Sometimes EPA will conduct surveillance and/or confirmatory testing to establish evidence of failure in use, or the manufacturer may conduct its own testing and investigations that may result in voluntary recalls. Most of the time, manufacturers issue voluntary recalls without direct EPA intervention.

Some recall campaigns involve defects that occur in a small number of vehicles within a class, and the malfunction is very evident to the vehicle owner such that they seek repair. These are usually termed "self-campaigning." If these defects result in emissions failures, and can occur outside of the warranty period for the emission-related component, manufacturers can conduct a warranty extension campaign where letters are sent to owners to notify them of the potential failure and tell them that the repair will be covered for a certain time and mileage. EPA deems these recalls to be Voluntary Service Campaigns, and encourages manufacturers to conduct these when it is not appropriate to fix vehicles that do not have the problem.

## Warranty and defect reporting:

The CAA requires manufacturers to warranty certain emission control components on vehicles. The warranties protect vehicle owners from the cost of repairs for emission-related failures resulting from defects in design, materials, and workmanship that cause the vehicle or engine to exceed emission standards.

There are two types of warranties: Performance Warranty and Design and Defect Warranty. The Performance Warranty covers any repair or adjustment which is necessary to make your vehicle pass an approved, locally-required emissions test (like an I/M) during the first 2 years/24,000 miles of vehicle use as long as the vehicle has been properly maintained according to the manufacturer's specifications and has not been misused. Specified major emission control components, like catalytic converters, electronic control units, and onboard diagnostic devices, are covered for the first 8 years or 80,000 miles. The Design and Defect Warranty covers repair of emission related parts that become defective because of a defect in materials or workmanship during the warranty period. The warranty period for all emission control and emission related parts is the first 2 years or 24,000 miles of vehicle use, and for specified major emission control components is the first 8 years or 80,000 miles of vehicle use.

EPA requires manufacturers to monitor identified defects in emission control systems of properly maintained and used engines and submit defect reports to EPA whenever there are 25 or more vehicles within the same model year are found to have a particular emission-related defect. The defect reports must estimate the proportion of vehicles that contain a defective part and estimate the impact of the defect on emissions. A recall can be initiated if as little as 1% of an engine family has the same defective part and the defect has a significant impact on emissions.

# 10. APPENDIX A: EU EMISSIONS STANDARDS

### Emission Limits for Petrol Cars (g/km) (a)

| PETROL | As from (b): | CO | HC | NOx |
|---|---|---|---|---|
| EURO I* | 1/7/1992 | 4.05 | 0.66 | 0.49 |
| EURO II* | 1/1/1996 | 3.28 | 0.34 | 0.25 |
| EURO III | 1/1/2000 | 2.30 | 0.20 | 0.15 |
| EURO IV | 1/1/2005 | 1.00 | 0.10 | 0.08 |
| EURO V | 9/30/2009 | 1.00 | 0.10 | 0.06 |
| EURO VI | 9/30/2014 | 1.00 | 0.10 | 0.06 |

** As measured on new test cycle for application in year 2000.*

### Emission Limits for Diesel Cars (g/km) (a)

| DIESEL | As from (b): | CO | NOx | PM | Particle Number |
|---|---|---|---|---|---|
| EURO I* | 1/7/1992 | 2.88 | 0.78 | 0.14 | |
| EURO II* | 1/1/1996 | 1.06 | 0.73 | 0.10 | |
| EURO III | 1/1/2000 | 0.64 | 0.50 | 0.05 | |
| EURO IV | 1/1/2005 | 0.50 | 0.25 | 0.025 | |
| EURO Va | 9/30/2009 | 0.50 | 0.18 | 0.005 | |
| EURO Vb | 9/30/2011 | 0.50 | 0.18 | 0.0045 | 6 x 1011 |
| EURO VI | 9/30/2014 | 0.50 | 0.06 | 0.0045 | 6 x 1011 |

** As measured on new test cycle for application in year 2000.*

NOTES:

a) "Euro 3 and 4" (Directive 98/69/EC): Standards also apply to light commercial vehicles (<1305 kg).

b) The above dates refer to new vehicle types; dates for new vehicles are 1 year later.

Emission Limits for Heavy Duty Vehicles. (G/kWh)

| | As from: | Test cycle | CO | Total HC | Non-Methane HC | NOx | Particulate Matter | Particle Number |
|---|---|---|---|---|---|---|---|---|
| **EURO I** | 1/10/1993 | 13-mode | 4.5 | 1.10 | - | 8 | 0.612 <85 kW<br>0.36 >85 kW | |
| **EURO II** | 1/10/1996 | 13-mode | 4.0 | 1.10 | - | 7 | 0.15 (a) | |
| **EURO III** | 1/1/2000 | ESC (c) | 2.1 | 0.66 | - | 5 | 0.10 0.13 (b) | |
| | | ETC (d) | 5.5 | 0.78 | 1.6 | 5 | 0.16 0.21 (b) | |
| **EURO IV** | 1/10/2005 | ESC (c) | 1.5 | 0.46 | - | 3.5 | 0.02 | |
| | | ETC (d) | 4.0 | 0.55 | 1.1 | 3.5 | 0.03 | |
| **EURO V** | 1/10/2008 | ESC (c) | 1.5 | 0.46 | - | 2 | 0.02 | |
| | | ETC (d) | 4.0 | 0.55 | 1.1 | 2 | 0.03 | |
| **EURO VI** | 1/1/2013 | WHTC | 1.5 | 0.13 | | 0.40 | 0.01 | 8 x 1011 |

NOTES:

*(a) Until 30/11/1998 the particulate limit for engines <700 cc per cylinder and with a rated power speed of more than 3000 rpm was 0.25 g/kWh*

*(b) For engines <750 cc per cylinder and with a rated power speed greater than 3000 rpm*

*(c) Measured on the European Standard Cycle (ESC)*

*(d) Measured on the European Transient Cycle (ETC)*

# 11. APPENDIX B: US EPA TIER 3 PROGRAM

On March 3rd, 2014, the U.S. Environmental Protection Agency (EPA) finalized Tier 3 emission standards for vehicles and gasoline that will cut harmful soot, smog and toxic emissions from cars and trucks, reducing standards for smog-forming volatile organic compounds and nitrogen oxides by 80 percent, establishing a 70 percent tighter particulate matter standard and virtually eliminating fuel vapor emissions. These standards will also reduce vehicle emissions of toxic air pollutants, such as benzene by up to 30 percent.

The final fuel standards will reduce gasoline sulfur levels by more than 60 percent – down from 30 to 10 parts per million (ppm) in 2017.

The final standards will work together with California's clean cars and fuels program to create a harmonized nationwide vehicle emissions program that enables automakers to sell the same vehicles in all 50 states. The standards are designed to be implemented over the same timeframe as the next phase of EPA's national program to reduce greenhouse gas (GHG) emissions from cars and light trucks beginning in model year 2017.

### *Tailpipe Standards for Light-Duty Vehicle (LDV), Light-Duty Truck (LDT), and Medium-Duty Passenger Vehicle (MDPV) Tailpipe Emissions*

EPA is establishing a comprehensive program that includes new fleet-average standards for the sum of NMOG and NOX tailpipe emissions (presented as NMOG+NOX) as well as new per-vehicle standards for PM. These standards, when applied in conjunction with reduced gasoline sulfur content, will result in very significant improvements in vehicle emissions from the levels of the Tier 2 program. For these pollutants, the standards are measured on test procedures that represent a range of vehicle operation, including the Federal Test Procedure (or FTP, simulating typical driving) and the Supplemental Federal Test Procedure (or SFTP, a composite test simulating higher ambient temperatures, higher vehicle speeds, and quicker accelerations). In addition to the standards, EPA is extending the regulatory useful life period during which the standards apply and making test fuel more representative of expected real-world fuel. The final standards are in most cases identical to those of California's LEVIII program, which provides the 50-state harmonization strongly supported by the auto industry.

The Tier 3 FTP and SFTP NMOG+NOX standards are fleet-average standards, meaning that a manufacturer calculates the average emissions of the vehicles it sells in each model year and compares that average to the applicable standard for that model year. The manufacturer certifies each of its vehicles to a per-vehicle "bin" standard and sales-weights these values to calculate its fleet-average NMOG+NOX emissions for each model year. Table I-1 summarizes the fleet average standards for NMOG+NOX evaluated over the FTP. Table I-1A summarizes the per vehicle bins. The standards for light-duty vehicles begin in MY 2017 at a level representing a 46 percent reduction from the Tier 2 requirements. For the light-duty fleet over 6000 lbs GVWR, and MDPVs, the standards apply beginning in MY 2018. As shown, these fleet-average standards decline during the first several years of the program, becoming increasingly stringent until ultimately reaching an 81 percent reduction when the transition is complete. The FTP NMOG+NOX program includes two separate sets of declining fleet-average standards, with LDVs and small light trucks in one grouping and heavier light trucks and MDPVs in a second grouping, that converge at 30 milligrams per mile (mg/mi) in MY 2025 and later. EPA is also providing alternative percent phase-in schedules for this and the other light-duty standards.

### Table I-1 Tier 3 LDV, LDT, and MDPV Fleet Average FTP NMOG+NOX Standards (mg/mi)

| Model Year | 2017[a] | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 and later |
|---|---|---|---|---|---|---|---|---|---|
| LDV/LDT1b | 86 | 79 | 72 | 65 | 58 | 51 | 44 | 37 | 30 |
| LDT2,3,4 and MDPV | 101 | 92 | 83 | 74 | 65 | 56 | 47 | 38 | 30 |

a. For LDV and LDTs above 6000 lbs GVWR and MDPVs, the fleet average standards apply beginning in MY 2018.

b. These standards apply for a 150,000 mile useful life. Manufacturers can choose to certify some or all of their LDVs and LDT1s to a useful life of 120,000 miles. If a vehicle model is certified to the shorter useful life, a proportionally lower numerical fleet-average standard applies, calculated by multiplying the respective 150,000 mile standard by 0.85 and rounding to the nearest mg.

### Table I-1A Tier 3 FTP Standards for LDVs, LDTs and MDPVs (mg/mi)

| Bin | NMOG+NOX (mg/mi) | PMa (mg/mi) | CO(g/mi) | HCHO(mg/mi) |
|---|---|---|---|---|
| Bin 160 | 160 | 3 | 4.2 | 4 |
| Bin 125 | 125 | 3 | 2.1 | 4 |
| Bin 70 | 70 | 3 | 1.7 | 4 |
| Bin 50 | 50 | 3 | 1.7 | 4 |
| Bin 30 | 30 | 3 | 1.0 | 4 |
| Bin 20 | 20 | 3 | 1.0 | 4 |
| Bin 0 | 0 | 0 | 0 | 0 |

a. In MYs 2017-20, the PM standard applies only to that segment of a manufacturer's vehicles covered by the percent of sales phase-in for that model year.

Similarly, the NMOG+NOX standards measured over the SFTP are fleet-average standards, declining from MY 2017 until MY 2025, as shown in Table I-2. In this case, the same standards apply to both lighter and heavier vehicles in the light-duty fleet. In MY 2025, the SFTP NMOG+NOX standard reaches its final fleet average level of 50 mg/mi.

**Table I-2 Tier 3 LDV, LDT, and MDPV Fleet Average SFTP NMOG+NOX Standards (mg/mi)**

| Model Year | 2017a | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 and later |
|---|---|---|---|---|---|---|---|---|---|
| NMOG + NOX | 103 | 97 | 90 | 83 | 77 | 70 | 63 | 57 | 50 |

a. For LDVs and LDTs above 6000 lbs GVWR and MDPVs, the fleet average standards apply beginning in MY 2018.

Manufacturers can also earn credits if their fleet average NMOG+NOX performance is better than the applicable standard in any model year. Credits that have been previously banked or obtained from other manufacturers can be used, or credits can be traded to other manufacturers. Manufacturers will also be allowed to carry forward deficits in their credit balance.

EPA is also establishing PM standards as part of the Tier 3 program, for both the FTP and US06 cycles (US06 is a component of the SFTP test).

Research has demonstrated that the level of PM from gasoline light-duty vehicles is more significant than previously thought.[90] Although many vehicles today are performing at or near the levels of the new standards, the data indicate that improvements, especially in high-load fuel control and in the durability of engine components, are possible.

Under typical driving, as simulated by the FTP, the PM emissions of most current-technology gasoline vehicles are fairly low at certification and in use, well below the Tier 2 PM standards. At the same time EPA sees considerable variation in PM emissions among vehicles of various makes, models, and designs. As a result, EPA is setting the

90 Nam, E.; Fulper, C.; Warila, J.; Somers, J.; Michaels, H.; Baldauf, R.; Rykowski, R.; and Scarbro, C. (2008). Analysis of Particulate Matter Emissions from Light-Duty Gasoline Vehicles in Kansas City, EPA420-R-08-010. Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency Ann Arbor, MI, April 2008.

new FTP PM standard at a level that will ensure that all new vehicles perform at the level already being achieved by well-designed Tier 2 vehicles. The PM standards apply to each vehicle separately (i.e., not as a fleet average). Also, in contrast to the declining NMOG+NOX standards, the PM standard on the FTP for certification testing is 3 mg/mi for all vehicles and for all model years. As for the NMOG+NOX standards, for vehicles over 6000 lbs GVWR, the FTP PM standard applies beginning in MY 2018. Manufacturers can phase in their vehicle models as a percent of U.S. sales through MY 2022. Most vehicles are already performing at this stringent PM level, and the primary intent of the standard is to bring all light-duty vehicles to the typical level of PM performance being demonstrated by many of today's vehicles.

The Tier 3 program also includes a temporary in-use FTP PM standard of 6 mg/mi for the testing of in-use vehicles that applies during the percent phase-in period only. This in-use standard will address the in-use variability and durability uncertainties that accompany the introduction of new technologies. Table I-3 presents the FTP certification and in-use PM standards and the phase-in percentages.

**Table I-3 Phase-In for Tier 3 FTP PM Standards**

| | 2017a | 2018 | 2019 | 2020 | 2021 | 2022 and later |
|---|---|---|---|---|---|---|
| Phase-In (percent of U.S. sales) | 20b | 20 | 40 | 70 | 100 | 100 |
| Certification Standard (mg/mi) | 3 | 3 | 3 | 3 | 3 | 3 |
| In-Use Standard (mg/mi) | 6 | 6 | 6 | 6 | 6 | 3 |

a. For LDVs and LDTs above 6000 lbs GVWR and MDPVs, the FTP PM standards apply beginning in MY 2018.
b. Manufacturers comply in MY 2017 with 20 percent of their LDV and LDT fleet under 6,000 lbs GVWR, or alternatively with 10 percent of their total LDV, LDT, and MDPV fleet.

Finally, the Tier 3 program includes PM standards evaluated over the US06 driving cycle (the US06 is one part of the SFTP procedure) of 10 mg/mi through MY 2018 and of 6 mg/mi for 2019 and later model years, for light-duty vehicles. As in the case of the FTP PM standards, the intent of the US06 PM standard is to bring the emission performance of all vehicles to that already being demonstrated by many vehicles in the current light-duty fleet.

## Heavy-Duty Vehicle Tailpipe Emissions Standards

EPA is setting Tier 3 exhaust emissions standards for complete heavy-duty vehicles (HDVs) between 8,501 and 14,000 lbs GVWR. Vehicles in this GVWR range are often referred to as Class 2b (8,501-10,000 lbs) and Class 3 (10,001-14,000 lbs) vehicles, and are typically heavy-duty pickup trucks and work or shuttle vans. Most are built by companies with even larger light-duty truck markets, and as such they frequently share major design characteristics and emissions control technologies with their LDT counterparts. However, in contrast to the largely gasoline-fueled LDT fleet, roughly half of the heavy-duty pickup and van fleet in the U.S. is diesel-fueled. This is an important consideration in setting emissions standards, as diesel engine emissions control strategies differ from those of gasoline engines.

The key elements of the Tier 3 program for HDVs parallel those being adopted for passenger cars and LDTs, with adjustments in standard levels, emission test requirements, and implementation schedules appropriate to this sector. These key elements include combined NMOG+NOX declining fleet average standards, a phase-in of PM standards, adoption of a new emissions test fuel for gasoline-fueled vehicles, extension of the regulatory useful life to 150,000 miles or 15 years (whichever occurs first), and a first-ever requirement for HDVs to meet standards over an SFTP drive cycle that addresses real-world driving modes not well-represented by the FTP cycles.

EPA is adopting the Class 2b and Class 3 fleet average NMOG+NOX standards shown in Table I-4. The standards become more stringent in successive model years from 2018 to 2022, with voluntary standards made available in 2016 and 2017, all of which are set at levels that match those of California's LEV III program for these classes of vehicles. Each covered HDV sold by a manufacturer in each model year contributes to this fleet average based on the mg/mi NMOG+NOX standard level of the "bin" declared for it by the manufacturer, who chooses from a set of seven discrete Tier 3 bins specified in the regulations. (Table I-4A summarizes the available bin categories for HDVs.) These bin standards then become the compliance standards for the vehicle over its useful life, with some adjustment provided for in-use testing in the early model years of the program.

Manufacturers can also earn credits for fleet average NMOG+NOX levels below the standard in any model year. Tier 3 credits that were previously banked, obtained from other manufacturers, or transferred across the Class 2b/Class 3 categories can be used to help demonstrate compliance. Unused credits expire after 5 model years.

Manufacturers will also be allowed to carry forward deficits in their credit balance for up to 3 model years.

### Table I-4 Tier 3 HDV Fleet Average FTP NMOG+NOX Standards (mg/mi)

| Voluntary | | | | Required Program | | | | |
|---|---|---|---|---|---|---|---|---|
| Model Year | 2016 | 2017 | | 2018 | 2019 | 2020 | 2021 | 2022 and later |
| Class 2b | 333 | 310 | | 278 | 253 | 228 | 203 | 178 |
| Class 3 | 548 | 508 | | 451 | 400 | 349 | 298 | 247 |

### Table I-4A FTP Standard Bins for HDVs

| | NMOG+NOX (mg/mi) | PM (mg/mi) | CO (g/mi) | Formaldehyde (mg/mi) |
|---|---|---|---|---|
| Class 2b (8501-10,000 lbs GVWR): | | | | |
| | | | | |
| Bin 395 (interim) | 395 | 8 | 6.4 | 6 |
| Bin 340 (interim) | 340 | 8 | 6.4 | 6 |
| Bin 250 | 250 | 8 | 6.4 | 6 |
| Bin 200 | 200 | 8 | 4.2 | 6 |
| Bin 170 | 170 | 8 | 4.2 | 6 |
| Bin 150 | 150 | 8 | 3.2 | 6 |
| Bin 0 | 0 | 0 | 0 | 0 |
| Class 3 (10,001-14,000 lbs GVWR): | | | | |
| Bin 630 (interim) | 630 | 10 | 7.3 | 6 |
| Bin 570 (interim) | 570 | 10 | 7.3 | 6 |
| Bin 400 | 400 | 10 | 7.3 | 6 |
| Bin 270 | 270 | 10 | 4.2 | 6 |
| Bin 230 | 230 | 10 | 4.2 | 6 |
| Bin 200 | 200 | 10 | 3.7 | 6 |
| Bin 0 | 0 | 0 | 0 | 0 |

EPA is adopting the FTP PM standards of 8 mg/mi and 10 mg/mi for Class 2b and Class 3 HDVs, respectively, phasing in as an increasing percentage of a manufacturer's sales per year. EPA is adopting the same phase-in schedule as for the light-duty sector during model years 2018-2019-2020-2021: 20-40-70-100 percent, respectively, and a more flexible but equivalent alternative PM phase-in is also being adopted. Tier 3 HDVs will also be subject to CO and formaldehyde exhaust emissions standards that are more stringent than the existing standards.

Finally, EPA is setting first-ever nationwide SFTP standards for HDVs to ensure a robust overall control program that precludes high off-FTP cycle emissions by having vehicle designers consider them in their choice of compliance strategies. As for light-duty vehicles, EPA is requiring that SFTP compliance be based on a weighted composite of measured emissions from testing over the FTP cycle, the SC03 cycle, and an aggressive driving cycle, with the latter tailored to various HDV sub-categories: the US06 cycle for most HDVs, the highway portion of the US06 cycle for low power-to-weight Class 2b HDVs, and the LA-92 (or "Unified") cycle for Class 3 HDVs. The SFTP standards are the same as those adopted for California LEV III vehicles, and apply to NMOG+NOX, PM, and CO emissions.

## Evaporative Emission Standards

Gasoline vapor emissions from vehicle fuel systems occur when a vehicle is in operation, when it is parked, and when it is being refueled. These evaporative emissions, which occur on a daily basis from gasoline-powered vehicles, are primarily functions of temperature, fuel vapor pressure, and activity. EPA first instituted evaporative emission standards in the early 1970s to address emissions when vehicles are parked after being driven. These are commonly referred to as hot soak plus diurnal emissions. Over the subsequent years the test procedures have been modified and improved and the standards have become more numerically stringent. EPA has addressed emissions which arose from new fuel system designs by putting in place new requirements such as running loss emission standards and test procedure provisions to address permeation emissions. Subsequently standards were put in place to control refueling emissions from all classes of gasoline-powered motor vehicles up to 10,000 lbs GVWR. Evaporative and refueling emission control systems have been in place for most of these vehicles for many years. These controls have led to significant reductions, but evaporative and refueling emissions still constitute 30-40 percent of the summer on-highway mobile source hydrocarbon inventory. These fuel vapor emissions are ozone and PM precursors, and also contain air toxics such as benzene.

To control evaporative emissions, EPA is establishing more stringent standards that will require covered vehicles to have essentially zero fuel vapor emissions in use. These include more stringent evaporative emissions standards, new test procedures, and a new fuel/evaporative system leak emission standard. The program also includes refueling emission standards for all complete heavy-duty gasoline vehicles (HDGVs) over 10,000 lbs GVWR. EPA is including phase-in flexibilities as well as credit and allowance programs. The standards, harmonized with California's "zero evap" standards, are designed to allow for a use of common technology in vehicle models sold throughout the U.S. The level of the standard remains above zero to account for nonfuel background emissions from the vehicle hardware.

Requirements to meet the Tier 3 evaporative emission regulations phase in over a six model year period. EPA is finalizing three options for the 2017 model year, but after that the sales percentage requirements are 60 percent for MYs 2018 and 2019, 80 percent for model years 2020 and 2021, and 100 percent for model years 2022 and later. In

Table I-5 EPA presents the Tier 3 evaporative hot soak plus diurnal emission standards by vehicle class. The standards are approximately a 50 percent reduction from the existing standards. To enhance flexibility and reduce costs, EPA is finalizing provisions that allow manufacturers to generate allowances through early certifications (basically before the 2017 model year) and to demonstrate compliance using averaging concepts. Manufacturers may comply on average within each of the four vehicle categories, but not across these categories. EPA is not making any changes to the existing light-duty running loss or refueling emission standards, with the exception of the certification test fuel requirement discussed below.

**Table I-5 Tier 3 Evaporative Emission Standards (g/test)**

| Vehicle Class | Highest Hot Soak + Diurnal Level |
|---|---|
| | (Over both 2-day and 3-day diurnal tests) |
| LDV, LDT1 | 0.300 |
| LDT2 | 0.400 |
| LDT3, LDT4, MDPV | 0.500 |
| HDGVs | 0.600 |

Flexible Fuel Vehicles (FFVs) must meet the same evaporative emission standards as non-FFVs using Tier 3 emissions certification test fuel. However, FFVs must meet the refueling emission standards using 10 psi RVP fuel to account for emissions resulting from commingling with non-E85 blends that may be in the vehicle's fuel tank.

EPA is establishing the canister bleed emission test procedure and emission standard to help ensure fuel vapor emissions are eliminated. Under this provision, manufacturers are required to measure diurnal emissions over the 2-day diurnal test procedure from just the fuel tank and the evaporative emission canister and comply with a 0.020 gram per test (g/test) standard for all LDVs, LDTs, and MDPVs, without averaging. The corresponding canister bleed test standard for HDGVs is 0.030 g/test. The Tier 3 evaporative emission standards will be phased in over a period of six model years between MY 2017 and MY 2022, with the leak test phasing in beginning in 2018.

Data from in-use evaporative emissions testing indicates that vapor leaks from vehicle fuel/evaporative systems are found in the fleet and that even very small leaks have the potential to make significant contributions to the mobile source VOC inventory. To help address this issue, EPA is also adding a new standard and test procedure to control vapor leaks from vehicle fuel and vapor control systems. The standard will prohibit leaks with a cumulative equivalent diameter of 0.02 inches or greater. EPA is adding this simple and inexpensive test and emission standard to help ensure vehicles maintain zero fuel vapor emissions over their full useful life. New LDV, LDT, MDPV, and HDGV equal to or less than 14.000 lbs GVWR meeting the Tier 3 evaporative emission regulations are also required to meet the leak standard beginning in the 2018 model year. Manufacturers must comply with the leak standard phase-in on the same percentage of sales schedule as that for the Tier 3 evaporative emission standards. Manufacturers will comply with the leak emission standard during certification and in use. The leak emission standard does not apply to HDGVs above 14,000 lbs GVWR.

EPA is also establishing new refueling emission control requirements for all complete HDGVs equal to or less than 14,000 lbs GVWR (i.e., Class 2b/3 HDGVs), starting in the 2018 model year, and for all larger complete HDGVs by the 2022 model year. The existing refueling emission control requirements apply to complete Class 2b HDGVs, and EPA is extending those requirements to other complete HDGVs, since the fuel and evaporative control systems on these vehicles are very similar to those on their lighter-weight Class 2b counterparts.

## Onboard Diagnostic Systems (OBD)

EPA and CARB both have OBD regulations applicable to the vehicle classes covered by the Tier 3 emission standards. In the past the requirements have been very similar, so most manufacturers have met CARB OBD requirements and, as permitted in EPA regulations, EPA has generally accepted compliance with CARB's OBD requirements as satisfying EPA's OBD requirements. Over the past several years CARB has upgraded its requirements to help improve the effectiveness of OBD in ensuring good in-use exhaust and evaporative system emissions performance. EPA has reviewed these provisions and agree with CARB that these revisions will help to improve in-use emissions performance, while at the same time harmonizing with the CARB program. Toward that end, EPA is adopting and incorporating by reference the current CARB OBD regulations, effective for the 2017 MY, with a few minor differences including phase-in flexibility provisions and specific additions to enhance the implementation of the leak standard. EPA is retaining the provision that certifying with CARB's program would permit manufacturers to seek a separate EPA certificate on that basis.

## Emissions Test Fuel

After reassessing market trends and considering comments, EPA is finalizing E10 as the ethanol blend level in emissions test gasoline for Tier 3 light-duty and heavy-duty gasoline vehicles. EPA will continue to monitor the in-use gasoline supply and based on such review may initiate rulemaking action to revise the specifications for emissions test fuel to include a higher ethanol blend level. EPA is also making additional changes that are consistent with CARB's LEV III emissions test fuel specifications, including new specifications for octane, distillation temperatures, aromatics, olefins, sulfur and benzene.

EPA is requiring certification of all Tier 3 light-duty and chassis-certified heavy-duty gasoline vehicles on federal E10 test fuel. The new test fuel specifications will apply to new vehicle certification, assembly line, and in-use testing.

With a change in the ethanol content of the test fuel, EPA also needed to consider whether a change is warranted in the volatility of the test fuel, typically expressed as pounds per square inch (psi) Reid Vapor Pressure (RVP). After considering several technical and policy implications as well as stakeholder comments, EPA has concluded that the most appropriate approach is to maintain an RVP of 9 psi for the E10 certification fuel at this time.

In addition to finalizing a new E10 emissions test fuel, EPA is also finalizing detailed specifications for the E85 emissions test fuel used for flexible fuel vehicle (FFV) certification. [91] This will resolve uncertainty and confusion in the certification of FFVs designed to operate on ethanol levels up to 83 percent. Furthermore, EPA allows vehicle manufacturers to request approval for an alternative certification fuel such as a high-octane 30 percent ethanol by volume blend (E30) for vehicles that may be optimized for such fuel.

## Fuel Standards

Under the Tier 3 fuel program, gasoline must contain no more than 10 ppm sulfur on an annual average basis beginning January 1, 2017. Similar to the Tier 2 gasoline program, the Tier 3 program will apply to gasoline in the U.S. and the U.S. territories of Puerto Rico and the Virgin Islands, excluding California. The program will result in gasoline that contains, on average, two-thirds less sulfur than it does today. In addition, following discussions with numerous refiners and other segments of the fuel market (e.g., pipelines, terminals, marketers, ethanol industry representatives, transmix processors, additive manufacturers, etc.), the Tier 3 fuel program contains considerable flexibility to ease both initial and long-term implementation of the program. The program that EPA is finalizing includes an averaging, banking, and trading (ABT) program that allows refiners and importers to spread out their investments over nearly a 6 year period through the use of an early credit program and then rely on ongoing nationwide averaging to meet the 10 ppm sulfur standard. In addition there is a three-year delay for small refiners and "small volume refineries". As a result of the early credit program, EPA anticipates considerable reductions in gasoline sulfur levels prior to 2017, with a complete transition to the 10 ppm average occurring by January 1, 2020.

Under the Tier 3 gasoline sulfur program, EPA is maintaining the current 80 ppm refinery gate and 95 ppm downstream per-gallon caps. EPA also evaluated and sought

91 Flexible fuel vehicles are currently required to meet emissions certification requirements using both E0 and E85 test fuels. However, there were no detailed regulatory specifications regarding the composition of E85 test fuels before those finalized today.

comment on the potential of lowering the per-gallon caps. While there are advantages and disadvantages with each of the sulfur cap options that EPA proposed, EPA believes that retaining the current Tier 2 sulfur caps is prudent at this time. Further, the stringency of the 10 ppm annual average standard will result in reduced gasoline sulfur levels nationwide. The program requires that manufacturers of gasoline additives that are used downstream of the refinery at less than 1 volume percent must limit the sulfur contribution to the finished gasoline from the use of their additive to less than 3 ppm when the additive is used at the maximum recommended treatment rate. This requirement will preclude the unnecessary use of high sulfur content additives in gasoline.

## Other relevant references:


- *http://www.meca.org/resources/reports*
- *http://www.epa.gov/airtrends/2011/*
- *http://www.ec.gc.ca/rnspa-naps/77FECF05-E241-4BED-8375-5A2A1DF3688C/NAPS_Annual_Report_August2013_E.pdf*
- *http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=1F4E5D8A-1*
- *http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=27256118-1*
- *http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=82CB88DE-1*
- *http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=7A8F92ED-1*
- *http://www.ec.gc.ca/Air/default.asp?Lang=En&n=DDBB166E-1*
- *http://www.ec.gc.ca/Air/default.asp?lang=En&n=800CCAF9-1*
- *http://www.tbs-sct.gc.ca/rtrap-parfa/gfrpg-gperf/gfrpg-gperftb-eng.asp*
- *http://www.ec.gc.ca/rnspa-naps/*
- *http://www.tbs-sct.gc.ca/rtrap-parfa/gfrpg-gperf/gfrpg-gperftb-eng.asp*
- *http://www.airnow.gov/*
- *http://www.airqualityontario.com/science/pollutants/ozone.php*
- *https://ec.gc.ca/cas-aqhi/*
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- *http://retireyourride.ca/*
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