Environmental Protection Department

Agreement No CE 57/2006 (EP) Review of Air Quality Objectives and Development of a Long Term Air Quality Strategy for Hong Kong - Feasibility Study

Final Report

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Final Report

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Contents

1 Introduction

1.1 Objectives and Scope

The Hong Kong Air Quality Objectives (AQO) are established under the Air Pollution Control Ordinance (Cap. 311) (hereafter referred to as "APCO"). They are a set of concentration limits for seven common air pollutants (namely sulphur dioxide (SO_2), nitrogen dioxide (NO_2), total suspended particulates (TSP), respirable suspended particulates (RSP), carbon monoxide (CO), ozone (O_3) and lead in the ambient air for promoting the conservation and best use of air in the public interest. Thus, a primary objective of the AQO is protection of public health.

The current AQO was established in 1987 making reference to the air quality standards of the USA at that time. Since then, there have been new research findings on the health implications of air pollution. Taking account of these findings, the World Health Organization (WHO) announced in 2006 its Air Quality Guidelines (AQG) update, which can provide guidance to countries/economies to develop/update their air quality standards. Countries such as the USA and the European Union have also updated or been updating their air quality standards.

In view of the above developments, the Environmental Protection Department of the Hong Kong SAR Government (hereafter referred to as "the EPD") has commissioned this study (hereafter referred to as "the Study") to review the AQO and develop a long-term air quality management strategy. The objective of the Study is to assess the need for and the implications of revising the AQO as well as to identify options and propose alternative strategies and plans needed for achieving the revised AQO. Below is the scope of the Study:

- Review and characterise the current state of air quality in Hong Kong, including the prevailing exposure levels, developing trends, major pollution sources and origins, the impacts of external and non-anthropogenic sources on Hong Kong's air quality, as well as policies, programmes and legislation in place for controlling air pollution and the costs and implication due to air pollution;
- Examine and make reference to the different reasoning of the WHO and the US EPA in devising their respective air quality guidelines or standards, including concrete research results on long-term and short-term health impacts;
- Use methods including air modelling to assess air quality under different scenarios and with mitigation measures adopted; to recommend specific measures required and options available to achieve interim targets and the standards if the new WHO AQG are to be adopted; to examine in depth the need for co-operation with neighbouring cities and provinces;
- Assess the implications of implementing the measures identified under different options, including economics and social costs, the time required for introducing the measures, the need to work with the Mainland and other air quality management authorities outside Hong Kong as well as impacts on other policy areas such as energy, transportation, industrial development, urban planning and conservation;
- Derive practicable options to revise Hong Kong's AQO, including whether it is necessary to have different targets for roadside air quality, and to identify strategies and measures required in the form of action plan to achieve the revised AQO, with implications identified for each option, so as to facilitate public participation and comments; and
- Review the need and means to harmonize air quality monitoring data and air pollution indices with other economically advanced cities to facilitate fair comparison.

To steer the Study, the EPD has set up an Advisory Panel, which is chaired by the Permanent Secretary for the Environment/Director of Environmental Protection and has members comprising renowned academics, medical professionals, industrial stakeholders and representatives from various bureaux. The membership of the Advisory Panel is presented in **Appendix A**.

This study does not cover greenhouse gases such as carbon dioxide and toxic air pollutants (TAP) such as chemical carcinogens. For the former, the issues on climate changes and greenhouse gases are being addressed separately in another study, also commissioned by the EPD. For the latter, the EPD study on "Assessment of Toxic Air Pollutant Measurements in Hong Kong" and the monitoring by EPD have indicated that the ambient levels of the TAP are low.

1.2 Public Engagements

In addition to prevailing international practices, a good understanding of the local perspectives and aspirations on air quality is of equal importance. As part of the Study, three public engagement fora were conducted. Two were conducted in the early stages of the Study – one for professionals on 18 December 2007, and one for the general public on 31 January 2008 - to gauge their views on what AQO and air quality management strategy will best suit our society. The feedback revealed a strong support for prompt actions to clean up air pollution and expectation of the AQO to provide better protection to public health. The other public engagement forum was held on 20 March 2009 to present the initial findings of the Study. The feedback revealed again the strong desire for prompt and effective actions to clean up air pollution and a set of new AQO to better protect public health.

The views and opinions expressed during the fora have been summarized and presented in **Appendix B**. They have been fully considered and incorporated in this study.

1.3 Background

1.3.1 Legal Framework of Hong Kong SAR

The Air Pollution Control Ordinance (APCO) (Cap 311) is the principal legislation for managing air quality. Regulations under the Ordinance covers specific areas related to air pollution, such as power plant emissions, motor vehicle fuel and emissions, and industrial emissions.

Under section 7 of the APCO, the Secretary of Environment is empowered to promulgate AQO with a Technical Memorandum. These AQO are statutory objectives for promoting the conservation and best use of air in the public interest. The protection of public health, even though not stated explicitly, is already a key consideration because to do otherwise will not be in the "public interest".

The current AQO were established in Year 1987 for 7 major air pollutants, i.e. sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), lead (Pb), total suspended particulates (TSP) and respirable suspended particulates (RSP), by referencing to the health protection criteria established by the US Environmental Protection Agency at that time. Details of these AQO are presented in **Table 1.1.**

Table 1.1: The current Hong Kong Air Quality Objectives

Pollutant	Concentration in micrograms per cubic metre[1]							
	1 Hour	No. of Ex. [2]	8 Hours	No. of Ex.[2]	24 Hours	No. of Ex.[2]	3 Months	1 Year
Sulphur Dioxide	800	3			350	1		80
Total Suspended					260	1		80

Pollutant	Concentration in micrograms per cubic metre[1]							
	1 Hour	No. of Ex. [2]	8 Hours	No. of Ex.[2]	24 Hours	No. of Ex.[2]	3 Months	1 Year
Particulates								
Respirable Suspended Particulates[3]					180	1		55
Carbon Monoxide	30,000	3	10,000	1				
Nitrogen Dioxide	300	3			150	1		80
Photochemical Oxidants (as ozone)[4]	240	3						
Lead							1.5	

Notes:

[1] Measured at 298K(25 ^{o}C) and 101.325 kPa (one atmosphere).

[2] Number of exceedences allowed.

[3] Respirable suspended particulates mean suspended particles in air with nominal aerodynamic diameter of 10 micrometres or smaller.

[4] Photochemical oxidants are determined by measurement of ozone only.

1.3.2 Statutory Roles of AQO

To enable the Air Pollution Control Authority to fulfil the statutory requirement to achieve and maintain the air quality as prescribed by the AQO, the Authority will have to consider compliance with AQO when deciding on the application of permits for specified process such as power plants. Under the Environmental Impact Assessment Ordinance, compliance with AQO is also a key consideration in deciding on the issue of environmental permits for designated development projects.

1.3.3 Emission Targets

In April 2002, the Hong Kong Special Administrative Region (HKSAR) Government and the Guangdong Provincial Government reached a consensus to reduce on a best endeavour basis the anthropogenic emissions of a number of pollutants. These included sulphur dioxide (SO_2), nitrogen oxides (NO_X), respirable suspended particulates (PM_{10}) [also known as RSP] and volatile organic compounds (VOC) by 40%, 20%, 55% and 55% respectively in the Pearl River Delta (PRD) Region (i.e. covering the PRD Economic Zone in Guangdong and the HKSAR) by 2010, using 1997 as the base year. The Guangdong Provincial Government published the PRD Environmental Protection Planning Outline (2004 – 2020) < 珠江三角洲环境保护规划纲要（2004-2020 年）>实施方案》in Yr 2005. The plan outlines the environmental strategies and emission targets to be achieved by Yr 2020. For SO_2, NO_X and RSP, their emission targets are 358,000, 395,000 and 270,000 tonnes respectively by Yr 2020.

2 State of Hong Kong Air Quality

This section analyses the trend of local emissions and air quality. The analysis will help identify major areas, where emission reduction efforts should be made for further air quality improvement.

2.1 Existing Air Quality Management Strategy

To achieve the AQO, Hong Kong has developed and implemented air quality management strategies on air quality, including:

- Implementing a wide range of measures to control emissions from motor vehicles, power plants, and industrial and commercial processes locally.
- Working with Guangdong Provincial Authorities to implement a joint plan to tackle the regional air quality problem.
- Imposing emission reduction target for the power plants.
- Keeping in pace with Euro standards for vehicular emission.
- Reviewing the effectiveness of implemented air quality strategies.
- Promoting energy efficiency.
- Imposing restrictions on ship emissions of harmful substances such as ozone-depleting substances, VOC, NO_X and SO_2.

To improve local and regional air quality, the Hong Kong SAR Government reached a consensus with Guangdong Provincial Government in April 2002 to reduce, on a best endeavour basis, the emission of SO_2, NO_X, RSP and VOC by 40%, 20%, 55% and 55% respectively in the region by 2010, using 1997 as the base year. It is expected that the achievement of these targets will enable Hong Kong to meet our current AQO, significantly improve the air quality of the PRD region and relieve the regional smog problem.

In December 2003, the two governments jointly drew up the PRD Regional Air Quality Management Plan (the "Management Plan") with a view to meeting the above emission reduction targets. The PRD Air Quality Management and Monitoring Special Panel was set up under the Hong Kong/Guangdong Joint Working Group on Sustainable Development and Environmental Protection (JWG) to follow up on the tasks under the Management Plan. The PRD Regional Air Quality Monitoring Network established under the Management Plan is now in full operation to provide comprehensive and accurate air quality data.

In the Policy Address 2008-09[1], the Government has stated that it is considering to pressing ahead with sustainable development. It has recognized that there is a need to work hand-in-hand with neighbouring areas to foster the development of an economy that is based on low energy consumption and low pollution in the PRD Region. To further strengthen the co-operation on environmental protection, the Government has reached a consensus with the Guangdong Provincial Government on jointly transforming the PRD Region into a green and quality living area under the principle of promoting environmental protection and sustainable development. The goal is to enhance the appeal and competitiveness of the Province and the Region. To achieve this goal, Hong Kong and Guangdong will work together in the areas of post-2010 emission reduction arrangements, the optimization of the fuel mix for power generation, the development and wider use of renewable energy, vehicle emissions reductions, enhanced conservation and greening, scientific research, as well as publicity and education.

The air quality related legislation and policy in Hong Kong and China are shown in **Appendix C**.

2.2 Emissions

Since the early 90s, Hong Kong has been taking actions to reduce the emission of air pollutants from major sources such as power plants, polluting industrial activities and motor vehicles. As a result, the emissions of key air pollutants such as SO_2, NO_X, RSP, non-methane volatile organic compounds and CO have fallen by 55% to 83% from their peaks. Details are presented in the subsequent paragraphs.

2.2.1 Sulphur Dioxide

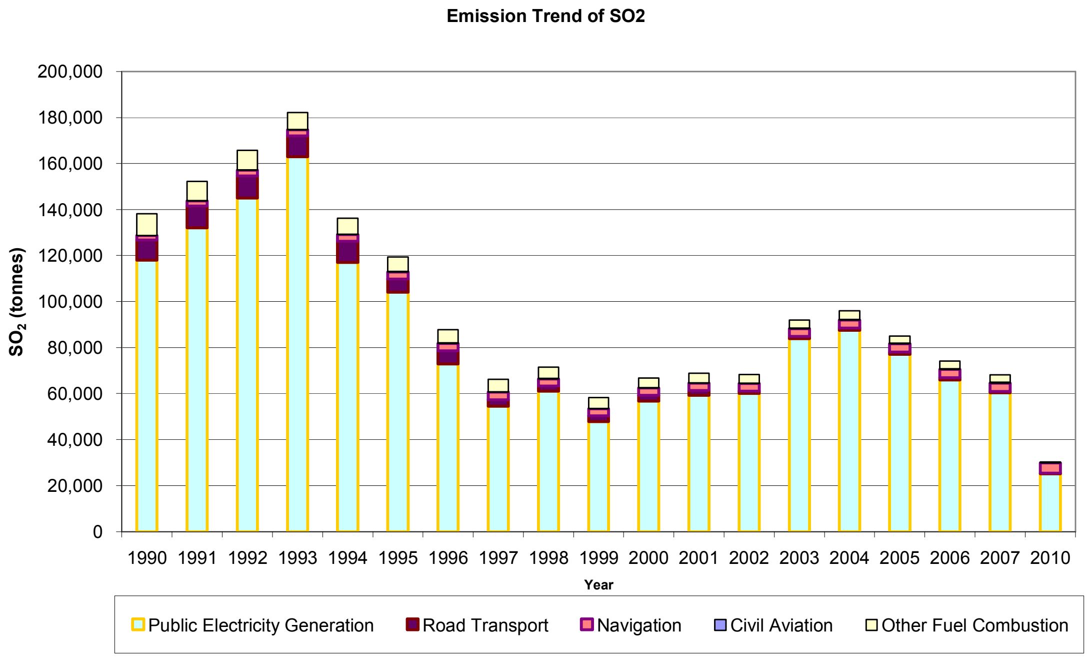
The emission trend for SO_2 is illustrated in **Figure 2.1**. Subsequent to a decrease in SO_2 emission from Year 1993 to Year 1997, the level of SO_2 was roughly stabilised between Year 1997 and Year 2002 before it rebounded in Year 2003 and Year 2004. After Year 2004, the SO_2 emission decreased again. As a whole, the amount of SO_2 in the territory reduced by more than a half from 182,000 tonnes/year in Year 1993 to 68,100 tonnes/year in Year 2007. Achieving the emission reduction target agreed between Hong Kong and Guangdong would further cut the emission of SO_2 to around 30,200 tonnes by Year 2010.

Public electricity generation is the primary source of SO_2 emission. It contributed to 89 % of the total emission in Year 2007. There was a sharp reduction in Year 1994 due to the intake of nuclear electricity from Daya Bay. The use of natural gas and the installation of flue gas desulphurization units at coal-fired power generating units had further reduced the emissions from Year 1995 to Year 1999. The rise in Year 2003 and Year 2004 was due to the increased power generation from coal-fired units. Since Year 2005, emission caps had been set in licences of power plants and the emissions in Year 2007 decreased by 9 % from 2006.

Road transport was once an important source of SO_2, particularly to the roadside, together with other fuel combustion sources. Road transport constituted about 6% of SO_2 emission before the implementation of Air Pollution Control (Motor Vehicle Fuel) Regulations in Year 1995 for controlling motor vehicle fuel quality. The emission of SO_2 from this source was further reduced to around 2040 tonnes/year (i.e. around 3% of the total emission) following the introduction of ultra low sulphur diesel for vehicle fleet in Year 2000. Regarding other fuel combustion sources, there was a declining trend in SO_2 emission in general since the introduction of the Air Pollution Control (Fuel Restriction) Regulations in Year 1990 for cutting sulphur content of industrial fuels.

Navigation was minor sources of SO_2 comprising a total of less than 1.4% of the emission in early 1990s. Nevertheless, there was a rising trend of emission attributed to the development of Hong Kong into a major regional transportation hub. In fact, navigation has become the second most important emission source of SO_2 since Year 2003 and constituted nearly 5.4% on its own in Year 2007.

Figure 2.1: Emission trend of SO_2 in HKSAR



2.2.2 Nitrogen Oxides

The emission trend for NO_X is illustrated in **Figure 2.2**. There was a declining trend in NO_X from Year 1992 to Year 2002 in general, with a reduction of 56% emission from 224,000 tonnes/year in Year 1992 to 97,600 tonnes/year in Year 2002, in spite of occasional mild fluctuations in Year 1995 and Year 2000. However, the level of NO_X in the territory rebounded after Year 2002 due to the increase in power generation from coal-fired power generating units. Subsequent to a decrease in NO_X emission in Year 2004, the level of NO_X was roughly stabilised between Year 2004 and Year 2007. Achieving the emission reduction target agreed between Hong Kong and Guangdong would further cut the emission of NO_X to around 92,800 tonnes by 2010.

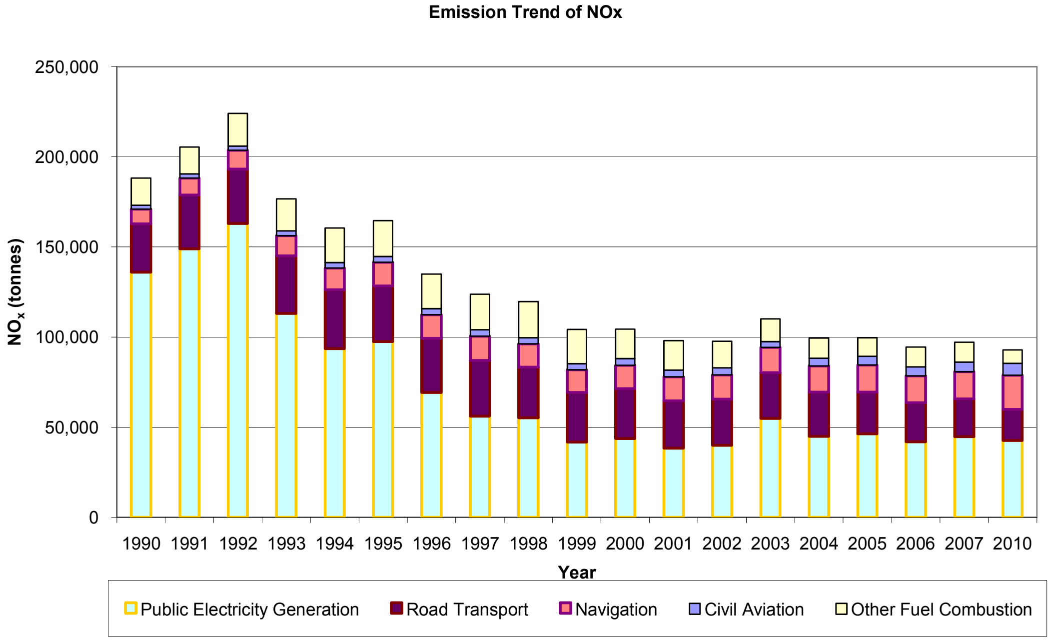
Public electricity generation was the major source of NO_X emissions. It contributed to 46 % of the total emission in Year 2007. Since the implementation of a low NO_X burner programme at coal-fired power generating units in Year 1993, emissions have reduced drastically. The increase in Year 2003 and Year 2004 was due to the increased power generation from coal-fired units. Since Year 2005, emission caps had been set in the licenses of power companies. The emissions in Year 2007 increased by 7% from Year 2006 due to the increased use of coal-fired generating units.

Emission from vehicles was one of the major sources of NO_X emission. It contributed to 22% of the total emission in Year 2007. The tightening of vehicle emission standards progressively from Euro I in Year 1995 to Euro IV in Year 2006 have had apparent effects on NO_X reduction. For instance, NO_X emission from a Euro IV vehicle was about 60% lower than a Euro I vehicle. The various incentive schemes launched in Year 2007 to encourage owners to early phase-out their pre-Euro and Euro I commercial vehicles or to switch to new environmental friendly petrol private cars have also helped to reduce emissions.

Navigation was another important source of NO_X. A rising trend in its relative significance to NO_X in the territory was noted, increasing gradually from about 4% (early 1990s), 10% (mid 1990s) to 15.5% (Year 2007). A similar trend of increase was also seen for civil aviation, but to a lesser extent. The increased emission of NO_X from these sources was attributed to the development of Hong Kong into a major regional transportation hub. Other fuel combustion sources were minor to NO_X emission, with a declining trend from Year 1998 to

Year 2007 for more than 45% (i.e. from 20,100 tonnes/year in Year 1998 to 11,000 tonnes/year in Year 2007).

Figure 2.2: Emission trend of NO_X in HKSAR



2.2.3 Particulate Matter (PM)

The emission trend for PM is illustrated in **Figure 2.3**. A declining trend in particulate matter emission was observed in general from Year 1993 to Year 2003 in Hong Kong, with occasional fluctuations in Year 1995 and Year 2000. The amount of particulate matter in the territory has shown a slight rebound in Year 2004, due to an increase in power generation from coal-fired power generating units. Afterwards, there was a drop in particulates emission. Particulate matter released into the atmosphere was reduced by more than half from some 12,600 tonnes/year in early 1990's to 5,640 tonnes/year in Year 2007. Achieving the emission reduction target agreed between Hong Kong and Guangdong would further cut the emission of PM to around 4,737 tonnes by Year 2010.

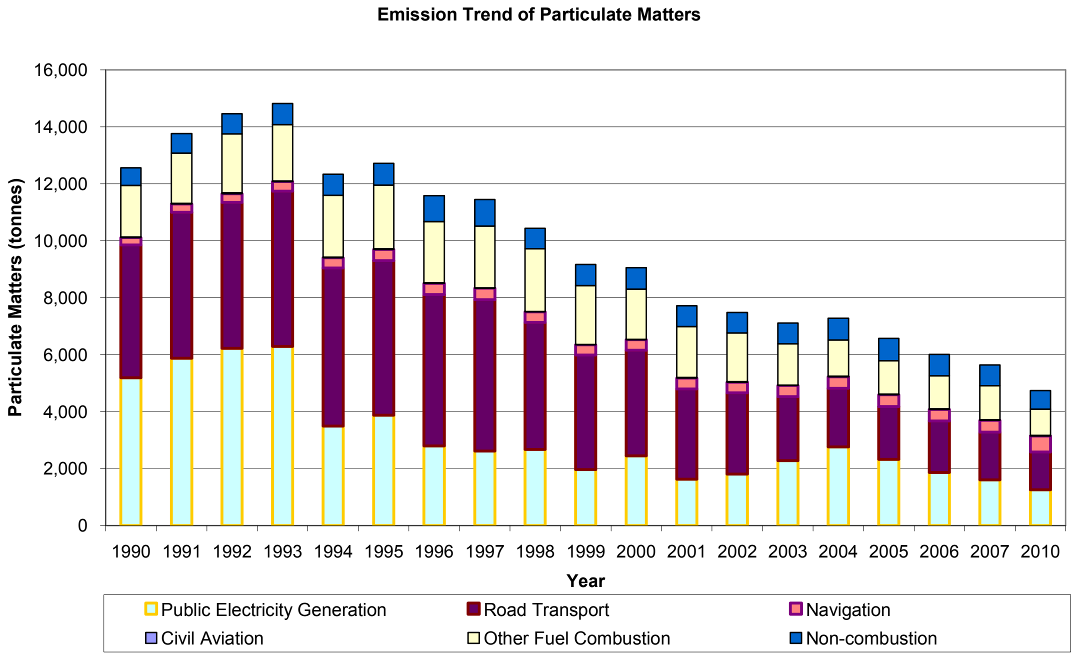
Public electricity generation is one of the major sources of PM emission. It contributed to 28% of total emission in Year 2007. The import of nuclear electricity from Daya Bay of the Mainland in 1994 and the use of natural gas for power generation since 1995 resulted in a downward emission trend. The increase in Year 2003 and Year 2004 was due to the increased power generation from coal-fired units. Since Year 2005, emission caps have been set in the licenses of the power plants and the emissions in Year 2007 decreased by 14% from Year 2006.

Road transport is one of the major sources of PM emissions. It contributed to 30% of total emissions in Year 2007. The implementation of a series of control measures, namely, the tightening of vehicle emission standards progressively from Euro I in Year 1995 to Euro IV in Year 2006, the incentive scheme to replace diesel taxis with LPG in Year 2000, the incentive scheme to replace diesel minibuses with LPG/ electric in Year 2002, and the incentive scheme to install particulate filter at pre-Euro diesel vehicles from Year 2002 to Year 2005, have reduced PM emissions from road transport in recent years. The various incentive schemes launched in Year 2007 to encourage owners to early phase-out their pre-Euro and Euro I commercial vehicles also helped reduce the emissions.

Non-combustion sources contributed about 5% - 13% emission of particulate matter from Year 1990 to Year 2007. It should be noted that the relative significance of these sources has been increasing gradually. Other fuel combustion, navigation and civil aviation were comparatively minor sources of particulate matter comprising a total of about 8% of their emission based on Year 2007 data. The emission from other fuel combustion has been reducing steadily since Year 1992. Alternatively, increasing trends in emissions from navigation was observed and attributable to the continuous development of Hong Kong into a major regional transportation hub.

Navigation was another important source of PM. A rising trend in its relative significance to PM in the territory was noted, increasing gradually from about 2.1% (early 1990s), 3.4% (mid 1990s) to 7.4% (2007). A similar increasing trend was also noticed for civil aviation, but to a lesser extent. The increased emission of PM from these sources was also attributed to the development of Hong Kong into a major regional transportation hub.

Figure 2.3: Emission trend of PM in HKSAR



2.2.4 Non-methane VOC (NMVOC)

The emission trend for NMVOC is illustrated in **Figure 2.4**. Following the plateau of VOC emission of some 69,000 tonnes/year between Year 1995 and Year 1997, a generally declining trend was observed thereafter. The amount of NMVOC in the territory was further stabilised between Year 2002 and Year 2004. Afterwards, there was a drop on NMVOC at around 42% reduction in VOC emission from Year 1997 (68,800 tonnes/year) to Year 2007 (39,700 tonnes/year). Achieving the emission reduction target agreed between Hong Kong and Guangdong would further cut the emission of VOC to around 31,000 tonnes by Year 2010.

Non-combustion sources and road transport were highly significant to the concentration of VOC in the territory, which contributed to an average of 75% and 20% of emissions respectively (i.e. 95% in total) in Year 1990. The relative significance of non-combustion sources to VOC emissions had been maintained at a level of some 70% until Year 2002, which then increased gradually and reached 75% in Year 2007. The major components of non-combustion sources consist of consumer product, paints and solvents.

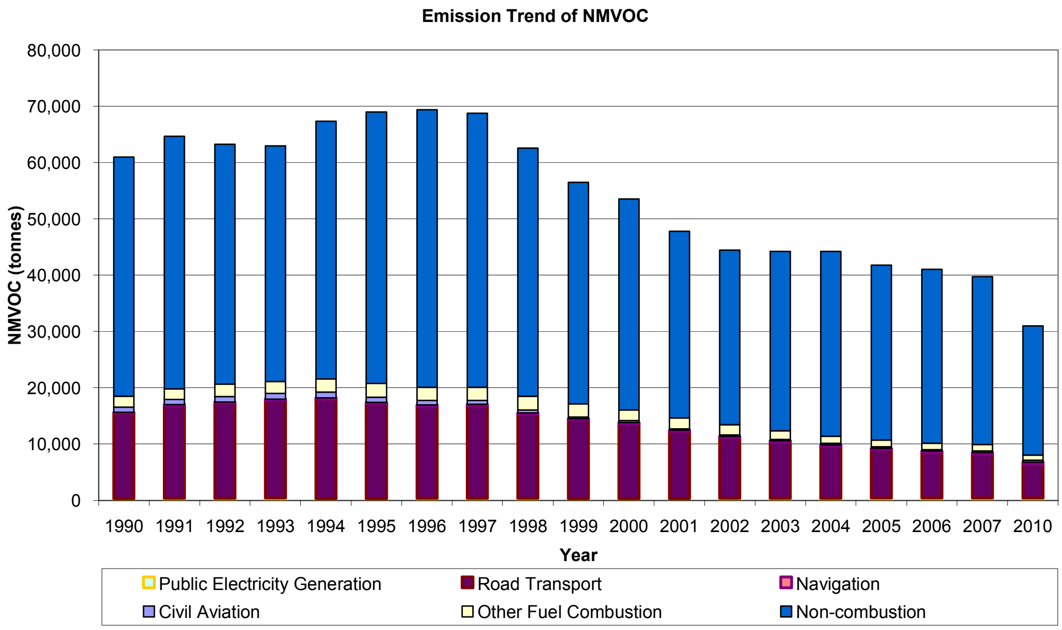
Emissions from consumer products is one of the major sources of VOC. It contributed to about 30% of the total emission in Year 2007. Starting from 1 April 2007, new legislation has been enacted to impose statutory limits on the VOC content of six categories of consumer products, namely hairspray, air freshener, insecticide, insect repellent, floor wax stripper and multi-purpose lubricant. Emissions from paints and solvents are one of the major sources of

VOC and contributed about 24% of the total emission in Year 2007. Starting from 1 April 2007, a new legislation has been enacted to impose statutory limits on the VOC content of 51 categories of architectural paints, to take effect in three phases, starting from 1 January of 2008, 2009 and 2010 respectively.

The percentage contribution of road transport to VOC dropped progressively from 25% in late 1990s to 20% in Year 2007. The tightening of vehicle emission standards progressively from Euro I in 1995 to Euro IV in Year 2006 and the evaporative emission standard for newly registered vehicles in 1999 have reduced VOC emissions in recent years. The various incentive schemes launched in Year 2007 to encourage owners to early phase-out their pre-Euro and Euro I commercial vehicles or to switch to new environmental friendly petrol private cars also helped reduce the emissions.

Other sources like civil aviation, public electricity generation, navigation and other fuel combustion (in descending order) were comparatively minor to the emission of VOC constituting a total of 2-3%. Since a significant portion of VOC originated from non-combustion sources, such as consumer products, paint and printing, it is anticipated that its level could be further reduced following the recent implementation of VOC Regulation under the Air Pollution Control Ordinance.

Figure 2.4: Emission trend of NMVOC in HKSAR

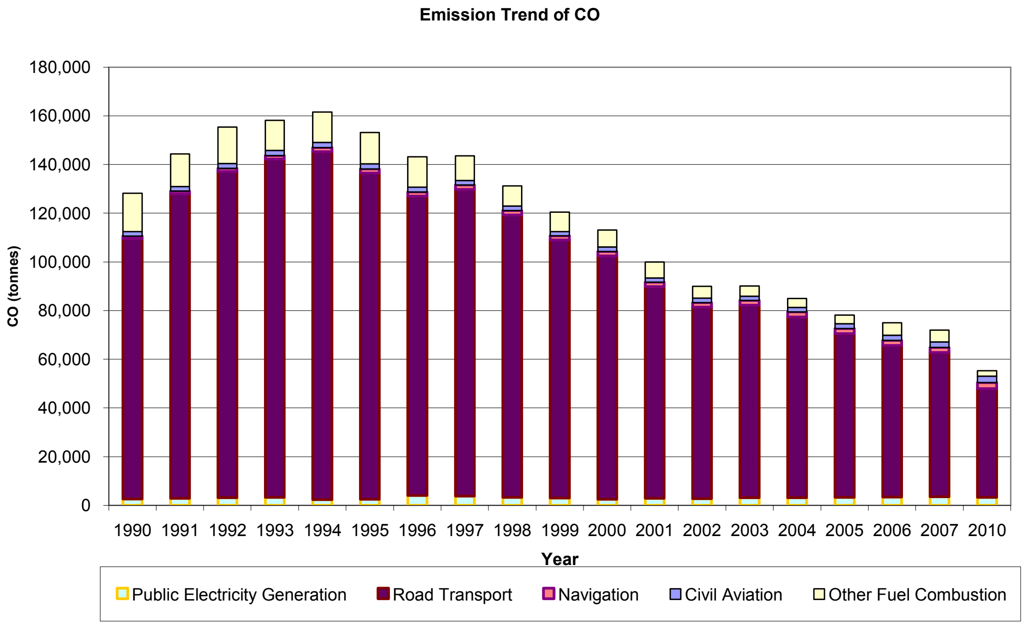


2.2.5 Carbon Monoxide

The emission trend for CO is given in **Figure 2.5**. A general decrease in CO was observed from Year 1994 to Year 2007, though a mild fluctuation was noted in Year 1997. CO emissions reduced by about 55% from 161,000 tonnes/year in Year 1994 to 72,000 tonnes/year in Year 2007, possibly due to the implementation of more stringent emission standards and in-used tailpipe emission controls for motor vehicles in Hong Kong. Achieving the emission reduction target agreed between Hong Kong and Guangdong would further cut emissions of CO to around 55,000 tonnes by Year 2010.

Road transport was the most significance source of CO in the territory, contributing to over 82% of the total emission according to Year 2007 data. Other sources were comparatively minor over the last decade. The relative significances of these sources in 2007 in descending order were: other fuel combustion, public electricity generation, navigation and civil aviation.

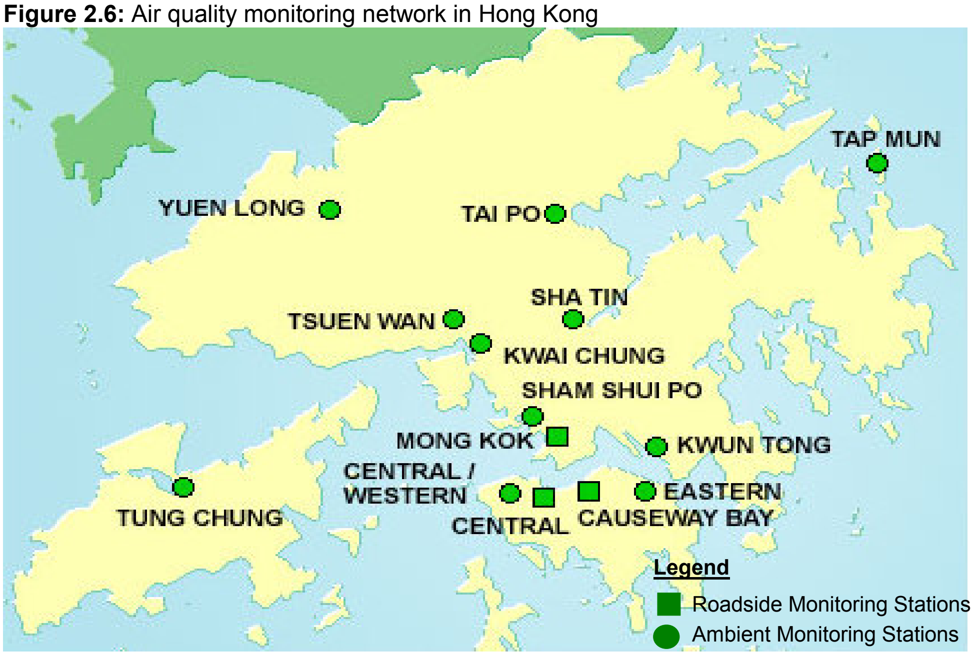
Figure 2.5: Emission trend of CO in HKSAR



2.3 Air Pollution Trends

Hong Kong monitors its air quality with a comprehensive air quality monitoring programme at 11 ambient monitoring stations and 3 roadside stations (**Figure 2.6**). The sites of these stations have been carefully selected to provide a good understanding of our air quality and representative of population and roadside exposure. Other than the Tap Mun air quality monitoring station, which is located at a remote island at the northeast of the territory for representing air quality with minimum influence of local emissions, all other stations are located in densely populated areas for proper representation of the population and roadside exposures.

Figure 2.6: Air quality monitoring network in Hong Kong

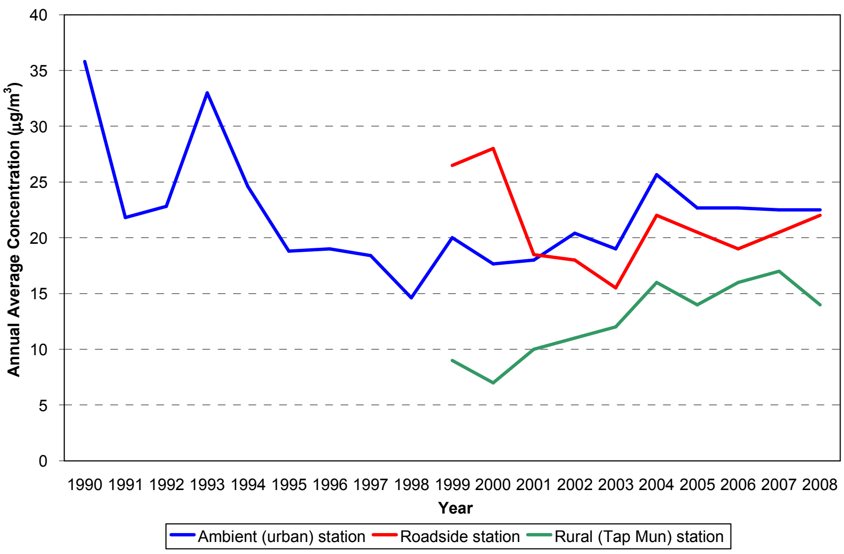


Hong Kong is mainly faced by two air pollution issues, namely local street-level pollution and the regional smog problem. Despite the significant reduction in local emissions since 1990, the air quality in Hong Kong has not been improved commensurately. The air quality monitoring data show that the ambient air quality has worsened on average by 13 to 47% (by comparing monitoring data between Year 1990 and Yr 2008) for some pollutants. The air quality deterioration is also observed at Tap Mun, which is located far from local sources. The air quality deterioration can be attributed to the worsening regional air quality in the Pearl River Delta Region. Contrary to the deteriorating trend for ambient air quality, there are some discernible improvements to roadside air quality. The long-term (annual) trends of various air pollutants are analysed in the following paragraphs.

2.3.1 Sulphur Dioxide

The long-term trend (annual) for SO_2 is illustrated in **Figure 2.7**. The trend for each station is shown in **Appendix D.** The SO_2 concentrations in Hong Kong have reduced and remained at levels well below the annual AQO because of a number of control measures including the implementation of the Air Pollution Control (Fuel Restriction) Regulations in Year 1990 for limiting sulphur content of industrial fuels, the Air Pollution Control (Motor Vehicle Fuel) Regulations in Year 1995 for controlling motor vehicle fuel quality and the measures to reduce emissions in power plants such as the introduction of natural gas for power generation. There was a slight increase in SO_2 emissions in Years 2003 and 2004 due to increased emissions from coal-fired power generation in Hong Kong and the PRD but the trend levelled off in the last 5 years as a result of control measures implemented in the region in recent years. Furthermore, as a result of the introduction of ultra low sulphur diesel for the vehicle fleet in late 2000, the average SO_2 concentrations at the roadside in Year 2008 (22 μg/m^3) dropped by 19% as compared with the Year 1999 value (27 μg/m^3). The SO_2 concentrations recorded at the Tap Mun Ambient Monitoring Station, which is located at a remote site at the north-east of Hong Kong away from local emission sources, shows an increasing trend from Year 1998. This reflects the regional influence on local air quality.

Figure 2.7: Long-term annual SO_2 trend



2.3.2 Oxides of Nitrogen / Nitrogen Dioxide

NO_X includes both NO and NO_2 which are produced in combustion processes. Major contributors of NO_X are from vehicular emissions, power plants and other major combustion facilities. NO and NO_2 participate in complex photochemical reactions and hence their actual concentrations and ratio of NO to NO_2 depends heavily on the intensity of sunlight and ozone concentration.

Figures 2.8 and **2.9** show the long term trends of NO_X and NO_2, respectively. The trend for each station is shown in **Appendix D.** The NO_2 concentration levels have exhibited slow rising trends during the period from Year 1990 to Year 2008 despite the general decrease of emissions and ambient concentrations of NO_X. Apart from the concentration of NO_X, the concentrations of NO_2 are also dependent on the concentrations of ozone and VOCs in the ambient air which promote the conversion of nitric oxide to NO_2. Given that the long term NO_X trend is slowly decreasing, the slowly increasing trend of NO_2 levels in urban and new town areas suggests the aggravation of regional photochemical and ozone pollution. The average NO_2 concentration level at the roadside is almost constant at about 97 µg/m^3. The NO_2 data of the Tap Mun Ambient Monitoring Station are much lower than the ambient and roadside readings, suggesting that NO_2 in urban area of Hong Kong is mainly due to local sources in particular the emissions from motor vehicles.

Figure 2.8: Long term annual NO_X trend

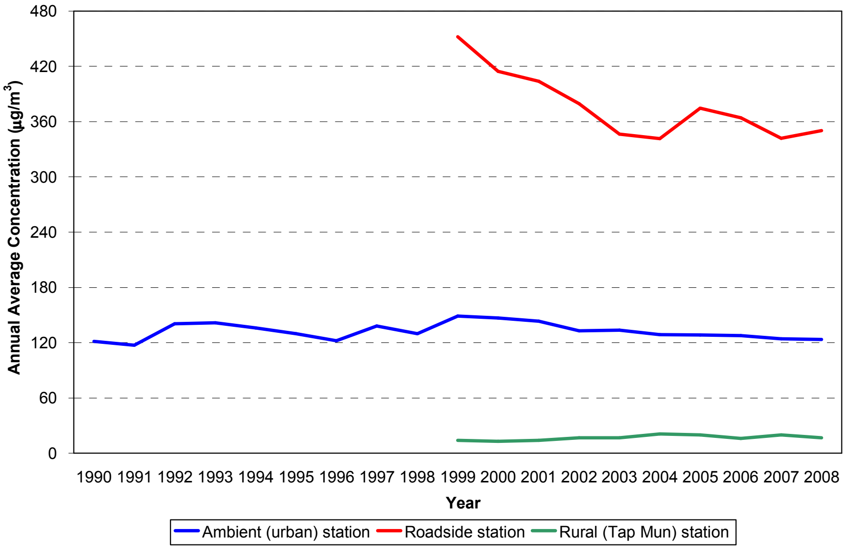
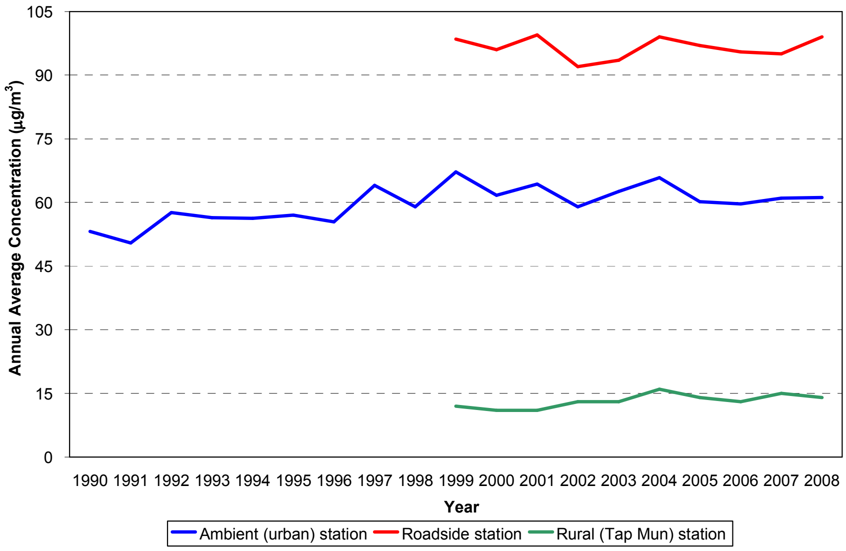


Figure 2.9: Long-term annual NO_2 trend



2.3.3 Particulate Matter

Figure 2.10 shows the long term trends of PM_{10}. The trend for each station is shown in **Appendix D.** The PM_{10} concentrations recorded in the territory showed a primarily downward trend between Year 1995 and Year 2002 but rebounded afterwards in Year 2003 and 2004 due to the increase in regional background PM_{10} levels. The gentle rising trend of PM_{10} in the territory since Year 2002 was mainly caused by the increase in regional background levels. In Hong Kong, high level of roadside PM_{10}, caused mainly by the exhaust emissions of diesel vehicles, has long been a major air pollution concern. In the last 5 years, the ambient PM_{10} level exhibited a mild decreasing trend, as a result of the joint efforts by the HKSAR and Guangdong governments in cutting emissions in the region. At the roadside, the PM_{10} concentration has exhibited a discernible decreasing trend with the annual average reduced by 22% between Years 1999 and 2008, reflecting that the vehicle emission control measures implemented over the last decade have taken effect.

It is noted that the PM_{10} concentrations at Tap Mun, which is far away from local emission sources, are comparable with those measured at the urban ambient stations. This suggests that our PM_{10} are significantly influenced by sources outside Hong Kong. The increasing trend from 1998 also reflects the growing influence of these sources on local PM_{10} concentration.

Figure 2.10: Long-term annual PM_{10} (RSP) trend

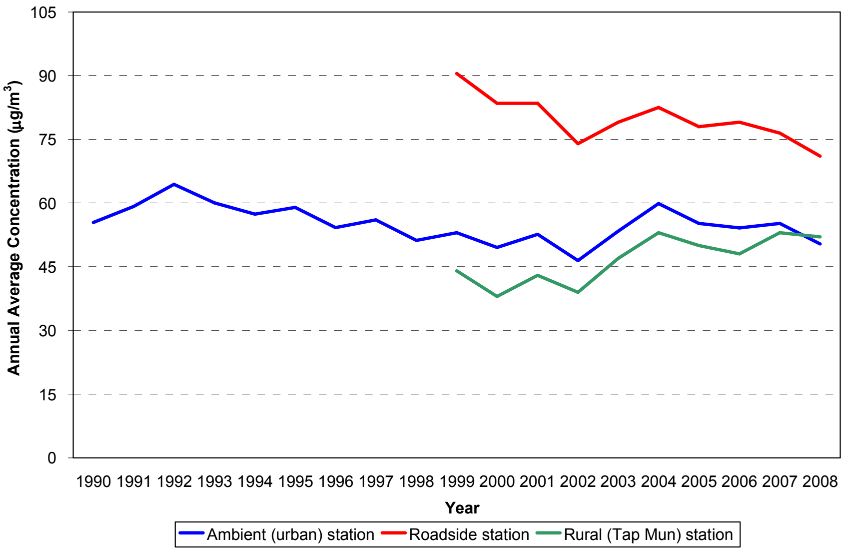
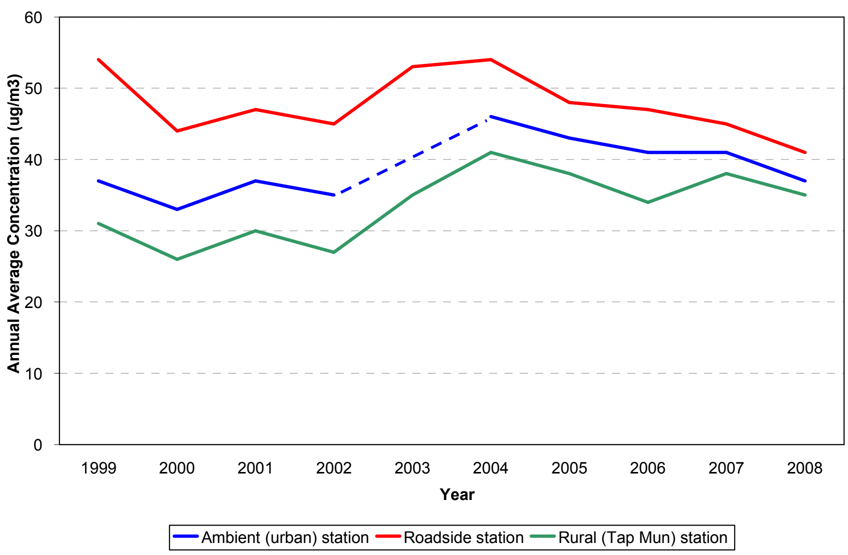


Figure 2.11 shows the long term trends of $PM_{2.5}$ with ambient (urban) and roadside stations referring to Tsuen Wan general station and Central roadside station respectively. The trend for each station is shown in **Appendix D.** The gap between the $PM_{2.5}$ concentrations at ambient stations and roadside stations had been narrowed significantly over the period. The closing gap could be indicative of the effectiveness of various measures to reduce the emissions of particulates from the vehicle fleet.

Figure 2.11: Long-term annual $PM_{2.5}$ (FSP) trend



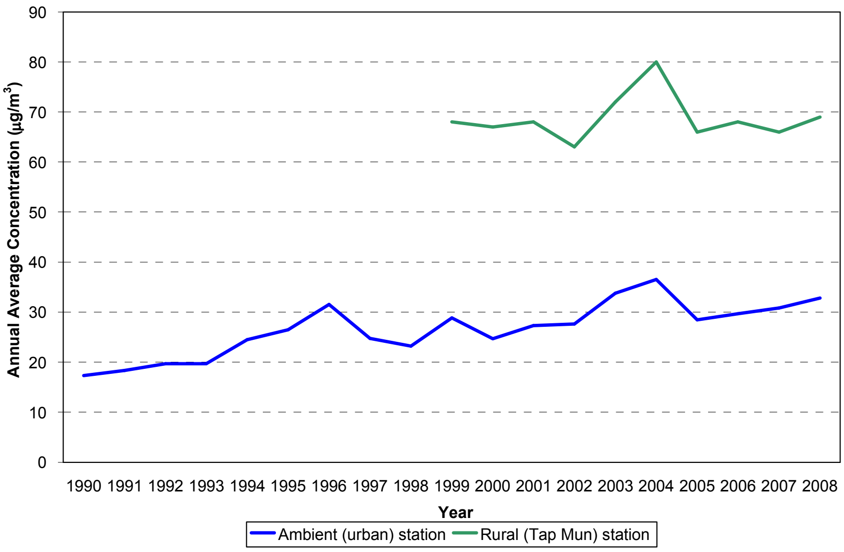
Note: Dotted line denotes that data in 2003 is not available

2.3.4 Ozone

The long-term trend (annual) for ozone is illustrated in **Figure 2.12**. The trend for each station is shown in **Appendix D.** The ambient ozone concentrations have shown a moderate upward trend since Year 1990. Ozone is generated from the photochemical reaction between VOC and NO_X under sunlight. Due to the abundance of its precursors (VOC and NO_X) from a great variety of sources such as motor vehicles, industries, power plants and consumer products, etc., ozone can be widely formed in the region and can be transported over long distances. The general rising trend of ozone levels in Hong Kong over the past years reflects a worsening in the photochemical smog problem on a regional scale.

As nitric oxide emissions from motor vehicles can react with and remove ozone in the air, areas with heavy traffic normally have lower ozone levels than areas with light traffic. This explains why the ozone level in Tap Mun rural station is much higher than that measured in the urban ambient stations. The rising trend of ozone generally reflects deterioration in air quality on a regional scale over the past decade.

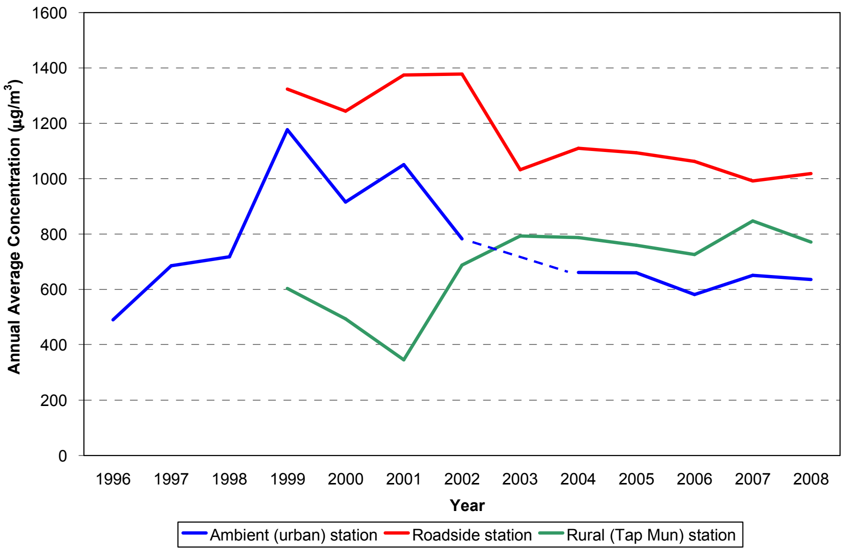
Figure 2.12: Long-term annual ozone trend (ambient monitoring stations)



2.3.5 Carbon Monoxide

Figure 2.13 shows the long term trends of CO. The trend for each station is shown in **Appendix D.** CO comes mainly from vehicular emissions although small amounts may also come from incomplete combustion of fuels from factories and power stations. The CO concentrations in Hong Kong remained very low (< 1600 µg/m^3) in the past few years and were well within the current AQO, even at the roadside close to the vehicular emission sources.

Figure 2.13: Long-term annual carbon monoxide trend (ambient and roadside monitoring stations)

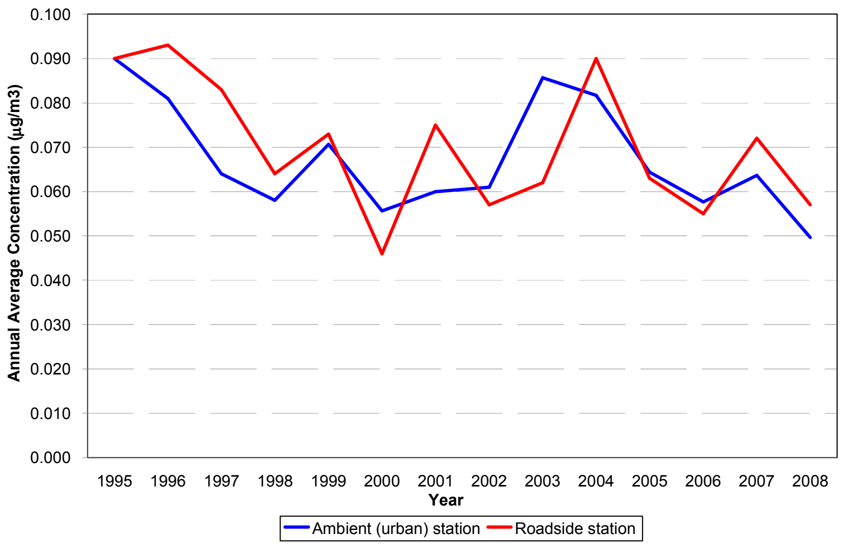


Note: Dotted line denotes that data in 2003 is not available

2.3.6 Lead

Figure 2.14 shows the long term trends of Pb. In Hong Kong, the sale and supply of leaded petrol, which is a known major source of lead, was banned from 1 April 1999. As in previous years, the ambient lead concentrations continued to linger at very low levels during Year 2008. The annual ambient and roadside averages were 0.05 µg/m^3 and 0.057 µg/m^3 respectively, which were well within the current AQO.

Figure 2.14: Long-term annual lead trend (ambient and roadside monitoring stations)



2.3.7 Visibility

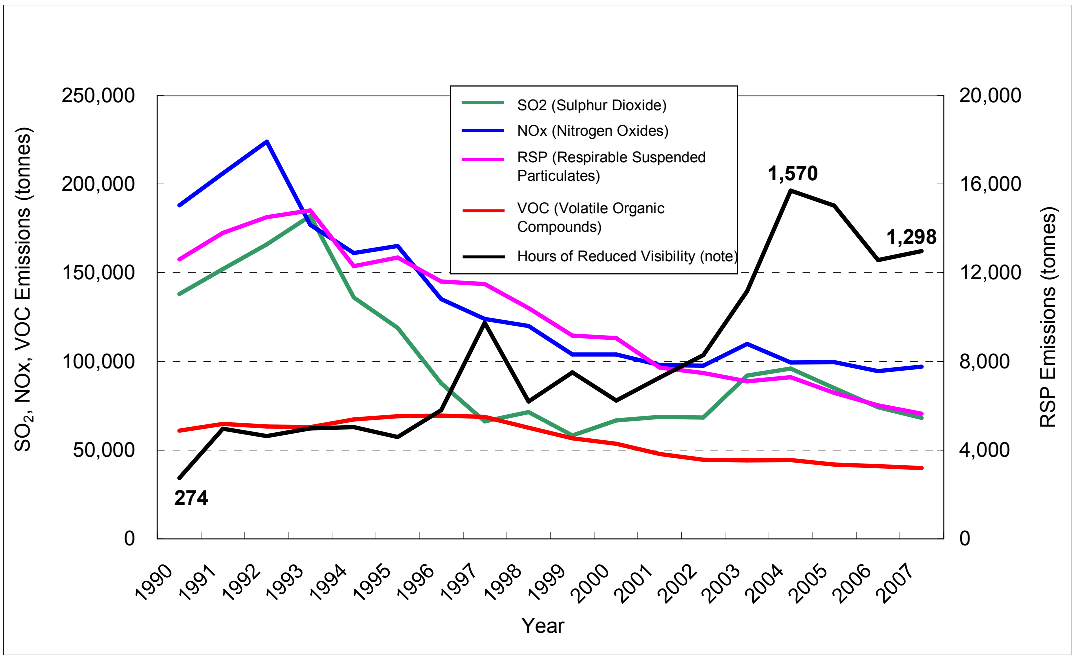
The long-term trend (annual) for visibility is illustrated in **Figure 2.15**. According to the EPD report "Study of Visibility Reduction and its Causes in Hong Kong" in Year 2003, Ammonium sulfate, organic carbon, elemental carbon and ammonium nitrates are the key contributors to the total light extinction. Their contributions are summarized as follows:

- Ammonium sulfate contributes to 51% in rural areas and 33% in urban areas.
- Organic carbon contributes to 17% in rural areas and 21% in urban areas;

- Elemental carbon contributes to 12% in rural areas and 26% in urban areas; and
- Ammonium nitrate had a minor contribution of 4 – 5 %.

The frequency of visibility impairment in Hong Kong showed an increasing trend from Years 1990 to 2007. Notwithstanding the very substantial reduction in local emissions (Section 2.2), the visibility has been deteriorating due to worsening of the regional background air quality. Smog has now become a common phenomenon for the entire PRD area.

Figure 2.15: Emission and Reduced Visibility Trends of Hong Kong



Note: Hours of reduced visibility observed at the Hong Kong Observatory. Visibility below 8 kilometres when there is no fog, mist or precipitation.

2.4 Regional Influence

To improve the air quality of the PRD Region, the Hong Kong SAR Government reached a consensus with the Guangdong Provincial Government in April 2002 to reduce, on a best endeavour basis, the emissions of four major air pollutants, namely SO_2, NO_X, RSP and VOC by 40%, 20%, 55% and 55% respectively in the region by 2010, using 1997 as the base year. To attain the 2010 emission reduction targets, the Guangdong Provincial Government has undertaken the following measures -

(a) establishing a diversified clean energy production and supply system, including development of gas-fired power plants and transmission of electricity from the western provinces;

(b) requiring all large-scale thermal power generating units to carry out FGD;

(c) requiring thermal power plants to install continuous emissions monitoring systems (CEMS) with instant on-line access by local authorities;

(d) requiring all thermal power plants that are under construction, alteration or expansion to carry out flue gas denitrification;

(e) closing down small thermal power plants and other serious polluting industries (including cement plants and iron and steel plants with low production capacity);

(f) stepping up annual inspections and on-road spot checks on vehicles;

(g) restricting the growth of motorcycles at key cities and banning them in the Guangzhou and Dongguan city areas;

(h) implementing an environment labeling pilot system for vehicles at key cities, so that vehicles of specific categories are restricted from using the roads when the ambient air quality is poor;

(i) constructing metro expressway systems, developing green transportation and strengthening tailpipe emission standards; and

(j) enhancing technological improvement at enterprises and promoting cleaner production (for example, requiring new projects to meet advanced cleaner production standards).

The regional co-operation efforts have borne fruits. There are signs of improvement in the regional air quality. As compared with Year 2007 levels, the average annual concentration of sulphur dioxide and respirable suspended particulates in the region in 2008 decreased by 19% and 11% respectively.

Apart from the emissions in the rest of the Pearl River Delta Region, the air quality of Hong Kong is also affected by the emissions outside the PRD regions which are referred to as the “super-regional sources”. Based on a study on visibility and particulate level[2] conducted by the Hong Kong Polytechnic University and the analysis of data at Hok Tsui from a $PM_{2.5}$ study of EPD, these further afield sources alone could contribute to a $PM_{2.5}$ level of 13 μg/m^3, which is already higher than the ultimate guideline of 10 μg/m^3 recommended by the WHO for $PM_{2.5}$.

To further illustrate the impact of these super-regional sources, a hypothetical modelling exercise has been done making use of the emission inventory data prepared by the Centre for Global and Regional Environmental Research[3], which specializes in studying environmental issues on a regional or global basis, and with all emissions from man-made sources of Hong Kong and PRD removed. The modelling exercise shows that the predicted concentrations of some air pollutants, in particular, PM_{10} and $PM_{2.5}$, would still exceeds the respective ultimate guidelines recommended by the WHO. It supports that influence of air pollution from super-regional sources could be significant. Further details can be found in **Appendix E**.

3 The Latest Development on AQO

This section summarizes the WHO Air Quality Guidelines, and the international practices in setting their air quality standards. The air quality standards in different countries have been compared with the WHO AQG.

3.1 WHO Air Quality Guidelines

The World Health Organization (WHO) announced a new set of Air Quality Guidelines (AQG) on 5 October 2006 for global application. The WHO has also recommended AQG interim targets for countries to progressively improve the air quality. **Table 3.1** summarizes the WHO Air Quality Guidelines.

Table 3.1: WHO Air Quality Guidelines

Pollutants	Avg. Time	IT-1 (μg/m^3)	IT-2 (μg/m^3)	IT-3 (μg/m^3)	AQG (μg/m^3)
Sulphur Dioxide	10-min	-			500
	24-hour	125	50	-	20
Respirable Suspended Particulates (PM_{10})	24-hour	150	100	75	50
	1-year	70	50	30	20
Fine Suspended Particulates ($PM_{2.5}$)	24-hour	75	50	37.5	25
	1-year	35	25	15	10
Nitrogen Dioxide	1-hour	-			200
	1-year	-			40
Ozone	8-hour	160	-	-	100
Carbon Monoxide	15-min				100,000
	30-min				60,000
	1-hour	-			30,000
	8-hour	-			10,000
Lead	1-year	-			0.5

The WHO AQG are the most authoritative set of guidelines and provide a good source of reference for all countries to build their air quality standards to minimize the risk of air pollution to public health. They are, however, far tougher than the national standards being applied in many parts of the world. Achievement of such levels will be a challenge for many cities. WHO accepts the need for governments to set national standards according to their own particular circumstances.

> *"The guidelines are written for worldwide use, and are intended to support actions aiming for the optimal achievable level of air quality in order to protect public health."*
>
> *"The standards set in each country will vary according to specific approaches to balancing risks to health, technological feasibility, economic considerations and other political and social factors"*
>
> *"In formulating policy targets, governments should consider their own local circumstances carefully before using the guidelines directly as legal standards"*

The guidelines therefore also suggest interim targets (ITs) on sulphur dioxide (SO_2), respirable suspended particulates (PM_{10}), fine particulate matters ($PM_{2.5}$) and ozone to facilitate a progressive approach for achieving the ultimate AQG and provide milestones in achieving better air quality:

"Given that air pollution levels in some countries often far exceed the recommended guideline levels, interim target levels are proposed, in excess of the guideline levels themselves, to promote steady progress towards meeting the WHO guidelines"

WHO has not proposed any ITs for the 10-minute limit on SO_2 and 1-hour limit on NO_2 on account of the fact that there exists strong scientific and medical evidence to support the respective WHO AQGs as the thresholds beyond which public health is at risk.

For easy reference, the WHO AQG, interim targets and their basis of selected levels are summarised in **Tables 3.2** to **3.8**.

Table 3.2: Air quality guideline and interim target for SO_2: 10 min and 24 hour mean

SO_2	24-hour average ($\mu g/m^3$)	10-minute average ($\mu g/m^3$)	Basis of the selected level
Interim target-1 (IT-1)	125	-	An uncertainty factor of 2 has been applied to the lowest-observed-adverse-effect level. At low levels of exposure (with daily levels usually not exceeding 125 $\mu g/m^3$), effects on mortality (cardiovascular and respiratory) and on hospital emergency admissions for total respiratory causes and chronic obstructive pulmonary disease (COPD) have been consistently demonstrated (WHO, 2000). [1].
Interim target-2 (IT-2)	50	-	Intermediate goal based on controlling either motor vehicle emissions, industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal which would lead to significant health improvements that, in turn, would justify further improvements.
Air quality guideline (AQG)	20	500	For 10-min average, controlled studies involving exercising asthmatics indicate that a proportion experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes. Based on this evidence, it is recommended that a SO_2 concentration of 500$\mu g/m^3$ should not be exceeded over averaging periods of 10 minutes duration. For 24hr average, there is uncertainty of SO_2 in causality. There is practical difficulty of attaining levels that are certain to be associated with no effects. Hence, the proposed level provides a greater degree of health protection

Note:
[1] Formerly the WHO Air Quality Guideline (WHO, 2000).

Table 3.3: Air quality guideline and interim target for NO_2: 1-hour and annual mean

NO_2	WHO air quality guidelines (AQG) ($\mu g/m^3$)	Basis of the selected level
1-hour mean level	200	Studies of bronchial responsiveness among asthmatics suggest an increase in responsiveness at levels upwards from 200$\mu g/m^3$.

NO_2	WHO air quality guidelines (AQG) (µg/m^3)	Basis of the selected level
Annual mean level	40	It was set to protect the public from the health effects of gaseous NO_2. Since most abatement methods are specific to NO_X, they are not designed to control other co-pollutants, and may even increase their emissions. If, however, NO_2 is monitored as a marker for complex combustion-generated pollution mixtures, a lower annual guideline value should be used (WHO, 2000).

Table 3.4: Air quality guideline and interim target for O_3: 8-hour mean

Ozone	Daily maximum 8-hour mean (µg/m^3)	Basis of the selected level
High level	240	Significant health effects; substantial proportion of vulnerable population affected.
WHO interim target 1 (IT-1)	160	Important health effects; an intermediate target for populations with ozone concentrations above this level. Does not provide adequate protection of public health. Lower level of 6.6-hour chamber exposures of healthy exercising young adults, which show physiological and inflammatory lung effects. Ambient level at various summer camp studies showing effects on health of children. Estimated 3–5% increase in daily mortality (based on findings of daily time series studies)
WHO air quality guidelines (AQG)	100	This concentration will provide adequate protection of public health, though some health effects may occur below this level. Estimated 1–2% increase in daily mortality (based on findings of daily time series studies) Extrapolation from chamber and field studies based on the likelihood that real-life exposure tends to be repetitive and chamber studies do not study highly sensitive or clinically compromised people or children. Likelihood that ambient ozone is a marker for related oxidants.

Table 3.5: Air quality guideline and interim targets for PM: 24-hour mean[1]

PM - 24-hr mean level	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	Basis of the selected level
WHO interim target 1 (IT-1)	150	75	Based on published risk coefficients from multicentre studies and meta-analyses (about 5% increase in short-term mortality over AQG)
WHO interim target 2 (IT-2)	100	50	Based on published risk coefficients from multicentre studies and meta-analyses (about 2.5% increase in short-term mortality over AQG)

PM - 24-hr mean level	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	Basis of the selected level
WHO interim target 3 (IT-3)	75	37.5	About 1.2% increase in short-term mortality over AQG
WHO air quality guidelines (AQG)	50	25	Based on relation between 24-hour and annual PM levels

Note:
[1] 99th percentile.

Table 3.6: Air quality guideline and interim targets for PM: annual mean

PM - Annual mean level	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	Basis of the selected level
WHO interim target 1 (IT-1)	70	35	These levels are estimated to be associated with about 15% higher long-term mortality than at AQG levels.
WHO interim target 2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% (2–11%) compared to IT-1.
WHO interim target 3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risk by approximately another 6% (2–11%) compared to IT-2 levels.
WHO air quality guidelines (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to $PM_{2.5}$ in the ACS study (Ruuskanen J et al., 2000). The use of the $PM_{2.5}$ guideline is preferred.

Table 3.7: CO air quality guideline

CO	WHO air quality guidelines (AQG) (μg/m^3)	Basis of the selected level
15-minute mean level (μg/m^3)	100,000	Epidemiological studies have shown that to protect nonsmoking, middle-aged and elderly population groups with documented or latent coronary artery disease from acute ischaemic heart attacks, and to protect the fetuses of nonsmoking pregnant women from untoward hypoxic effects, a COHb level of 2.5% should not be exceeded.
30-minute mean level (μg/m^3)	60,000	
1-hour mean level (μg/m^3)	30,000	
8-hour mean level (μg/m^3)	10,000	

Table 3.8: Air quality guideline for Pb: annual mean

Lead	WHO air quality guidelines (AQG) (μg/m^3)	Basis of the selected level
Annual mean level (μg/m^3)	0.5	Guideline for lead in air is based on the concentration of lead in blood. Critical effects to be considered in the adult organism include elevation of free erythrocyte protoporphyrin, whereas for children cognitive deficit, hearing impairment and disturbed vitamin D metabolism (Rosen et al., 1980; Mahaffey et al., 1982) are taken as the decisive

Lead	WHO air quality guidelines (AQG) (µg/m^3)	Basis of the selected level
		effects. All of these effects are considered adverse.

3.2 International Development

Table 3.9 compares the rationales in setting their air quality standards taken by other countries/economies and the WHO on establishment and achievement of the Air Quality Objectives/Standards (AQO/AQS) with the one prescribed under the APCO. In general, it can be seen that protection of public health is a primary consideration in setting the AQO/AQS. Almost all of the countries/economies surveyed require the publication and implementation of the air quality management plans and / or certain kind of regular review of their AQO/AQS and management plans. A more comprehensive review of the international approach to setting their air quality standards is given in **Appendix F**.

Table 3.9: Summary of the rationales for setting the air quality standards

Jurisdiction	AQO/AQS Rationale	Reference
Hong Kong	"The air quality objectives for any particular air control zone or part thereof shall be the quality which, in the opinion of the Secretary, should be achieved and maintained in order to promote the conservation and best use of air in the zone in the public interest."	Air Pollution Control Ordinance (311) Section 7
WHO	"The WHO Air Quality Guidelines (AQG) are intended for worldwide use but have been developed to support actions to achieve air quality that protects public health in different contexts. Air quality standards, on the other hand, are set by each country to protect the public health of their citizens and as such are an important component of national risk management and environmental policies. National standards will vary according to the approach adopted for balancing health risks, technological feasibility, economic considerations and various other political and social factors, which in turn will depend on, among other things, the level of development and national capability in air quality management. "	WHO Air Quality Guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide, Global update 2005 Summary of risk assessment, WHO, 2005
European Union	"Limit values" shall mean a level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained.	Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe
UK	"The UK Government's and devolved administrations' primary objective is to ensure that all citizens should have access to outdoor air without significant risk to their health, where this is economically and technically feasible." "In setting objectives derived from the health and ecosystem advice, the UK Government and the devolved administrations have also taken account of economic efficiency, practicability, technical feasibility and timescale."	The Air Quality Strategy for England, Scotland, Wales, and Northern Ireland Volume 1, DEFRA , 2007
US	National primary ambient air quality standards: "Ambient air quality standards the attainment and	Clean Air Act, 1990

Jurisdiction	AQO/AQS Rationale	Reference
	maintenance of which in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect the public health." National secondary ambient air quality standards: "A level of air quality the attainment and maintenance of which in the judgment of the Administrator, based on such criteria, is requisite to protect public welfare from any known or anticipated adverse effects associated with the presence of such air pollutant in the ambient air."	
Australia	"The desired environmental outcome of this Measure is ambient air quality that allows for the adequate protection of human health and well-being."	National Environment Protection (Ambient Air Quality) Measure made under the Australian National Environment Protection Council Act 1994
Japan	The environmental standard against air pollution have been established to protect human health and preserve the living environment	Basic Environment Law, 1993
Singapore[1]	--	--

Note
[1] Singapore does not have its own air quality standards. The National Environment Agency uses USEPA air quality standard to assess ambient air quality in Singapore.

Table 3.10 summarizes the comparison of overseas AQO and WHO AQG. Review of air quality standards in the USA, EU, UK, Australia, and other jurisdictions indicate that none has fully adopted or committed to the adoption of the WHO's ultimate AQG. EU and UK adopted standards comparable to a combination of WHO interim targets and guidelines, with allowances for exceedences, based on their local circumstances. Moreover, US conduct regular review once every 5 years.

In overseas jurisdictions, the adoption of interim or progressive targets in their legal air quality standards is common. Among developed countries, the EU has the most stringent air quality standards, which were updated on 21 May 2008. Its air quality standards for SO_2, ozone, PM_{10} and $PM_{2.5}$ are still less stringent than those prescribed under the WHO AQG. For example, the EU has chosen an annual $PM_{2.5}$ standard of 25 µg/m^3, which is equivalent to WHO's IT-2 value for $PM_{2.5}$. So far, it has not been found any jurisdictions adopting the WHO AQG in their entirety as legal standards.

Table 3.10: Comparison of overseas AQO and WHO AQG

Pollutant	**Avg. Time**	**WHO AQG µg/m³**	**USA[7,8]**		**EU[9]**		**UK[9]**		**Australia[10]**		**Japan**		**Singapore[6]**	
			µg/m³	**No of Ex.**	**µg/m³**	**No of Ex.**	**µg/m³**	**No of Ex.**	**µg/m³**	**No of Ex.**	**µg/m³**	**No of Ex.**	**µg/m³**	**No of Ex.**
SO_2	10-min	500	-	-	-	-	266 [1]	35	-	-	-	-	-	-
	1-hour	-	-	-	350	24	350	24	524	1	262	Note [11]	-	-
	24-hour	20 (IT-1: 125, IT-2: 50)[2]	365	1	125	3	125	3	210	1	105	Note [11]	-	-
	Annual	-	80	NA	-	-	-	-	52	NA	-	Note [11]	-	-
RSP (PM_{10})	24-hour	50 (IT-1: 150, IT-2: 100, IT-3: 75)	150	3 times in 3 years	50	35	50	35	50	5	100	Note [11]	-	-
	Annual	20 (IT-1: 70, IT-2: 50, IT-3: 30)	-	-	40	NA	40	NA	-	-	-	-	-	-
FSP ($PM_{2.5}$)	24-hour	25 (IT-1: 75, IT-2: 50, IT-3: 37.5)	35	3-y avg. of 98th percentile	-	-	-	-	25 [3]	NA	-	-	-	-
	Annual	10 (IT-1: 35, IT-2: 25, IT-3: 15)	15 [4]	NA	25	NA	25	NA	8 [3]	NA	-	-	-	-

Pollutant	Avg. Time	WHO AQG µg/m^3	USA[7,8]		EU[9]		UK[9]		Australia[10]		Japan		Singapore[6]	
			µg/m^3	No of Ex.	µg/m^3	No of Ex.	µg/m^3	No of Ex.	µg/m^3	No of Ex.	µg/m^3	No of Ex.	µg/m^3	No of Ex.
NO_2	1-hour	200	-	-	200	18	200	18	226	1	-	-	-	-
	24-hour	-	-	-	-		-		-		75 – 113	Note [11]	-	-
	Annual	40	100	NA	40	NA	40	NA	57	NA	-	-	-	-
O_3	1-hour	-	-		-		-		200	1	120	Note [11]	-	-
	4-hour	-	-		-		-		160	1	-	-	-	-
	8-hour	100 (High levels: 240, IT-1: 160)	147	3-year of 4th highest values	120	25	100	10	-	-	-		-	-
CO	15-min	100,000	-	-	-	-	-	-	-	-	-		-	-
	30-min	60,000	-	-	-	-	-	-	-	-	-		-	-
	1-hour	30,000	40,000	1	-		-		-	-	23000	Note [11]	-	-
	8-hour	10,000	10,000	1	10,000	0	10,000	0	10,000	1	-		-	-
Pb	3-month	-	1.5	NA	-	-	-	-	-	-			-	-
	Annual	0.5	0.15 [5]	NA	0.5	NA	0.25	NA	0.5	NA			-	-

Note:

[1] 15-minute average

[2] IT stands for interim target.

[3] Advisory reporting standard only, not air quality standard

[4] 3-year average of the weighted annual mean

[5] Rolling 3-month average

[6] Singapore does not have own air quality standard. The National Environment Agency uses US NAAQS to assess the ambient air quality in Singapore

[7] Measured at 298K(25 °C) and 101.325 kPa (one atmosphere)

[8] $PM_{2.5}$ Measured at ambient conditions

[9] Measured at 293K(20 °C) and 101.325 kPa (one atmosphere)

[10] Measured at 273K (0 °C) and 101.325 kPa (one atmosphere)

[11] SO_2, CO, PM: Of the mean daily values obtained over 1 year, those within the top 2% (equivalent to the values of 7 days, if daily measurements are taken for 365 days) are excluded (2% exclusion value) and the highest remaining values are compared with the environmental standard. If the measurement values exceed the environmental standard on more than 2 consecutive days, they are judged as nonattainment

NO_2: For the mean daily values obtained over 1 year, those within the lower 98% are selected and compared with the environmental standard.

O_3: If the 1-hr mean value exceeds 0.06ppm, it is judged not to have attained the standard.

4 New AQO for Hong Kong

The section summarizes the guiding principles in setting the new AQO for Hong Kong. The guiding principles have been drawn up with reference to the air quality guidelines of WHO. According to the established principles, the new AQO for Hong Kong is proposed. The implication of AQO on the legislation and policy has also been identified.

4.1 Guiding Principles

In deciding the AQO, the key principles considered were:

- Protection of public health including that of the vulnerable population groups as the primary objective;
- Adopting a progress, forward looking approach to setting the AQO with reference to the WHO guidelines and interim targets with a view to achieving continued progressive long term air quality improvement;
- Regular review system to update the AQO for the protection of public health;

4.1.1 Protection of Public Health

Section 7(2) of the Air Pollution Control Ordinance (Cap. 311) has stipulated that the AQO "should be achieved and maintained in order to promote the conservation and best use of air in the zone in the public interest." The protection of public health should thus be a key consideration in updating the AQO because to do otherwise will not be in "public interest".

To uphold this principle of protecting public health, WHO AQG, which have been developed to support actions to achieve air quality that protects public health in different contexts, have been taken to be an important reference in this review alongside practices of other environmentally advanced countries.

The practice of stating "the protection of public health" as the purpose of AQO varies from country/economy to country/economy. Some countries/economies, such as the USA and EU, specify in their Acts or Directives the purpose of protecting public health, together with the other purposes including protection of welfare and environment. Others, such as Australia, only specify the purposes in their statutory or policy instruments, which in the case of Hong Kong is the Technical Memorandum issued under the Air Pollution Control Ordinance, for promulgating the AQO.

In setting the AQO, some countries, in particular, the USA, are required under the law to consider only the health protection factor. Some others, e.g. the U.K., New Zealand and the Mainland, however, also prescribe in their legislations that cost effectiveness and economic factors need to be considered.

Having reviewed the practices of other countries/economies, it is considered that one possible option for further reinforcing the need to consider "the protection of public health" in setting the AQO would be to spell out this principle in the Technical Memorandum under which the new AQO are promulgated to supplement Section 7(2) of the Air Pollutoin Control Ordinance.

4.1.2 Progressive and Forward Looking Approach

As a world city, Hong Kong community has aspiration for a high quality environment. However, as the situation stands, the challenges for Hong Kong to adopt WHO AQG in its entirety as its new AQO is too great to overcome. A progressive, forward-looking approach having regard to the local circumstances, technological developments and international practices is recommended for attaining the WHO AQG as the long term goal.

To illustrate the scale of the challenge, **Table 4.1** compares the air quality monitored at the Tap Mun, which is far away from local emission sources, with WHO AQG. The table shows that at that station, the WHO AQG could be exceeded up to 60% of the time in a year for pollutants such as particulates. The comparison also demonstrates the need to tackle air pollution at the regional context on top of local emissions.

Table 4.1: Air monitoring data at Tap Mun Monitoring Station in 2008

<table>
<tr><th>Air Pollutant</th><th>Avg time</th><th>Concentration (µg/m^3)</th><th>No. of Exceedences in 2008 [1,2,3]</th></tr>
<tr><td rowspan="4">SO_2</td><td>10-min</td><td>AQG: 500</td><td>0</td></tr>
<tr><td rowspan="3">24-hour</td><td>IT-1:125</td><td>0</td></tr>
<tr><td>IT-2: 50</td><td>1</td></tr>
<tr><td>AQG: 20</td><td>63</td></tr>
<tr><td rowspan="8">PM_{10} or RSP</td><td rowspan="4">24-hour</td><td>IT-1: 150</td><td>0</td></tr>
<tr><td>IT-2: 100</td><td>19</td></tr>
<tr><td>IT-3: 75</td><td>78</td></tr>
<tr><td>AQG: 50</td><td>167</td></tr>
<tr><td rowspan="4">Annual</td><td>AQO: 55</td><td>✓</td></tr>
<tr><td>IT-2: 50</td><td>×</td></tr>
<tr><td>IT-3: 30</td><td>×</td></tr>
<tr><td>AQG: 20</td><td>×</td></tr>
<tr><td rowspan="8">$PM_{2.5}$ or FSP</td><td rowspan="4">24-hour</td><td>IT-1: 75</td><td>13</td></tr>
<tr><td>IT-2: 50</td><td>87</td></tr>
<tr><td>IT-3: 37.5</td><td>160</td></tr>
<tr><td>AQG: 25</td><td>219</td></tr>
<tr><td rowspan="4">Annual</td><td>IT-1: 35</td><td>✓</td></tr>
<tr><td>IT-2: 25</td><td>×</td></tr>
<tr><td>IT-3: 15</td><td>×</td></tr>
<tr><td>AQG: 10</td><td>×</td></tr>
<tr><td rowspan="2">NO_2</td><td>1-hour</td><td>AQG: 200</td><td>0</td></tr>
<tr><td>Annual</td><td>AQG: 40</td><td>✓</td></tr>
<tr><td rowspan="2">Ozone</td><td rowspan="2">8-hr</td><td>IT-1: 160</td><td>19</td></tr>
<tr><td>AQG: 100</td><td>184</td></tr>
</table>

Note:
[1] IT – Interim Target ;
[2] ✓ – denotes “compliance with the AQO”
[3] × – denotes “non-compliance with the AQO”

If local emissions are included, the challenge will become even greater as shown in **Table 4.2**, which compares the monitoring data at ambient monitoring station in 2008 with the WHO guidelines of which the exceedences refer to the aggregate of any one monitoring station over the measurement period. The exceedence would be more acute at the roadside where exceedence could amount to about 85% of the time in a year.

Table 4.2: 2008 Monitoring data comparison with WHO guidelines

<table>
<tr><th>Air Pollutant</th><th>Avg time</th><th>Concentration (µg/m^3)</th><th>No. of Exceedences in 2008 [1,2,3,4]
(Ambient)</th></tr>
<tr><td rowspan="2">SO_2</td><td>10-min</td><td>AQG: 500</td><td>20</td></tr>
<tr><td>24-hour</td><td>IT-1:125</td><td>2</td></tr>
</table>

Air Pollutant	Avg time	Concentration (μg/m^3)	No. of Exceedences in 2008 [1,2,3,4] (Ambient)
		IT-2: 50	86
		AQG: 20	284
PM_{10} or RSP	24-hour	IT-1: 150	4
		IT-2: 100	51
		IT-3: 75	134
		AQG: 50	211
	Annual	AQO: 55	✓
		IT-2: 50	×
		IT-3: 30	×
		AQG: 20	×
$PM_{2.5}$ or FSP	24-hour	IT-1: 75	39
		IT-2: 50	128
		IT-3: 37.5	191
		AQG: 25	259
	Annual	IT-1: 35	×
		IT-2: 25	×
		IT-3: 15	×
		AQG: 10	×
NO_2	1-hour	AQG: 200	84
	Annual	AQG: 40	×
Ozone	8-hr	IT-1: 160	29
		AQG: 100	185

Note
[1] IT – Interim Target
[2] ✓ - denotes "compliance with the AQO"
[3] × - denotes "non-compliance with the AQO"
[4] Exceedences refer the aggregate of any one monitoring station over the measurement period.

4.1.3 Regular Review Mechanism

A regular review should be introduced to regularly ascertain the extent to which the new AQO have been achieved, the progress of the air management strategy, as well as the need and practicality of further tightening of AQO. This is to achieve progressively the long term target of achieving the ultimate AQG. Given the need for periodic review of the air quality standards against the latest findings on health effect from air pollution, a mechanism should be established for scheduled review of the air quality objectives for Hong Kong either by legislative or administrative means. US have their review mechanisms under the legislative framework. In EU, the Directive 2008/50/EC on ambient air quality and cleaner air for Europe requires that the Commission shall review the provisions related to $PM_{2.5}$ and, as appropriate, other pollutants, and shall present a proposal to the European Parliament and the Council in Year 2013. It is considered that review mechanism by administrative means can allow more flexibility. Moreover, the needs and means of any established implementation requirements for air quality management plan should be regularly reviewed and updated at the same time. This will ensure phased achievement approach to balance the health risks, technological feasibility, social implications and economic goals.

4.2 The proposed AQO

WHO AQG and their interim targets are authoritative air quality objectives supported by the latest scientific evidence on health effects due to ambient air pollution. As we are committed to the protection of public health in setting the new AQO, we should be guided by the air quality targets recommended by the WHO. The WHO AQG are, however, far tougher than the national standards being applied in many parts of the world. Achievement of such levels will be a challenge for many cities. WHO accepts the need for governments to set national standards according to their own particular circumstances. As shown in **Table 4.1** and **Table 4.2**, a large number of exccedences is observed when comparing the Yr 2008 monitoring data with the WHO AQG. The 24-hr SO_2, 24-hr PM_{10}, 24-hr $PM_{2.5}$, 8-hr O_3 concentrations in ambient stations have exceeded the WHO AQG by 284 times, 211 times, 259 times and 185 times in a year respectively. The 24-hr SO_2, 24-hr PM_{10}, 24-hr $PM_{2.5}$, 8-hr O_3 concentrations in Tap Mun station have exceeded the WHO AQG by 63 times, 167 times, 219 times and 184 times in a year respectively. This further suggests the significant impact of the regional influence and the challenge to meet the WHO AQG. Hence, the WHO AQG will be pursued as the long term goal for air quality improvement.

The EU Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe (http://vlex.com/vid/ambient-air-quality-cleaner-europe-38714884), were updated on 21 May 2008. It is the latest document that is made reference to the WHO standards in setting their air quality standard. Hence, in deriving our new AQO, we have benchmarked to the EU air quality standards as a practical example.

4.2.1 Sulphur Dioxide

The WHO sets interim target, IT1 of 125 μg/m^3, IT 2 of 50 μg/m^3 and AQG of 20 μg/m^3 for 24-hr SO_2. The EU Directive 2008/50EC adopted the WHO IT-1 of 125 μg/m^3 with 3 days exceedence according to their local circumstances. There is no interim target of 10-min SO_2 in WHO document. The WHO AQG for 10-min SO_2 is 500 μg/m^3. The EU Directive 2008/50EC has not set a corresponding standard on this guideline. However, UK has the 15-min SO_2 limit at 266 μg/m^3 with 35 exceedences a year.

Table 4.3 summarizes the SO_2 data at ambient stations in Hong Kong in Year 2008. The SO_2 data at Tap Mun ambient station, which is representative of the local Hong Kong background from regional influence, is also presented for comparison.

Table 4.3a: 2008 SO_2 Monitoring data comparison (Concentration) with WHO guidelines

Air Pollutant	Avg time	Concentration (μg/m^3)	Concentration in 2008 (Ambient)	Concentration in 2008 (Tap Mun)
SO_2	10-min	AQG: 500	1173	409
	24-hour	IT-1:125	149	71
		IT-2: 50		
		AQG: 20		

Table 4.3b: 2008 SO_2 Monitoring data comparison (Exceedence) with WHO guidelines

Air Pollutant	Avg time	Concentration (μg/m^3)	No. of Exceedences in 2008 (Ambient)	No. of Exceedences in 2008 (Tap Mun)
SO_2	10-min	AQG: 500	20	0
	24-hour	IT-1:125	2	0
		IT-2: 50	86	1

Air Pollutant	Avg time	Concentration (µg/m^3)	No. of Exceedences in 2008 (Ambient)	No. of Exceedences in 2008 (Tap Mun)
		AQG: 20	284	63

The 2008 monitoring data show that the 24-hr SO_2 levels in ambient monitoring station exceeded the WHO IT1, WHO IT2 and WHO AQG by 2, 86 and 284 times respectively. The highest recorded concentrations at ambient and Tap Mun monitoring stations were 149 µg/m^3 and 71 µg/m^3 respectively. As Tap Mun monitoring station is representative of the local Hong Kong background, this suggests that SO_2 in urban area is contributed mainly by the local sources. Taking into account the local circumstances and making reference to the EU air quality standards, the interim target WHO IT1 of 125 µg/m^3 with 3 exceedences is proposed.

According to 2008 monitoring data, the 10-min SO_2 at ambient and Tap Mun monitoring stations exceeded the WHO AQG by 20 times and 0 time respectively. The highest recorded concentrations at ambient and Tap Mun monitoring stations were 1173 µg/m^3 and 409 µg/m^3 respectively. As Tap Mun monitoring station is representative of the local Hong Kong background, this suggests that SO_2 in urban area is contributed mainly by the local sources.

EU has not set any limit for 10-min SO_2. However, UK has adopted a limit value for 15-min SO_2 of 266 µg/m^3 but allowed 35 exceedences a year (average over 3 years). The proposal of adopting the WHO AQG of 500 µg/m^3 and allowed 3 exceedences a year for 10-min SO_2 is more consistent with WHO's guideline. As for the proposed limit for 24-hour SO_2, it is same as that of EU.

4.2.2 Nitrogen Dioxide

As explained in section 3.1, there is no interim target for NO_2 in WHO document. The WHO AQG for annual NO_2 and 24-hr NO_2 are 40 µg/m^3 and 200µg/m^3 respectively. The EU Directive 2008/50 / EC adopted the WHO AQG of 40µg/m^3 for annual NO_2 limit. For 1-hr NO_2, the EU directive has adopted WHO AQG of 200 µg/m^3 with 18 exceedences a year.

Table 4.4 summarizes the NO_2 data at ambient stations in Hong Kong in Year 2008. The NO_2 data at Tap Mun ambient station, which is representative of the local Hong Kong background from regional influence, is also presented for comparison.

Table 4.4a: 2008 NO_2 monitoring data comparison (Concentration) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	Concentration in 2008 (Ambient)	Concentration in 2008 (Tap Mun)
NO_2	1-hour	AQG: 200	282	119
	Annual	AQG:40	69	14

Table 4.4b: 2008 NO_2 monitoring data comparison (Exceedences) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	No. of Exceedences in 2008 (Ambient)	No. of Exceedences in 2008 (Tap Mun)
NO_2	1-hour	AQG: 200	84	0
	Annual	AQG: 40	×	✓

Based on 2008 monitoring data, the annual NO_2 at Hong Kong ambient (excluding Tap Mun) exceeded the WHO AQG. There was no exceedence observed in Tap Mun monitoring station. The highest recorded concentrations at ambient and Tap Mun monitoring stations were 69 µg/m^3 and 14 µg/m^3 respectively. As Tap Mun monitoring station is representative of the local Hong Kong background, this suggests that NO_2 is contributed mainly by local sources. Based on the data, local emission reduction is required in order to achieve the WHO AQG. There are practicable measures to further reduce the NO_2 level by controlling the tailpipe NO_X emission of vehicle and transport management measures. On benchmarking the EU directive, the WHO AQG of 40 µg/m^3 is thus proposed for annual NO_2.

According to 2008 monitoring data, the 1-hr NO_2 at Hong Kong ambient monitoring stations exceeded the AQG by 84 times. The highest recorded concentrations at ambient monitoring stations was 282 µg/m^3. The EU directive has allowed 18 exceedences according to its local circumstances. On benchmarking the EU directive, the WHO AQG of 200 µg/m^3 with 18 exceedences is thus proposed for 1-hr NO_2.

4.2.3 Ozone

The WHO sets interim target, IT1 of 160 µg/m^3 and AQG of 100 µg/m^3 for 8-hr ozone. The EU Directive 2008/50EC has adopted an interim target of 120 µg/m^3 (which is in between the WHO IT1 and WHO AQG) with 25 exceedences according to their local circumstances.

Table 4.5 summarizes the ozone data at ambient monitoring stations in Hong Kong in Year 2008. The ozone data at Tap Mun ambient station, which is representative of the local Hong Kong background, is also presented for comparison.

Table 4.5a: 2008 O_3 monitoring data comparison (Concentration) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	Concentration in 2008 (Ambient)	Concentration in 2008 (Tap Mun)
Ozone	8-hr	IT-1: 160	320	320
		AQG: 100		

Table 4.5b: 2008 O_3 monitoring data comparison (Exceedance) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	No. of Exceedences in 2008 (Ambient)	No. of Exceedences in 2008 (Tap Mun)
Ozone	8-hr	IT-1: 160	29	19
		AQG: 100	185	184

The 8-hr O_3 in Hong Kong ambient monitoring stations exceeded the WHO IT1, and WHO AQG by 29 and 185 times respectively. The highest recorded concentration at ambient monitoring stations was 320 µg/m^3, which occurred at Tap Mun background station. The 8-hr O_3 in Tap Mun Stations exceeded the WHO IT-1 and WHO AQG by 19 and 184 times respectively. It suggests that the 8-hr O_3 is largely affected by regional sources. Based on the data, it is difficult to achieve the WHO IT-1 interim target without further NO_X and VOC reduction in the region. Taking into account the local circumstances, the interim target WHO IT1 of 160 µg/m^3 is proposed.

It is noted that the EU sets the O_3 at 120 µg/m^3 with allowance of 25 exceedences according to its local circumstances. However, given the difference between the proposed objectives for Hong Kong and EU's limit values, and taking account of the results of the mathematical air quality modelling following implementation of Phase I control measures, it is proposed that an exceedence of 9 times per year be allowed. The proposed new AQO with exceedences for ozone is statistically similar to the EU air quality standard for ozone.

4.2.4 Fine Suspended Particulates ($PM_{2.5}$)

According to WHO document, health risk attributable to exposure to particulate matter is better represented by $PM_{2.5}$. In view of the latest findings on the health effects of $PM_{2.5}$ in WHO, US, UK, and other leading countries on the subject, it is recommended to include $PM_{2.5}$ in the new AQO to reflect its importance as a pollutant of significant risk on health. The WHO document sets interim targets, IT1 of 35 µg/m^3, IT2 of 25 µg/m^3, IT3 of 15 µg/m^3 and AQG of 10 µg/m^3 for annual $PM_{2.5}$. The EU directive 2008 / 90 / EC has adopted WHO IT2 of 25 µg/m^3 as the annual $PM_{2.5}$ limit. However, the EU directive has not set limit value for 24-hr $PM_{2.5}$.

Table 4.6 summarizes the $PM_{2.5}$ data at ambient monitoring stations in Hong Kong in Year 2008. The $PM_{2.5}$ data at Tap Mun ambient station, which is representative of the local Hong Kong background, is also presented for comparison.

Table 4.6a: 2008 $PM_{2.5}$ monitoring data comparison (Concentration) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	Concentration in 2008 (Ambient)	Concentration in 2008 (Tap Mun)
$PM_{2.5}$	24-hour	IT-1: 75	113	99
		IT-2: 50		
		IT-3: 37.5		
		AQG: 25		
	Annual	IT-1: 35	41	35
		IT-2: 25		
		IT-3: 15		
		AQG: 10		

Table 4.6b: 2008 $PM_{2.5}$ monitoring data comparison (Exceedences) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	No. of Exceedences in 2008 (Ambient)	No. of Exceedences in 2008 (Tap Mun)
$PM_{2.5}$	24-hour	IT-1: 75	39	13
		IT-2: 50	128	87
		IT-3: 37.5	191	160
		AQG: 25	259	219
	Annual	IT-1: 35	×	✓
		IT-2: 25	×	×
		IT-3: 15	×	×
		AQG: 10	×	×

Based on 2008 monitoring data, the annual $PM_{2.5}$ at Hong Kong ambient (including Tap Mun) monitoring stations exceeded the WHO IT1 interim target. The highest recorded concentrations at ambient and Tap Mun monitoring stations were 41 µg/m^3 and 35 µg/m^3 respectively. As Tap Mun monitoring station is representative of the local Hong Kong background, this suggests that $PM_{2.5}$ is contributed mainly by the regional sources. Based on the data, it is difficult to achieve the WHO IT-1 interim target without further $PM_{2.5}$ reduction in the region. Taking into account the local circumstances, the interim target of WHO IT-1 of 35 µg/m^3 is proposed for annual $PM_{2.5}$. The corresponding WHO IT-1 interim target for 24-hr $PM_{2.5}$ is 75 µg/m^3.

According to 2008 monitoring data, the 24-hr $PM_{2.5}$ at Hong Kong ambient monitoring stations exceeded the WHO IT1 by 39 times. The highest recorded concentration at ambient monitoring stations was 113 µg/m^3.

The EU directive does not have 24-hr $PM_{2.5}$ limit. US adopt 3 yr average of 98th percentile as the allowable exceedences. Given that $PM_{2.5}$ concentration is contributed significantly by regional sources, the number of exceedences, which is proposed as 9 times in a year, was determined from the results of the mathematical air quality modelling under Phase I control measures.

4.2.5 Respirable Suspended Particulates (PM_{10})

The WHO sets interim targets, IT1 of 70 µg/m^3, IT2 of 50 µg/m^3, IT3 of 30 µg/m^3 and AQG of 20 µg/m^3 for annual PM_{10}. The corresponding interim target for 24-hr PM_{10} are IT1 of 150 µg/m^3, IT2 of 100 µg/m^3, IT3 of 75 µg/m^3 and AQG of 50 µg/m^3. The EU directive 2008 / 90 / EC has adopted 40 µg/m^3 (which is in between WHO IT2 and WHO IT3) as their annual PM_{10} limit. For 24-hr PM_{10}, the EU directive has adopted WHO AQG of 50µg/m^3 with 35 exceedences as their limit value.

Table 4.7 summarizes the PM_{10} data at ambient monitoring stations in Hong Kong in Year 2008. The PM_{10} data at Tap Mun ambient station, which is representative of the local Hong Kong background, is also presented for comparison.

Table 4.7: 2008 PM_{10} monitoring data comparison (Concentration) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	Concentration in 2008 (Ambient)	Concentration in 2008 (Tap Mun)
PM_{10}	24-hour	IT-1: 150	164	147
		IT-2: 100		
		IT-3: 75		
		AQG: 50		
	Annual	IT-1: 70	60	52
		IT-2: 50		
		IT-3: 30		
		AQG: 20		

Table 4.7: 2008 PM_{10} monitoring data comparison (Exceedences) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	No. of Exceedences in 2008 (Ambient)	No. of Exceedences in 2008 (Tap Mun)
PM_{10}	24-hour	IT-1: 150	4	0
		IT-2: 100	51	19
		IT-3: 75	134	78
		AQG: 50	211	167
	Annual	IT-1: 70	✓	✓
		IT-2: 50	×	×
		IT-3: 30	×	×
		AQG: 20	×	×

Based on 2008 monitoring data, the annual PM_{10} at Hong Kong ambient (including Tap Mun) monitoring stations exceeded the WHO IT2 interim target. The highest recorded concentrations at ambient and Tap Mun monitoring stations were 60 μg/m^3 and 52 μg/m^3 respectively. As Tap Mun monitoring station is representative of the local Hong Kong background, this suggests that PM_{10} is contributed mainly by the regional sources. Based on the data, both local and regional emission reduction are required in order to achieve the WHO IT-2 interim target. Taking into account the local circumstances and the local $PM_{2.5}$ / PM_{10} ratio, which has demonstrated a high fraction of $PM_{2.5}$ of greater than 0.7, the interim target WHO IT-2 of 50μg/m^3 is proposed for annual PM_{10}. The corresponding WHO IT-2 interim target for 24-hr PM_{10} is 100 μg/m^3.

The local $PM_{2.5}$ / PM_{10} ratio is estimated to be in the region of 0.7. Taking account of this $PM_{2.5}$ / PM_{10} ratio and the targets for $PM_{2.5}$ proposed above, the WHO IT-2 of 50μg/m^3 and 100 μg/m^3 are proposed for annual and 24-hr PM_{10} respectively. In line with the number of exceedances for $PM_{2.5}$, 9 exceedences per year are proposed for PM_{10}.

4.2.6 Carbon Monoxide

As explained in section 3.1, there is no interim target for CO in WHO document. The WHO AQG for 15-min CO, 30-min CO, 1-hr CO and 8-hr CO are 100,000 μg/m^3, 60,000 μg/m^3, 30,000 μg/m^3 and 10,000μg/m^3 respectively. The EU Directive 2008/50 / EC adopted the WHO AQG of 10,000μg/m^3 for 8-hr CO limit.

Table 4.8 summarizes the CO data at ambient stations in Hong Kong in Year 2008. The CO data at Tap Mun ambient station, which is representative of the local Hong Kong background from regional influence, is also presented for comparison.

Table 4.8a: 2008 CO monitoring data comparison (Concentration) with WHO guidelines

Air Pollutant	Avg time	Concentration (μg/m^3)	Concentration in 2008 (Ambient)	Concentration in 2008 (Tap Mun)
CO	15-min	AQG: 100,000	3,439	2,312
	30-min	AQG:60,000	3,324	2,116
	1-hour	AQG: 30,000	3,220	2,060
	8-hr	AQG:10,000	3,034	1,536

Table 4.8b: 2008 CO monitoring data comparison (Exceedences) with WHO guidelines

Air Pollutant	Avg time	Concentration (μg/m^3)	No. of Exceedences in 2008 (Ambient)	No. of Exceedences in 2008 (Tap Mun)
CO	15-min	AQG: 100,000	0	0
	30-min	AQG:60,000	0	0
	1-hour	AQG: 30,000	0	0
	8-hr	AQG:10,000	0	0

Based on 2008 monitoring data, the 15-min CO, 30-min CO, 1-hr CO and 8-hr CO at Hong Kong ambient (including Tap Mun) complied with the WHO AQG. The highest recorded 15-min CO concentrations at ambient and Tap Mun monitoring stations were 3,439 μg/m^3 and 2,312 μg/m^3 respectively. As Tap Mun monitoring station is representative of the local Hong Kong background, this suggests that CO is contributed by both local and regional sources.

The EU directive only adopts WHO AQG for 8-hr CO limit with no exceedence allowed. US adopt both 1-hr CO limit and 8-hr CO limit with allowance of 1 exceedence for each limit. On making reference to the international practices and taking into account our local circumstances, short term CO measurement (i.e 15-min and 30 min averaging time) is not proposed for Hong Kong. Instead, WHO AQG of 30,000 μg/m^3 for 1-hr CO limit and WHO

AQG of 10,000 µg/m^3 for 8-hr CO limit are proposed. As the CO levels are already below the respective WHO AQG, no allowance of exceedence is proposed.

4.2.7 Lead (Pb)

As explained in section 3.1, there is no interim target for Pb in WHO document. The WHO AQG for annual Pb is 0.5 µg/m^3. The EU Directive 2008/50 / EC adopted the WHO AQG of 0.5 µg/m^3 for annual Pb limit.

Table 4.9 summarizes the Pb data at ambient stations in Hong Kong in Year 2008.

Table 4.9a: 2008 Pb monitoring data comparison (Concentration) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	Concentration in 2008 (Ambient)
Pb	Annual	AQG: 0.5	0.064

Table 4.9b: 2008 Pb monitoring data comparison (Exceedences) with WHO guidelines

Air Pollutant	Avg time	Concentration (µg/m^3)	No. of Exceedences in 2008 (Ambient)
Pb	Annual	AQG:0.5	0

Based on 2008 monitoring data, the annual Pb at Hong Kong ambient monitoring stations complied with the WHO AQG. The highest recorded annual Pb concentration at ambient monitoring stations was 0.064 µg/m^3. On making reference to the EU directive, the WHO AQG of 0.5 µg/m^3 is thus proposed for annual Pb.

4.2.8 Other Pollutants

As the effect of total suspended particulates (TSP) is rather a dust nuisance than health threat, it is proposed that the existing AQO of TSP should be revoked.

4.2.9 Proposed New AQO

Taking into account of the above principles, the practices adopted by advanced countries such as EU, the guiding principles recommended by WHO and local circumstances, It is recommended to take a combination of ITs and AQG for revising the AQO, i.e.:

- WHO IT-1 for sulphur dioxide (24-hr), $PM_{2.5}$ and ozone
- WHO IT-2 for PM_{10}
- WHO AQG for nitrogen dioxide, sulphur dioxide (10-min), carbon monoxide and lead

Table 4.10 summarizes the proposed new AQO.

Table 4.10: Proposed new AQO

Pollutants	Avg. Time	Current AQO		Proposed AQO [*]							
				IT-1		IT-2		IT-3		AQG	
		(µg/m^3)	#	(µg/m^3)	#	(µg/m^3)	#	(µg/m^3)	#	(µg/m^3)	#
Sulphur Dioxide	10-min	-		-						**500**	**3**
	24-hour	350	1	**125**	**3**	50		-		20	
Respirable Suspended Particulates (PM_{10})	24-hour	180	1	150		**100**	**9**	75		50	
	1-year	55	0	70		**50**	**0**	30		20	
Fine	24-hour	-		**75**	**9**	50		37.5		25	

Pollutants	Avg. Time	Current AQO		Proposed AQO [*]							
				IT-1		IT-2		IT-3		AQG	
		($\mu g/m^3$)	#	($\mu g/m^3$)	#	($\mu g/m^3$)	#	($\mu g/m^3$)	#	($\mu g/m^3$)	#
Suspended Particulates ($PM_{2.5}$)	1-year	-		**35**	**0**	25		15		10	
Nitrogen Dioxide	1-hour	300	3	-						**200**	**18**
	1-year	80	0	-						**40**	**0**
Ozone	8-hour	240 [1]	3	**160**	**9**	-				100	
Carbon Monoxide	15-min	-								100,000	
	30-min	-								60,000	
	1-hour	30,000	3	-						**30,000**	**0**
	8-hour	10,000	1	-						**10,000**	**0**
Lead	1-year	1.5 [2]	0	-						**0.5**	**0**

Note:

[*] The proposed AQO are presented in bold faces with greyish background.

[#] Number of exceedences to be allowed: Any exceedence measured at the ambient air quality monitoring station(s) at any one time would be counted as one exceedence against the number allowed for a calendar year. The number of exceedences is recommended with reference to the current practices overseas as well as to the predicted air quality situation of Hong Kong after full implementation of the Phase I measures.

[1] There is no existing 8-hour AQO for ozone in Hong Kong. The figure presented above is the 1-hour AQO.

[2] There is no annual AQO for lead in Hong Kong. The figure presented above is the 3-month AQO

4.2.10 Air Quality Objectives for Roadside

Some countries and economies such as USA and Australia, apply AQO to outdoor ambient air (i.e., excluding roadsides) only while others such as UK and New Zealand apply their AQO to cover non-occupational, outdoor locations where a person might reasonably be expected to be exposed over the relevant averaging period.

Roadside air quality is of high importance in Hong Kong as a large portion of the population is subjected to exposure to this type of pollution. Particularly vulnerable groups include outdoor workers such as police, shop attendants, street hawkers, construction workers and drivers. The short averaging time AQO that are proposed is designed to protect this portion of the population where exposure to roadside pollution is normally less than 8 hours per day. It is proposed that the existing practice of having same AQO applicable to both ambient and roadside exposure should be continued. Following the UK practices, it is recommended that the AQO with long averaging time (i.e. annual limit) will not be applicable for roadside locations.

4.3 Implication of AQO

Any changes in the AQO will also have major implications in respect of the permitted emission standards for "specified processes" (such as electricity works) under the APCO or evaluating the air quality impact of designated projects under the Environmental Impact Assessment Ordinance (EIAO) (Cap 499), which are determined with reference to the prevailing legal AQO. For the former, changes in AQO will affect the permitted emission standards for specified process under APCO and the associated license application. For the latter, change in AQO will affect the criteria for evaluating the air quality impact of a proposed development.

5 Proposed Control Measures

This section identifies potential new measures to achieve the new AQO. Selection criteria have been developed to short list the new measures and categorizes them into different phases taking into account their practicability, maturity, availability and effectiveness. For each of the short listed measures, cost benefit analysis has been conducted to determine the benefit to cost ratio. Air quality modelling has been conducted to study the effectiveness of the measures and to forecast achievements of each phase of the control strategy implementation.

5.1 Potential New Measures

5.1.1 Selection of Proposed Control Measures

To achieve the proposed new AQO, it necessitates implementation of a series of drastic improvement measures across different sectors including power generation, energy efficiency, road and marine transportation sectors.

Apart from existing or committed control measures, the overseas experiences show that there are other potential measures that might help further reduce the emission in different sectors. After consideration of the potentials of these additional measures and the suggestions of local professionals and other concerned groups [4, 5, 6,7,8], a host of 36 comprehensive emission reduction measures has been identified and are grouped into Phases I, II and III according to the practicability, maturity of the technologies and feasibility of local adaptation. Broadly speaking, the measures target at the following areas -

- Emission capping and control
- Transport management
- Infrastructure development and planning
- Energy efficiency measures

5.1.2 Cost Benefit Analysis

Other than the technical feasibility and emission reduction potential of the proposed control measures, it is often a practice for other countries/economies (e.g., UK and New Zealand) to carry out cost benefit analysis (CBA) to quantified the effectiveness of the measures in monetary terms to provide another dimension for determining if the concerned measures should be proceeded. The CBA will inform consideration of any proposed changes in advance of the actual making of decisions on the proposed control measures. While the estimates on costs and benefits of the proposed measures are subject to variations depending on the detailed design and delivery arrangements as and when specific proposals are taken forward, the analysis provides a broad indication on their relative cost-effectiveness.

The CBA estimates the economic costs to be borne by the entire community and makes no distinction as to whether the costs would eventually be borne by Government, the operators or consumers at this stage.

For this study, the CBA applies the same and standard methodology as those used in the report of UK Department for Environment Food and Rural Affairs on “An Economic Analysis to inform the Air Quality Strategy – Updated Third Report of the Interdepartmental Group on Costs and Benefits – 2007”. There are also many references and practical guidance documents that have been referenced. For example, the UK Government has for many years produced CBA guidance in the Green Book of the HM Treasury[9], which provides the methodology for analysing investments by the public sector and which is widely referred to in Hong Kong. This guidance provides a clear and definitive set of principles and practical applications. The International Financial Institutions of the World Bank, Asian Development Bank and others also provide general guidance for CBA since it is a requirement that investment projects financed by the IFIs are subjected to economic analysis. Of the guidance available from these sources, a useful and very readable guide is by Pedro Belli et al (2007b)[10].

The costs referred to in this study include those of the policy instruments (i.e. developing the policy and the implementation details), and any other incidental capital and operational costs on the entire community as a consequence of implementation. According to the nature of the measures, the following assumptions have been made in estimating the capital costs-

(a) for those proposed measures which have already been commissioned or planned, such as expanding the rail network, their costs would not be included in the cost-benefit analysis as they would have already been borne by the respective projects;

(b) for those proposed measures involving accelerated replacement of assets, such as early retirement of aged/heavy polluting vehicles, only the residual values of the assets but not the entire cost of replacement would be included because the proposal has merely advanced their replacement; and

(c) for new proposed measures, e.g., district cooling system, full capital costs would be included.

The benefits of pollution control considered are primarily cost savings of a direct nature (principally short and long term health related cost savings, including the reduced costs of illness and reduced premature mortality, and savings in electricity cost) and indirect nature (principally impacts on the workforce and costs of maintenance and repair to buildings and structures arising from material damage caused by the air pollutants, and some lesser items).

The cost and benefit estimates, which are expressed in money terms, and are adjusted for a period of 50 years and are expressed on a common basis in terms of their 'present value (PV)' at 2008. Historical prices have been escalated to 2008 levels using the GDP deflator. This index is used in preference to the CPI as the prices to be escalated are far wider than consumer goods.

The health benefits considered in this study include both acute and chronic impacts. In assessing the acute medical cost due to air pollution, reference has been made to the findings of the local studies[11,12] conducted by health experts of local universities for the EPD. The unit acute medical costs, which are summarized in **Table 5.1**, include both estimates with exclusion and inclusion of productivity losses. The latter were used in the CBA of this study. For chronic health impacts, the estimates are based on figures presented in the UK Report DEFRA (2007), An Economic Analysis to inform the Air Quality Strategy – Updated Third Report of the Interdepartmental Group on Costs and Benefits, in the absence of local data Among air pollutants, PM-2.5 has chronic impacts significantly higher than others and is taken to be the pollutant for estimating chronic health costs.

Health benefits have been escalated at 2% pa to reflect an effect of rising real incomes and population on the valuation of health benefits.

Table 5.1: Acute medical cost due to 10 µg /m^3 change of the respective air pollutant

Air Pollutant	Excluding productivity loss (HK$M)	Including productivity loss (HK$M)
NO_2	227.3	289.7
RSP	114.3	142.6
SO_2	142.7	207.2
O_3	178.9	213.4

The discount rate used in this analysis is 4% as used by the Financial Services and the Treasury Bureau. This is the measure of social time preference advised by the Government and is roughly equal to the Government's long-term borrowing costs.

In order to undertake the discounted cash flow calculations assumptions have had to be made about the timing and phasing of the individual control strategy costs and benefits. The principal assumptions made are as follows:

(a) Implementation begins at the earliest practical date from 2009 onwards

(b) Allowance is made for phasing of changes in sectors, such as the phased retiring of older vehicles (rather than a one-year abolition)

(c) Allowing for the time taken to make the developments of policy itself, or in some cases the introduction of new technology such as hydrogen fuel cells, or sometimes of commercial factors such as power units, some strategies are referred to as follows:

- Phase I measures – assume to be implemented by 2015
- Phase II measures – assume to be implemented by 2020
- Phase III measures – assume to be implemented by 2030.

It should be emphasized that while every attempt has been made to make these assumptions as realistic as possible, they are, at best, representing one of the possible scenarios. As the actual implementation would be quite different from what have been assumed, the findings of the CBA should be read with caution.

All costs and benefits have been calculated to 2058 (i.e., a 50 years time horizon). They may not end then, of course, but this is a practical cut-off that reflects in discounted cash flow terms the fact that the influence of events after that date on the findings of the analysis is negligible. Moreover, the base case or "do-nothing" option against which the strategies are assessed becomes increasingly difficult to define.

Details of the CBA findings are in **Section 5.3**.

5.1.3 Phase I Control Measures

Phase I Measures comprise a total of 19 initiatives which are considered to be technological matured and feasible for implementation in short term, provided that some technical pre-requisites and social acceptance are provided. Following are the details of the proposed measures.

(a) Emission Capping and Control

(1) <u>Increasing the ratio of natural gas in local electricity generation to 50% together with additional emission abatement measures</u>

Natural gas is the cleanest and most energy-efficient fossil fuel available in the market today. It is clean burning, producing virtually no particulates, and less NO_X than other fossil fuels. As sulphur is almost entirely removed during the fuel processing such as liquefied process, combustion of natural gas emits negligible amounts of SO_2. In addition, electricity generation by NG combined cycle gas turbines have significantly higher generation efficiency than other fossil fuel units.

Switching to cleaner fuel or energy for electricity generation has become a trend for emission reduction. For example, in California, USA, the electricity generated from natural gas, renewable energy and nuclear energy has increased from 86.7% in 2002 to 92.3% in 2006. In Singapore, the electricity generated from natural gas has also doubled from 43.3% in 2002 to 77.8% in 2006.

For Hong Kong, the current policy on control of emission from electricity generation is to require the use of best practicable means for prevention of emissions and that no new coal fire plant will be allowed to be erected since 1997. At present, about 28% of the local electricity generation are produced by NG firing.

In order to increase the NG ratio, the security of a long term natural gas supply is also a pre-requisite. The Memorandum of Understanding signed between the HKSAR Government and the National Energy Administration on 28 August 2008 would provide a good opportunity to guarantee a long-term and stable supply of natural gas from three different sources — namely, offshore gas, piped gas, and liquefied natural gas (LNG) to be supplied through an LNG terminal to be built, as a joint venture, on a neighbouring Mainland site.

Electricity generation is the largest source of emissions in Hong Kong, accounting for 89% of SO_2, 46% of NO_X, and 28% of RSP emitted locally in 2007. Increase of the use of NG for electricity generation will help reduce significantly the air pollutant emissions. However, due to the high level discharge and proper location of the existing power plants away from the densely populated centres, the emission reduction to be resulted from this proposed measure would help mainly the improvement of the regional instead of local air pollution.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Increasing the ratio of natural gas in local electricity generation to 50% together with additional emission abatement measures	13,402	25,225	523	0

It is anticipated that additional two 313MW / 335MW gas fired unit would be required for this strategy.

This measure generates significant air quality benefits. The benefits of the emission reduction are mainly regional. However, the costs associated with advancing the retirement age of coal units at the power plants and switching to more expensive fuel are also substantial. As a result the overall strategy cost-effectiveness is marginal. The benefit/cost (B/C) ratio was calculated to be below unity.

(2) <u>Early retirement of aged / heavily polluting vehicles (pre-Euro, Euro I and Euro II commercial diesel vehicles and franchised buses)</u>

The proposed measure requires early retirement of Pre-Euro, Euro I and Euro II commercial vehicles and franchised bus.

Hong Kong has been implementing a policy to require the most stringent motor vehicle emission standards in tandem with EU's requirements. Notwithstanding this, road vehicles remain the second largest source of air pollution in Hong Kong, contributing to 25% and 27% of the territory-wide emissions of respirable suspended particulates ($PM_{2.5}$) and nitrogen oxides (NO_X) respectively. Of the vehicle fleet, diesel commercial vehicles are key contributors to air pollution, accounting for 90% and 80% of the total vehicular emission of RSP and NO_X respectively. Despite the fact that the number of pre-Euro to Euro II diesel commercial vehicles would decrease as a result of natural phasing out, it is expected that by Year 2015, there would still be about 26283 commercial diesel vehicles and 2850 franchised buses of these categories (projected based on Yr 2007 vehicle population profile from EPD). As their pollutant emissions contribution are much higher than other vehicles, early replacement of these vehicles with the latest Euro ones will help reduce significantly the vehicle emissions.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Early retirement of aged / heavily polluting vehicles (pre-Euro, Euro I and Euro II commercial diesel vehicles and franchised buses)	0	3102	300	184

The benefits of the emission reduction are likely to be Territory-wide. This strategy has substantial benefits due to the removal of heavily polluting vehicles. The benefits are considerably in excess of the costs associated with removing these vehicles from the roads. This strategy is one of the most cost-effective.

(3) <u>Earlier replacement of Euro III commercial diesel vehicles with models meeting latest Euro standards</u>

The number of vehicles to uptake the latest Euro V standard will depend on various factors including availability of Euro V vehicle models in the local market, operational situation of the transport trade and amount of incentives provided. To encourage the use of environment-friendly commercial vehicles, which have low emissions, starting from 1 April 2008, reduction in the First Registration Tax (FRT) will be offered to buyers of newly registered environment-friendly commercial vehicles. However, as commercial diesel vehicles are often more durable and it is expected by Year 2015, there would still be about 20,332 and 13,509 Euro III light goods vehicles (LGV) and heavy goods vehicles (HGV) in use (projected based on Yr 2007 vehicle population profile from EPD).Given the latest Euro vehicles, i.e. Euro V vehicles, will emit only 36% (for LGV) to 40% (for HGV) of NO_X comparing to Euro III models, early uptake of latest Euro vehicles will help reduce their emissions.

It is noted that similar measures has also been implemented in other countries and economies such as EU which requires all new registration for passenger cars (M1 type) to be Euro 5 in 2011 and all new registration for goods vehicles (N1- Class 1, 2, 3 and N2) to be Euro 5 in 2011 - 2012.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Earlier replacement of Euro III commercial diesel vehicles with models meeting latest Euro standards	0	743	75	24

The benefits of the emission reduction are likely to be Territory-wide. As with the previous strategy of early retirement of polluting vehicles, the earlier uptake of latest Euro standards for diesel commercial vehicles also provides considerable benefits and these are well in excess of the likely costs. Accordingly, this strategy is highly cost-effective.

(4) <u>Wider use of hybrid / electric vehicles or other environment-friendly vehicles with similar performance (20% private cars and 10% franchised buses)</u>

A hybrid vehicle is a vehicle that adopts two or more distinct power sources to propel the vehicle. Common power sources include: on-board rechargeable energy storage system and a fuelled power source (e.g. internal combustion engine). The use of rechargeable battery to provide electrical power to drive a car can help reduce air pollutant emissions of about 80% less of both RSP and NO_X emissions.

Failure of hybrid buses was observed in the past in Toronto, Canada, primarily because of the short working life (around 1.5 years) of the lead acid batteries used. In recent years, however, there have been breakthroughs in the technology for electric vehicles. New generation batteries are used to develop electric vehicles with longer travel range that can better satisfy drivers' needs. The hybrid buses in Ottawa, Canada, have adopted newer lithium ion batteries with a working life of more than five years, requiring only little maintenance, lightweight and very efficient. In London, UK, double deck hybrid buses have also been in operation. The London Transport Department has planned to add 40 double-decker hybrid buses to the fleet in Year 2007 and then gradually increased up to 500 per year by the time of the 2012 Olympics[13].

Although the cost of a hybrid vehicle is 20% (for private car) to 66% (for franchised buses) higher than the conventional model, the improvement in its fuel efficiency in hybrid vehicles, which could offset the higher vehicle cost, would provide an incentive for car owners, especially when high fuel cost prevails.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Wider use of hybrid / electric vehicles or other environment-friendly vehicles with similar performance (20% private cars and 10% franchised buses)	15	216	7	173

The benefits of the emission reduction are likely to be Territory-wide. The additional costs of hybrid vehicles over conventionally-powered vehicles are high and this partly explains their slow take up in Hong Kong. Although this strategy generates significant benefits, the costs outweigh these and as a result the B/C ratio is well below unity. This strategy is less cost-effective than many others in the transport sector.

(5) <u>Ultra low sulphur diesel (ULSD) for local vessels</u>

Industrial diesel of 0.5% sulphur content is being used by local vessels other than Government vessels which have been using ULSD with sulphur content of less than 0.005% by weight since 2001. This proposed measure is to require the extension of the use of this cleaner diesel to other local vessels, which will help reduce the SO_2 emissions by 99%.

Noting that some local ferry operators are still concerned about the technical feasibility of using ULSD in their vessels, in particular, those equipped with two-stroke engines, the Government is planning to launch a trial scheme in 2009 to ascertain the feasibility. The information collected in the trial, such as pattern of fuel consumption, maintenance requirement and logistics for supplying ULSD for refill, will help to map out the detailed proposal and way forward.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Ultra low sulphur diesel (ULSD) for local vessels	675	0	18	0

The benefits of the emission reduction are likely to be Territory-wide. ULSD for local vessels generates considerable benefits and the costs are modest. Therefore this strategy is highly cost-effective.

(6) <u>Selective catalytic reduction (SCR) for local vessels</u>

Selective catalytic reduction (SCR) of NO_X has been used in other advanced countries/economies (e.g. USA) in stationary and marine diesel applications. It is a means of converting nitrogen oxides in exhaust gas, with the aid of a catalyst, into the inert nitrogen and water. In California, USA, the California Air Resources Board (CARB) has proposed cleaner engine (new or retrofits) for reducing vessel emission, expected to be implemented in 2010. By 2014, ships visiting California's ports would have either new engines or a mix of retrofit technology that would achieve an overall reduction of NO_X and PM of 30%.

The SCR technology is mature and can be applied on new vessels. For existing fleets, it would be more feasible to make the retrofit in larger vessels. The technical issues need to be considered is the tuning of the SCR system to the engine operating cycle. This requires running the engine through a simulation of the operating cycle of the machine which will be fitted. Another issue is the possible release of un-reacted ammonia, or commonly referred to as ammonia slip, which can occur when catalyst temperatures are not in the optimal range for the reaction or when too much ammonia is injected into the process. However, these issues can be solved with the current technologies.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Selective catalytic reduction (SCR) for local vessels	0	304	0	0

The benefits of the emission reduction are likely to be Territory-wide. In contrast with the use of ULSD, selective catalytic reduction for local vessels generates relatively low benefits and although the costs are modest, the B/C ratio is small and this is not a cost-effective strategy.

(7) <u>Electrification of aviation ground support equipment</u>

Ground support equipment (GSE) in airport includes the heavy diesel-fuelled compression ignition equipment to service and support aircraft operations. It comprises a diverse range of vehicles and equipment to service aircraft after landing and before takeoff. Major services include cargo loading and unloading, passenger loading and unloading, potable water storage, lavatory waste tank drainage, aircraft refuelling, engine and fuselage examination and maintenance, and food and beverage catering. Overseas experience shows that GSE emissions would amount to about 10-15% of total airport NO_X emissions.

Experience of US airports, e.g., Los Angeles International, shows that it would be practical to reduce these emissions by electrification. The CARB also encourages the use of electric GSE and proposes a progressive tightening fleet emission target to be met for the GSE, starting from 2009. There are different requirements for small, medium and large fleets. The application of electric GSE requires early phasing out of existing equipment.

In order to accommodate the GSE electricity supply, the electricity infrastructure inside the airport will have to be modified.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Electrification of aviation ground support equipment	85	759	21	67

The benefits of the emission reduction are likely to be Territory-wide. There is considerable uncertainty associated with some of the assumptions for this strategy but it is clear that the benefit level is very low. Therefore, this is a low cost-effective strategy.

(8) <u>Emission Control for off-road vehicles / equipment</u>

Off-road vehicles and equipment, which consist of diesel engines, are found mostly in construction industry in Hong Kong. The number of construction sites in Year 2007 was about 946. Some more common off-road vehicles are tractors, excavators, dozers, scrapers, portable generators, irrigation pumps, welders, compressors, scrubbers, and sweepers in construction sites.

Many new off-road diesel engines are now able to comply with the latest USEPA and CARB emission requirements. For existing off-road vehicles and equipment, the technology and control measures of controlling emissions such as the use of USLD as fuel, emission control retrofit, such as exhaust gas re-circulation, diesel particulate filters, are becoming more mature[14]. Requiring the application of these technologies/measures will help reduce emissions from off-road vehicles and equipment.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Emission control for off-road vehicles / equipment	4	950	239	326

The benefits of the emission reduction are likely to be Territory-wide. The control over emissions for building and construction vehicles and equipment can generate considerable air quality benefits and the costs would be modest in comparison. Therefore this strategy is cost-effective with a high B/C ratio.

(9) Strengthening Volatile Organic Compounds control

Volatile organic compounds (VOC) are important precursors of smog and will react with nitrogen oxides under sunlight to form ozone and other photochemical oxidants. To help reduce smog formation, it is important to ensure the VOC emissions from all sources will be kept to minimum.

For VOC-containing products, the Air Pollution Control (Volatile Organic Compounds) Regulation 2007 imposes maximum limits on the VOC content of architectural paints/coatings, printing inks and six selected consumer products, viz., air fresheners, hairsprays, multi-purpose lubricants, floor wax strippers, insecticides and insect repellents. The VOC limits prescribed are in line with those adopted in California, which are the most stringent standards in the world.

Further extension of the scope of control to other VOC-containing products is feasible. Among others, non-architectural paints, solvents, sealants and adhesives, which have also been control in California, would be in the priority list. VOC emission limits referencing to those adopted in California, with adequate adjustments to suit local circumstance, is considered feasible and will help promote the use of the less toxic water-based alternatives.

Extension of other VOC-containing products, such as the fragrances and cosmetic products is significantly less effective although they are also currently controlled in California. It requires careful consideration and assessment before proceed further.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Strengthening volatile organic compounds control	0	0	0	700

The benefits of the emission reduction are likely to be Territory-wide. Strengthening VOC control would be very low cost and would also generate low level of benefits. However, the ratio of B/C is high and even though the overall benefit level is one of the smallest of the strategies which have been investigated. It would appear that this would be a very cost-effective strategy to adopt.

(b) Transport management

(10) Low Emission Zones

A low emission zone (LEZ) is a traffic management measure aiming at reducing road transport emissions over a defined geographic area, by restricting certain vehicle types, ages or technologies from entering the zone.

The LEZ has been in place in Sweden since 1996, targeting at all diesel lorries and buses over 3.5 tonnes. On introduction, the scheme required all these vehicles to meet the Euro 1 standard. Vehicles between 9 and 15 years old were also allowed to operate in the zone if they had been retrofitted with a certified emissions control device or new engine. There was also a special permit for vehicles that only travelled rarely in the zone. The zone is enforced using a permit system for older vehicles (windscreen stickers) with visual inspections. Vehicles driving illegally in the zone are subject to a fee, enforced by police authorities. The zone does not have any signage. The compliance rate is around 90% (based on visual inspections). The zone is simple and has low costs to administer.

In London, UK, the LEZ of London came into effect on February Year 2008. The emissions standards for the Low Emission Zone (LEZ) are based on Euro standards. The following summarizes the emission standards adopted in London LEZ:

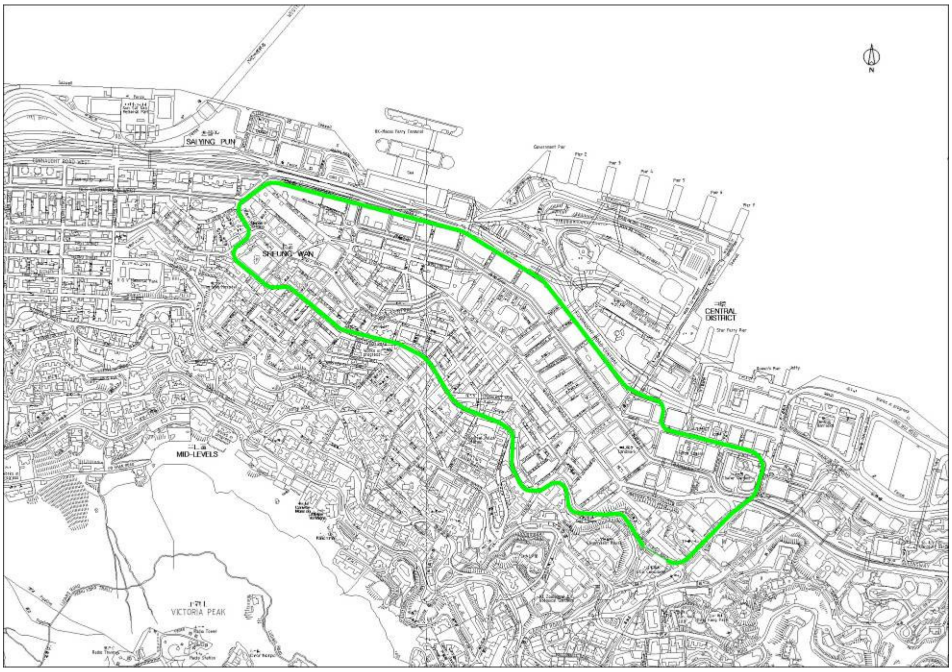
- From 4 February 2008, a standard of Euro III for particulate matter (PM) for lorries over 12 tonnes
- From 7 July 2008, a standard of Euro III for particulate matter for lorries between 3.5 and 12 tonnes and buses and coaches with more than eight seats plus the driver's seat over 5 tonnes.
- From 4 October 2010, a standard of Euro III for particulate matter for larger vans and minibuses
- From 3 January 2012, a standard of Euro IV for particulate matter for lorries over 3.5 tonnes and buses and coaches over 5 tonnes

The LEZ is intended to improve the quality of air in London and to reduce the concentrations of harmful pollutants, by accelerating the introduction of cleaner vehicles and reducing the numbers of older, more individually polluting vehicles within the LEZ. Non-compliant vehicles, although could still drive within the LEZ, will be required to pay a charge (up to £200 per day) to do so. The demarcation of the LEZ allows diversionary routes and facilities other vehicles to turn around without entering the zone.

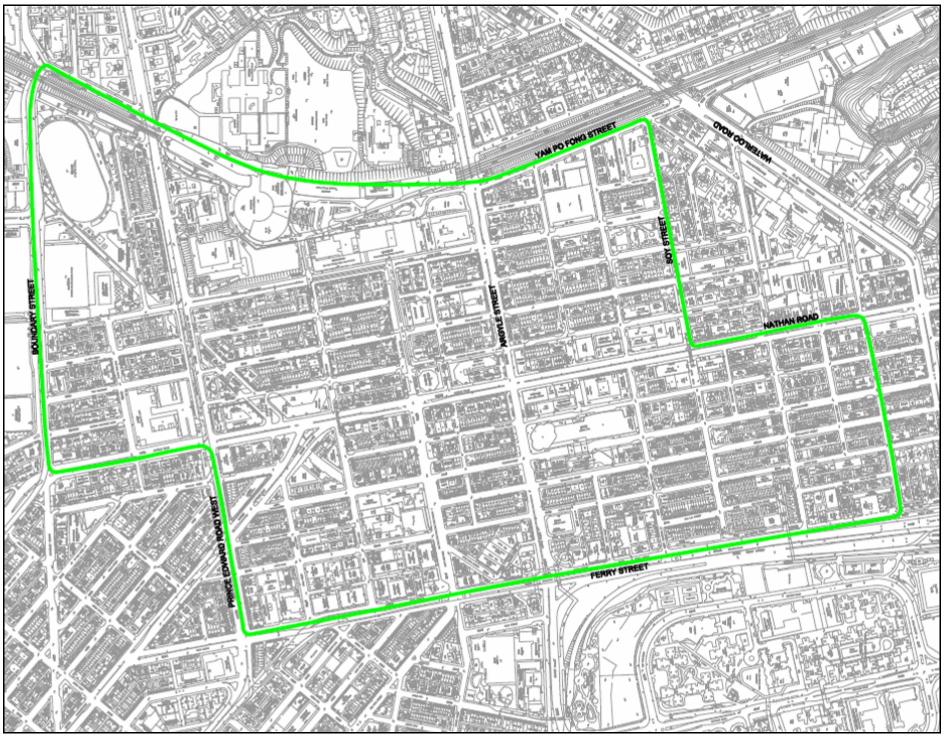
Study[15] shows that the LEZ would deliver reduced emissions of both NO_X and PM_{10}, particularly after 2012 following the implementation of Euro IV standard. The results would be greatest along main roads, and in the background areas within London. It is, therefore, reasonable to expect that the introduction of LEZ by banning the pre-Euro, Euro I, Euro II and Euro III vehicles from entering into these zones should also help reduce significantly the roadside air pollution exposures of passers-by, roadside workers and residents living in these districts even though the net emission reduction in the whole territory would not be significant as traffic might be diverted to other areas.

A successful implementation of LEZ requires lifestyle and behaviour changes, not only to the vehicle owners, but also the community as a whole. It is expected that the imposition of emission charges for non-compliant vehicles would not be welcome by vehicle owners. Also, the shop owners inside the LEZ may also raise their objection as they may worry that their business may be affected by the scheme. It may, therefore, more appropriate to start off with a smaller scale LEZ, focusing on the pollution hot spots of busy districts, such as Central, Mongkok and Causeway Bay. With more experience gained, a full scale LEZ scheme such as those proposed in the following figures may be considered in these districts. Further extension to other areas can be considered once the effectiveness of the LEZ in improving roadside air quality have been confirmed.

Proposed LEZ in Central



Proposed LEZ in Mongkok



Proposed LEZ in Causeway Bay

The estimated emission potential is summarized as follows:

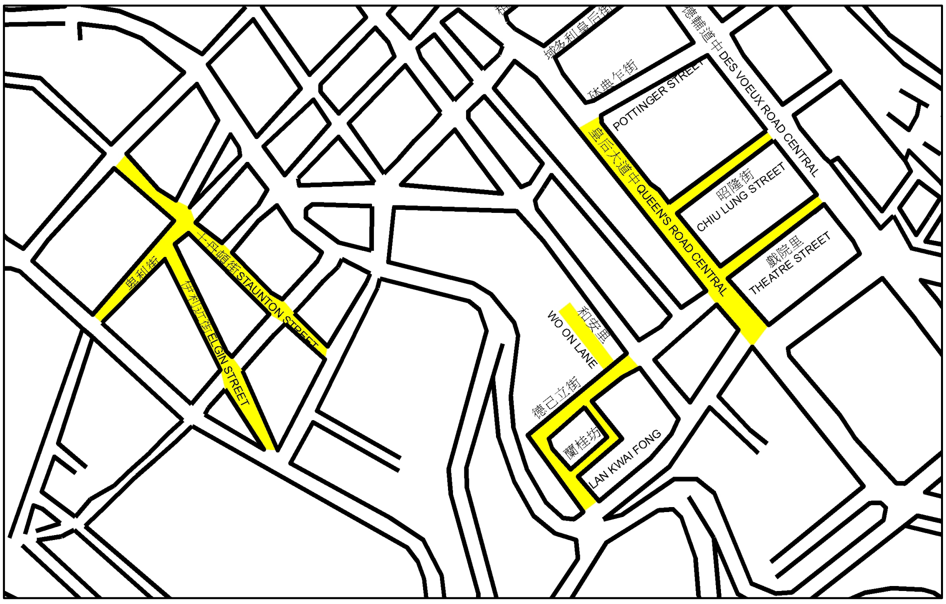
	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Low emission zones	NA	NA	NA	NA

The LEZ are transport management strategies. They will divert traffic to other districts. Hence, the overall emission reduction is zero. The benefits of the emission reduction are likely to be specific to the zone. Introduction of LEZs would have variable impacts across the territory, being a high benefit approach to air quality improvement in dense area. As a result the strategy, if applied at several locations across the territory, would not be cost-effective but selective applications such as in dense area would appear to be cost-effective.

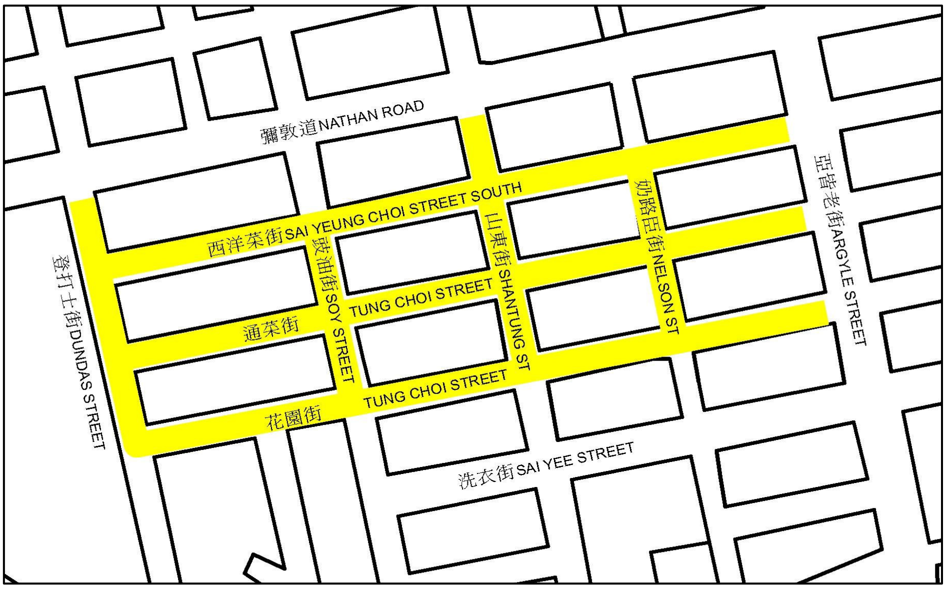
(11) <u>Car-free zone / pedestrianisation scheme</u>

In a car-free zone or pedestrisation scheme, automobile is prohibited. Since 2000, the Transport Department (TD) has started to implement some pedestrian schemes in several areas, including Causeway Bay, Central, Wan Chai, Mong Kok, Tsim Sha Tsui, Jordan, Sham Shui Po, Stanley and Shek Wu Hui. Extending the present restriction to all time all type of vehicles in pedestrian streets and traffic calming streets in busy districts, such as Mongkok, Causeway Bay and Central will be helpful in further reducing the roadside exposures by the public. The following figures show the extension of the car free zones for Central, Mongkok and Causeway Bay.

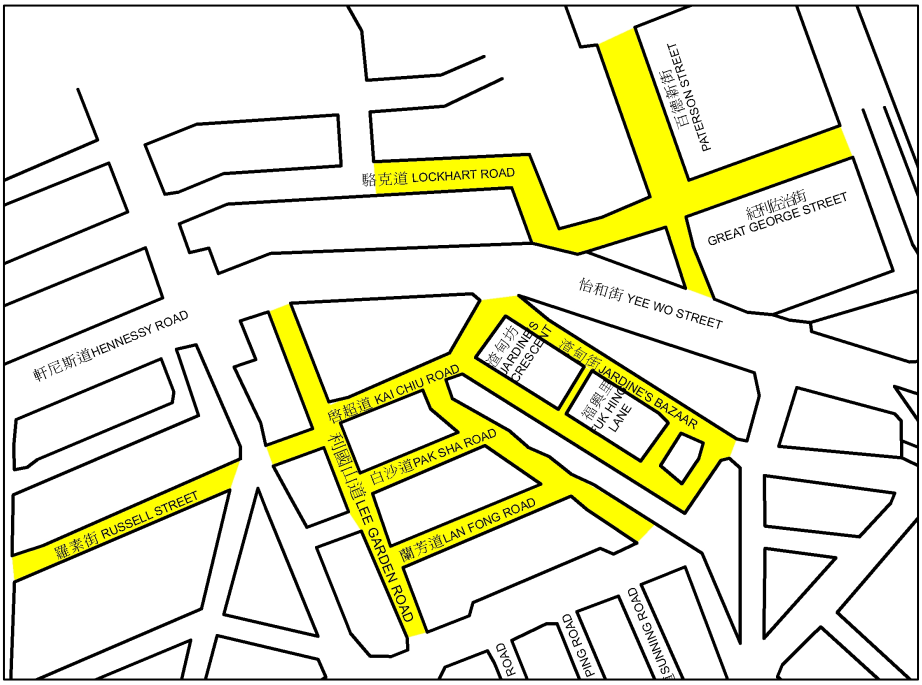
Proposed CFZ in Central



Proposed CFZ in Mongkok



Proposed CFZ in Causeway Bay



The segregation of traffic from nearby residents and passers-by will help further reduce the air pollution exposure. However, similar to LEZ, the success of a car-free zone or pedestrianisation scheme requires lifestyle and behaviour changes, not only to the vehicle owners, but also the community as a whole. It is appropriate to start off with a scheme at smaller scale focussing on traffic hot spots. Extension to other streets can be made when sufficient experiences are gained.

Similar to LEZ, a net emission reduction in the whole territory is not expected beause of the possible diversion of traffic to non-car free or non-pedestrisation streets.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Car-free zone / pedestrianisation scheme	NA	NA	NA	NA

The car free zones / pedestrianisation schemes are transport management strategies. They will divert traffic to other districts. Hence, the overall emission reduction is zero. The benefits of the emission reduction are likely to be specific to the zone. The car free zones / pedestrianisation schemes also have variable benefits depending upon their location and, as with LEZs, would be highest in dense areas. However the air quality benefits are relatively modest in size. There are many other reasons for pursuing these schemes than air pollution reduction and overall these schemes would appear to be highly cost-effective.

(12) Bus route rationalization

Rationalization of bus routes will optimise the bus trips and hence reduce the number of buses travelling on roads. According to TD's information, as a result of the bus route rationalization from 1999 to 2007, a total of 109 franchised buses have been withdrawn from the road, and some 5,700 bus trips per day and 4,800 bus stoppings per peak hour at the relevant busy corridors were reduced. On comparing the data between 2002 (when the franchised bus fleet reached the high of 6,378 buses) and 2007 (5,889 in 2007), the total no. of buses withdrawn is 489.

Bus route rationalization will likely cause inconvenience to some commuters and local communities. Further bus route rationalization, if proceeded with, should, therefore, come from bus trips in non-peak hours. Should further progressive steps be taken to rationalise bus routes such that about 10% of these non-peak hour bus trips be reduced, this will help further reduce emissions at roadsides.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Bus route rationalization	4	156	7	9

The benefits of the emission reduction are likely to be Territory-wide. Bus route rationalisation generates considerable local air quality benefits which are well in excess of the costs of the strategy. Therefore this strategy is highly cost-effective even though the benefits are modest in size.

(c) Infrastructure development and planning

(13) Expand rail network

Vehicles using road networks will contribute to air pollution, in particular NO_X and RSP. Railway based transportation, which emits less pollutants than vehicles even if the emissions from power plants are also counted, is a cleaner mode of transportation and would help reduce significantly the near source exposures resulted from vehicles at roadsides.

In the Policy Address Year 2007 - 2008, the Government has committed to developing rail system as an important backbone of transportation infrastructure in Hong Kong. Among others, rail projects including the Express Rail Line, Sha Tin to Central Link (the Tai Wai to Hung Hom section), West Island Line, South Island Line (East), Kowloon Southern Link, and Kwun Tong Line Extension are scheduled to be in place by Year 2016 (Note: North Island Line will not be completed earlier than 2021). Although the construction of these rail networks is driven by factors including economics, travelling time and transport policy which are not environmentally related, they will help bring in air quality benefits to all sectors of the community.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Expand rail network	17	501	46	207

The benefits of the emission reduction are likely to be Territory-wide. The air quality benefits are a ride on effect.

(14) Cycling network to major public transport hubs

Cycling does not emit air pollutant emissions. Using bicycles to replace short vehicle trips and city driving will help reduce emissions even though they may not be very significant. It has attracted more attention by some major cities. For example, Sydney is implementing their BikePlan 2010 which involves the construction of over 200 km of cycleways per year and provision of bike lockers at transport interchanges. Similarly, London is building a London Cycle Network (LCN+) which aims to provide a network of safe convenient and conspicuous cycle routes linking residential areas with all major centres of employment, retailing, leisure and transport across London. The LCN+, which comprises a 900km network of radial and orbital routes for cyclists covering the whole of London will be completed in 2010.

In Hong Kong, a Cycle Track Network in the New Territories with a total length of about 82km (Tuen Mun – Ma On Shan section, and Tsuen Wan – Tuen Mun section) is proposed[16]. The cycle track network is planned for completion in phases from 2013 onwards.

A well-planned cycling track can serve not only the recreational purpose but also to connect to the public traffic hub as well if facilities and infrastructure such as parking lots, lighting and bike lockers etc. can be provided. Due to the constraints and road safety consideration, it is considered that this proposed measure is feasible only in new development areas.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Cycling network to major public transport hubs	0.1	2.3	0.1	0.1

The benefits of the emission reduction are likely to be Territory-wide. Cycle networks generate very small air quality benefits and the B/C ratio is one of the lowest of the strategies considered. However, it is recognised that there are additional benefits from cycling other than improvements in air quality which have not been included.

(d) Energy efficiency measures

(15) Mandatory Implementation of Building Energy Codes

Since 1998, the Electrical and Mechanical Services Department (EMSD) has issued five sets of Building Energy Codes (BECs), covering four key types of fixed building services installations – lighting, air-conditioning, electrical and lift and escalator, and the performance-based BEC – and has been operating the voluntary Hong Kong Energy Efficiency Registration Scheme for Buildings (HKEERSB).

However, voluntary compliance with the BECs does not appear to be forthcoming in Hong Kong. The Government consider that it is necessary to pursue mandatory implementation of the BECs to complement market driven changes. It is in fact a well-established international practice to require buildings to comply with minimum energy efficiency standards by means of legislation. For example, the Mainland and some overseas countries, including Australia, Singapore, the United Kingdom and the United States have implemented minimum energy efficiency requirements for buildings[17 18 19 20 21 22].

The consultation document "A Proposal on the Mandatory Implementation of the Building Energy Codes" sets out the Administration's proposals on the mandatory implementation of the scheme as follows:

(a) new commercial buildings and the communal areas of new residential and industrial buildings in both the private and public sectors as well as major retro-fitting works in existing buildings should comply with the BECs promulgated by EMSD. The list of buildings with Certificates of Compliance issued would be made available for public inspection;

(b) to enhance energy efficiency, energy audits are required for certain buildings once every 10 years. The results of the audits would be made available to occupants; and

(c) to complement the proposed legislative scheme, buildings that have exceeded the minimum building energy efficiency standards by a prescribed percentage will be recognised by an energy mark through a voluntary administrative scheme.

The Policy address 2008 – 2009 has indicated that the Government would legislate for the mandatory compliance of Building Energy Codes to improve energy efficiency in new and existing buildings as soon as possible.

When adopting the mandatory building energy performance code, an additional capital outlay in the region of 3%-5% of the building construction cost may have to be incurred in return for about 10 to 15% annual saving in energy bills[23]. On average, the payback period for the additional capital investment is six years.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Mandatory Implementation of Building Energy Codes	151	256	8	3

The benefits of the emission reduction are likely to be Territory wide. Building energy codes would generate considerable benefits at very modest cost, and have a very high B/C ratio. This is one of the most cost-effective of the strategies considered.

(16) <u>Energy efficiency standards for domestic electrical appliances</u>

To facilitate the public in choosing energy efficient appliances and raise public awareness on energy saving, the Government has introduced a mandatory Energy Efficiency Labelling Scheme (EELS) through the Energy Efficiency (Labelling of Products) Ordinance (Cap. 598) to cover room air conditioners, refrigerating appliances and compact fluorescent lamps in the first phase. Starting from 9 November 2009, all prescribed products are also required to be supplied with energy labels to help consumers in choosing energy efficient products

The implementation of the mandatory EELS for these three prescribed products, will help the public to change their lifestyle which, in turn, would result in reduction of both the electricity consumption and emissions. It is estimated that an additional electricity saving of 150 GWh per year (amounting to a saving about $135 million in electricity bill per year) could be achieved[24].

According to the Policy Address 08 – 09, the Government will propose amendments to the Energy Efficiency (Labelling of Products) Ordinance in 2009 for the second phase of the Scheme. This will further facilitate the public in choosing energy-efficient products.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Energy efficiency standards for domestic electrical appliances	84	142	4	1

The benefits of the emission reduction are likely to be Territory wide. The costs of implementing improvements to energy efficiency for electrical appliances for domestic use are low and the benefits are considerable. This is one of the most cost-effective of the strategies considered.

(17) Light Emitting Diode or equivalent alternatives for traffic signal / street lighting

The use of light-emitting diode (LED) as a lighting device will reduce the electricity consumption because of higher efficiency. This will lead to a reduction in emissions through savings in electricity used. The technology is already quite mature. Although high upfront installation cost is required, this will be compensated by lower running cost. Since 2004, the Transport Department has gradually installed LED traffic signals at about 150 junctions on a trial basis. In April 2008, the Legislative Council Finance Committee approved funding for replacement of all conventional traffic signal at 1,900 signalised junctions in Hong Kong with LED traffic signals by phases at about $140 million before end 2012. This initiative is expected to save electricity of some 7.6 million kWh each year.

Extension of the use of LED or other lighting devices with equivalent performance to street lighting may be also feasible. Researchers from the Department of Industrial and Systems Engineering of Hong Kong Polytechnic University show that a high-power LED street lighting system which would be longer lasting, energy saving and cost-effective may be developed in the near future. Subject to further evaluation of its technical feasibility and acceptance by the public, it could serve as a measure to help reduce the electricity consumption and air pollutant emissions.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Light-emitting diode or equivalent alternatives for traffic signal / street lighting	3	5	0.1	0

The benefits of the emission reduction are likely to be Territory wide. The introduction of LED for street lighting would produce very low level of benefit but this would exceed the costs of doing so by a significant margin. So despite its small contribution to improved air quality, this would be a cost-effective strategy to pursue.

(18) Tree planting/ roof-top greening

A green roof is a roof of a building that is partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane. The green roof can bring a number of benefits including reducing heat gain from roof and mitigating urban heat island effect which would accelerate the chemical reactions for pollution formation and air pollutant re-circulation.

Green roofs have been applied in small scales in the United States and Canada. An example is the green roofs of the Ford Motor Company's River Rouge Plant, Dearborn, Michigan, USA. In Hong Kong, the Two International Financial Centre (IFC2) Hong Kong provides a local example of an intensive green roof system. The IFC2 development contributes a number of open spaces which enhance the public realm of the Central Business District. These comprise large urban public open spaces, two of which are Designated Public Open Spaces and are accessible 24-hours a day. The Second Public Open Space comprises a Podium Garden at Level 4, and the Harbour-side Terrace at Level 3. Both the garden and the terrace serve community needs for more passive recreation spaces in the Central Business District, and are fully integrated with adjoining retail and entertainment uses in the retail podium. As usable urban public open space is highly prized in the Central Business District, the usability of the public open space is maximised by minimising low planting and planters which visually and physically break up the space and inhibit free pedestrian circulation. 'Greening' is provided in the form of a series of raised lawns, which can be used as informal recreation areas, and groves of semi-mature trees which will, in time, create a virtually continuous shade canopy. Selected trees comprise blocks of dark-foliage semi-mature *Ficus altissima* at the podium edge, and larger blocks of light green foliage semi-mature, semi-deciduous *Ficus rumphii* which provide light shade to seating areas. *Cerbera manghas* are planted along the Harbourside Terrace, and *Plumeria rubra* on the roof of the retail bridges.

The Architectural Services Department has conducted a comprehensive study on the green roof application in 2007[25]. The study considered that Intensive Green Roofs should be promoted as the prime direction for the future of green roofs in Hong Kong. Extensive Green Roofs could be considered for retro-fitting projects and situations where Intensive Green Roofs are not practical. In considering the adoption of green roof, there are number of issues to be taken into account including: high winds, high summer rainfall with low winter rainfall, high & exposed buildings, and little experience in using low-maintenance plant species that fit the defining criteria of extensive green roofs.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Tree planting / roof-top greening[1]	---	---	---	---

Note [1]: No local data available

The benefits of the emission reduction are likely to be Territory wide. There are significant costs associated with roof top greening and the benefits would be low in comparison. It would be a small B/C ratio. This strategy has a low level cost-effectiveness.

(19) <u>District cooling system for Kai Tak Development</u>

District cooling system has higher energy efficiency as compared to individual cooling tower. Its use will reduce the electricity usage and eventually lead to a reduction in emissions.

To promote energy efficiency and conservation, and to reduce carbon dioxide emissions substantially, the Government has committed to implementing a district cooling system at the Kai Tak Development to supply chilled water to buildings in the new development area for centralised air-conditioning[1],. Apart from the benefits of saving energy, this system can eliminate the need of chiller plant rooms in individual buildings and provide the following intangible benefits:

- Better building design by allowing more flexible and innovative building design as space and external louver provision for chillers or cooling towers will no longer be required
- More efficient and effective utilization of building floor space
- Less noisy operation.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
District cooling system for Kai Tak Development	6	16	0.5	0.2

The benefits of the emission reduction are likely to be Territory wide. District cooling at Kai Tak, largely because of its well researched and already advanced design, would be cost-effective.

5.1.3 Phases II Control Measures

Phases II and III Measures comprise a total of 11 and 6 initiatives, respectively. They are either emerging technologies which are not yet fully developed or measures that would be of great controversy or subject to international agreements. It is considered most of them would only be ready for implementation in medium or even long term. Following are the details of the proposed measures.

(a) Phase II Measures

(20) <u>Increasing the ratio of natural gas in local electricity generation to 75% with additional abatement measures</u>

This proposed measures extends further the NG electricity generation proposed in item (1) of the Phase I Measure. While it is considered electricity generation by 75% NG should still be acceptable without significant impact on fuel safety, the issue of fuel diversity may become more relevant if any further increase of NG electricity generation percentage is to be pursued.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Increasing the ratio of natural gas in local electricity generation to 75% with additional abatement measures (Additional to Phase I measure) [1]	5,163	5,761	178	0

It is anticipated that additional four 313MW / 335MW gas fired unit would be required for this strategy.

This measure can reduce substantially local air pollution emission. However the resulting significant air quality benefits are mainly regional. As with Strategy (1), the costs would be relatively high of advancing natural gas units in substitution for coal units ahead of the latters' natural lives, when compared with the local air quality benefits that would result. This strategy is not cost-effective in comparison with other ways of reducing air pollution in the local context.

(21) Increasing the ratio of renewable energy (2% wind energy)

Renewable energy is derived from natural processes that are replenished constantly. For example, it derives directly from the sun, or from heat generated deep in the earth. The renewable energy can be in different forms such as solar, wind, ocean, hydropower, biomass, geothermal resources, etc. According to the "Study of Potential Application of Renewable Energy in Hong Kong" by EMSD, the following renewable energy technologies are potentially suitable for wide scale application in HK: Solar photovoltaic system, Wind Energy (rural wind farm and near-shore wind farm), Energy from waste and Building Integrated Fuel Cells.

One of the prerequisites of the use of renewable energy will always require a comprehensive and stable electricity grid system. The practical potential is limited by a number of factors, including cost, variability, intermittency and siting. The Hong Kong Government has pledged to have 1% to 2% of the generation coming from renewable energy by 2012 and is very likely coming from the proposed Integrated Waste Management Facilities. A Technical Guidelines on Grid Connection of Small-scale Renewable Energy Power Systems was released by the EMSD to provide information on the safety, equipment protection, reliability, and power quality aspects of small-scale renewable energy systems. In Year 2005, the EMSD put into service the largest photovoltaic (350kW) installation in Hong Kong and a 1kW small wind turbine on the roof of the EMSD Headquarters building.

A further 2% penetration of renewable energy is assumed in this study. One possible option to achieve this target is to the further exploitation of wind energy. Rough estimation indicates that about 220 sets of 2.5 MW wind turbines will be required with the capacity factor around 15%. The availability of land for accommodating such a large number of turbines would be a big challenge and hence off shore wind farm might be more feasible, provided the other environmental issues are acceptable. Another option is to purchase from or jointly develop renewable energy with the Mainland. In either case, it is expected that the implementation of the proposed measure will unlikely to be commenced in near future.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Increasing the ratio of renewable energy (2% wind energy)	502	852	25	8

The benefits of the emission reduction are mainly regional owing to the reduction of emission from power generation. The high costs of wind power make this strategy very low in terms of the level of cost effectiveness for air quality improvements alone.

(22) <u>Wider use of hybrid / electric vehicles or other environment-friendly vehicles with similar performance [30% private cars, 15% buses (including franchised buses), 15% light goods vehicles (LGVs) plus 15% heavy goods vehicles (HGVs)]</u>

This proposed measure is a continuation of the proposed item (4) of the Phase I Measure. It is assumed in the study in medium term, about 30% private cars, 15% franchised buses,15% light goods vehicles and 15% heavy goods vehicles might be able to be replaced by hybrid types

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Wider use of hybrid / electric vehicles or other environment-friendly vehicles with similar performance [30% private cars, 15% buses (including franchised buses), 15% light goods vehicles (LGVs) plus 15% heavy goods vehicles (HGVs)] (Additional to Phase I measure)	40	849	79	174

The benefits of the emission reduction are likely to be Territory wide. As the number of hybrid and related vehicles in Hong Kong increases so the cost-effectiveness of this strategy improves. One contributory factor is that the overhead costs are spread across more vehicles in the territory. So, as the strategy of purchasing hybrid vehicles develops the B/C ratio exceeds unity and this becomes an increasingly cost-effective strategy to pursue for air quality benefits.

(23) <u>Ultra low sulphur diesel for ocean-going vessels and local vessels</u>

This proposed measure is to extend the use of ULSD (Sulphur content of 0.005%) to ocean going vessels. According to the International Maritime Organization (IMO), the average sulphur content of ocean-going vessels was about 2.9% which was much lower than the sulphur limit (4.5%) stipulated in MARPOL Annex VI (International Convention for the Prevention of Pollution from Ships) . Recently, the Annex VI had been revised and adopted by IMO in order to tighten the standard of fuel sulphur content to 3.5% by 2012 and, subject to feasibility reviews and availability of supply of low sulphur fuel, to 0.5% by 2020.

Under MARPOL Annex VI, member countries can designated their waters as a 'Sulphur Emission Control Area' (SECA), in which ships will be required to burn lower sulphur fuel. Within a SECA, vessels had to use fuel with a sulphur content not exceeding 1.5%. At present, there were only two SECAs, one in the Baltic Sea and the other in the North Sea. However, unless an area covered a large stretch of waters, it would not be meaningful to set up a SECA as the environmental benefit brought about by fuel switch would be very small. In view of the small territory of the Hong Kong waters, it would not be practical to set up a SECA without including the neighbouring ports in the Mainland or even other ports on this side of the Pacific Ocean.

Recently, the concept of Micro-Emission Control Area (MECA) has been proposed by shipping organisations to restrict fuel sulphur content to 0.1% at a distance of no more than 24 nautical miles from the baseline. The stretch of Hong Kong waters is still too small for becoming MECA. Cooperation with Guangdong is required for establishment of MECA in the region.

One important issue is that, like other ports, Hong Kong had to follow international conventions in controlling the emissions from ocean-going vessels.

At present, there is no SECA and MECA requiring the ocean vessel to adopt ULSD. Hence, this strategy is considered as medium term.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Ultra low sulphur diesel for ocean-going vessels and local vessels (Additional to Phase I measure)	2,392	1,145	15	0

The benefits of the emission reduction are likely to be Territory wide. ULSD diesel for ocean going vessels as well as local vessels is highly cost-effective given the high level of pollution currently generated by the larger ships.

(24) Selective catalytic reduction for ocean going and local vessels

This measure is to extend the use of SCR for local vessels in near term to ocean going vessels in medium term. It is technologically feasible and the CARB has proposed to require cleaner engine (new or retrofits) for reducing vessel emission, expected to be implemented in 2010. By 2014, ships visiting California's ports would have either new engines or a mix of retrofit technology that would achieve an overall reduction of NO_X and PM of 30%.

However, it would be difficult to put forward this proposed measure if the requirement is confined to Hong Kong waters. Regional collaboration should be considered and secured before the measure can be effectively implemented.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Selective catalytic reduction for ocean-going vessels and local vessels (Additional to Phase I measure)	0	7,153	0	0

The benefits of the emission reduction are likely to be Territory wide. SCR for ocean going vessels as well as local vessels generates benefits which are slightly greater then the costs, and this measure is therefore regarded as marginally cost-effective.

(25) Electrification of on-shore power supply

This measure requires provision of on shore power supply (OSP) in container terminals and cruise terminals. On-shore power supply could reduce engine emissions. It allows ships to turn off their auxiliary engines and plug into an electrical system or power supply at dock.

In fact, OPS is not yet a common application and had been installed only in a few ports. The main problem of promoting OPS was that international standards for OPS had not yet been drawn up. Hong Kong, like many other major ports such as the ports of Los Angeles and Singapore, was closely watching the development and promulgation of the international standards for OPS. Moreover, not too many vessels had the necessary facilities onboard for hooking up to OPS. In addition, it was difficult to encourage ship-owners to take the initiative to install the expensive facilities onboard before the OPS standards were finalized. Furthermore, as not many terminals in the world had installed OPS, the ship-owners were reluctant to install OPS facilities onboard, which might not be used on a frequent basis.

The on-shore power commissioned in 2004 for the Port of Los Angeles was the first of its kind in the world. According to the Green Port Annual Report 2005, the Port of Long Beach also initiated a master plan for upgrading its electrical infrastructure to accommodate shore-power throughout the Port. Also, Nippon Yusen Kabushiki Kaisha has built the world's first container vessel designed according to POLA's shore-side power specifications and plans to retrofit or build 39 container ships with shore-side electrification technology by 2010 ["Green Harbours: Hong Kong and Shenzhen" by Civic Exchange, 2008].

The CARB proposes on shore support power supply for reducing auxiliary engine emissions, to be implemented in 2010, aiming at reducing emission by 80% in 2020. Ocean-going vessels always adopt different power standards. In order to accommodate the on-shore electricity supply, the vessels power standards will have to be changed. It is difficult to enforce this measure to all ocean-going vessels without international agreement.

In HK, there is a proposal for development of on shore support power supply in cruise terminal at Kai Tak. Tourism Commission of HK has indeed included the provision of on-shore support power supply to cruise vessels during berthing as a condition in the development of the cruise terminal. However, the lease conditions do not restrict the vessels to use the on-shore power supply.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Electrification of on-shore power supply	377	2,361	297	404

The benefits of the emission reduction are likely to be Territory wide. Given the size and importance of the port, provision of on-shore power supply would generate significant benefits and would appear to be cost-effective.

(26) Tightening aviation emission standards

Most air pollution due to aviation is produced during landing and take-off (including climb-out, final approach and taxiing modes). In 2006, the NO_X and RSP emissions due to civil aviation contributed about 5% and 0.4% of total emission respectively.

The emissions from aircraft are constrained by international standard. International collaboration is required to tighten the standard. Moreover, trade off between emissions (e.g. CO and NO_X) shall be considered.

According to Statement from the International Civil Aviation Organisation (ICAO) to the Twenty-Sixth Session of the UNFCCC (United Nations Framework Convention on Climate Change) Subsidiary Body for Scientific and Technological Advice, 2007, aircraft produced today are required to meet engine certification standards adopted by ICAO. The first standards for NO_X were adopted in 1981 and made more stringent in 1993, 1999 and 2004. Based on the reviewing work of the organization's committee on Aviation Environmental Protection held in its seventh meeting (CAEP/7), the medium and long term technology goals for NO_X were developed. Relative to mid term goals (2016), the group estimated a 45% reduction from the current standards. As for the long term goal (2026), it estimated that a reduction of some 60% would be attainable under specific pressure ratio conditions.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Tightening aviation emission standards	0	3,587	0	0

The benefits of the emission reduction are likely to be Territory wide. The full costs of implementing tighter aviation emission standards have not been assessed. However, the air quality benefits accruing to Hong Kong of such a strategy are very low.

(27) Further Strengthening Volatile Organic Compounds control

The current VOC regulation controls the VOC emissions of certain products. The new VOC regulation imposes maximum limits on the VOC content of architectural paints/coatings, printing inks and six selected consumer products - air fresheners, hairsprays, multi-purpose lubricants, floor wax strippers, insecticides and insect repellents, which are in line with that adopted in California, which is the most stringent standards in the world.

In California US, three measures have been developed by California Air Resources Board (CARB) to address this issue.

- **Measure CONS-1: Set New Consumer Products Limits for 2006.** The CARB committed to developing a measure to be proposed to the Board between 2003 and 2004, and implemented by 2006, that would achieve VOC emission reductions from consumer products of at least 2.3 tons per day (tpd) in the South Coast Air Basin in 2010. Statewide, this measure would achieve 5.3 tpd in emission reductions by 2010.
- **Measure CONS-2: Set New Consumer Products Limits for 2008 - 2010.** The ARB committed to developing new consumer product category limits to be proposed to the Board between 2006 and 2008, with implementation in 2008 and 2010, that would achieve VOC emission reductions from consumer products of between 8.5 tpd and 15 tpd in the South Coast Air Basin in 2010. Statewide, this measure would achieve 20-35 tpd in emission reductions by 2010.
- **Further Reductions from Consumer Products**: In addition, it is expected that further emission reductions will be needed from all source categories, including consumer products, to meet the long-term emission reduction targets included in the South Coast SIP. More reductions will also be needed to satisfy the new 8-hour ozone standard. As such there is an ongoing commitment to pursue additional technologically and commercially feasible reductions in consumer product emissions.

Very often, it is not possible to eliminate the use of VOC in products (e.g. organic solvents), even after reformulation. A more practical solution is to replace the VOC with those with lower ozone-forming potentials, if further control of photochemical oxidation is required. In California, this approach has already been adopted when they set the emission limits for aerosol coatings in 2004 (http://www.arb.ca.gov/research/reactivity/regulation.htm). The VOC limits make reference not only to the total mass of VOC, but also the reactivity of the VOC on ozone formation. The CARB is continuing to evaluate development of more reactivity limits for other categories on a case-by-case basis. It is suggested that Hong Kong may keep in view of the further development and consider the feasibility of adopting similar practice locally in the future.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Further Strengthening Volatile Organic Compounds control	0	0	0	4870

The benefits of the emission reduction are likely to be Territory wide. Further strengthening VOC control would result in significant benefits for which the strategy implementation costs are very modest. The B/C ratio is very high in comparison with other strategies. Therefore this strategy is regarded as highly cost-effective.

(28) Electronic road pricing (ERP) / congestion charging scheme for Hong Kong Island North

Electronic Road Pricing (ERP) allocates road space more efficiently. Those prepared to pay can use the roadways. Under normal condition, other vehicles will remain using non-toll roadways. As ERP can reduce traffic volume, it will in turn improve the air quality inside the charging areas. As a feasibility study, the strategy is targeted to the area in Island North.

There are schemes being operated in the United States of America and Singapore which have proven that the concept is workable. At present, Electronic Road Pricing (ERP) is being considered in the Netherlands, United Kingdom and Japan.

The UK Department of Transport are now proceeding (started in Yr 2008) with the Demonstrations Project to understand better how they might target congestion by charging on the basis of where and when a journey is being made. According to the 6th annual report on Central London Congestion Charging –Impact Monitoring, 2008 by Transport for London, the extended charging scheme has modest beneficial impacts to emissions of key road traffic pollutants, with estimated scheme-attributable reductions inside the western extension zone of 2.5 percent to oxides of nitrogen (NO_X) and 4.2 percent to fine particles (PM_{10}). The UK Department of Transport considers that a national road pricing scheme is an option for the future, and they do not yet have the answers to people's concerns about fairness and personal privacy. Therefore they are also focusing on what can be done now to deal with congestion, and targeting those parts of the network that are busiest - urban roads and motorways.

The main purpose of the ERP scheme is to reduce traffic congestion, and the benefit to air quality is a side effect. In order to receive public support, the income generated can be used to encourage greener vehicles and transport choices. Nevertheless, traffic may be diverted to other districts, which may cause traffic congestion in other areas.

According to Feasibility Study of Electronic Road Pricing by TD 2001, the estimated cost for the proposed ERP scheme is $1 billion (including the cost of in vehicle units for existing vehicles) with an annual recurrent cost of $200 million. The annual gross revenue of ERP is ranging from $0.4 to 1.3 billion.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Electronic road pricing (ERP) / congestion charging scheme for Hong Kong Island North	NA	NA	NA	NA

The Electronic road pricing / congestion charging schemes are the transport management strategies. They will divert traffic to other districts. Hence, the overall emission reduction is zero. The benefits of the emission reduction are likely to be specific to the zone. The costs of the electronic road pricing scheme have not been assessed. However the benefits in terms of air quality improvements are modest.

(29) <u>Reduce parking provision (25%) to restrain car usage for Central</u>

Parking control is traffic demand side management to control the private car trips. This strategy is targeted to reduce the parking provision to restrain car usage for Central by 25%.

Reducing the number of parking spaces may help to discourage drivers from entering the central business areas. However, the needs for disabled people should also be considered. It is feasible to convert existing public car parks to other uses. This requires consensus from public as it may affect local economic activities. Strong opposition may come from shopping malls, as the number of customer will be significantly reduced with the reduction of car parks. On the contrary, the developers may welcome the potential to expand their shop tenants space. The government may also consider reviewing the parking space provision standards under the Hong Kong Planning Standards and Guidelines.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Reduce parking provision (25%) to restrain car usage for Central	NA	NA	NA	NA

Reduce parking provision (25%) to restrain car usage for Central is a transport management strategy. They will divert traffic to other districts. Hence, the overall emission reduction is zero. The benefits of the emission reduction are likely to be specific to the zone. There would be very low levels of benefits for a policy to reduce parking provision in Central. The costs would be significantly greater and this is regarded as a low cost-effective strategy.

(30) <u>District cooling system (35% in existing areas and 90% in other new development areas)</u>

District cooling system has higher energy efficiency as compared to individual cooling tower. Hence, the use of district cooling system will reduce the electricity usage and eventually lead to a reduction in emissions. This measure is targeted to the whole Territories. According to EMSD study, 35% in existing areas and 90% in other new development areas are able to adopt district cooling system.

The system is only suitable for area close to the Harbour. Moreover, a suitable institutional framework for implementation is required to oblige the developers and future owners / tenants to use the system.

Apart from the benefits of saving energy, District cooling system can eliminate the need of chiller plant rooms in individual buildings. This scheme can also provide the following intangible benefits:

- Better city building design by allowing more flexible and innovative building design (no need for space and external louver provision for chillers or cooling towers)
- More efficient and effective utilization of building floor space
- More environmental friendly, as there are less noise pollution, global warming and ozone layer depletion

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
District cooling system (35% in existing areas and 90% in new development areas)	120	197	5.5	1.9

The benefits of the emission reduction are likely to be Territory wide. District cooling systems other than at Kai Tak would be expensive to introduce and the costs are likely to exceed the benefits in air quality that would result. There is considerable uncertainty surrounding the estimates given the lack of detail for such schemes, particularly the level of demand, but the initial findings suggest a low level of cost-effectiveness.

5.1.3 Phases III Control Measures

(31) <u>Increasing the ratio of natural gas in local electricity generation to 100%</u>

This proposed measure extends further the NG electricity generation proposed in item (20) of the Phase II Measure. It is considered that the increase the ratio of natural gas to 100% is feasible but subject to the security of the natural gas sources. It should be noted that fuel diversity would be one of the key issues associated with the emission reduction strategy. Balance of the fuel reliability, fuel cost and environmental benefits must be weighted against each other.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Increasing the ratio of natural gas in local electricity generation to 100% (additional to Phase II measure)	6,553	7,430	270	0

It is anticipated that additional seventeen 313MW / 335MW gas fired unit would be required for this strategy.

This strategy generates significant air quality benefits. The benefits of the emission reduction are likely to be regional. As the introduction of natural gas units at the power plants increases to 100 per cent so the costs of this strategy exceed the air quality benefits alone and this strategy has a reducing level of cost-effectiveness.

(32) <u>50% nuclear power and 50%natural gas</u>

This is an alternative to item (20) or item (31). Being a power source with virtually no emission of SO_2, NO_2 and particulate matters, this proposed measure could be an attractive option if the nuclear safety and radioactive waste disposal issues can be dealt with properly.

Nuclear power is a technology designed to extract usable energy from either spitting or fusing atomic nuclei via controlled nuclear reactions. The extracted energy is used to heat a working media to steam, which is then converted into mechanical work for the purpose of generating electricity. In Hong Kong, 22% of the total electricity consumption is from nuclear energy (c.f. The fuel mix in CLP in Yr 2007 is 45% coal, 25% Natural gas and 30% nuclear). To increase the nuclear energy, building our own nuclear plant in Hong Kong is a non-option due to the close proximity to densely populated urban centres. The only possible option is to obtain nuclear energy from the Mainland, in particular, Guangdong Province. At present, the Daya Bay nuclear plant has already been suppling about 70% of its electricity generation to Hong Kong (https://www.clpgroup.com/HK/Bus/Fac/Gen/GDNuclear/Pages/GenerationGuangdongNuclearPowerStation.aspx). It would be necessary to secure supply from other nuclear plants (e.g. proposed Shaoguan nuclear plant) so as to increase nuclear power ratio in Hong Kong.

To meet 50% electricity demand, it is estimated that 2 new 1000MW nuclear plants are required in order to fulfil the need.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
50% nuclear power and 50% natural gas (Alternative Case, compared to Base Case of 75% natural gas)	6,554	8,422	381	210

It is anticipated that additional nine 313MW / 335MW gas fired unit would be required for this strategy.

This measure can bring further significant emission reduction. The air quality benefits of the emission reduction are regional. The costs of nuclear power are lower then LNG and as a result this measure is more cost effective than the alternative of increasing local LNG generation to 100%.

(33) <u>Wider use of hybrid / electric vehicles or other environment- friendly vehicles with similar performance (50% private cars, 50% buses (including franchised buses), 50% HGVs plus 50% LGVs)</u>

This proposed measure is a continuation of the proposed item (22) of the Phase II Measure. According to "TRENDS IN VEHICLE AND FUEL TECHNOLOGIES: Scenarios for Future Trends", European Commission Joint Research Centre, 2003, the projected share of new registration for hybrid vehicles and electric vehicles in 2020 will be 32%. Hybrid buses have gained a substantial fleet share in certain cities in the US. Although hybrid goods vehicles such as delivery vans and trucks are still in the prototype phase, it is expected that the technology will be mature in medium term. By extrapolating the trends to long term and assuming a growth rate of 2 – 3% (IA-HEV outlook, March 2009), it is predicted that about 50% private cars, 50% franchised buses, 50% light goods vehicles and 50% heavy goods vehicles might be able to be replaced by hybrid types.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	**NO_X**	**PM_{10}**	**VOC**
Wider use of hybrid / electric vehicles or other environment- friendly vehicles with similar performance (50% private cars, 50% buses (including franchised buses), 50% HGVs plus 50% LGVs) (Additional to Phase II measure)	63	789	42	232

The benefits of the emission reduction are likely to be Territory wide. The wider use of hybrid / electric vehicles or other environmentally friendly vehicles with similar performance generates benefits which are only marginally different from the replacement costs, and this measure is therefore regarded as marginally cost-effective.

(34) <u>Vehicle permit quota system (to reduce around 50% private cars and 50% motorcycles)</u>

The introduction of a vehicle quota system is to restrict the number of vehicles on road. This kind of system has been proved effective in air quality improvement as demonstrated by the Beijing Olympics. Similar measure in Singapore also demonstrates the effective control on vehicle growth but it will also be necessary to supplement it with emission control at the same time to control ageing vehicles on roads if necessary.

In Singapore, the Land Transport Authority (LTA) controls the number of vehicles on roads using the Vehicle Quota System. The system requires owners of vehicles (except for buses and emergency vehicles) to have a certificate of entitlement. Under this system, the authority determines the number of new vehicles allowed for registration while the market determines the price of owning a vehicle. In this system, vehicle owners must bid for a Certificate of Entitlement (COE) before the vehicle can be registered. Only a fixed number of COEs are made available every month. Prospective owners must bid to obtain a COE. Successful bidders then pay the quota premium for their vehicle. In determining the number of cars allowed for registration, LTA takes into account the prevailing traffic conditions and the number of vehicles taken off the roads permanently. The quota allocated to each vehicle category is in proportion to that category's share of the total vehicle population. Making cars more expensive may impact heavily upon people living in rural areas. Car ownership may become a burden for businesses and erode quality of life for people. Under the COE system, the right to own a vehicle would become an expensive commodity that only few can afford.

It is anticipated that the introduction of vehicle permit quota system in HK may receive strong public objection both from the driver and public because this system will artificially limit the right of car ownership regardless of the affordability issue. Moreover, the shares of emission from private car to the total vehicular emission are 8.2%, 0.9%, 0.2% and 2.2% for SO_2, NO_X, RSP and VOC respectively, and are relatively low. In addition, the effectiveness of this system in Hong Kong is in question as this system is likely affecting the private car owners who are mostly weekend drivers and currently amount to only 20% in car ownership.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Vehicle permit quota system (to reduce around 50% private cars and 50% motorcycles)	28	93	3	119

The benefits of the emission reduction are likely to be Territory wide. Reducing substantially the number of vehicles through the adoption of a permit quota system would generate very modest air quality benefits and would be costly in transport terms. Overall it is not regarded as being cost-effective.

(35) <u>Use of hydrogen fuel cell vehicles or equivalent alternatives (40% penetration)</u>

It is claimed that hydrogen-powered vehicles have zero emissions because the tail-end product is only water vapour and heat. The fuel cell in the vehicle will generate hydrogen which can be produced by using a range of feedstocks, including natural gas, methanol, ethanol, biomass, and water. As an emerging transportation fuel, the promise of hydrogen is driving innovative designs of high-efficiency vehicles that will provide important environmental and energy diversification benefits.

The hydrogen technology is still under development and yet to be commercially viable because the associated cost and durability are the major challenges to fuel cell commercialization. In addition, the size, weight, thermal and water management of the fuel cell are other barriers to the commercialization of fuel cell technology. In transportation applications, extensive infrastructure is required to produce, distribute, store and dispense the hydrogen fuel. However, the California Air Resources Board (CARB) has predicted that mass production will be likely in 2014.

In order to distribute hydrogen to cars, the current gasoline fueling system would need to be replaced, or at least significantly supplemented with hydrogen fuel stations. Safety is a major issue for developing hydrogen infrastructure in Hong Kong and it is anticipated that there will be strong objection from the public.

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Use of Hydrogen Fuel Cell vehicles or equivalent alternatives (40% penetration)	140	2,778	94	1,453

The benefits of the emission reduction are likely to be Territory wide. The technology for hydrogen fuel cells for vehicles is not yet proven and hence the costs have not been estimated. However, the benefit level for this strategy would be relatively high.

(36) <u>Rail for transport of cross-boundary goods</u>

The use of rail for freight transport for cross-boundary goods can reduce the amount of heavy goods vehicles. This will in turn reduce the air emission by reducing the number of cross border heavy goods vehicles.

Port Rail Line (PRL), connection from Lo Wu to Kwai Chung, has been considered by the Highway Department. It allows direct cross-boundary freight service from Lo Wu to the Kwai Chung terminal before transfer by truck to the container port terminals. The number of heavy vehicle trips will be reduced to a certain extent with the PRL.

The capital cost for railway construction is huge. The consideration of the feasibility of rail is subject to other dominant factors, including economic attractiveness to direct good delivery by vehicle to rail freight to Lo Wu of Hong Kong, travelling time and policy of Guangdong and Hong Kong. If PRL is implemented, it will bring an additional benefit. The estimated emission potential is summarized as follows:

The estimated emission potential is summarized as follows:

	Emission Reduction Potential (Tonnes)			
	SO_2	NO_X	PM_{10}	VOC
Rail for transport of cross-boundary goods	1	11	1	9

The benefits of the emission reduction are likely to be Territory-wide. The air quality benefits are an additional effect.

5.2 Baseline and Projected Emissions

This section describes the approach to estimating future emissions of air pollutants with and without the proposed Phases I to III measures. Details of the assumptions made in projecting the future emissions and estimating the emission reduction potential of each of the control measures proposed in the previous section are presented in **Appendix G**.

5.2.1 Emissions of Hong Kong

In projecting the future emissions, the EPD's emission inventory of 2006, which is summarized in **Table 5.2**, is taken as the baseline.

Table 5.2: Baseline emissions (tonnes) in 2006

Sector	SO_2	NO_X	PM_{10}	VOC
Power	66,000	41,800	1,860	416
Transport	5,170	43,520	2,330	8,645
Vehicles	*956*	*21,800*	*1,810*	*8,080*
Marine (Figure in brackets for local vessels)	*3,920 (682)*	*16,700 (3994)*	*499 (179)*	*304 (91)*
Aviation	*294*	*5,020*	*21*	*261*
Industry and Others	2,660	9,530	1,675	32,198

The projection of emissions without the proposed new control measures assumes that the policies or commitments, including the 2010 emission reduction targets reached by consensus with the Guangdong Provincial Government, that are already in place or those on which agreement has been reached, even if the full administrative and legal procedures have not been finalized. The economic growth factors and other assumptions used in the projection are consistent with those forecast by the relevant authorities such as Planning Department, Marine Department, Transport Department, etc. Further details can be found in **Appendix G**.

Assuming the proposed Phases I, II and III control measures are to be implemented by 2015, 2020 and 2030, respectively, the projected total and sectoral emissions, with and without these proposed measures have been estimated and presented in **Tables 5.3** to **5.5**, respectively.

Table 5.3a: Projected emissions (tonnes) – Emissions without Phase I Measures

Sector	SO_2	NO_X	PM_{10}	VOC
Power	25,120	42,600	1,260	420
Transport	5,706	43,832	2,407	6,705
Vehicles	*299*	*14,075*	*1,697*	*5,854*
Marine (Figure in brackets for local vessels)	*4938 (682)*	*21,684 (3,994)*	*676 (179)*	*436 (91)*
Aviation	*469*	*8,073*	*34*	*415*
Industry and Others	16	4,608	624	24,131

Table 5.3b: Projected emissions (tonnes) – Emissions with Phase I Measures

Sector	SO_2	NO_X	PM_{10}	VOC
Power	11,718	17,375	737	420
Transport	4,910	38,048	1,933	6,040
Vehicles	*263*	*9,354*	*1,262*	*5,257*
Marine (Figure in brackets for local vessels)	*4,263 (7)*	*21,380 (3690)*	*658 (161)*	*436 (91)*
Aviation	*384*	*7,314*	*13*	*348*
Industry and Others	12	3,658	385	23,104

Table 5.4a: Projected emissions (tonnes) – Emissions without Phase I and Phase II Measures

Sector	SO_2	NO_X	PM_{10}	VOC
Power	25,120	42,600	1,260	420
Transport	6,451	45,133	2,244	6,304
Vehicles	*331*	*11,231*	*1,416*	*5,290*
Marine (Figure in brackets for local vessels)	*5,569 (682)*	*24,412 (3,994)*	*788 (179)*	*526 (91)*
Aviation	*552*	*9,490*	*40*	*488*
Industry and Others	15	4,632	625	24,761

Table 5.4b: Projected emissions (tonnes) – Emissions with Phase I and Phase II Measures

Sector	SO_2	NO_X	PM_{10}	VOC
Power	6,053	10,762	534	412
Transport	2,861	28,317	1,760	5,442

Sector	SO_2	NO_X	PM_{10}	VOC
Vehicles	*270*	*9,722*	*1,284*	*4,900*
Marine (Figure in brackets for local vessels)	*2,124 (7)*	*13,450 (3,690)*	*457 (161)*	*122 (91)*
Aviation	*466*	*5,145*	*19*	*421*
Industry and Others	11	3,682	386	18,865

Table 5.5a: Projected Emissions (tonnes) – Emissions without Phase I, Phase II and Phase III Measures

Sector	SO_2	NO_X	PM_{10}	VOC
Power	25,120	42,600	1,260	420
Transport	7,734	49,154	2,438	6,501
Vehicles	*353*	*9,797*	*1,388*	*5,306*
Marine (Figure in brackets for local vessels)	*6,829 (682)*	*29,866 (3994)*	*1,010 (179)*	*707 (91)*
Aviation	*552*	*9,490*	*40*	*488*
Industry and Others	14	4,720	629	25,980

Table 5.5b: Projected emissions (tonnes) – Emissions with Phase I, Phase II and Phase III Measures

Sector	SO_2	NO_X	PM_{10}	VOC
Power	0	2340	153	202
Transport	3,952	29,515	1,894	4,000
Vehicles	*101*	*5,466*	*1,195*	*3,276*
Marine (Figure in brackets for local vessels)	*3,385 (7)*	*18,904 (3690)*	*680 (161)*	*303 (91)*
Aviation	*466*	*5,145*	*19*	*421*
Industry and Others	10	3,770	391	20,083

For easy reference, the respective emission reduction figures of the individual Phases I to III measures are also presented in **Table 5.6** – **Table 5.8**.

Tables 5.6: Emission reduction potentials for Phase I Measures

Phase I Measures		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		SO_2	NO_X	PM_{10}	VOC
1.	Increasing the ratio of natural gas in local electricity generation to 50% together with additional emission abatement measures[5]	13,402	25,225	523	0
2.	Early retirement of aged / heavily polluting vehicles (pre-Euro, Euro I and Euro II commercial diesel vehicles and franchised buses)	0	3,102	300	184
3.	Earlier replacement of Euro III commercial diesel vehicles with models meeting latest Euro standards	0	743	75	24
4.	Wider use of hybrid / electric vehicles or other environment- friendly vehicles with similar	15	216	7	173

Phase I Measures		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		**SO_2**	**NO_X**	**PM_{10}**	**VOC**
	performance (20% private cars and 10% buses including franchised buses)				
5.	Ultra low sulphur diesel (ULSD) for local vessels	675	0	18	0
6.	Selective catalytic reduction (SCR) for local vessels	0	304	0	0
7.	Electrification of aviation ground support equipment	85	759	21	67
8.	Emission control for off-road vehicles / equipment	4	950	239	326
9.	Strengthening volatile organic compounds control	0	0	0	700
Transport Management					
10.	Low emission zones	Note [1]	Note [1]	Note [1]	Note [1]
11.	Car-free zone / pedestrianisation scheme	Note [1]	Note [1]	Note [1]	Note [1]
12.	Bus route rationalization	4	156	7	9
Infrastructure Development and Planning					
13.	Expand rail network	17	501	46	207
14.	Cycling network to major public transport hubs	0.1	2.3	0.1	0.1
Energy Efficiency Measures					
15.	Mandatory implementation of Building Energy Codes	151	256	8	3
16.	Energy efficiency standards for domestic electrical appliances	84	142	4	1
17.	Light-emitting diode or equivalent alternatives for traffic signal / street lighting	3	5	0.1	0
18.	Tree planting / roof-top greening	Note [2]	Note [2]	Note [2]	Note [2]
19	District cooling system for Kai Tak Development	6	16	0.5	0.2

Tables 5.7: Emission reduction potentials for phase II measures

Phase II Measures		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		**SO_2**	**NO_X**	**PM_{10}**	**VOC**
20.	Increasing the ratio of natural gas in local electricity generation to 75% with additional abatement measures (Additional to Phase I measure)[5]	5,163	5,761	178	0
21.	Increasing the ratio of renewable energy (2% wind energy)	502	852	25	8
22.	Wider use of hybrid / electric vehicles or other environment-friendly vehicles with similar performance [30% private cars, 15% buses (including franchised buses), 15% light goods vehicles (LGVs) plus 15% heavy goods vehicles (HGVs)] (Additional to Phase I measure)	40	849	79	174

Phase II Measures		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		**SO_2**	**NO_X**	**PM_{10}**	**VOC**
23.	Ultra low sulphur diesel for ocean-going vessels and local vessels (additional to Phase I measure)	2,392	1,145	15	0
24.	Selective catalytic reduction for ocean-going vessels and local vessels (Additional to Phase I measure)	0	7,153	0	0
25.	Electrification of on-shore power supply	377	2,361	297	404
26.	Tightening aviation emission standards	0	3,587	0	0
27	Further strengthening volatile organic compounds control	0	0	0	4870
Transport Management					
28.	Electronic road pricing (ERP) / congestion charging scheme for Hong Kong Island North	Note [3]	Note [3]	Note [3]	Note [3]
29.	Reduce parking provision (25%) to restrain car usage for Central	Note [1]	Note [1]	Note [1]	Note [1]
Energy Efficiency					
30.	District cooling system (35% in existing areas and 90% in other new development areas)	120	197	5.5	1.9

Tables 5.8: Emission reduction potentials for phase III measures

Phase III measures		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		**SO_2**	**NO_X**	**PM_{10}**	**VOC**
31.	Increasing the ratio of natural gas in local electricity generation to 100% (Additional to Phase II measure) [4]	6,553	7,430	270	0
32	50% nuclear power and 50% natural gas (Alternative Case compared to Base Case of 75% natural gas) [4]	6,554	8,422	381	210
33.	Wider use of hybrid / electric vehicles or other environment- friendly vehicles with similar performance (50% private cars, 50% buses (including franchised buses), 50% HGVs plus 50% LGVs) (Additional to Phase II measure)	63	789	42	232
34.	Vehicle permit quota system (to reduce around 50% PC and 50% motorcycle)	28	93	3	119
35.	Use of hydrogen fuel cell vehicles or equivalent alternatives (40% penetration)	140	2,778	94	1,453
Infrastructural Development and Planning					
36.	Rail for transport of cross-boundary goods	1	11	1	9

Notes:

[1] Emission reduction potential would not be substantial as it involves mainly transferring emission from one place to another.

[2] The proposed measures help reduce urban heat island effect and improve the air pollution dispersion. Emission reduction potential is not available.

[3] The ERP strategy will have additional ride-on effect on improvement of air quality. The overall emission reduction potential would not be substantial

[4] The "Increase ratio of natural gas in local electricity generation to 100%" scenario and "50% Nuclear & 50% natural gas" scenario are either-or case. Adoption of only one of these measures would be expected.

[5] The possible additional emission abatement measures include enhancing the selective catalytic reduction (SCR) systems of the existing coal-fired units and that the technical feasibility and financial viability of retrofitting the existing coal-fired units with enhanced SCR systems are not yet established and subject to more detailed examination with the concerned power company.

Further details of the major assumptions and technical consideration of the respective emission projections have also been set out in **Appendix G**.

5.2.1 Emissions of the PRD Region

The air pollution of Hong Kong and PRD affect each others seriously in view of the close proximity. It will not be possible to predict the air quality of Hong Kong without a good understanding of the emissions of PRD region. In this study, the projection of PRD emissions is made with the assumptions that the Guangdong Province will continue to align itself with the best practices in the world to curb emissions from its power, transport and industrial sectors in tandem with its economic growth. Among others, the primary references used in this study include the control strategies stated in the Pearl River Delta Environmental Planning Outline (2004-2020) and the National Plans such as "The white paper on PRC energy status and policy", "Medium and Long Term development of Renewable Energy" , "Pan PRD Energy Co-operation-11th 5 year plan", "Medium and Long Term development of nuclear Energy 2003 - 2020", etc.

Table 5.9 summarizes the emission inventory for PRD from Yr 2010 to Yr 2020. The emission inventory in Yr 2015 is derived by interpolating the emission inventories between Yr 2010 and Yr 2020. The emission breakdown for each sector is presented in **Appendix F.**

Table 5.9: PRDEZ emission inventory from Year 2010 to Year 2020 (in tonnes) with planned mitigation measures

Pollution Sources (in tones)	SO_2	NO_X	PM_{10}	VOC
Year 2010	431,300	503,600	207,500	178,200
Year 2015	401,487	452,312	206,800	187,412
Year 2020	371,673	401,024	206,099	196,624

For projections beyond 2020, having no public available environmental planning information available, two scenarios have been constructed as follows:

(a) High emission scenario:

To be conservative, the emissions after Year 2020 are assumed to be same as Yr 2020.

(b) Low emission scenario:

With the continual growth of GDP, greater public expectation of better air quality and further advancement in technology, it would be more likely that PRD would choose to adopt the most advanced control technologies and practices beyond 2020.

The estimated emissions under these scenarios for PRD in Year 2030 are shown in **Table 5.10**. The details of the associated emission reduction estimates have been summarized in **Appendix G.**

Table 5.10: PRDEZ emission inventory under hypothetic scenario for Year 2030

Pollution Sources (in tones)	SO_2	NO_X	PM_{10}	VOC

High emission scenario	371,673	401,024	206,099	196,624
Low emission scenario	16,002	133,370	64,502	101,020

Further details of the emission baseline and projection of the PRD region can be found in **Appendix G.**

5.3 Cost Benefit Analysis

5.3.1 The CBA Findings

The CBA section presents the central estimates of the results which lie within a range produced through a comprehensive sensitivity analysis. A summary of the CBA findings is presented below in **Table 5.11 – Table 5.13**. These table show the best estimates derived in the analysis of costs and benefits and the strategy performance measures of the benefit cost ratio (B / C ratio).

In these cases, the analysis has been limited to an estimate of those quantifiable costs and air pollution benefits that are likely to be associated with the strategy, if implemented. The concerned responsible authorities can take these estimates into account, together with other relevant factors, in particular, the emission reduction potentials and social acceptance, when arriving at decisions about whether to proceed with those particular strategies.

Table 5.11: CBA summary of findings for Phase I measures

Control Measure		Cost (HK$M)	Benefit (HK$M)	B/C Ratio
1	Increasing the ratio of natural gas in local electricity generation to 50% together with additional emission abatement measures[h]	2032	1803	0.9
2	Early retirement of aged / heavily polluting vehicles (pre-Euro, Euro I and Euro II commercial diesel vehicles and franchised buses)	3,882	24,344	6.3
3	Earlier replacement of Euro III commercial diesel vehicles with models meeting latest Euro standards	2,668	6,134	2.3
4	Wider use of hybrid / electric vehicles or other environment- friendly vehicles with similar performance (20% private cars and 10% franchised buses)	4,326	2,417	0.56
5	Ultra low sulphur diesel (ULSD) for local vessels	378	6331	16.7
6	Selective catalytic reduction (SCR) for local vessels	249	74	0.3
7	Electrification of aviation ground support equipment	1,449	3.8	0.003[g]
8	Emission control for off-road vehicles / equipment	845	2,123	2.5
9	Strengthening volatile organic compounds control	18	124	6.9
10	Low emission zones	3,696	2,586	0.7
a	Low emission zone (banning pre-Euro, Euro I , Euro II and Euro III commercial vehicles) for Central	1,100	1,899	1.7
b	Low emission zone (banning pre-Euro, Euro I ,	1,575	318	0.2

Control Measure		Cost (HK$M)	Benefit (HK$M)	B/C Ratio
	Euro II and Euro III commercial vehicles) for Mongkok			
c	Low emission zone (banning pre-Euro, Euro I , Euro II and Euro III commercial vehicles) for Causeway Bay	1,021	369	0.4
11	Car-free zone / pedestrianisation scheme	42	400	10
a	Car-free zone / pedestrianisation scheme for Causeway Bay	14	61	4.4
b	Car-free zone / pedestrianisation scheme for Central	14	303	21.8
c	Car-free zone / pedestrianisation scheme for Mongkok	14	36	2.6
12	Bus Route Rationalisation	14	548	39
13	Expand rail network	Note [a]	3,850	Note [a]
14	Cycling network to major public transport hubs	836	8	0.1
15	Mandatory implementation of Building Energy Codes	95	2,634	28
16	Energy efficiency standards for domestic electrical appliances	84	2,277	27
17	Light-emitting diode (LED) or equivalent alternatives for traffic signal / street lighting	47	105	2.2
18	Tree planting / roof-top greening	6,357	1,603	0.3
19	District cooling system for Kai Tak Development	2,788	4,047	1.5

Table 5.12: CBA summary of findings for Phase II measures

Control Measure		Cost (HK$M)	Benefit (HK$M)	B/C Ratio
20	Increasing the ratio of natural gas in local electricity generation to 75% with additional abatement measures (Additional to Phase I measure)[][h]	1702	383	0.2
21	Increasing the ratio of renewable energy (2% wind energy)	13,069	206	0.02
22	Wider use of hybrid / electric vehicles or other environment-friendly vehicles with similar performance [30% private cars, 15% buses (including franchised buses), 15% light goods vehicles (LGVs) plus 15% heavy goods vehicles (HGVs)] (Additional to Phase I measure)	9,026	14,447	1.6
23	Ultra low sulphur diesel for ocean-going vessels and local vessels (Additional to Phase I measure)	4,563	15,087	3.3
24	Selective catalytic reduction for ocean-going vessels and local vessels (Additional to Phase I measure)	1,333	1,173	0.9
25	Electrification of on-shore power supply	1,579	6,243	4.0
26	Tightening aviation emission standards	Note [b]	12	Note [b]

Control Measure		Cost (HK$M)	Benefit (HK$M)	B/C Ratio
27	Further strengthening volatile organic compounds control	37	634	17.2
28	Electronic road pricing (ERP) / congestion charging scheme for Hong Kong Island North	Note [c]	577	Note [c]
29	Reduce parking provision (25%) to restrain car usage for Central	757	18	0.02
30	District cooling system (35% in existing areas and 90% in other new development areas)	19,347	11,578	0.6

Table 5.13: CBA summary of findings for Phase III measures

Control Measure		Cost (HK$M)	Benefit (HK$M)	B/C Ratio
31	Increasing the ratio of natural gas in local electricity generation to 100% (Additional to Phase II measure)	348	255	0.7
32	50% nuclear power and 50% natural gas (Alternative Case compared to Base Case of 75% natural gas)	-2,894[d]	91	-
a	Base Case 75% LNG	341,375	1,562	-
b	Alternative Case 50% Nuclear 50% natural gas	338,481	1,654	-
33	Wider use of hybrid / electric vehicles or other environment- friendly vehicles with similar performance (50% private cars, 50% buses (including franchised buses), 50% HGVs plus 50% LGVs) (Additional to Phase II measure)	8,530	7,751	0.91
34	Vehicle permit quota system (to reduce around 50% private cars and 50% motorcycles)	691	251	0.4
35	Use of hydrogen fuel cell vehicles or equivalent alternatives (40% penetration)	Note [e]	10,420	Note [e]
36	Rail for transport of cross-boundary goods	Note [f]	115.0	Note [f]

Notes:

[a] The railway strategy includes the Express Rail Line, the Sha Tin to Central Link (the Tai Wai to Hung Hom section), the West Island Line, the South Island Line (East), the Kowloon Southern Link and the Kwun Tong Line Extension. Only air quality improvement benefits are estimated. For reference, Capital Cost of these Lines would be about HK$56 Billion

[b] Costs for this measure will be borne by the aircraft industry (and hence consumers) worldwide and only air quality benefits to Hong Kong have been calculated

[c] The ERP measure will have incidental improvements to air quality but only these benefits have been calculated. The estimated cost for the proposed ERP scheme is about $1 billion (including the cost of in-vehicle units for existing vehicles) with an annual recurrent cost of about $200 million

[d] Reported as saving – Alternative Case (50% LNG 50% Nuclear) is HK$2,803 M cheaper than the Base Case. Based on Natural Gas fuel price of US$70/MWh

[e] This measure has not yet matured, and there are no local cost data. Hence only the likely air quality improvement benefits have been calculated

[f] This railway measure will have additional improvements to air quality but only the air quality improvement benefits have been calculated here. The capital cost would be about HK$ 5-9 Billion.

[g] Due to the remoteness of the airport from the populated urban centres, only a relatively small resident population can benefit from the improved air quality. The B/C ratio would, therefore, be low. However, the emission reduction would help improve the regional air quality and a higher B/C ratio will be resulted if it is considered in a regional context.

[h] The possible additional emission abatement measures include enhancing the selective catalytic reduction (SCR) systems of the existing coal-fired units and that the technical feasibility and financial viability of retrofitting the existing coal-fired units with enhanced SCR systems are not yet established and subject to more detailed examination with the concerned power company.

Detailed methodology and assumptions for cost benefit analysis are listed in **Appendix H**

As a whole, the CBA analysis showed that the overall benefit is expected to be higher than the overall cost of implemenation of the measures. It should be noted that in deciding if certain measures should be prioritized, factors other than the respective cost and benefit, in particular, the emission reduction potential, are also important. In addition, some of the measures would have significant cost/tariff implications. For instance, raising the current share of natural gas of our domestic electricity generation to 50% or even higher could increase tariff by phases to at least 20% from the current level because of the need to install additional gas-fired generators and other emission reduction measures and that natural gas is significantly more expensive than coal. However, the actual level of tariff increase will depend on a number of factors, such as the price of the natural gas and the capital investments required by the power companies.

Subject to further formulation of implementation details, the control measures affecting the transport sector may likewise carry tariff implications due to an increase in the capital expenditure and operational costs of the transport trades. For example, depending on the scale of the exercise, advancing the replacement of franchised buses could drive the fare increase pressure to about 15% in a single year. This will be on top of fare increases due to factors such as higher operating costs. However, bus fare increase impact is only one facet of the implications. The questions of how to fund the early replacement of nearly three thousand buses which cost billions of dollars, as well as how this would impact on bus companies' financial accounts and operations will also need to be addressed. Furthermore, some measures may require legislation and impose significant resources implications on the Government. All these would need to be carefully assessed when the full consultation is being rolled out.

5.3.2 Health Benefits

The calculated health benefits show that the chronic benefits arising from the reduction of $PM_{2.5}$ exposure would be dominating, with the remainder comprising acute benefits. UK ICGB report indicates that long term exposure to background levels of $PM_{2.5}$ is the most important effect of air quality on public health. The calculations currently being performed in CBAs in the UK and the EU further suggest that the long-term chronic pollution impacts on health and longevity dominate the analyses in terms of the magnitude of health benefits when pollution is reduced.

Upon the implementation of the Phases I, II and III measures, it is expected that about 4,200, 5,900 and 3700 unnecessary hospital admissions, respectively, would be avoided.

The middle, low and high estimates of the number of life years saved per year from reduced risk of chronic illness due to reduction of $PM_{2.5}$ exposure assuming implementation of all control strategies are presented in **Table 5.14**. Upon implementation of the Phase I measures, about 7,400 statistical life years would be saved per year, i.e., roughly 1 month improvement in life expectancy, for each year.

Table 5.14: Estimated life years saved per year

Measures	Middle Estimate	Low Estimate	High Estimate
Phase I	7,348	2,450	13,470
Phase II	5,928	1,976	10,868
Phase III	5,734	1,911	10,511

5.4 Air Quality Prediction

The Pollutants in the Atmosphere and their Transport over Hong Kong (PATH) model is used to predict the future air quality upon the implementation of proposed Phase I, Phase II and Phase III measures. The PATH model is a sophisticated regional photochemical modelling system which incorporates the regional and Hong Kong emission inventories, meteorological data and chemical reaction features for predicting the ambient concentration of Hong Kong. Like most air quality models, PATH model is subject to uncertainties in much of the input data including emissions, meteorology and the chemical reaction schemes used. It, however, will still provide good insight on how effective the proposed control measures would be in achieving the proposed new AQO as well as the WHO's AQG and ITs. The details of the PATH model and its features are presented in **Appendix I**.

Analyses are made for the Years 2015, 2020 and 2030 at a horizontal spatial resolution of 1.5 km by 1.5 km for SO_2, NO_2, RSP (PM_{10}) and O_3. For FSP ($PM_{2.5}$), there is no model available at present that may predict the local levels with acceptable accuracy. The concentration and the number of exceedences of FSP is estimated by assuming that the level of FSP is roughly equal to 70% of RSP which is commonly observed at the existing air quality monitoring stations. As the PATH model predicts concentration with time average of 1 hour or more, the 10-minute SO_2 levels are estimated by applying the correlation of 10-minute and 1-hour SO_2 levels derived from the existing monitoring data.

5.4.1 Modelling Results - Phase I measures

On the basis that the Guangdong side will continue to align itself with the best practices in the world to curb emissions from its power, transport and industrial sectors in tandem with its economic growth, the PATH modelling shows that with the full implementation of the Phase I control measures, it is able to achieve the proposed new AQO subject to suitable allowance for exceedence.

5.3.4.1 Number of Exceedences

Table 5.15 shows the predicted number of exceedences of the WHO's AQG and ITs after the implementation of the Phase I measures. For sake of comparison, the numbers of exceedences actually observed in 2007 and 2008 are also presented in the table.

Table 5.15 Predicted no. of exceedences upon implementation of Phase I measures

Air Pollutant	Avg time	Concentration (μg/m^3)	Predicted No. of Exceedences (with Phase I measures implemented)	No. of Exceedences in 2007 [1]	No. of Exceedences in 2008 [1]
SO_2	10-min	AQG: 500	0 [4]	13	20
	24-hour	IT-1:125	1	0	2
		IT-2: 50	78	90	86
		AQG: 20	208	300	284
RSP	24-hour	IT-1: 150	0	8	4
		IT-2: 100	9 [2]	72	51
		IT-3: 75	86	136	134

Air Pollutant	Avg time	Concentration (μg/m³)	Predicted No. of Exceedences (with Phase I measures implemented)	No. of Exceedences in 2007 [1]	No. of Exceedences in 2008 [1]
		AQG: 50	210	236	211
	Annual	AQO: 55	✓	✓	✓
		IT-2: 50	[✓]	×	×
		IT-3: 30	×	×	×
		AQG: 20	×	×	×
FSP	24-hour	IT-1: 75	9 [3]	50	39
		IT-2: 50	109 [3]	139	128
		IT-3: 37.5	197 [3]	199	191
		AQG: 25	257 [3]	259	259
	Annual	IT-1: 35	[✓]	×	×
		IT-2: 25	×	×	×
		IT-3: 15	×	×	×
		AQG: 10	×	×	×
NO_2	1-hour	AQG: 200	12	76	84
	Annual	AQG: 40	✓	×	×
Ozone	8-hr	IT-1: 160	8	18	29
		AQG: 100	65	169	185

Note:

[1] 2007 and 2008 figures are presented for comparison only.

[2] A few spots at the border might have higher number of exceedences.

[3] The present air quality model does not provide for the prediction of the FSP levels. The number of exceedences of FSP is estimated by assuming that the level of FSP is roughly equal to about 70% of that of RSP.

[4] The 10-minute SO_2 levels are estimated from the predicted 1-hour SO_2 concentrations.

"✓" denotes "compliance with the AQO".

"×" denotes "non-compliance with the AQO".

"[✓]" denotes compliance over nearly the whole of Hong Kong except those remote areas close to the boundary.

5.3.4.2 Sulphur Dioxide

Figure 5.1 and **Figure 5.2** show the spatial distribution of the projected 4th highest 10-minute and 24-hour SO_2 concentrations at general ambient locations. The predicted concentrations are in compliance with the respective proposed new AQO.

Figure 5.1: 4th highest ambient 10-min SO_2 concentration upon implementation of Phase I measures

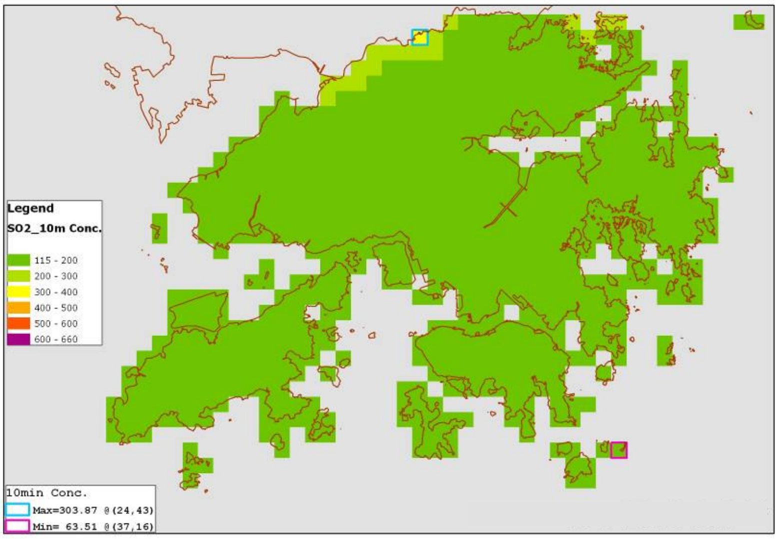
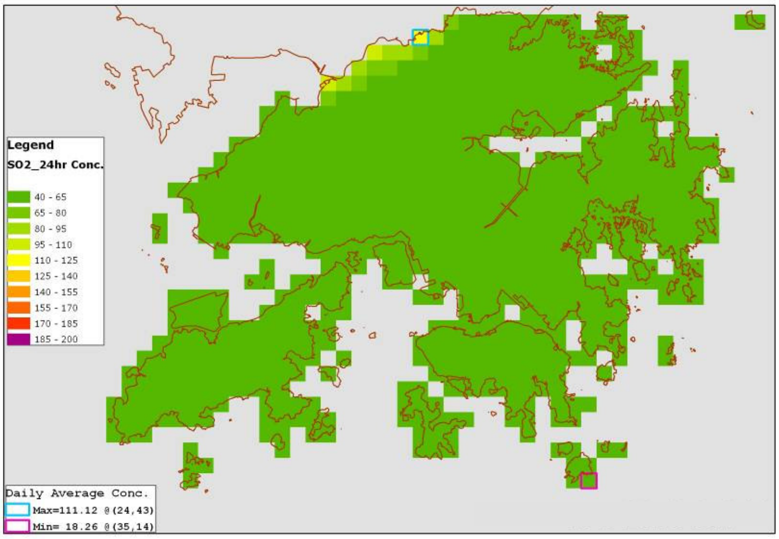


Figure 5.2: 4th highest ambient 24-hr SO_2 concentration upon implementation of Phase I measures



5.3.4.3 Nitrogen Dioxide

The spatial distribution of the 19th highest 1-hr ambient NO_2 concentrations at general ambient locations is shown in **Figure 5.3** and are in compliance with the respective proposed new AQO. **Figure 5.4** shows the predicted annual NO_2 concentrations. Other than a few spots at the container terminal areas which are of less concern to the general public, the annual NO_2 in all general ambient locations are in compliance with the proposed new AQO.

Figure 5.3: 19th highest ambient 1-hr NO_2 concentration upon implementation of Phase I measures

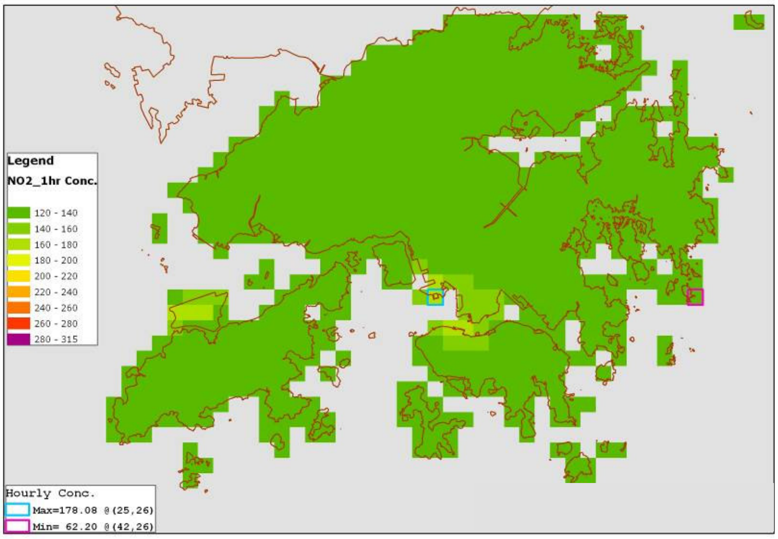
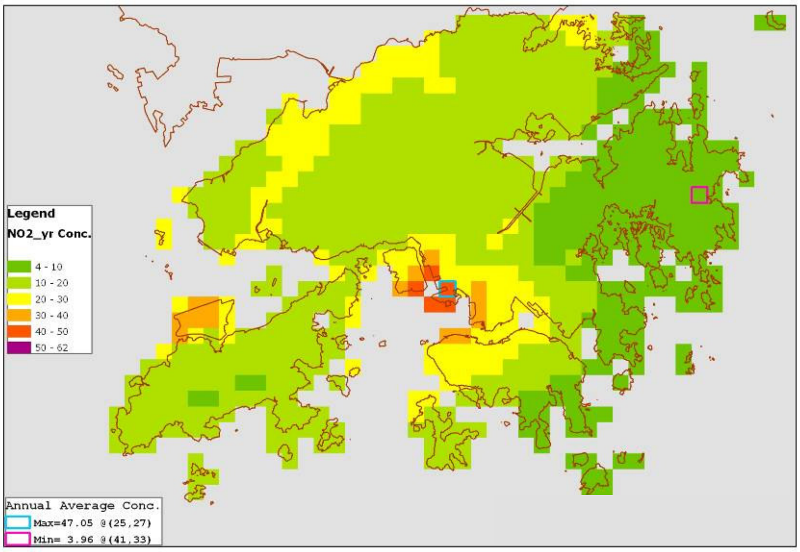


Figure 5.4: Annual ambient NO_2 concentration upon implementation of Phase I measures



5.3.4.4 Respirable Suspended Particulates

Figure 5.5 presents the spatial distribution of the predicted 10th highest 24-hour RSP concentrations. The highest figure upon implementation of the Phase I control measures is 102 $\mu g/m^3$, which is marginally higher than the respective proposed new AQO of 100 $\mu g/m^3$. Owing to the susceptibility of being influenced by trans-boundary air pollution, the maximum 24-hr averaged PM_{10} concentration would be observed at the boundary with Shenzhen. Other than the few spots at the area near the boundary, the highest figure is 100 $\mu g/m^3$, which is in compliance with the respective proposed new AQO.

For annual concentrations, they are marginally higher than the respective proposed new AQO value due to the likely contribution of the trans-boundary emissions. More details of the spatial distribution of the annual RSP are shown in **Figure 5.6**.

Figure 5.5: 10th highest ambient 24-hr RSP concentration upon implementation of Phase I measures

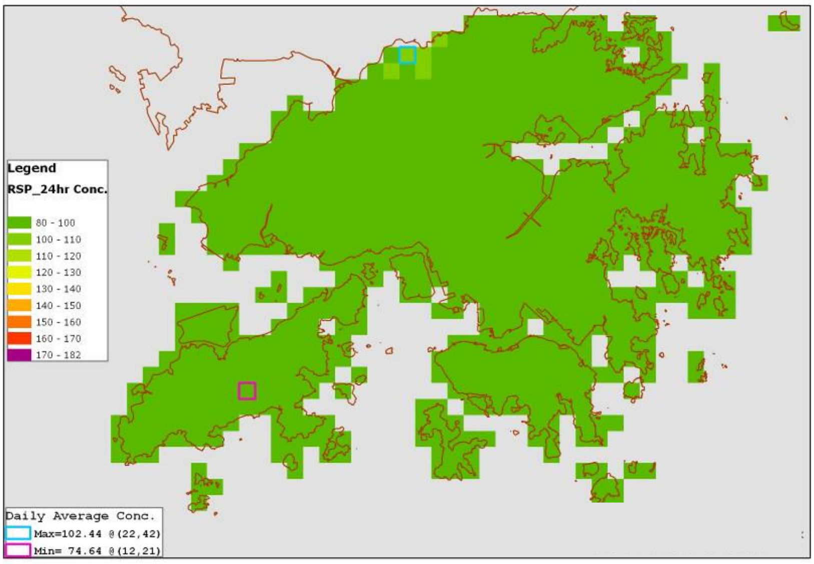
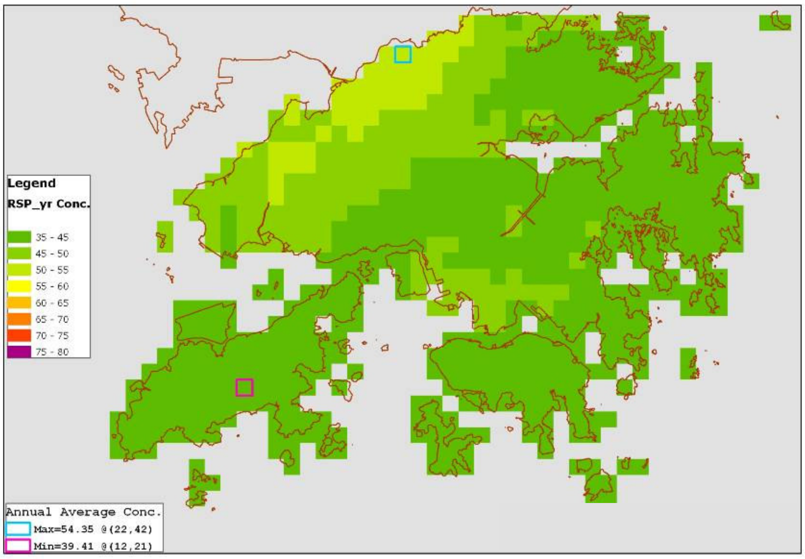


Figure 5.6: Annual ambient RSP concentration upon implementation of Phase I measures



5.3.4.5 Fine Suspended Particulates

The FSP levels are expected to follow similar patterns of RSP, given that they are closely correlated. **Figure 5.7** and **Figure 5.8** show respectively the predicted spatial distributions of the 10th highest 24-hour FSP and the annual FSP levels. The 10th highest 24-hr FSP concentration is in compliance with the respective proposed new AQO. Due to the likely contribution of the trans-boundary emissions, the annual FSP concentration is marginally higher than the respective proposed new AQO value.

Figure 5.7: 10th highest 24-hr ambient FSP concentration upon implementation of Phase I measures

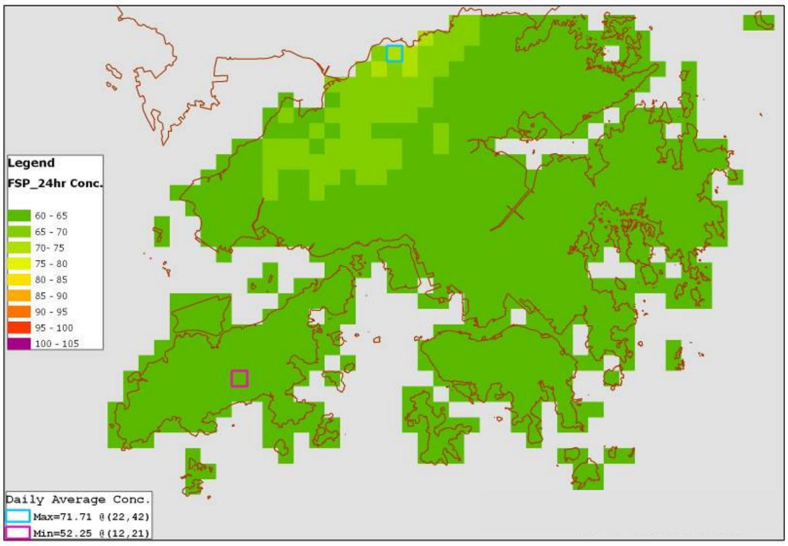
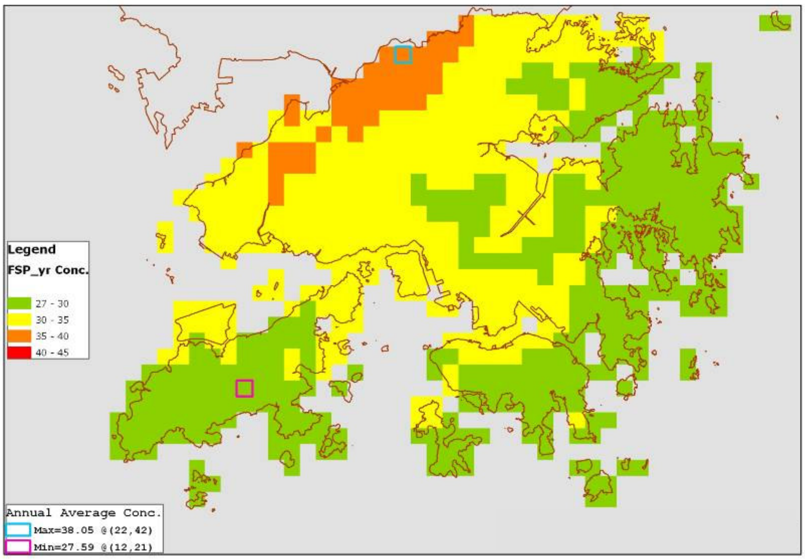


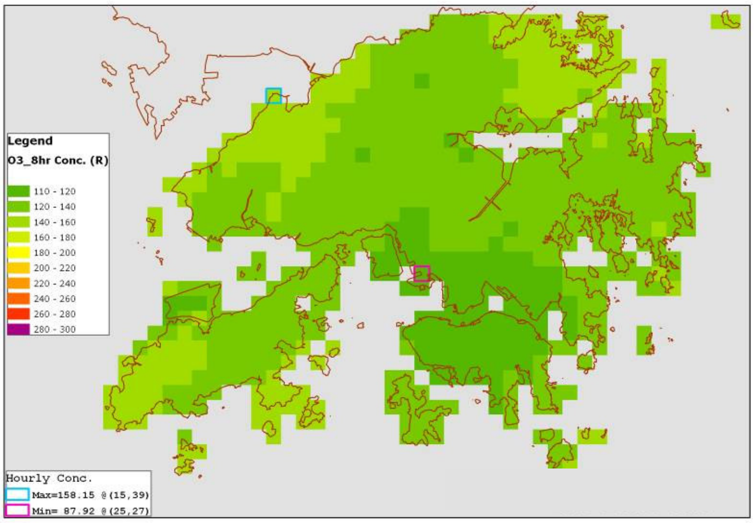
Figure 5.8: Annual ambient FSP concentration upon implementation of Phase I measures



5.3.4.6 Ozone

The spatial distribution of the predicted 10th highest 8-hr O_3 concentrations at general ambient locations is shown in **Figure 5.9** and they are in compliance with the respective proposed new AQO.

Figure 5.9: 10th highest 8-hr ambient O_3 concentration upon implementation of Phase I measures



As a whole, it is proposed that Phase I measures should be implemented whenever it is demonstrated to be practicable and acceptable to the public.

5.4.2 Modelling Results - Phases II and III measures

To go beyond the proposed new AQO, more radical measures are required in both Hong Kong and Guangdong. Implementation of the Phases II and III measures will further reduce the local emissions and help take us towards achieving the next higher targets, where applicable, under the WHO AQG. Some of these additional measures will require more drastic changes or technologies that are still not yet fully developed.

Table 5.16 shows the predicted numbers of exceedences of the WHO's AQG and ITs after the implementation of the Phase II and III measures. It is noted that unless there are significant reduction of PRD emissions, as presented in the Low PRD Emission Scenario under the case where the Phase III measures are implemented, the additional air quality improvement would be quite marginal.

Table 5.16 Estimated no. of exceedences upon implementation of Phases II and III measures

Air Pollutant	Averaging time	Concentration (μg/m^3)	Predicted No. of Exceedences (with Phase II measures implemented)	Predicted No. of Exceedences (with Phase III measures implemented)	
				High PRD Emission Scenario	Low PRD Emission Scenario
SO_2[3]	10-min	AQG: 500	0	0	0
	24-hour	IT-1:125	1	1	0
		IT-2: 50	81	81	0
		AQG: 20	208	207	26
RSP	24-hour	IT-1: 150	0	0	0
		IT-2: 100	9[1]	9[1]	1
		IT-3: 75	87	87	39
		AQG: 50	211	209	183
	Annual	AQO: 55	✓	✓	✓
		IT-2: 50	×	×	✓
		IT-3: 30	×	×	×

Air Pollutant	Averaging time	Concentration (µg/m^3)	Predicted No. of Exceedences (with Phase II measures implemented)	Predicted No. of Exceedences (with Phase III measures implemented)	
				High PRD Emission Scenario	Low PRD Emission Scenario
		AQG: 20	×	×	×
FSP[2]	24-hour	IT-1: 75	6	6	0
		IT-2: 50	107	107	59
		IT-3: 37.5	196	196	164
		AQG: 25	255	255	236
	Annual	IT-1: 35	×	×	✓
		IT-2: 25	×	×	×
		IT-3: 15	×	×	×
		AQG: 10	×	×	×
NO_2	1-hour	AQG: 200	5	6	2
	Annual	AQG: 40	✓	✓	✓
Ozone	8-hr	IT-1: 160	9[4]	9[4]	3
		AQG: 100	64	63	51

Note:

[1] A few spots at the border might have higher number of exceedences.

[2] The present air quality model does not provide for the prediction of the FSP levels. The number of exceedences of FSP is estimated by assuming that the level of FSP is roughly equal to about 70% of that of RSP.

[3] The 10-minute SO_2 levels are estimated from the predicted 1-hour SO_2 concentrations

[4] Occasional spots at the remote area close to Deep Bay might have higher number of exceedences.

"✓" denotes "compliance with the AQO".

"×" denotes "non-compliance with the AQO".

"[✓]" denotes compliance over nearly the whole of Hong Kong except those remote areas close to the boundary.

6 Review of the AQO

6.1 Recommendation of AQO Review

The SAR Government has been implementing a comprehensive air quality management programme to reduce the local emissions The policy objective for air quality management in Hong Kong through the AQO is to achieve as soon as reasonably practicable, and to promote the conservation and best use of air in the public interest. Generally speaking, the aim in conservation and use of air includes the sustaining of life, health and welfare of the people, the sustaining of life and well-being of flora and fauna, the attainment of good visibility and aesthetic enjoyment, and to ensure a useful working life of property and materials. To achieve this goal, the APCO Cap 311 was established as the principal law for managing air quality in Hong Kong.

The EPD (Environmental Protection Department) is the principal department for enforcement of the APCO. Under the Technical Memorandums of APCO, technical references such as principles, procedures, guidelines, standards and limits are set out for the purposes of prediction, measurement, determination and assessment of air pollution. The scope of emission sources scope has covered power plants, motor vehicles, industrial processes and products containing VOC (Volatile Organic Compounds) which are precursors for ozone formation.

For ensuring better protection of public health, in addition to the adoption of a new set of AQO, the formulation of the air quality management plan with regular review and update of the air quality standards against the latest findings on health effects and action plan against technological advancement is appropriate. This will also ensure a phased achievement approach with a balanced consideration of the health risks, technological feasibility, social implications and economic goals and being subject to a scheduled progress review.

Hong Kong is facing two air pollution issues, namely local street-level pollution and the regional smog problem. To tackle these problems, the HKSAR government has been adopting an air quality management strategy that aims to reduce the local emissions as far as practicable and to cooperate with the Guangdong Provincial Government to ensure concerted efforts in combating the regional air pollution. As these two air pollution issues will remain the dominating problems affecting the achievement of the proposed new AQO, it is appropriate to continue to adopt and strengthen the existing air quality management strategy for ensuring improvement of air quality for protection of the public health and environment as soon as possible.

An effective and robust air quality management framework is required to implement the strategy satisfactorily and effectively. This framework should comprise the following elements:

(i) Establishment of new AQO

(ii) Development and implementation of control measures

(iii) Monitoring of air quality

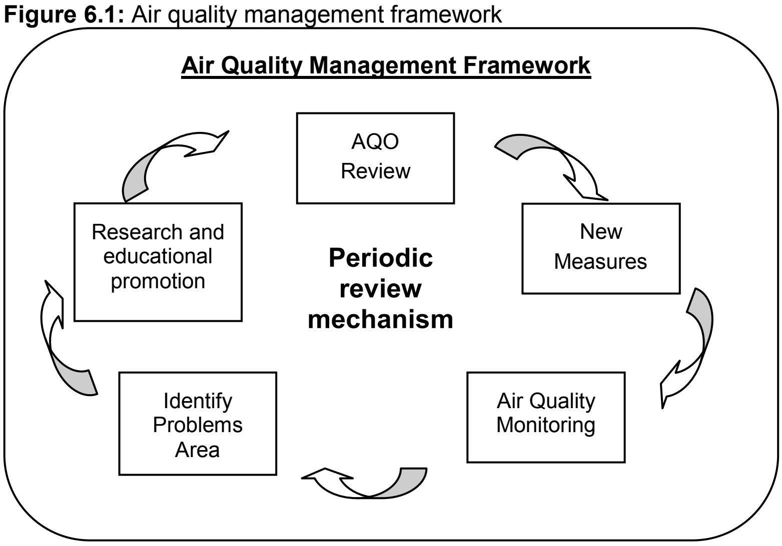
(iv) Identification and assessment of air pollution problem areas

(v) Research and educational promotion

(vi) Periodic review of the progress and the AQO

A robust review mechanism should be formulated as part of the Air Quality Management Plan structured under the proposed Framework to ensure the current AQO supports the objective of public health protection, steer towards compliance with the AQO, identify the problem areas and assess the effectiveness of control strategies for continued improvement on progressive achievement of the WHO AQG in the long term. **Figure 6.1** shows a schematic concept of air quality management framework.

Figure 6.1: Air quality management framework



6.2 Establishment of New AQO

The previous sections show that the proposed new AQO would be achieved with the full implementation of the proposed Phase I control measures subject to suitable allowance for exceedence if the Guangdong side will continue to align itself with the best practices in the world to curb emissions from its power, transport and industrial sectors in tandem with its economic growth. As the achievement of these new AQO would bring in significant health benefits to the public, it would be desirable to ensure earliest adoption wherever possible.

The new AQO need to be established through the issue of a Technical Memorandum (TM) of the APCO. The opportunity should be taken to reinforce the need to consider the principle of “the protection of public health” by spelling out explicitly in the TM when the new AQO are promulgated. Similar practice is also adopted in other advanced countries/economies such as Australia.

6.3 Development and Implementation of Control Measures

In this study, new measures have been assessed and proposed for development and implementation over three phases, i.e., near term, medium term and long term according to technological advancement and practicability. Together with the close and strengthened co-operation with the Guangdong Provincial Government, these proposed measures should be implemented as soon as possible.

Given the different natures of pollution sources, the control strategies can be grouped into six types, namely:

Emission capping and control: This strategy involves the emission control through the use of structural, technical measures and setting emission cap for different sectors (e.g. wider use of natural gas, use of renewable energy, earlier phase out of vehicles, etc).

Transport management: This strategy involves the control of emission from transportation sector through the demand management (e.g. low emission zone, car free zone, etc)

Infrastructure development and planning: This strategy involves the control of emission through proper infrastructure development and planning (e.g. expansion of rail network, cycling network, etc)

Energy efficiency measures: This strategy involves the control of power plant emission indirectly through the use of energy efficiency measures on demand side (e.g. Mandatory building energy codes, district seawater cooling, etc)

Regional collaboration: This strategy involves the collaboration with the PRD government to control emission from cross border (e.g. ULSD application on ocean going vessels, declare the low sulphur emission zone for PRD water, etc)

Indirect measures: This strategy involves the indirect control of emission through the public awareness and education.

6.4 Air Quality Monitoring

Comprehensive and representative air quality monitoring provides the necessary sound scientific basis for assessment of compliance with the objectives of the Air Quality Strategy. It forms the backbone of the assessment and review process on the AQO compliance status and the health risk posed to the public.

The ultimate purpose of air quality monitoring is not merely to collect data, but to provide the necessary information required for development of an effective air quality management plan and ensure an informed decision on managing and improving the air quality will be made. Air monitoring provides the necessary sound scientific basis for policy and strategy development, objective setting, compliance measurement against targets, and enforcement action. Air monitoring serves the following essential key functions:

- Review of current state of air quality
- Assessment of population health impacts
- Identification of problem areas and pollutants requiring regulatory/control action
- Provision of baseline data for predictive models and environmental impact assessments
- Validation of emission inventory and model predictions
- Determination of long-term trends
- Assessment of the effectiveness of control strategies over time
- Raising public awareness and promoting responsible action to tackle pollution

In Hong Kong, an air quality monitoring programme has established with the reference to the international practice. The programme is in full compliance with the requirements of USEPA and EU for producing comprehensive and representative air quality data required for proper assessment of the air pollution exposures by the public. Notwithstanding this, in view of the possible changes in economy and development, both in Hong Kong and PRD region, it will be appropriate that the operation will be reviewed periodically to ensure if it is serving its purposes and whether there is a need to expand or modify the monitoring network for better and more representative coverage. In addition, the EPD should also consider extending the $PM_{2.5}$ monitoring to all monitoring stations.

The EPD will be expected to continue to issue an annual report that details the monitoring data over the past year and identify new problem areas to address.

6.5 Identification and Assessment of Air Pollution Problem Areas

Based on the air quality monitoring data the compliance status of air quality against the AQO as well as the effectiveness of the control measures can be analysed. Use of this data will identify where there are particular problem areas or episodes that require further attention, resources and investigation. Moreover, baseline source apportionment can be conducted to allow authorities to identify the extent to which different sources contribute to the air quality exceedences that have been identified. This will assist authorities to correctly target the most important sources, and to focus the principal measures within the Action Plan. The result would also identify the reduction in pollutant emissions that is required to attain the objectives and this will assist authorities in identifying the scale of emissions reduction that needs to be addressed within the Action Plan.

The outcome of the assessment can also be used to investigate the air quality effects of particular policy measures, ie how implementing measures would influence the baseline source apportionment. For example, the implementation of a local traffic management scheme, etc would potentially reduce the contribution of one or more types of vehicles. This will assist authorities when preparing their Action Plans to show that they have adequately considered a range of measures, and have evaluated the cost-effectiveness and proportionality of their chosen approach.

6.6 Research and Education Promotion

The causes of the most critical air pollution problem areas identified will form part of the focus for future studies. This in turn will facilitate further development of new control measures and air policy. Upon completion of the API review, a plan should be developed to educate the public on the air pollution risk communication system. Over the next few years, the major challenges facing the air quality researches will be:

- Developing a more sophisticated understanding of the source attribution of the effects associated with air pollutants exposure, in particular PM and ozone.
- Incorporating social science research to allow the development of targeted policies to reduce air pollution.
- Refining of the Regional Air Quality Model for the secondary particulates and ozone formation.
- Conducting research on the chronic health impact due to pollution

In completing the review cycle as shown in **Figure 6.1**, the AQO needs to be reviewed and updated as necessary on the basis of the latest health effect evidence as well as technical feasibility.

Apart from researches, human capital can be further developed through general education. For the general public, the green groups have done a lot of works to promote public awareness (e.g. energy efficiency scheme). As pollution abatement now cut across many policy areas that impact on people’s live, the public campaign should now transcend the interest of any sector or group to be a cross-sector co-operation. The government, through the education and conservation fund, will have a useful coordinating role in various programmes in public education targeted at different groups of the population.

6.7 Periodic Review of AQO and Management Measures

The proposed new AQO, although are compatible with those adopted in other advanced countries such as EU and USA (other than particulate matters for which more practical AQO have been proposed in view of the strong influence of the external sources), some of them are still fall short of the WHO AQG. In addition, with better understanding of the health effects of the air pollutants, it is possible that some of these AQO might need further revision in the future.

Periodic reviews of air quality standards to take into account emerging evidence about the health effects of air pollution are conducted in many parts of the world. The USEPA are required under the Clean Air Act to review air quality standards every five years and is currently undertaking a review of their National Ambient Air Quality Standards for NO_2.

The EU has also stated clearly in their Directive 2008/50/EC for promulgating the ambient air quality limit and target values that a review on the $PM_{2.5}$ will be made with a view to presenting a proposal for considered by the European Parliament and the European Council in Year 2013.

To help achieve progressively the long term target of achieving the ultimate AQG, the introduction of a review mechanism should be introduced to regularly ascertain the extent to which the new AQO have been achieved, the progress of the air management strategy, as well as the need and practicality of further tightening the AQO. This establishment of this mechanism may take the form of a mandatory requirement to be stipulated in the TM for promulgation of the proposed new AQO or an administrative arrangement. It is also appropriate that the air quality strategy, the needs and means of any established implementation requirements for air quality management plan should be preferably be reviewed and updated at the same time when the AQO are reviewed. This will ensure phased achievement approach to balance the health risks, technological feasibility, social implications and economic goals.

In conducting the review, a review committee comprising members from air sciences, health professionals, industrial engineers, representatives of the public, EPD, other government departments as well as other related stakeholders should be considered. Such committee may help:

(i) review the latest knowledge on health studies to appraise the adequacy and basis of current, new, or revised air quality objectives,

(ii) outline the means on research efforts necessary to provide the required information,

(iii) review the relative contribution to air pollution concentrations of natural as well as anthropogenic activity, and

(iv) advise on the need to revise the AQO

(v) advise the Government of any adverse public health, welfare, social, economic, or energy effects which may result from various strategies for attainment and maintenance of the AQO.

(vi) Similar to the practice of other advanced countries, it is considered appropriate that the review should be conducted at a frequency of not less than once every five years.

7 Conclusion

The WHO AQG are the most authoritative guidelines that provides a good source of reference for all countries to build their air quality standards to minimize the risk of air pollution to public health. They are, however, far tougher than the national standards being applied in many parts of the world. WHO accepts the need for governments to set national standards according to their own particular circumstance. The guidelines therefore also suggest interim targets (ITs) on sulphur dioxide (SO_2), respirable suspended particulates (PM_{10}), fine particulate matters ($PM_{2.5}$) and ozone to facilitate a progressive approach for achieving the ultimate AQG and provide milestones in achieving better air quality.

In overseas jurisdictions, the adoption of interim or progressive targets in their legal air quality standards is common. Among developed countries, the EU has the most stringent air quality standards, which were updated on 21 May 2008. Its air quality standards for SO_2, ozone, PM_{10} and $PM_{2.5}$ are still less stringent than those prescribed under the WHO AQG. So far, it has not been found that any jurisdictions adopt the WHO AQG in their entirety as legal standards.

Taking account of Hong Kong's status as a world city, international practices and our local situations, the WHO AQG should be pursued as our long term goal while progressive steps should be taken to tighten the existing legal AQO.

Taking into account the local circumstances, views received at the Advisory Panel, international practices and scientific air quality modelling findings, a progressive, forward-looking approach in determining the new AQO is proposed. The proposed AQO is summarized in **Table 7.1**.

Table 7.1: Proposed AQO

Pollutants	Avg. Time	Concentration (μg/m^3)	No. of exceedences
SO_2	10-min	500	3
	24-hr	125	3
PM_{10}	24-hour	100	9
	1-year	50	0
$PM_{2.5}$	24-hour	75	9
	1-year	35	0
NO_2	1-hr	200	18
	1-yr	40	0
O_3	8-hr	160	9
CO	1-hr	30,000	0
	8-hr	10,000	0
Pb	1-yr	0.5	0

Section 7(2) of the APCO provides that the AQO "should be achieved and maintained in order to promote the conservation and best use of air in the zone in the public interest." Though not explicitly stated, the protection of public health is already a key consideration because to do otherwise will not be in "public interest". Taking into account the aspiration for an explicit commitment on the principle of protection of public health, and the best practices being pursued by other advanced countries, it is recommended that protection of public health should be taken as the key parameter for determining the new AQO. Consideration could be given to stating this principle in amending the Technical Memorandum for stipulating the AQO under the APCO.

Any changes in the AQO will also have major implications in respect of the permitted emission standards for "specified processes" (such as electricity works) under the APCO or evaluating the air quality impact of designated projects under the Environmental Impact Assessment Ordinance (EIAO) (Cap 499), which are determined with reference to the prevailing legal AQO.

A host of comprehensive emission reduction measures which Government may consider implementing for improving Hong Kong's air quality has been identified. Broadly speaking, the measures target at the following areas:

- cutting the emissions from power plants by increasing the proportion of natural gas from the current 28% to, say, 50% or even more of the fuel mix for local electricity generation;
- advancing the earlier replacement of more polluting vehicles (including franchised buses) and promoting the use of more environment-friendly vehicles;
- further tightening the control of emissions from vessels and other sources;
- introducing suitable traffic management measures to reduce roadside emissions (such as low emission zones, etc.);
- expanding rail/tram network; and
- promoting energy efficiency.

Upon delivery of the proposed new AQO in Phase I near term, it is expected that about 4,180 unnecessary hospital admissions and 7,348 statistical life years would be saved (i.e., about 1 month improvement in life expectancy) for each year.

On the basis that the Guangdong side will continue to align itself with the best practices in the world to curb emissions from its power, transport and industrial sectors in tandem with its economic growth, preliminary technical assessment shows that with the full implementation of the Phase I control measures, it is able to achieve the proposed new AQO subject to suitable allowance for exceedence. To go beyond the proposed new AQO, more radical measures are required in both Hong Kong and Guangdong. Implementation of the Phases II and III measures will further reduce the local emissions and help take us towards achieving the next higher targets, where applicable, under the WHO AQG. These additional measures will require more drastic changes or technologies that are still not yet fully developed.

Finally, it is recommended that a regular review should be introduced to regularly ascertain the extent to which the new AQO have been achieved, the progress of the air management strategy, as well as the need and practicality of further tightening the AQO. Based on overseas experience, an interval of about five years is recommended.

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