For discussion on
19 March 2009

LEGISLATIVE COUNCIL
PANEL ON ENVIRONMENTAL AFFAIRS
SUBCOMMITTEE ON IMPROVING AIR QUALITY

Review of Hong Kong's Air Quality Objectives and Development of Long-Term Air Quality Management Strategy

PURPOSE

This paper briefs Members on the consultant's preliminary findings of the Review of Hong Kong's Air Quality Objectives (AQOs) and development of a long-term air quality management strategy for achieving the revised AQOs and the way forward.

BACKGROUND

2. In Hong Kong, the legal AQOs are set out in the Technical Memorandum of the Air Pollution Control Ordinance (APCO) (Cap 311). The AQOs stipulate appropriate concentration targets for selected air pollutants and these standards serve as the references by the authority in deciding on emission permitted for specified process licences granted under the APCO and in assessing whether the air quality impacts of designated projects are acceptable for approval under the Environmental Impact Assessment Ordinance (EIAO) (Cap 499). The AQOs are also the references adopted in determining Air Pollution Index (API). The current AQOs, which cover seven major air pollutants, were established in 1987 and we consider that it is time for updating.

3. In October 2006, the World Health Organisation (WHO) released a new set of Air Quality Guidelines (AQGs), which have been drawn up based on a wealth of new studies on the health effects of air pollution and following extensive consultation with leading air scientists and health experts worldwide. **Annex A** gives a comparison between Hong Kong's existing AQOs and the air quality standards of international organization and overseas countries, including the guidelines released by the WHO.

4. In response to the release of the WHO AQGs, Government commissioned a consultancy study in June 2007 to recommend a new set of AQOs for Hong Kong and an air quality management strategy to achieve the new AQOs. An Advisory Panel comprising members from various disciplines including health, air science, industry and transport trades and representatives of relevant Government Bureaux and Departments has been formed to steer the Review. Two consultation forums had been conducted during the study to gauge the public and the professional's views on the Review.

THE PRELIMINARY FINDINGS OF THE REVIEW

5. The preliminary findings of the consultant are set out at **Annex B**. These include suggestions for updating the current AQOs and a package of emission control measures for attaining the proposed new AQOs.

WAY FORWARD

6. The consultant will hold another public forum in late March 2009 to canvass the views of the public on the above preliminary findings for finalizing his recommendations.

7. There is strong public consensus in improving our air quality. We are also mindful that attaining the new AQOs set out in the consultant's preliminary findings would be a tall order for the community. It necessitates implementation of a series of drastic improvement measures across different sectors including power generation, energy efficiency, road and marine transportation sectors. The consultant has conducted a cost-benefit analysis for these measures to provide a broad indication on their relative cost-effectiveness. While the analysis estimates the economic costs of proposed measures to be borne by the entire community, it makes no distinction as to whether the costs would eventually be borne by Government, the operators or consumers. At this stage, 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.

8. 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.

9. Cost aside, some recommendations require a new approach to infrastructure development (such as district cooling system), or lifestyle and behaviour changes to the community (such as car-free and low emission zones and bus route rationalization) and their implementation would require public acceptance.

10. The pace for implementing the proposed control measures or achieving the new AQOs would depend on the feasibility and the readiness of the community to bear the cost. This is an important area that needs to be thoroughly discussed within the community. Upon receipt of the final report of the Review from the consultant towards the second half of this year, we will conduct a full scale public consultation on the proposals as well as the pace, priority and price for their implementation before taking a view on how best the current AQOs are to be updated and what measures are to be adopted.

ADVICE SOUGHT

11. Members are invited to note and comment on the consultant's preliminary findings as set out at **Annex B** and the way forward as set out in paragraphs 6 to 10.

Environmental Protection Department
March 2009

Annex A

Hong Kong Existing AQOs, WHO and Overseas Standards/Guidelines

Pollutant	Avg Time	Hong Kong's Existing AQOs	WHO AQGs $\mu g/m^3$	USA		EU		UK		Australia	
				$\mu g/m^3$	No. of Exceedances Allowed	$\mu g/m^3$	No. of Exceedances Allowed	$\mu g/m^3$	No. of Exceedances Allowed	$\mu g/m^3$	No. of Exceedances Allowed
Sulphur Dioxide	10-min	-	500	-	-	-	-	266 [1]	35	-	-
	1-hour	800	-	-	-	350	24	350	24	524	1
	24-hour	350	20 (IT-1: 125, IT-2: 50)[2]	365	1	125	3	125	3	210	1
	Annual	80	-	80	NA	-	-	-	-	52	NA
Respirable Suspended Particulate (PM10)	24-hour	180	50 (IT-1: 150, IT-2: 100, IT-3: 75)	150	3 times in 3 years	50	35	50	35	50	5
	Annual	55	20 (IT-1: 70, IT-2: 50, IT-3: 30)	-	-	40	NA	40	NA	-	-
Fine Suspended Particulate (PM2.5)	24-hour	-	25 (IT-1: 75, IT-2: 50, IT-3: 37.5)	35	3-y avg of 98^{th} percentile	-	-	-	-	25 [3]	NA

Pollutant	Avg Time	Hong Kong's Existing AQOs	WHO AQGs µg/m^3	USA		EU		UK		Australia	
				µg/m^3	No. of Exceedances Allowed	µg/m^3	No. of Exceedances Allowed	µg/m^3	No. of Exceedances Allowed	µg/m^3	No. of Exceedances Allowed
(PM2.5 cont'd)	Annual	-	10 (IT-1: 35, IT-2: 25, IT-3: 15)	15 [4]	NA	25	NA	25	NA	8 [3]	NA
Nitrogen Dioxide	1-hour	300	200	-	-	200	18	200	18	226	1
	24-hour	150	-	-	-	-		-		-	
	Annual	80	40	100	NA	40	NA	40	NA	57	NA
Ozone	1-hour	240	-	-		-		-		200	1
	4-hour	-	-	-		-		-		160	1
	8-hour	-	100 (High levels: 240, IT-1: 160)	147	3-year of 4th highest values	120	25	100	10	-	-
Carbon Monoxide	15-min	-	100,000	-	-	-	-	-	-	-	-
	30-min	-	60,000	-	-	-	-	-	-	-	-
	1-hour	30,000	30,000	40,000	1	-		-		-	-
	8-hour	10,000	10,000	10,000	1	10,000	0	10,000	0	10,000	1
Lead	3-month	1.5	-	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] reporting standard
[4] 3-year average of the weighted annual mean
[5] Rolling 3-month average

Annex B

THE CONSULTANTS' PRELIMINARY FINDINGS OF THE AQO REVIEW

WHO AQGs as a Long-term Aspirational Goal

The WHO AQGs are seen as the most authoritative set of 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. 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 therefore also suggest interim targets (ITs) on sulphur dioxide (SO_2), respirable suspended particulates (PM10), fine particulate matters (PM2.5) and ozone to facilitate a progressive approach for achieving the ultimate AQGs and provide milestones in achieving better air quality.

2. 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, PM10 and PM2.5 are still less stringent than those prescribed under the WHO AQGs. For example, the EU has chosen an annual PM2.5 standard of 25 ug/m3, which is equivalent to WHO's IT-2 value for PM2.5. So far, the consultant has not found any jurisdictions adopting the WHO AQGs in their entirety as legal standards.

3. In addition, under section 8 of the Air Pollution Control Ordinance (Cap 311) (APCO), the Authority (i.e. Director of Environmental Protection) is required to achieve the relevant AQOs as soon as practicable. Any changes in the AQOs 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 AQOs.

4. Taking account of Hong Kong's status as a world city, international practices and our local situations, the consultant's preliminary finding is that the WHO AQGs should be pursued as our long term aspirational goal while progressive steps should be taken to tighten the existing legal AQOs.

A Progressive, Forward-looking Approach with an Explicit Reference to the Protection of Public Health as a Key Parameter in Determining AQOs

5. Section 7(2) of the APCO provides that the AQOs "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". The Advisory Panel which steers the Review has discussed in detail how the consideration of protection of public health should be better articulated in the APCO and in determining the tightened AQOs.

6 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, the consultant recommends that protection of public health should be taken as the key parameter for determining the new AQOs. Consideration could be given to stating this principle in amending the Technical Memorandum for stipulating the AQOs under the APCO.

7. As regards the setting of the revised AQOs, there are divergent views in the community and in the discussion at the Advisory Panel on the Review. Some critics have been advocating an overhaul of the existing AQOs and to replace them by the WHO AQGs so as to take protection of public health as the only consideration. On the other hand, there are other views which advocate pragmatism in tightening AQOs so as to balance health risk against economic costs and technological readiness. Taking into account the local circumstances, views received at the Advisory Panel, international practices and scientific air quality modelling findings, the consultant recommends a progressive, forward-looking approach in determining the new AQOs.

Proposed New AQOs for Hong Kong

8. WHO AQGs 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 AQOs, the consultant is of the view that we should be guided by the air quality targets recommended by the WHO. Taking account of our local circumstances, the consultant's initial findings suggest that we should consider adopting the proposed new AQOs at **Appendix I**.

Emission Control Measures Required to Achieve the New AQOs and Cost/benefit Analysis

9. The consultant has preliminarily identified a host of comprehensive emission

reduction measures which Government may consider implementing for improving Hong Kong's air quality. The conceptual outline of these measures together with a broad assessment of their emission reduction potential and a cost-benefit analysis are at **Appendix II**. Broadly speaking, the measures target at the following areas -

(a) 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;

(b) advancing the earlier replacement of more polluting vehicles (including franchised buses) and promoting the use of more environment-friendly vehicles;

(c) further tightening the control of emissions from vessels and other sources;

(d) introducing suitable traffic management measures to reduce roadside emissions (such as low emission zones, etc.);

(e) expanding rail/tram network; and

(f) promoting energy efficiency.

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 consultant's preliminary technical assessment shows that with the full implementation of the Phase I control measures set out at **Appendix II**, we would be able to achieve the proposed new AQOs subject to suitable allowance for exceedance[1]. To go beyond the proposed new AQOs, 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 AQGs. These additional measures will require more drastic changes or technologies that are still not yet fully developed.

10. Cost-benefit analysis is undertaken by the consultant to provide a systematic framework for providing a broad indication on the relative cost-effectiveness of different proposed control measures. However, the analysis only focuses on the

[1] It is a common practice internationally (e.g., in the EU, USA, Australia, etc.) to allow for certain number of hours or days where the concentration levels of the concerned air pollutants exceeds the limit values specified in the AQOs in determining their compliance.

economic cost of the proposals to the community as a whole and as these proposals are at conceptual stage, the estimates on costs and benefits are subject to uncertainties and variations depending on the timing, implementation details, the market situations and the community's responses, etc. when the individual measures are taken forward. Another point to note is that in assessing the proposal to replace old vehicles or machineries, the economic analysis aims to reflect the cost in forfeiting their corresponding residual values in the case of advancing their retirement but not the overall replacement costs. Moreover, the analysis focuses mainly on the economic costs to be borne by the entire community, making no distinction as to whether the costs would eventually be borne by Government, the operators or consumers. Different measures would have different impacts on the community in terms of the magnitude and the affected sectors.

11. The benefits of pollution control considered were 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).

12. It is also of interest to note from **Appendix II** that while the proposed measures to use more natural gas for electricity generation would bring about significant emission reduction, their benefit-cost ratios are much lower than those targeting at vehicles. The main reason is that due to the tall stacks of power plants and meteorological factors, the potential improvement to air quality or health benefits brought about by burning more gas for power generation in Hong Kong would not be entirely reaped by Hong Kong residents but by those in other cities in PRD, particularly those sitting to the north-western side of Hong Kong. These "external" benefits are not captured in the current cost-benefit analysis which focuses entirely on the benefits of the individual measures on Hong Kong. Likewise, similar measures to curb emission from power plants in other PRD cities would benefit Hong Kong. This complexity in assessing the air quality on health benefits of individual emission abatement measures on specific locality underlines the importance of taking a wider regional perspective in tackling the air pollution problem facing the PRD region. On the other hand, the package of proposed control measures targeting at vehicles, which produces less emission reduction impacts when compared with changing the fuel mix for electricity generation, has greater impact on roadside pollution and health benefits because of their proximity to local residents.

Regular Review Mechanism

13. The consultant also recommends that a regular review should be introduced to regularly ascertain the extent to which the new AQOs have been achieved, the progress of the air management strategy, as well as the need and practicality of further

tightening the AQOs. At this stage, the consultant has not made a firm recommendation on the interval between reviews. However, based on overseas experience, an interval of about five years is the normal practice.

Next Step

14. The consultant will hold another public forum in late March 2009 to canvass the views of the public on the above preliminary findings for finalizing his recommendations.

Appendix I to Annex B

Proposed New AQOs for Hong Kong

Pollutants	Averaging Time	Existing AQOs		Proposed AQOs [*]							
				IT-1		*IT-2*		*IT-3*		*AQG*	
		($\mu g/m^3$) [3]	#	($\mu g/m^3$) [3]	#	($\mu g/m^3$) [3]	#	($\mu g/m^3$) [3]	#	($\mu g/m^3$) [3]	#
Sulphur dioxide	10-min	-		-						**500**	**3**
	24-hour	350	1	**125**	**3**	50		-		20	
Respirable Suspended Particulates (PM10)	24-hour	180	1	150		**100**	**9**	75		50	
	1-year	55	0	70		**50**	**0**	30		20	
Fine Suspended Particulates (PM2.5)	24-hour	-		**75**	**9**	50		37.5		25	
	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**

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

[#] Number of exceedances to be allowed:
Any exceedance measured at the general air quality monitoring station(s) at any one time would be counted as one exceedance against the number allowed for a calendar year. The number of exceedances 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

Appendix II to Annex B

Proposed Emission Control Measures

(a) Emission Reduction Potential

Baseline Emissions (tonnes) in 2006 :

Sector	SO2	NOx	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

(i) Phase I Measures

Phase I Measures					
		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		**SO2**	**NOx**	**PM_{10}**	**VOC**
1.	Increase ratio of natural gas in local electricity generation to 50% with additional emission abatement measures	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 uptake of latest Euro standard for diesel commercial vehicles of Euro III (assumed to be about 50%)	0	743	75	24
4.	Wider use of hybrid / electrical vehicles or other environmentally friendly vehicles with similar performance (20% private cars and 10% franchised buses)	15	216	7	173
5.	Ultra low sulphur diesel for local vessels	675	0	18	0
6.	Selective catalytic reduction 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 VOC control for sealant and adhesives	0	0	0	700
	Transport Management				
10.	Low emission zone (banning pre-Euro, Euro I , Euro II and Euro III commercial vehicles) for	Note [1]	Note [1]	Note [1]	Note [1]

	Central, Mongkok and Causeway Bay				
11.	Car-free zone / pedestrianisation scheme for Central, Mongkok and Causeway Bay	Note [1]	Note [1]	Note [1]	Note [1]
12.	Bus route rationalization	4	156	7	9
Infrastructure Development and Planning					
13.	Expand rail / tram 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 efficient electrical appliances for domestic use	84	142	4	1
17.	LED for 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

Baseline Emissions (tonnes) Upon Completion of Phase I Measures :

Sector	**SO2**	**NOx**	**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	*4,263*	*21,380*	*658*	*436*
Aviation	*384*	*7,314*	*13*	*348*
Industry and Others	12	3,658	385	23,104

(ii)Phase II Measures

Phase II Measures					
		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		**SO2**	**NOx**	**PM_{10}**	**VOC**
20.	Increase the ratio of natural gas in local electricity generation to 75% with additional emission abatement measures (on top of Phase I measure)	5,163	5,761	178	0
21.	Increase ratio of renewable energy (2% wind energy)	502	852	25	8
22.	Wider use of hybrid / electrical vehicles or other environmentally friendly vehicles with similar performance (30% private cars and 15% buses including franchised buses + 15% LGV+ 15%HGV) (Additional to Phase I measure)	40	849	79	174
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	Strengthening VOC control for consumer products (50% reduction, California Air Resources Board)	0	0	0	4870
Transport Management					
28.	Electronic road pricing / 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

Baseline Emissions (tonnes) Upon Completion of Phase II Measures :

Sector	**SO2**	**NOx**	**PM_{10}**	**VOC**
Power	6,053	10,762	534	412
Transport	2,861	28,317	1,760	5,442
Vehicles	*270*	*9,722*	*1,284*	*4,900*
Marine	*2,124*	*13,450*	*457*	*122*
Aviation	*466*	*5,145*	*19*	*421*
Industry and Others	11	3,682	386	18,865

(ii) Phase III Measures

Phase III Measures					
		Emission Reduction Potential (Tonnes)			
Emission Capping and Control		**SO2**	**NOx**	**PM_{10}**	**VOC**
31.	Increase 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 / electrical vehicles or other environmentally friendly vehicles with similar performance (50% private cars, 50% buses including franchised buses, 50% HGV, 50%LGV) (Additional to Phase II measure)	63	789	42	232
34.	Vehicle permit quota system (to reduce around 50% private cars and 50% motorcycles)	28	93	3	119
35.	Use of Hydrogen Fuel Cell vehicles (not less than 40% penetration)	140	2,778	94	1,453
Infrastructural Development and Planning					
36.	Rail for transport of cross-boundary goods	1	11	1	9

Baseline Emissions (tonnes) Upon Completion of Phase III Measures :

Sector	SO2	NOx	PM_{10}	VOC
Power	0	2,340	153	202
Transport	3,952	29,515	1,894	4,000
Vehicles	*101*	*5,466*	*1,195*	*3,276*
Marine	*3,385*	*18,904*	*680*	*303*
Aviation	*466*	*5,145*	*19*	*421*
Industry and Others	10	3,770	391	20,083

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.

(b) Cost-Benefit Analysis

Phase I Measures				
		Cost – Benefit Analysis[1]		
Emission Capping and Control		**Cost ($M)**	**Benefit ($M)**	**Benefit-Cost Ratio**
1.	Increase ratio of natural gas in local electricity generation to 50% with additional emission abatement measures	2,032[13]	1,803	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[2]	24,344	6.3
3.	Earlier uptake of latest Euro standard for commercial diesel vehicles of Euro III (assumed to be about 50%)	2,668[2]	6,134	2.3
4.	Wider use of hybrid / electrical vehicles or other environmentally friendly vehicles with similar performance (20% private cars and 10% franchised buses)	4,326[2]	2,417	0.56
5.	Ultra low sulphur diesel for local vessels	378	6,331	16.7
6.	Selective catalytic reduction for local vessels	249	74	0.30

7.	Electrification of aviation ground support equipment	224	3.8	0.02
8.	Emission control for off-road vehicles / equipment	845	2,123	2.5
9.	Strengthening VOC control for sealant and adhesives	18	124	6.9
	Transport Management			
10.	Low emission zone (banning pre-Euro, Euro I , Euro II and Euro III commercial vehicles) for Central, Mongkok and Causeway Bay	3,696	2,586	0.7
11.	Car-free zone / pedestrianisation scheme for Central, Mongkok and Causeway Bay	42	400	10
12.	Bus route rationalization	14	548	39
Infrastructure Development and Planning				
13.	Expand rail / tram network	Note [3]	3,850	Note [3]
14.	Cycling network to major public transport hubs	836	8	0.01
Energy Efficiency Measures [4] (mostly savings in energy cost)				
15.	Mandatory implementation of Building Energy Codes	95	2,634	28
16.	Energy efficient electrical appliances for domestic use	84	2,277	27
17.	LED for street lighting	47	105	2.2
18.	Tree planting / roof-top greening [5]	6,357	1,603	0.3
19	District cooling system for Kai Tak Development	2,788[12]	4,047	1.5

Phase II Measures				
		Cost – Benefit Analysis[1]		
Emission Capping and Control		**Cost ($M)**	**Benefit ($M)**	**Benefit-Cost Ratio**
20.	Increase the ratio of natural gas in local electricity generation to 75% with additional emission abatement measures (Additional to Phase I measure)	1,702[13]	383	0.22
21.	Increase ratio of renewable energy (2% wind energy)	13,069	206	0.02
22.	Wider use of hybrid / electrical vehicles or other environmentally friendly vehicles with similar performance (30% private cars and 15% buses including franchised buses + 15% LGV+ 15%HGV) (Additional to Phase I measure)	9,026	14,447	1.60
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	6,242	4.0
26.	Tightening aviation emission standards	Note [6]	12	---
27	Strengthening VOC control for consumer	37	634	17.2

	products (50% reduction, California Air Resources Board)			
Transport Management				
28.	Electronic road pricing / congestion charging scheme for Hong Kong Island North	Note [7]	577	---
29.	Reduce parking provision (25%) to restrain car usage for Central	757	18	0.02
Energy Efficiency				
30.	District cooling system (35% in existing areas and 90% in other new development areas)	19,347	11,578	0.6

Phase III Measures				
		Cost – Benefit Analysis[1]		
Emission Capping and Control		**Cost ($M)**	**Benefit ($M)**	**Benefit-Cost Ratio**
31.	Increase ratio of natural gas in local electricity generation to 100% (Additional to Phase II measure) [8]	348	255	0.73
32	50% nuclear power and 50% natural gas (Alternative Case), compared to Base Case of 75% natural gas) [8]	(2,894) [9]	91	Note [9]
33.	Wider use of hybrid / electrical vehicles or other environmentally friendly vehicles with similar performance (50% private cars, 50% buses including franchised buses, 50% HGV, 50%LGV) (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	250	0.4
35.	Use of Hydrogen Fuel Cell vehicles (not less than 40% penetration)	Note [10]	10,420	Note [10]
Infrastructural Development and Planning				
36.	Rail for transport of cross-boundary goods	Note [11]	115	Note [11]

Notes:

[1] In its simplest form, the costs and benefits of each policy are quantified and valued in monetary terms. The cost-benefit analysis is subject to a wide range of assumptions used by the consultants for compiling the assessment of different control measures. As these assumptions are subject to change, the findings of the cost-benefit analysis should be read with caution. Nonetheless, it provides a systematic framework to compare the potential cost-effectiveness of different control measures.

[2] The cost of early retirement of the concerned vehicles is calculated based on the residual value foregone of these vehicles over the remaining period of their normal serviceable life. The upfront capital costs required for procuring the replacement vehicles would be higher than the figures set out in the table.

[3] The railway strategy includes North Island Line, Kwun Tong Line Extension, Kowloon Southern Link and Shatin Central Link. The railway strategy will have additional ride-on effect on improvement of air quality. Only benefit is presented.

[4] Benefits include material damage, energy saving, acute and chronic health benefits. For strategies 15, 16, 17 and 19 the majority of benefits are due to energy savings, not health benefits.

[5] No local emission and cost data. Estimates are based on overseas data for roof top greening of 10% of the urban area.

[6] Cost is assumed to be borne by the airlines worldwide

[7] The ERP strategy, if implemented, will have additional ride-on effect on improvement of air quality. Hence, only benefit is presented.

[8] 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.

[9] Cost is reported as saving – The "50% Nuclear & 50% natural gas" scenario is $2,894 M cheaper than the Base Case of 75% natural gas as the levelised cost of nuclear power is lower than natural gas. Benefit-cost ratio is not provided as only saving/benefit is incurred from the measure.

[10] Cost data are not available as the proposed measures are still under development.

[11] The railway strategy, if implemented, will have additional ride-on effect on improvement of air quality. Only benefit is presented.

[12] The figure includes both the capital and operational costs of plant for the coming 50 years.

[13] The figure includes estimated costs due to increasing the ratio of natural gas in local electricity generation to 50%. It does not include estimates on additional emission abatement measures, which would be subject to further studies.