For discussion on
18 December 2018

WG Paper 1/2018

AIR QUALITY OBJECTIVES REVIEW WORKING GROUP

FINDINGS OF THE AQOs REVIEW

PURPOSE

This paper summarises the work of the Air Quality objectives (AQOs) Working Group, presents the review findings (paragraphs 9 to 27) with the potential scope for tightening the AQOs (paragraphs 17 to 20), and seeks Members views on the way forward (paragraphs 28 to 29) .

BACKGROUND

World Health Organisation's Air Quality Guidelines and Interim Targets

2. The World Health Organisation (WHO) has promulgated a set of Air Quality Guidelines (AQGs) for various key air pollutants including respirable suspended particulates (RSP / PM_{10}), FSP/$PM_{2.5}$, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO) and lead (Pb), based on a wealth of studies on the effects of air pollution on health. Recognising the challenge of full compliance with the AQGs (to the extent that no country or region has fully adopted the AQGs as its air quality standards), the WHO has set Interim Targets (ITs) to promote steady progress towards meeting the AQGs. The WHO has recommended that in setting their air quality standards, countries should strike a balance between the needs of public health and local circumstances, and take into account practical circumstances, such as health risk due to air pollution, latest technological developments, as well as economic, political and social considerations.

AQOs in Hong Kong

3. The Air Pollution Control Ordinance (APCO) (Chapter 311) stipulates a set of AQOs. The prevailing AQOs, which relate to seven key air pollutants (RSP/PM_{10}, FSP/$PM_{2.5}$, SO_2, NO_2, O_3, CO and Pb), took effect on 1 January 2014. The AQOs are benchmarked against a combination of WHO AQGs and their ITs. Among the 12 AQOs for the seven air pollutants, six of them are already set at WHO AQGs levels, i.e. SO_2 (10-min), NO_2 (both 1-hour and annual), CO (both 1-hour and 8-hour) and Pb (annual), whereas the remaining are set at WHO ITs levels (**Annex A**).

4. As a result of a series of emission control measures implemented in recent years, the concentrations of key air pollutants have reduced by about 30 per cent over the past five years. In 2017, except for O_3 and NO_2, the AQOs for the remaining air pollutants (i.e. SO_2, PM_{10}, $PM_{2.5}$, CO and Pb) have already been attained, as set out in **Annex B**. With our on-going emission control programmes, the target of "broadly attaining the current ambient air quality AQOs by 2020" remains valid. The high roadside NO_2 level (whose annual concentrations are currently more than two times the AQO limit) as well as the rising trend of ozone however remain to be the key challenges of air pollution we need to tackle.

5. Under Section 7A of the APCO, the Secretary for the Environment (SEN) is required to review the AQOs at least once every five years and thereafter submit to the Advisory Council on the Environment (ACE) a report of the review.

THE REVIEW

6. To undertake the AQOs Review, a Working Group (the Working Group), led by the Under Secretary for the Environment (USEN), has been formed in mid 2016. There are some 60 members from the fields of air science, health, green groups, academics, chambers of commerce, professional bodies and trade representatives, as well as representatives from relevant Government bureaux/departments (B/Ds), including the Environment Bureau (ENB) and the Environment Protection Department (EPD) as the lead B/D, and the Development Bureau, the Transport and Housing Bureau, the Civil Engineering and Development Department, the Electrical and Mechanical Services Department, the Department of Health, the Marine Department, the Planning Department, and the Transport Department. Four dedicated Sub-groups, namely Energy and Power Generation (E&PG) Sub-group, Road Transportation (RT) Sub-group, Marine Transportation (MT) Sub-group and Air Science and Health (AS&H) Sub-group were formed under the Working Group. The first three Sub-groups are tasked to identify possible new air quality improvement measures under their respective areas, and evaluate the practicability of implementing the possible new measures. The focus of the AS&H Sub-group is on assessing the air quality improvements and health benefits that might result from the possible new measures, with a view to determining the possible scope for further tightening the AQOs. More in-depth discussions were also carried out under two respective Task Forces related to air quality modelling, and health and economic impact with members enlisted from the AS&H Sub-group. More than 35 meetings among these Working Group, four Sub-groups and two Task Forces have been held. The Terms of Reference and Membership of the Working Group and the Sub-groups are at **Annex C**.

7. Having regard to the recommendations of the WHO and the practices of other advanced economies, the following guiding principles have been adopted for conducting the AQOs Review –

(a) the AQOs should be set with a view to protecting public health;
(b) the AQOs should be updated by benchmarking against the AQGs and ITs of the WHO; and
(c) a progressive approach should be adopted in updating the AQOs, with a view to achieving the AQGs of WHO as an ultimate goal. The pursuit of such goal should be considered with reference to international practices, the latest technological developments and local circumstances, as recommended by the WHO.

8. As set out at the outset of the Review (WG Paper 1/2016), the AQOs are not merely a set of air quality goals, but also the benchmark for the issue of environmental permits for designated projects under the Environmental Impact Assessment Ordinance (EIAO) (Chapter 499). In line with the statutory requirement to achieve the AQOs as soon as is reasonably practicable, compliance with the AQOs is a key consideration when the Government assesses whether the air quality impact of a designated project is acceptable for issuing an environmental permit under the EIAO. Similarly, compliance with the AQOs is also a key factor when the Government decides whether licence applications of specified processes such as power plants under the APCO should be approved or otherwise. As such, it is of paramount importance for the AQOs review to identify new practicable air quality improvement measures and take into account their potential impact in assessing the possible scope of tightening the AQOs.

FINDINGS OF THE REVIEW

<u>New Air Quality Improvement Measures</u>

Possible New Air Quality Improvement Measures identified by the Working Group

9. The MT, RT and E&PG Sub-groups have identified **70** possible new measures and deliberated on their practicability of implementation, taking into account technical and operational feasibility, trade demand and reactions, cost-effectiveness, implementation time frame and likely public reactions, etc. Year 2025 has been used as the assessment year, taking into consideration the target of broadly attaining the current AQOs by 2020 and the statutory requirement to review the AQOs at least once every five years.

10. Amongst the possible new measures discussed, **27** are considered by the relevant Sub-groups as either on-going or already under consideration by the relevant B/Ds which are likely to produce results by 2025 or earlier (**short-term**); **four** measures are considered ready for further deliberation in the next AQOs review period (**medium-term**) (i.e. before the end of 2023); **13** measures require detailed planning or further study to ascertain the practicability for implementation beyond the next

review period (**long-term**) and **26** measures are considered as not practicable, short of air quality benefits or not suitable to be considered under the current scope of the review (**others**). A list of these 70 possible new measures is at **Annex D**.

Other Measures identified

11. EPD has also engaged relevant stakeholders through separate focus group meetings to explore possible new measures to control emissions from other emission sources that are not covered in the three Sub-groups, e.g. products containing volatile organic compounds (VOC), non-road mobile machinery (NRMM), civil aviation, etc. **Eight** additional measures including **three** short-term ones have been identified. A list of these eight possible new measures for other emission sources is also at **Annex D**.

12. In addition, two new Government initiatives targeting roadside emissions announced in the 2018 Policy Address are also likely to produce results by 2025. They are – (a) to tighten the emission standards for newly registered motor cycles to Euro IV in 2020; and (b) to launch an incentive-cum-regulatory scheme to progressively phase out Euro IV diesel commercial vehicles by end of 2023.

13. The practicability of the measures as set out in paragraphs 9-12 above are summarised in Table 1.

Table 1 Summary of New Air Quality Improvement Measures

	Short-term	**Medium-term**	**Long-term**	**Others**	**Total**
Working Group					
RT	14	2	7	15	38
MT	2	2	5	8	17
E&PG	11	-	1	3	15
Subtotal	*27*	*4*	*13*	*26*	*70*
Focus Groups					
Non-road mobile machinery	1	1	-	1	3
Cooking fumes	-	2	-	-	2
VOC-containing products	2	-	-	-	2
Civil aviation	-	-	-	1	1
Subtotal	3	3	-	2	8
2018 Policy Address	2	-	-	-	2
Total	**32**	**7**	**13**	**28**	**80**

Public views on the possible new measures

14. After the Working Group and the E&PG, MT and RT Sub-groups have deliberated on the possible new measures, EPD launched a 5-week public engagement exercise between 11 September and 14 October 2017, and held two public forums to solicit and gauge public views on the possible new air quality improvement measures

identified in the review (paragraphs 9-11 and **Annex D**). A dedicated webpage was also set up to collect public views on the possible new measures[1]. Of the about 370 written submissions received, most of them were related to air quality improvement measures which had been discussed at the RT Sub-group (e.g. fostering pedestrian-friendly and bicycle-friendly environment), E&PG Sub-group (e.g. promotion of renewable energy) and MT Sub-group (e.g. use of clean fuel). For those views which were not deliberated under the three Sub-groups, they were mainly covered in the current policies/initiatives, such as promotion of electric vehicles and expansion of the charging facilities, enforcement of idling engines, and enhancement of regional collaboration for improving air quality. A few comments related to the general air quality management and approach adopted for the current AQOs Review (e.g. suggestion on membership of the Working Group) were also received despite they were not directly related to air quality improvement measures.

Air Quality Assessments

Projection of Air Quality

15. To ascertain whether it is practicable to tighten the AQOs, EPD has assessed the air quality of Hong Kong in 2025 based on the following, in accordance with methodologies agreed at the AS&H Sub-group:

Hong Kong

(a) projected 2025 baseline emissions on a business-as-usual basis; and

(b) emission reductions arising from the implementation of on-going and committed measures[2], the 15 short-term measures identified by the Working Group and focus groups that have quantifiable emission reduction results, as well as the two new Government initiatives targeting roadside emissions announced in the 2018 Policy Address as mentioned in paragraphs 10-12.

Pearl River Delta (PRD) Region

(c) the PRD Region emission targets for 2020[3] were adopted as 2025 emissions,

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[1] Members of the public can submit their views on the following questions :-

1. Any views and comments on possible new air quality improvement measures discussed during the review?
2. Any other suggestions on possible new air quality improvement measures?

[2] Examples of the on-going and committed measures include -

- Phasing out some 82 000 old diesel commercial vehicles (i.e. pre-Euro, Euro I, Euro II and Euro III models) including light buses, goods vehicles and non-franchised buses through an incentive-cum-regulatory approach. Moreover, new diesel commercial vehicles registered after February 2014 are subject to a service life limit of 15 years.
- Starting from January 2019, a new legislation will be implemented to mandate vessels to use low sulphur fuel within Hong Kong waters to further reduce the emission from marine vessels. The new control requirement will dovetail with the establishment of a domestic emission control area (DECA) in the PRD Region.
- Progressive tightening up the statutory emission caps on three key air pollutants, namely SO_2, NO_x, and RSP (PM_{10}), of power plants via the promulgation of Technical Memorandum for Allocation of Emission Allowances in Respect of Specified Licences (TM) issued under the APCO.

[3] In November 2012, the Government of Hong Kong and the Guangdong (GD) Provincial Government endorsed an

since official projection beyond 2020 is currently not available.

Areas of the Mainland outside the PRD Region

(d) 2020 emissions in the outer areas of the Mainland obtained from other official sources.

16. The air quality assessment results indicate that there would be continuous improvement in PM_{10}, $PM_{2.5}$, NO_2 and SO_2, while O_3 levels would have slight increase[4]. The continuous improvement in air quality is brought by the implementation of the on-going measures and committed initiatives (see footnote 2), as well as new Government initiatives targeting roadside emissions (e.g. new measures in paragraph 12). The relevant figures are summarised in Table 2 and the pollutant concentration distributions over the Hong Kong territory are illustrated in **Annex E**.

Table 2 Comparison of 2025 air quality assessment and the air quality recorded in 2015

Pollutants	**Averaging Time**	**Prevailing HK AQOs**		**2015 Air Quality [a]**		**2025 Air Quality Assessment [b]**	
		Conc. ($\mu g/m^3$)	**No. of Exceedance Allowed Amongst Stations**	**Conc. ($\mu g/m^3$)**	**Highest No. of Exceedance Amongst Stations**	**Conc. ($\mu g/m^3$)**	**Highest No. of Exceedance**
Respirable Suspended Particulates (RSP/PM_{10})	Annual	50 (IT-2)	NA	45	NA	37	NA
	24-hr	100 (IT-2)	9	110 (10th highest)	18	90 (10th highest)	6
Fine Suspended Particulates (FSP/$PM_{2.5}$)	Annual	35 (IT-1)	NA	30	NA	24	NA
	24-hr	75 (IT-1)	9	78 (10th highest)	11	72 (10th highest)	8
Nitrogen Dioxide (NO_2)	Annual	40 (AQO)	NA	64	NA	67	NA
	1-hr	200 (AQO)	18	271 (19th highest)	67	199 (19th highest)	18
Sulphur Dioxide (SO_2)	24-hr	125 (IT-1)	3	58 (4th highest)	0	26 (4th highest)	0
Ozone	8-hr	160	9	182	24	216	30

emission reduction plan for the PRD Region up to 2020 which set the 2015 emission reduction targets and 2020 emission reduction ranges for four major air pollutants, namely SO_2, nitrogen oxides (NO_X), RSP and VOC, with 2010 as the base year. A mid-term review study was completed by the two Governments in December 2017 which concluded the achievement of emission reduction targets for 2015 and finalised the emission reduction targets for 2020. The two Governments will jointly launch a study on post-2020 air pollutant emission reduction targets and concentration levels for Hong Kong and GD.

[4] The projected slight increase in the O_3 concentration in 2020/2025 is largely due to reduction in nitric oxide (NO) emissions from motor vehicles as a result of control measures being/to be implemented (phasing out diesel commercial vehicles, tightened vehicle emission standards, etc.). While such vehicle emission control measures would help effectively reduce the concentrations of NO_2, which is one of the key pollutants causing health impacts to the public, the reduction in NO due to the control measures would reduce the titration effect on O_3 (i.e., removal of O_3 from its reaction with NO), thereby leading to slight increase in O_3 levels especially in areas with higher traffic flow.

Pollutants	Averaging Time	Prevailing HK AQOs		2015 Air Quality [a]		2025 Air Quality Assessment [b]	
		Conc. ($\mu g/m^3$)	No. of Exceedance Allowed Amongst Stations	Conc. ($\mu g/m^3$)	Highest No. of Exceedance Amongst Stations	Conc. ($\mu g/m^3$)	Highest No. of Exceedance
(O_3)		(IT)		(10th highest)		(10th highest)	

NA – Not Applicable

a. 2015 air quality is based on the measurement data of 12 general air quality monitoring stations. Highest concentration among the 12 general air quality monitoring stations is presented.

b. 2025 air quality assessment result is based on the territorial wide air quality modelling outcome. Spatial maximum concentration and maximum number of exceedances are presented.

Possible Scope for Tightening of the AQOs

17. The AQOs for NO_2, SO_2 (10-min), CO and Pb are already set at the most stringent WHO AQG levels. Hence our focus are on PM_{10}, $PM_{2.5}$, SO_2 (24-hr) and O_3, with a view to identifying possible scope for further tightening their current AQOs based on the air quality assessment results for Hong Kong in 2025 as set out in paragraph 16 above.

18. The 2025 air quality assessment results show that the concentrations of PM_{10} and O_3 in 2025 will not be able to meet the AQOs, if they are to be tightened to the next level, i.e. WHO IT-3 for **PM_{10} (both annual and 24-hr)** and AQG for **O_3**, as set out in Table 3 below. In fact, the concentrations in most areas in Hong Kong will far exceed the AQOs if raised to the next higher level.

Table 3 Comparison of 2025 air quality assessment with the next higher level of the AQOs for PM_{10} and O_3

Pollutants	Averaging Time	Prevailing HK AQOs		Next Higher Standard ($\mu g/m^3$)	2025 Air Quality Assessment Results [a]	
		Conc. ($\mu g/m^3$)	No. of Exceedance Allowed Amongst Stations		Conc. ($\mu g/m^3$)	Highest No. of Exceedance against the Next Higher Standard
PM_{10}	Annual	50 (IT-2)	NA	30 (IT-3)	37	NA
	24-hr	100 (IT-2)	9	75 (IT-3)	90 (10th highest)	22
O_3	8-hr	160 (IT)	9	100 (AQG)	216 (10th highest)	113

NA – Not Applicable

a. 2025 air quality assessment result is based on the territorial wide air quality modelling outcome. Spatial maximum concentration and maximum number of exceedances are presented.

19. The air quality assessment results indicate that the SO_2 concentrations in 2025 can meet the next higher level of AQO for **SO_2 (24-hr)** i.e. WHO IT-2, with the current number of exceedance allowable (three) remains unchanged (Table 4).

Table 4 Comparison of 2025 air quality assessment with the next higher level of AQO for SO_2

Pollutants	Averaging Time	Prevailing HK AQOs		Next Higher Standard (µg/m^3)	2025 Air Quality Assessment Results [a]	
		Conc. (µg/m^3)	No. of Exceedance Allowed Amongst Stations		Conc. (µg/m^3)	Highest No. of Exceedance against the Next Higher Standard
SO_2	24-hr	125 (IT-1)	3	50 (IT-2)	26 (4th highest)	0

a. 2025 air quality assessment result is based on the territorial wide air quality modelling outcome. The maximum number of exceedances is presented.

20. The air quality assessment results show that the annual averaged concentrations of $PM_{2.5}$ in 2025 can possibly meet the next **$PM_{2.5}$ (annual)** level at WHO IT-2). As for **$PM_{2.5}$ (24-hour)**, there is potential to meet the next level at WHO IT-2, if the number of allowable exceedances is to be relaxed from the current nine to 35[5] (Table 5).

Table 5 Comparison of 2025 air quality assessment with the next higher level of AQOs for $PM_{2.5}$

Pollutants	Averaging Time	Prevailing HK AQOs		Next Higher Standard (µg/m^3)	2025 Air Quality Assessment Results [a]		
		Conc. (µg/m^3)	No. of Exceedance Allowed Amongst Stations		Conc. (µg/m^3)		Highest No. of Exceedance against the Next Higher Standard
$PM_{2.5}$	Annual	35 (IT-1)	NA	25 (IT-2)	24 [b]		NA
	24-hr	75 (IT-1)	9	50 (IT-2)	72 (10th highest)	47 (36th highest)	33

NA – Not Applicable

a. 2025 air quality assessment result is based on the territorial wide air quality modelling outcome. Spatial maximum concentration and maximum number of exceedances are presented.

b. A small area of less than 2 km^2 near Hong Kong-Shenzhen Border reaches 24µg/m^3.

<u>Health and Economic Impact Assessment (HEIA)</u>

21. Improvements in air quality can bring along health benefits, such as reducing premature deaths, hospital admissions, clinic visits, and medical cost in particular in relation to respiratory and cardiovascular diseases, and indirectly raising labour

[5] According to the air quality modelling results, the number of exceedances against IT-2 is 33. A certain extent of buffer is needed, and hence it would be more realistic if the maximum number of allowable exceedances is set at 35. According to WHO's guidelines, criteria must be identified to determine compliance when the air quality standards are to be legally binding. Compliance criteria are defined in each economy in order to compare the ***most representative*** data with the standards, and to minimize the designation of non-compliance due to uncontrollable circumstances such as extreme weather. The European Union also allows 35 exceedances for the 24-hour air quality standard for PM_{10} though its PM_{10} standard (50µg/m^3) is more stringent than Hong Kong's prevailing AQO (100µg/m^3).

productivity. There are various methodologies and approaches for assessing the health and economic impact of air pollution, each with their specific assumptions as well as limitations. After discussions, the AS&H Sub-group, on the suggestion of the Health and Economic Impact Assessment (HEIA) Task Force set up under it, has agreed[6] to conduct the HEIA based on a tool developed by the Chinese University of Hong Kong[7].

22. As with all HEIA, the assessment could be limited by the availability of certain health and economic data for the estimation of the risks and costs of specific diseases. The choice of health outcomes for assessments (e.g. hospital admissions, clinic visits) was partly limited by insufficient epidemiological evidence of a cause-effect relationship, and partly by the wide variations in the relative risks (RR) of some pollutant-disease pairs reported in different studies. Regarding the economic benefits of the health impact, the indirect cost based on the Value of a Statistical Life (VOSL[8]) method (see paragraph 25 below) is an important source of uncertainty in the economic impact assessment. There are also views that attaching monetary value to one's health or life may not be appropriate. Hence, the HEIA methodology and findings below should be read bearing in mind the limitations and uncertainties, and are only for reference purpose.

23. To assess the ***Health Impact*** attributable to the changes in air quality level between 2015 (base year) and 2025 (target year), the RR (or concentration-response functions) of specific health outcomes (e.g. hospital admissions, clinic visits, mortality) as a result of a unit change in air pollutant concentration has been identified. In drawing up the RR, local references were adopted as far as practical; otherwise, references from the WHO or from other places were adopted (**Annex F**). The 2015 health statistics[9] baseline data and the RR are then used to assess the health benefits due to the projected air quality improvements in 2025. They are explained in the following paragraph.

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[6] AS&H Paper 4/2016 dated on 2 December 2016 and Annex C to AS&H Paper 2/2017 dated 7 June 2017.

[7] The tool was developed by the Chinese University of Hong Kong under the study "Developing an Instrument for Assessing the Health and Economic Impacts of Air Pollution in Hong Kong" commissioned by EPD, which was completed in 2016. The tool was developed based on the internationally accepted methodologies incorporating the local health statistics and air quality data. The association between long term and short term exposures of air pollution and the health outcomes was established by cohort studies, time-series studies and statistical models. For morbidities, local concentration-response (CR) functions were adopted. For mortalities, CR functions recommended by WHO were adopted in the study owing to a lack of local CR functions. To assess the health impact of air pollution, the pollutant concentration values of WHO AQGs were taken to be the reference level, assuming the health impact of the pollutant concentration level below the WHO AQGs was zero. Though pollutant concentrations below this level still have health effects, statistical uncertainties in the exposure-response function below the WHO AQGs levels are much higher.

[8] The "VOSL" approach refers to the amount of money a person (or society) is willing to spend to save a life. It is derived from the trade-offs people are willing to make between fatality risk and wealth. Hence, it varies among different areas/countries and could be diverse. The measurement of monetary gain in preventing premature mortality based on the VOSL approach is only for indicative purpose.

[9] Health statistics such as mortality and morbidities (e.g. respiratory and cardiovascular diseases) were obtained from the Census and Statistics Department and the Hospital Authority.

24. Based on the air quality assessment results of 2025, improvement in the long-term exposure (in terms of annual concentration level of $PM_{2.5}$ and NO_2) might reduce about 1,850 premature deaths, as compared with 2015. About 1,530 cases of hospital admission (through the Accident and Emergency Departments operated by the Hospital Authority) and 262,580 cases of clinic visits (both public and private practitioners) might be saved owing to improvement in short-term exposure (in terms of 1-hr or 24-hr concentration levels) of air pollutants, in particular the improvement of 1-hr concentration level of NO_2, as compared with 2015. Nevertheless, the slight increase in O_3 concentration level in 2025, as above-mentioned in paragraph 18, could offset some of the health benefits[10] owing to short-term exposure of air pollutants. A Summary is at **Annex G**.

25. On the ***economic benefits*** of the health impact attributable to the changes in air quality level between 2015 (base year) and 2025 (target year), the direct savings from hospital admissions and clinic visits[11] were estimated at about HK$ 96 million while the saving in productivity loss[12] which was broadly estimated at about HK$ 150 million. Based on the VOSL approach and with an estimated VOSL value of about HK$18 million[13], the monetary gain in preventing the premature death was estimated at a total of about HK$ 33 billion (equivalent to about 1,850 premature deaths saved). All costs are adjusted to 2017 values. A summary is at **Annex H**.

Discussion of the Review Findings at the AS&H Sub-Group

26. Assessment on air quality (paragraphs 15 to 16), possible scope for tightening the AQOs (paragraphs 18-20) and the HEIA (paragraph 21 to 25) were discussed at the meeting of the AS&H Sub-group held on 13 December 2018. The meeting ***supported*** the findings that the AQOs for SO_2 and $PM_{2.5}$ can be tightened in accordance with paragraphs 19 to 20 above.

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[10] The hospital admission and clinic visits owing to the predicted increase in O_3 concentration in 2025 were estimated at about 30 cases and 8,210 cases respectively.

[11] The savings due to the potential reduction in hospital admissions of patients with cardiovascular and respiratory diseases through the Accidents and Emergency Departments operated by the Hospital Authority are assumed at a unit attendance cost of HK$1,230 (as of 2017 value). The unit costs of clinic visits to general practitioner (GP) and general outpatient clinic (GOPC) are assumed at $250 and $445 respectively (as of 2017 value). All these costs are based on the study of the CUHK (footnote 7).

[12] The associated productivity loss due to hospital admission and clinic visit is estimated based on the median length of hospital stay (four days for cardiovascular illnesses and three days for respiratory illnesses) and a sick leave of one day granted by the attending doctor. The productivity loss is only a broad-brush estimate for reference only given that different estimation methods (e.g. different lengths of hospital stay, different lengths of sick leave) may yield quite different results.

[13] The VOSL is based on the average of VOSL in 2012 from European WHO Regional Office Report (US$2,872,817, as the upper limit) and VOSL in China from a World Bank reference (US$1,171,048 as the lower limit). These values were adjusted to the price in 2017 based on composite consumer price index, at about HK$18,103,200. These two references entailed the upper and lower bounds of the VOSL.

27. AS&H Sub-group members made suggestions on how to present the findings to facilitate the public's understanding (e.g. while agreeing that the official emission data from the Mainland Authorities should be adopted in the assessments, scenarios of better background air quality due to lower emissions from PRD Region can be shown if practicable). While commending the robustness of the methodology of the air quality assessments and HEIA, Members also made suggestions on how to further enhance the methodology in future AQOs reviews, having regard to the experience gained in this review (e.g. O_3 & particulates source characteristic analysis, etc.).

ADVICE SOUGHT AND NEXT STEPS

28. As set out in paragraphs 19 to 20, there is scope for tightening AQOs of SO_2 and $PM_{2.5}$ such that the concentrations of the pollutants could possibly meet the tightened AQOs by 2025 as below:

(a) the 24-hour AQO for SO_2 can be tightened from the WHO AQGs IT-1 level at 125µg/m^3 to IT-2 level at 50µg/m^3 with the current number of exceedance allowed (three) remains unchanged; and;

(b) the annual AQO for $PM_{2.5}$ can be tightened from IT-1 (35µg/m^3) to IT-2 (25µg/m^3), and its 24-hr AQO from IT-1 (75µg/m^3) to IT-2 (50µg/m^3), with the number of exceedances allowed increased from the current nine to 35.

29. Having regard to Members' comments, we will proceed to complete the Review by end of 2018. The Government will report the Review findings to the ACE and the Panel on Environmental Affairs (EA Panel) of the Legislative Council (LegCo). Subject to views from the ACE and the LegCo EA Panel, a 3-month public consultation will then be launched to collect public views on the proposed tightening of the AQOs.

Environmental Protection Department
December 2018

ANNEX A

Hong Kong Air Quality Objectives (AQOs) *vs.* World Health Organisation Air Quality Guidelines (AQGs)

Pollutants	Averaging Time	World Health Organization Air Quality Guidelines				Prevailing HK AQOs		2017 Compliance Status
		WHO IT-1[1] (µg/m^3)	WHO IT-2[1] (µg/m^3)	WHO IT-3[1] (µg/m^3)	WHO AQGs (µg/m^3)	Conc. (µg/m^3)	No of Exceedances Allowed	
Respirable Suspended Particulates (PM_{10})	24-hr	150	**100**	75	50	100 (IT-2)	9	✓
	Annual	70	**50**	30	20	50 (IT-2)	NA	✓
Fine Suspended Particulates ($PM_{2.5}$)	24-hr	**75**	**50**	37.5	25	75 (IT-1)	9	✓
	Annual	**35**	**25**	15	10	35 (IT-1)	NA	✓
Nitrogen Dioxide (NO_2)	1-hr	-	-	-	**200**	200 (AQGs)	18	×
	Annual	-	-	-	**40**	40 (AQGs)	NA	×
Sulphur Dioxide (SO_2)	10-min	-	-	-	**500**	500 (AQGs)	3	✓
	24-hr	**125**	**50**	-	20	125 (IT-1)	3	✓
Carbon Monoxide (CO)	1-hr	-	-	-	**30,000**	30,000 (AQGs)	0	✓
	8-hr	-	-	-	**10,000**	10,000 (AQGs)	0	✓
Ozone (O_3)	8-hr	**160**	-	-	100	160 (IT)	9	×
Lead (Pb)	Annual	-	-	-	**0.5**	0.5 (AQGs)	NA	✓

Notes:

[1]. IT – WHO's interim targets

xx **Current AQOs adopted**

✓ **Comply with AQO**

× **Not in compliance with AQO**

ANNEX B

AQOs Compliance Status in 2017

Station		Long-term				Short-term							
		PM_{10}	$PM_{2.5}$	NO_2	Pb	O_3	NO_2	PM_{10}	$PM_{2.5}$	SO_2		CO	
		1-year			1-year	8-hr	1-hr	24-hr	24-hr	10-min	24-hr	1-hr	8-hr
General Station	Central/Western	✓(35)	✓(23)	✓(40)	✓	✓	✓	✓	✓	✓	✓	--	--
	Eastern	✓(33)	✓(20)	✗(42)	✓	✓	✓	✓	✓	✓	✓	--	--
	Kwun Tong	✓(39)	✓(23)	✗(44)	✓	✓	✓	✓	✓	✓	✓	--	--
	Sham Shui Po	✓(33)	✓(21)	✗(54)	✓	✓	✓	✓	✓	✓	✓	--	--
	Kwai Chung	✓(35)	✓(23)	✗(57)	✓	✓	✗	✓	✓	✓	✓	--	--
	Tsuen Wan	✓(33)	✓(22)	✗(52)	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Tseung Kwan O	✓(31)	✓(18)	✓(28)	✓	✗	✓	✓	✓	✓	✓	✓	✓
	Yuen Long	✓(40)	✓(22)	✗(41)	✓	✗	✓	✓	✓	✓	✓	✓	✓
	Tuen Mun	✓(43)	✓(27)	✗(46)	✓	✗	✓	✓	✓	✓	✓	✓	✓
	Tung Chung	✓(34)	✓(21)	✓(36)	✓	✗	✓	✓	✓	✓	✓	✓	✓
	Tai Po	✓(32)	✓(22)	✓(39)	✓	✗	✓	✓	✓	✓	✓	--	--
	Sha Tin	✓(31)	✓(21)	✓(34)	✓	✗	✓	✓	✓	✓	✓	--	--
	Tap Mun	✓(35)	✓(20)	✓(10)	✓	✗	✓	✓	✓	✓	✓	✓	✓
Roadside Station	Causeway Bay	✓(46)	✓(31)	✗(97)	✓	✓	✗	✓	✓	✓	✓	✓	✓
	Central	✓(33)	✓(21)	✗(80)	✓	✓	✗	✓	✓	✓	✓	✓	✓
	Mong Kok	✓(38)	✓(27)	✗(81)	✓	✓	✗	✓	✓	✓	✓	✓	✓

Notes:
Unit of concentration : $\mu g/m^3$
"✓" Complied with the AQO
"✗" Not in compliance with the AQO
"--" Not measured
**Figures in brackets are concentration levels of three key air pollutants (RSP/PM_{10}, RSP/$PM_{2.5}$ and NO_2).*

ANNEX C

Terms of Reference and Membership of the Working Group and the Sub-groups

A. AQOs Review Working Group

Terms of Reference

1. To engage relevant stakeholders including air scientists, health experts, academics, professionals, green groups, community leaders and the business sector to enable thorough deliberations on key aspects of the AQO review including air science and health as well as potential air quality improvement measures on power and energy sector, road and marine transportation, etc.; and

2. To report findings of the Working Group to Secretary for the Environment for his consideration in the review of AQO.

Membership

Chairperson :	Under Secretary for the Environment
Vice-chairperson :	Deputy Director of Environmental Protection (3)
Members :	All members of the Sub-groups

B. Road Transportation Sub-group

Terms of reference:

1. To identify new practicable air quality improvement measures for road transportation;
2. To evaluate the feasibility of implementing the measures having regard to the availability of proven technology, time for implementation, economic and social implications and other relevant factors; and
3. To prioritize the new air quality improvement measures based on the practicability of implementation.

Membership

Chairperson :	Under Secretary for the Environment
Vice-chairperson :	Deputy Director of Environmental Protection
Members :	Mr. Evan AUYANG
	Mr. CHAING Stanley Tandon Lal
	Hon. CHAN Choi Hi, M.H.
	Ms. CHEUNG Kit Yi, Suzanne
	Ir Fung Man Keung
	Mr. FUNG Kin Wai, Patrick
	Ir Dr. HO Chi Shing, David, J.P.
	Dr. HUNG Wing Tat
	Hon. KWAN Sau Ling
	Mr. LEE Chak Cheong, Roger
	Dr. LEE Yiu Pui, Ringo
	Mr. Paul LI
	Mr. LING Chi Keung
	Mr. NG Hoi Shan, Aaron
	Mr. Daniel NG
	Mr. SO Sai Hung
	Mr. TANG Wing Hong, Madison
	Mr. TUNG Ching Leung
	Mr. WONG Leung Pak, Matthew
	Representatives from Development Bureau
	Representatives from Transport and Housing Bureau
	Representatives from Civil Engineering and Development Department
	Representatives from Environmental Protection Department
	Representatives from Planning Department
	Representatives from Transport Department

C. Marine Transportation Sub-group

Terms of reference:

1. To identify new practicable air quality improvement measures for marine transportation;

2. To evaluate the feasibility of implementing the measures having regard to the availability of proven technology, time for implementation, economic and social implications and other relevant factors; and

3. To prioritize the recommended air quality improvement measures based on the practicability of implementation.

Membership:

Chairperson :	Under Secretary for the Environment
Vice-chairperson :	Deputy Director of Environmental Protection
Members :	Mr. Arthur BOWRING
	Mr. Jeff BENT
	Mr. CHIANG Sui Ki
	Ms. Jessie CHUNG
	Mr. Ellis CHUNG
	Mr. FUNG Pak Sing
	Mr. HO Lap Kee, Sunny, J.P.
	Mr. KEUNG Siu Fai
	Mr. David KONG Cheuk Lum
	Mr. KWOK Tak Kee
	Mr. LIU Jian Hua, John
	Ms. Sandy MAK
	Mr. NG Ka Wing, Simon
	Mr. Tony TONG
	Mr. WONG Yui Cheong, David
	Mr. Danny WU
	Representatives from Transport and Housing Bureau
	Representatives from Environmental Protection Department
	Representatives from Marine Department

D. Energy and Power Generation Sub-group

Terms of reference:

1. To identify new practicable air quality improvement measures for energy and power generation;

2. To evaluate the feasibility of implementing the measures having regard to the availability of proven technology, time for implementation, economic and social implications and other relevant factors; and

3. To prioritize the new air quality improvement measures based on the practicability of implementation.

Membership:

Chairperson :	Under Secretary for the Environment
Vice-chairperson :	Deputy Director of Environmental Protection
Members :	Dr. CHAN Ka Lung
	Ir Cary CHAN
	Mrs. Christine CHEUNG*
	Professor Larry CHOW
	Ir FONG Wai Man, Edmond
	Mr. Prentice KOO
	Mr. LAW Ka Chun, Joseph
	Mr. Brandon LIU
	Ms. Susanna NG
	Professor SO Wai Man, Raymond, B.B.S, J.P.
	Ir YEE Tak Chow
	Dr. William YU
	Representatives from Development Bureau**
	Representatives from Environment Bureau
	Representatives from Electrical and Mechanical Services Department
	Representatives from Environmental Protection Department
	Representatives from Planning Department**

Note:

* Resigned from the Working Group in February 2017

**To attend on a need-basis

E. Air Science and Health Sub-group

Terms of reference:

1. To review the latest development on air quality standards and the health effects of air pollution;

2. To advise on the methodologies on air science and health assessments, including emission estimation, air quality assessment and projection, cost benefit analysis of air quality improvement measures and health impact assessment; and

3. To advise on the assessment of air quality improvements and health benefits under different control scenarios.

Membership:

Chairperson :	Under Secretary for the Environment
Vice-chairperson :	Deputy Director of Environmental Protection
Members :	Professor Peter BRIMBLECOMBE
	Professor FUNG Chi Hung, Jimmy*
	Dr. LAM Yun Fat, Nicky
	Professor LAU Kai Hon, Alexis
	Mr. LEE Tak Kong, Alfred, M.H.
	Dr. LEUNG Chung Chuen, Roland
	Ir LO Pak Cheong
	Mr. LOONG Tsz Wai
	Dr. MAK Hoi Cheung, Eunice
	Dr. MAN Chi Sum, J.P.
	Dr. NING Zhi
	Dr. SO Kit Ying, Loletta
	Professor TIAN Lin Wei
	Professor WANG Tao
	Professor WONG Tze Wai*
	Dr. YIM Hung Lam, Steve
	Representatives from Development Bureau
	Representatives from Civil Engineering and Development Department
	Representatives from Department of Health
	Representatives from Environmental Protection Department
	Representatives from Planning Department

Note:
* Resigned from the Working Group and took part in the assessments of the AQOs review.

ANNEX D

List of Possible New Air Quality Improvement Measures

A. PRACTICABILITY OF IMPLEMENTATION

The practicability to implement the possible new measures are identified as follows –

(a) "Short-term" measures refer to those that are either on-going or ready under consideration by the Government which are likely to produce results by 2025 or earlier;

(b) "Medium-term" measures refer to those that may be ready for consideration in the next AQOs review period of 2019 – 2023;

(c) "Long-term" measures refer to those that require detailed planning or further study to ascertain the practicability for implementation beyond the next review period;

(d) "Others" refer to those that are not practicable, short of air quality improvement benefits or not suitable to be considered under the current scope of the AQOs review.

B. KEY EMISSION SOURCES

Possible short-term new air quality improvement measures

Road Transportation

1. Review the tunnel toll policy and level to alleviate traffic congestion, thereby reducing the emission caused by congestion at the tunnels
2. Establish a maintenance information database of vehicle tailpipe emission system
3. Raise awareness on the importance of vehicle maintenance and repair
4. Foster "pedestrian-friendly" environment (such as widening of footpaths, construction of covered walkways and enhancing the pedestrian connections) to encourage people to walk in *existing new towns and urban areas* (Possible short-term and medium-term)
5. Foster "bicycle-friendly" environment and study into the provision of ancillary facilities for cycling (such as provision of cycling track network and bicycle parking spaces, park-and-ride facilities at public transport interchanges and bike-friendly policies to facilitate carriage of bicycles on public transport) in existing new towns and urban areas. (Possible short and medium-term) [Note: Cycling for commuting purposes in urban areas is not encouraged on road safety grounds.]
6. Use urban planning and design solutions together with transport management to improve air ventilation in high density development
7. Enhance district-based publicity on bus route rationalisation*
8. Manage the growth of vehicles in particular private cars

   [Updates: "Manage the growth of vehicles in particular private cars" and "Raise the first registration tax and annual licence fees of more polluting vehicles" were originally regarded as one item when deliberated at the RT Sub-group. As they are in fact two ideas, they are now separated into two items, i.e. "Manage the growth of vehicles in particular private cars" is now categorized as a short-term measure, while "Raise the first registration tax (FRT) of highly polluting vehicles" is categorised as "others"]

9. Enhance enforcement against illegal parking
10. Review on-street metered parking fees
11. Launch one-stop mobile app for the public to choose the most time-saving, economical and low-emission transportation mode

    [Updates: The Transport Department has launched an all-in-one mobile application "HKeMobility" since July 2018 which integrated the mobile applications namely "Hong Kong eTransport", "Hong Kong eRouting" and "eTraffic News". The public can acquire real-time traffic and transport information anytime and anywhere to plan their journeys in a single mobile app.]
12. Launch one-stop mobile app for the public to access real-time information on car parking vacancies which helps them choose the best parking location and shortening the driving distance [Please also refer to the updates in the item above.]
13. Introduce intelligent transport systems (e.g. manage traffic flow by traffic signal control, install smart sensors and surveillance cameras for illegal parking enforcement) <u>(This measure is considered as possible short, medium, and long-term practicality for implementation.)</u>
14. Raise public awareness on environmental protection, promote green living and encourage the public to use public transport systems as well as low emission transportation options

Marine Transportation

15. Ocean-going vessels (OGVs) at berth to use marine diesel with lower fuel sulphur content, e.g. not exceeding 0.1%*
16. Local vessels to use electricity from the power grid while at berth*

Energy and Power Generation

17. Encourage stakeholders in the commercial sector and the non-government sector, e.g. universities and hospital to adopt demand-side management measures*
18. Explore building energy efficiency measures for old existing buildings which are not covered by the Buildings Energy Efficiency Ordinance*
19. Encourage or provide incentives for the private sector to develop distributed renewable energy (RE)*
20. Facilitate distributed RE systems to connect to the power grid*
21. Encourage the development of more waste-to-energy facilities, such as waste incinerators, organic resources recovery centres, etc. for waste disposal as well as recovering energy for local use*
22. Increase the use of wind and solar energy in electricity generation*
23. Replacement of coal-fired generating units by gas-fired units*

24. Upgrade burners of gas-fired generating units to improve fuel efficiency and emission performance*
25. Review operations of gas-fired power generating units with a view to identifying further emission reduction potential
26. Explore the use of waste materials such as corncobs, waste wooden pallets (i.e. biomass) as fuel*
27. Encourage major electricity users to reduce peak load demand so as to reduce the operation and emissions from coal-fired generating units for coping with peak load demand

    [Updates: In the light of the approval of the power companies' 2018-2033 Development Plans by the Government in July 2018, the power companies will replace their electromechanical meters by smart meters in seven years to support the energy efficiency & conservation initiatives (including reducing peak load demand) under the post-2018 Scheme of Control Agreements. Hence, this measure which was regarded as a long term measure when deliberated in the Energy and Power Generation Sub-group is now brought forward as a short-term measure subject to Members' agreement.]

<u>Possible medium-term new air quality improvement measures</u>

Road Transportation

1. Conduct comprehensive review on the development of road transportation infrastructure and networks (such as construction of new tunnels and roads) to cope with population growth and to tackle road traffic congestion
2. Address the personal and operational needs of heavy vehicle drivers, such as provision of parking space and arrangement of meal and rest breaks at the Kwai Chung Container Terminals area, so as to reduce air pollution arising from idling engines

Marine Transportation

3. Impose emission standards on outboard engines of local vessels
4. Explore financial incentive and disincentive schemes to encourage liners to use less polluting OGVs calling Hong Kong ports

<u>Possible long-term new air quality improvement measures</u>

Road Transportation

1. Foster "pedestrian-friendly" environment (such as widening of footpaths, construction of covered walkways and enhancing the pedestrian connections) to encourage people to walk in *new towns and new development areas (NDAs)*
2. Foster "bicycle-friendly" environment and study into the provision of ancillary facilities for cycling (such as provision of cycling track network and bicycle parking spaces, park-and-ride facilities at public transport interchanges and bike-friendly policies to facilitate carriage of bicycles on public transport) in *new towns and NDAs* (Possible long-term) [Note: There are no plans to provide bicycle park-and-ride facilities at public transport interchanges. Cycling for

commuting purposes in urban areas is not encouraged on road safety grounds.]

3. Set up cycling and walking shared space at harbourfront areas.

4. Electric vehicles pilot schemes - switching the existing vehicle fleet of selected routes to electric vehicles
5. Implement electronic road pricing scheme to tackle road traffic congestion at busy roads
6. Through proper land use planning to redress the current imbalance in home-job distribution and bring jobs closer to home so as to reduce commuting time and private car usage
7. Provide low-emission transport mode to the residents of NDAs

Marine Transportation

8. Explore the use of Liquefied Natural Gas for marine vessels
9. Explore the use of biofuel (e.g. B5), fuel cell, Liquefied Petroleum Gas , compressed natural gas, methanol, nuclear and renewable energy, e.g. wind and solar energy, etc. for marine vessels
10. Explore the use of hybrid, diesel electric and electric vessels
11. OGVs to use onshore power supply (OPS) while at berth at Cruise Terminal
12. Encourage academia to carry out studies on fuel and energy efficient measures in terms of operation and maintenance for local vessels; and collaboration between academia and local marine trade for the development of best practice guidelines and award system to facilitate adoption of the measures

Energy and Power Generation

13. Explore the use of old EV batteries as an electrical energy storage system for the power grid

Other measures considered as not practicable, short of air quality benefits or not suitable to be considered under the current scope of the Review

Road Transportation

1. Consider replacing the existing toll collection system with completely automatic systems
2. Propose to use chassis dynamometer for testing vehicle tailpipe emissions
3. Tighten the annual vehicle examination for private cars from over six years old to over three years old (or consider adopting vehicle kilometres travelled as the vehicle examination criterion)
4. Provide vehicle tailpipe emission testing equipment for rent by small and medium-sized vehicle repair workshops
5. Establish lower vehicle speed limits zones (e.g. 30km/h) in community roads, school zone and areas with elderly centres, to foster pedestrian environment (Note: This measure has been assessed together with “Foster pedestrian-friendly

environment" above as it carries the same spirit.)

6. Tram or electric bus interchange schemes at busy road sections (e.g. Nathan Road) to replace the franchised bus services so as to reduce the number of buses and boarding/alighting passengers on the road section
7. Promotion of hybrid private cars
8. Exploring the use of new-energy vehicles
9. Provide information on the energy efficiency, emission performance and noise level of vehicles, etc. to facilitate the public to make a more environmentally-friendly choice
10. Set out objectives/policies to support the use of cleaner vehicle fuels
11. Extend the coverage areas of the existing low emission zones and its restriction to other vehicle types
12. Set up a continuous and effective priority road network for public vehicles
13. Review the policy on replacement of franchised buses
14. Provide funding to support District Councils for implementing air quality improvement projects
15. Raise the first registration tax and annual licence fees of more polluting vehicles

    [Updates: "Raise the first registration tax and annual licence fees of more polluting vehicles" and "manage the growth of vehicles in particular private cars" were originally regarded as one item when deliberated at the RT Sub-group. As they are in fact two ideas, they are now separated into two items, i.e. "Manage the growth of vehicles in particular private cars" is now categorized as a short-term measure, while "Raise the first registration tax (FRT) of highly polluting vehicles" is categorised as "others"]

Marine Transportation

16. River trade vessels to use OPS while at berth at terminals
17. Ocean-going vessels to use OPS while at berth at container terminals
18. Install emission reduction device (e.g. particulate filters) to reduce particulate matters emitted from local vessels
19. Impose control on nitrogen oxides emissions from engines of local vessels
20. Optimise port efficiency to shorten waiting and turnaround time of OGVs, river trade vessels at container terminals, river trade terminals and public cargo working areas
21. Slow-steaming of OGVs in Hong Kong waters
22. Remove floating rubbish for smooth operation of small local vessels (Note: This measure is not related to air quality improvement not further discussed in the respective Marine Transportation Sub-Group.)
23. Government to expedite the approval process of new local vessels (Note: This measure is not related to air quality improvement not further discussed in the respective Marine Transportation Sub-Group.)

Energy and Power Generation

24. Consider importing more nuclear electricity from the Mainland
25. Explore the idea of "SolarRoad" for promoting the use of solar energy
26. Explore the feasibility of using electric vehicles (EV) as electrical energy storage for power grid

C. OTHER EMISSION SOURCES

Possible short-term new air quality improvement measures

VOC-containing Products

1. Review the feasibility to impose VOC limits on consumer products that are not regulated under the Air Pollution Control (Volatile Organic Compounds) Regulation*
2. Review the feasibility to further tighten the VOC limits on regulated architectural paints*

Non-Road Mobile Machinery

3. Explore the feasibility to further tighten the emission standards on non-road vehicles newly supplied to Hong Kong*

Possible medium-term new air quality improvement measures

Non-Road Mobile Machinery

1. Explore the feasibility to further tighten the emission standards on regulated machines newly supplied to Hong Kong

Cooking Fume Emissions

2. Explore the feasibility of using new types of air pollution control equipment
3. Promote "low-emission" cooking (e.g. use of clean and efficient cooking stoves and healthy cooking style, etc.)

Possible new air quality improvement measures - Others

Non-Road Mobile Machinery

1. Explore the feasibility of retrofitting exempted regulated machines and non-road vehicles to improve their emission performance (Note: we have further explored the feasibility and practicality of certain regulated machines such as generators and air compressors for retrofitting diesel particulate removal devices.)

Civil Aviation

1. Review on aviation emission control in the local context (Note: This emission control has followed the international practice.)

Remarks: *These are short-term measures that have quantifiable emission reduction results.

ANNEX E

Predicted Air Quality in 2025

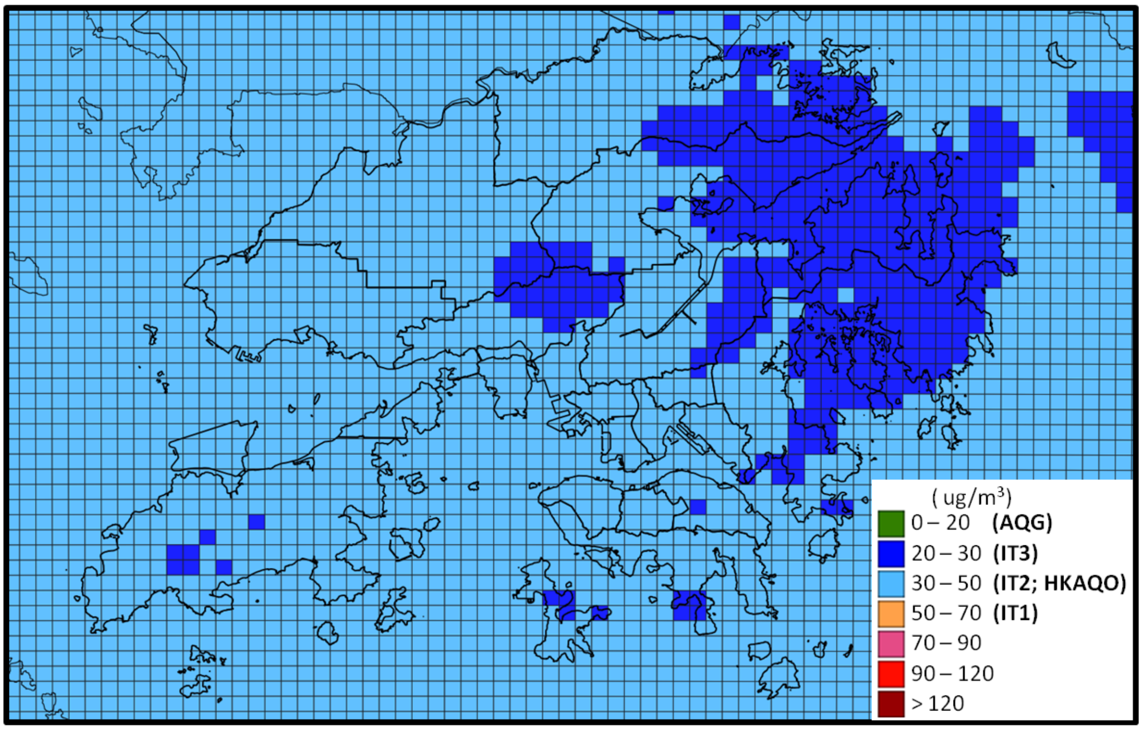

Figure 1 – Annual averaged PM_{10} concentration in 2025

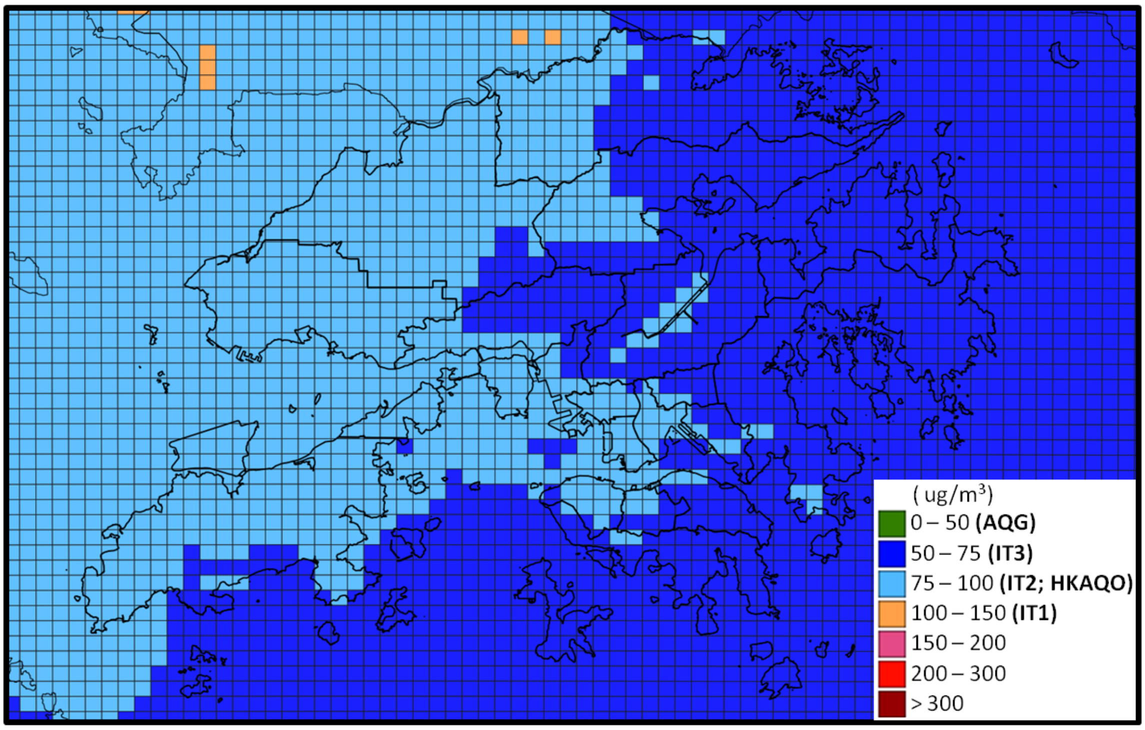

Figure 2 – 10th highest daily PM_{10} concentration in 2025

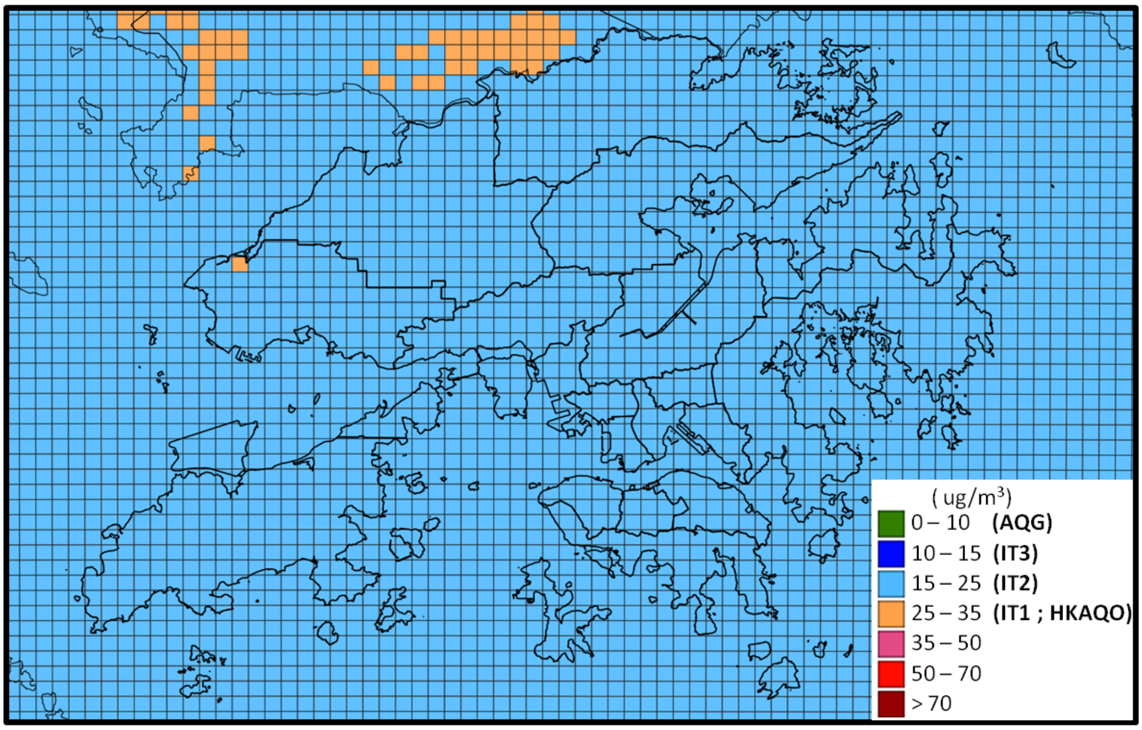

Figure 3 – Annual averaged $PM_{2.5}$ concentration in 2025

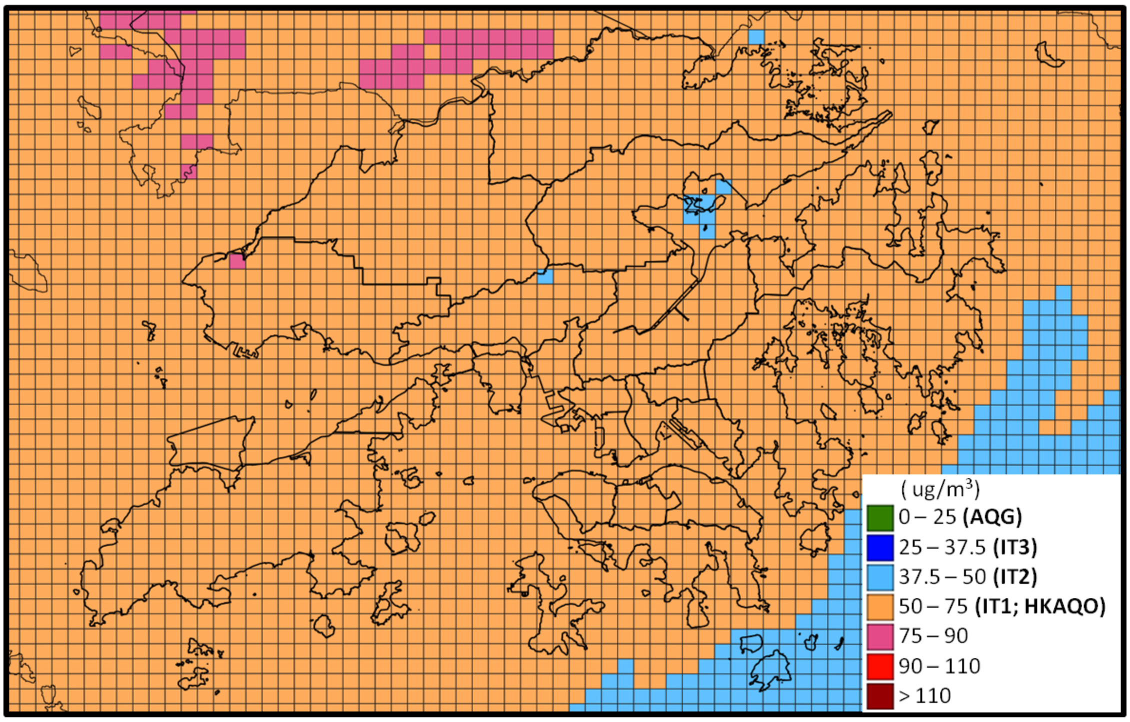

Figure 4 – 10th highest daily $PM_{2.5}$ concentration in 2025

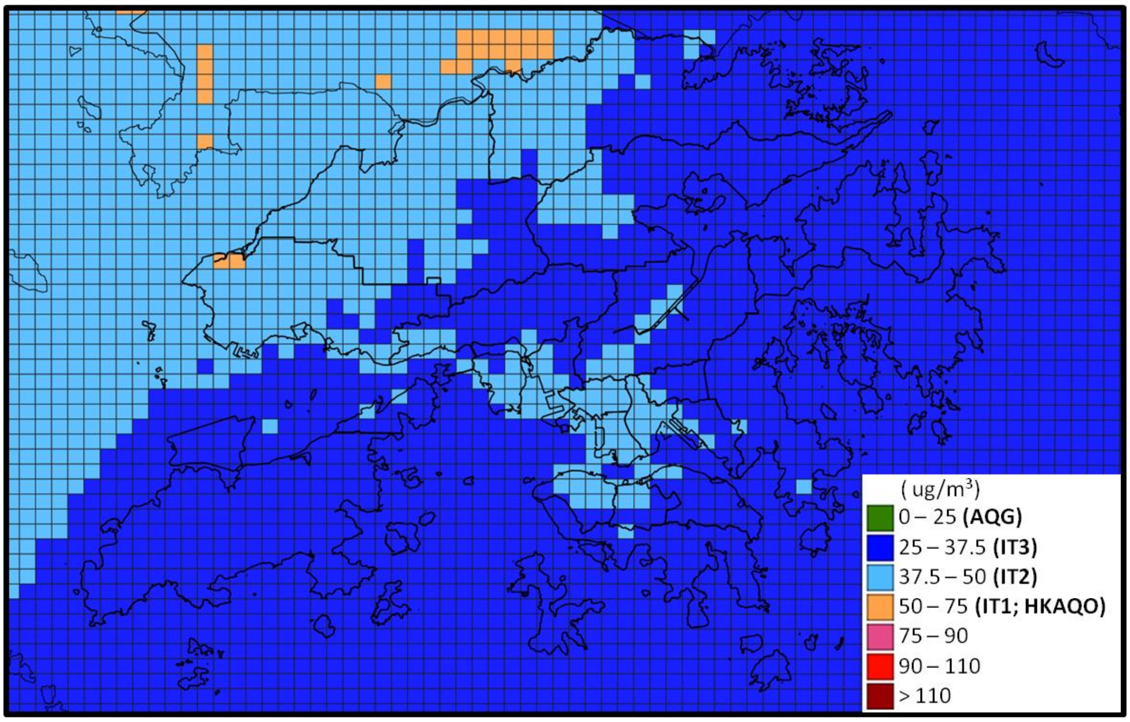

Figure 5 – 36th highest daily $PM_{2.5}$ concentration in 2025

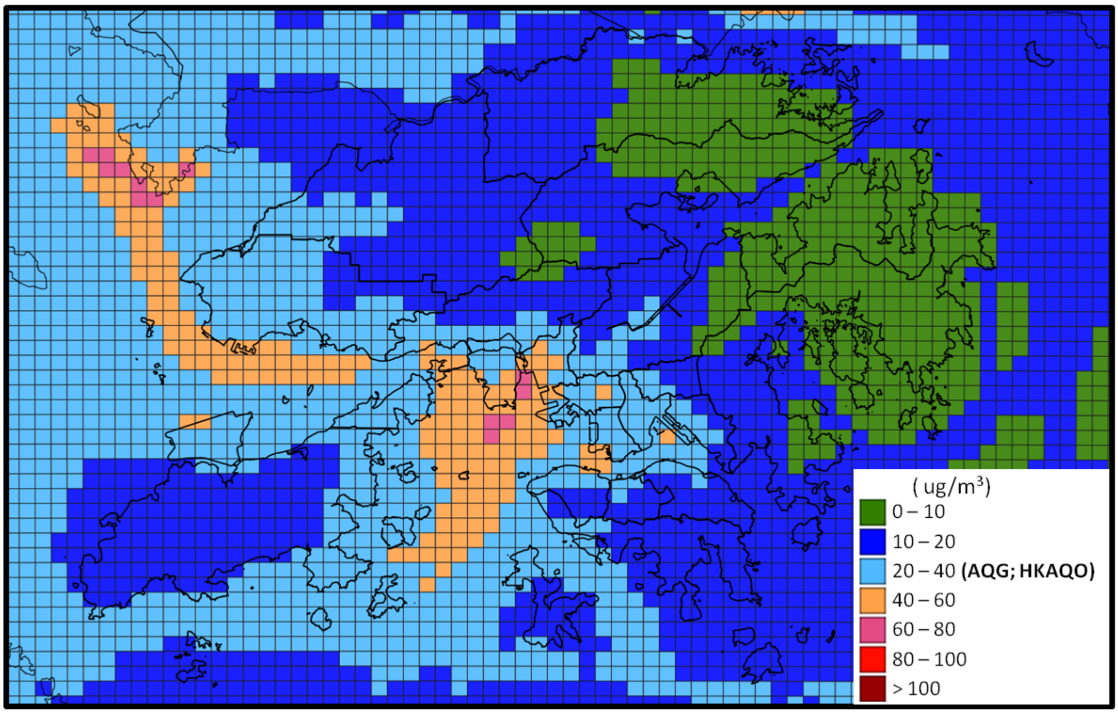

Figure 6 – Annual averaged NO_2 concentration in 2025

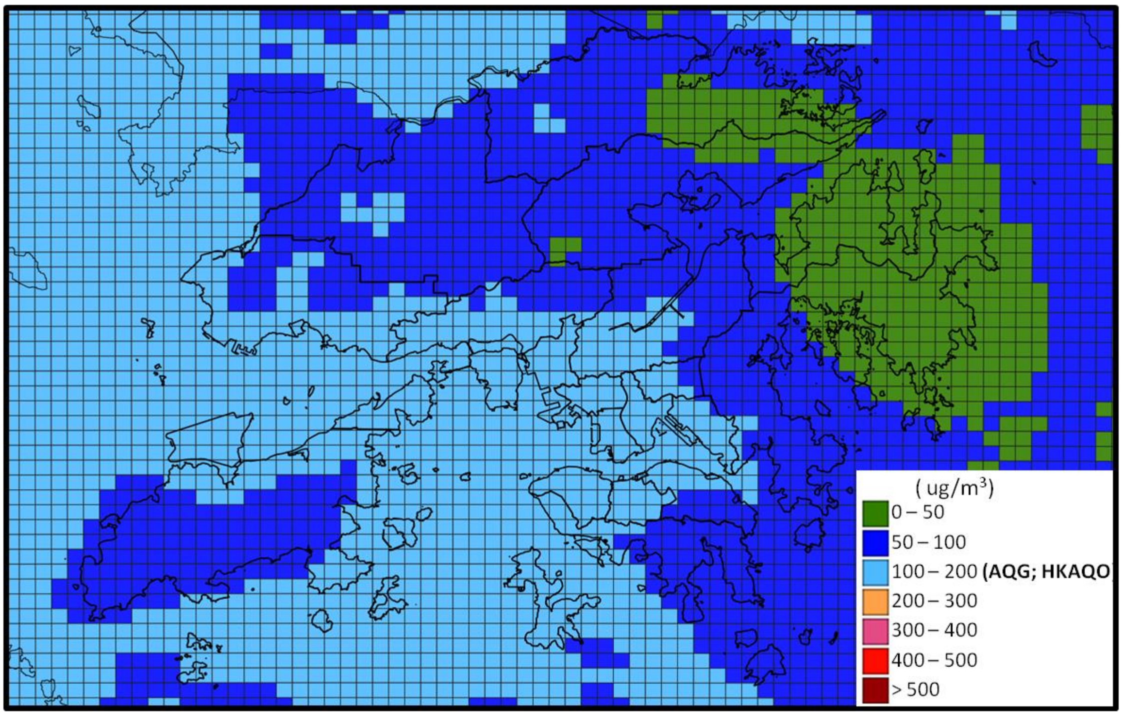

Figure 7 – 19th highest hourly NO_2 concentration in 2025

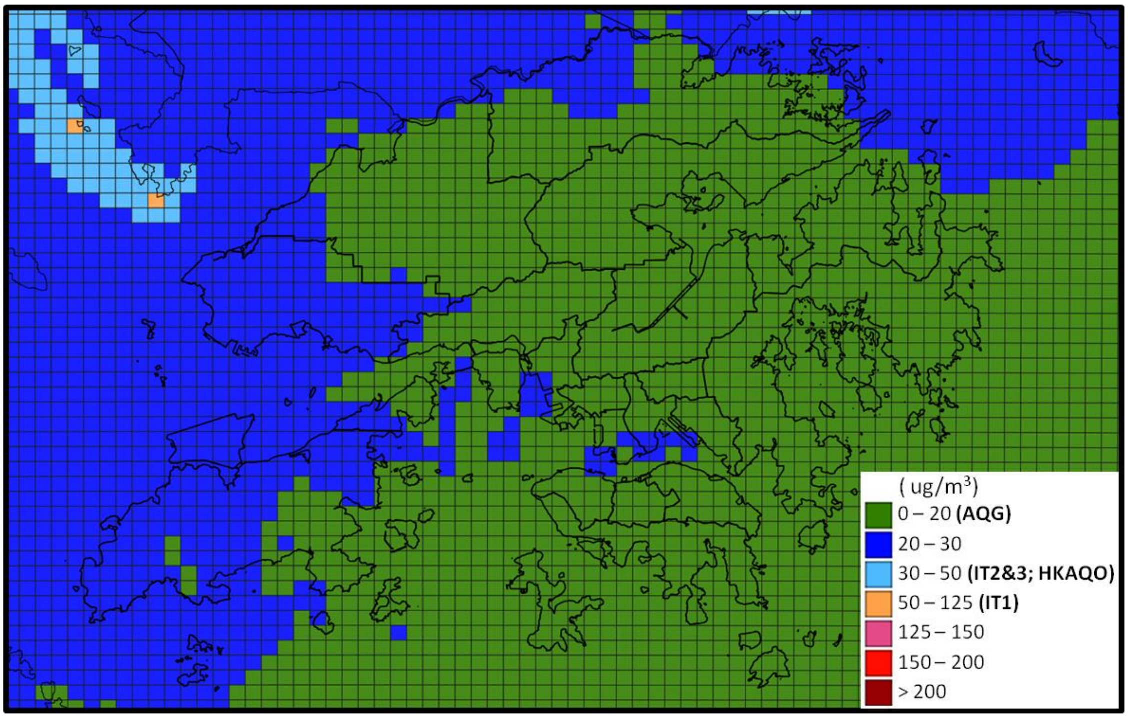

Figure 8 – 4th highest daily SO_2 concentration in 2025

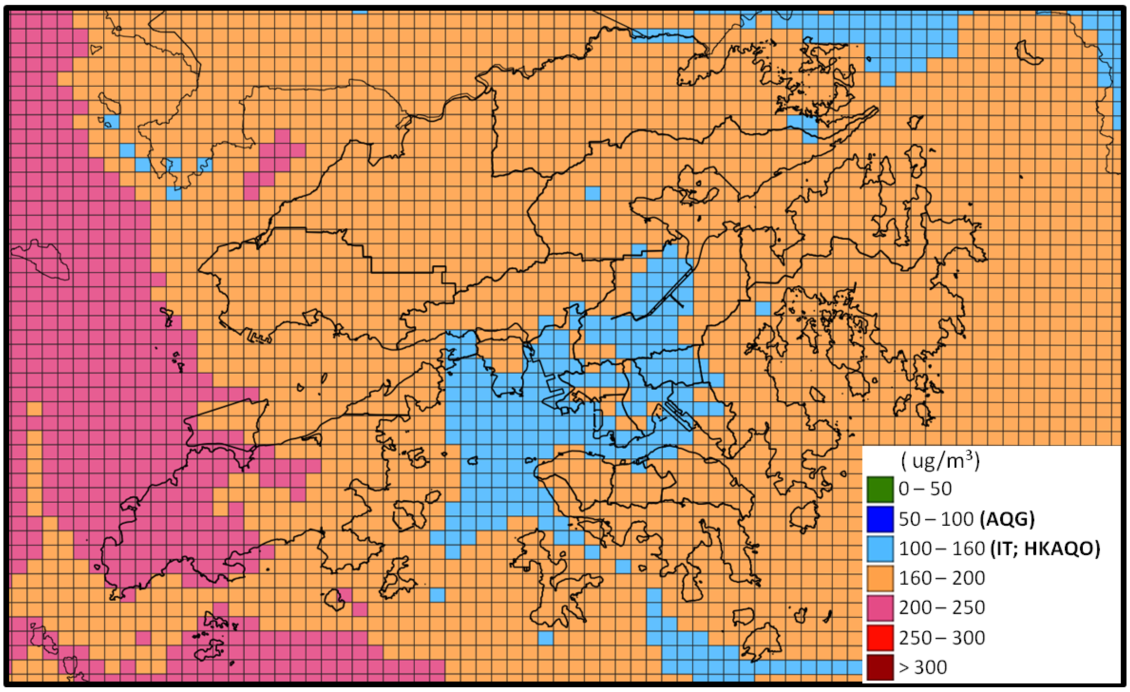

Figure 9 – 10th highest daily maximum 8-hour O_3 concentration in 2025

Annex F

Relative Risks of Health Outcomes and Formula to estimate the change in health outcome attributable to changes in air pollution level

A) Relative Risks of short-term and long-term exposures of air pollutants

Health Outcomes		Relative Risks per 10μg/m^3 (95% Confidence Interval)			
		$PM_{2.5}$ (Daily mean)	**NO_2 (Daily Mean)**	**O_3 (Daily 8-hr maximum)**	**SO_2 [1] (Daily mean)**
Short-term Health Outcomes (Morbidities)					
Emergency hospital admissions	Cardiovascular diseases (all ages)	1.0066 [2] (1.0036 - 1.0097)	1.0100 [3] (1.0073 - 1.0126)	NA	1.0098 [3] (1.0057 - 1.0139)
	Respiratory diseases (all ages)	1.0097 [4] (1.0065 - 1.0129)	1.0075 [3] (1.0050 - 1.0100)	1.0081 [3] (1.0058 - 1.0104)	NA
	COPD [5]	1.031 (1.026 - 1.036)	1.026 (1.022 - 1.031)	1.034 (1.030 - 1.040)	
	Asthma [6]	1.021 (1.015 - 1.028)	1.028 (1.021 - 1.034)	1.034 (1.029 - 1.039)	
New episodes of URTI	GP visits [7]	1.021 (1.010 - 1.032)	1.030 (1.020 - 1.040)	1.025 (1.012 - 1.038)	
	GOPC visits [8]	1.005 (1.002 - 1.009)	1.010 (1.006 - 1.013)	1.009 (1.006 - 1.012)	
Mortality		1.004097 [9] (1.001806-1.006394)	1.0103 [3] (1.0069-1.0137)	1. 0034 [3] (1.0002-1.0066)	1.0091 [3] (1.0040 -1.0142)
Long-term Health Outcome					
Mortality		1.062 [10] (1.040 - 1.083)	1.039 [11] (1.022 - 1.056)	NA	NA

Notes:

COPD = Chronic Obstructive Pulmonary Disease
GOPC = General Outpatient Clinic
GP = General Practitioner
URTI = Upper Respiratory Tract Infections
NA **=** Health outcome not assessed as the Relative Risk for the respective air pollutant is either statistically not significant or available.

1. Although the health outcome is comparatively less significant than other air pollutants, as some of the possible new air quality improvement measures would have emission reduction potential on SO_2, the Relative Risks for SO_2 is provided for reference.
2. Qiu et al, 2013. Differential Effects of Fine and Coarse Particles on Daily Emergency Cardiac Hospitalizations in Hong Kong. Atmospheric Environment *64* 296-302; and personal communications with Dr. H. Qiu. The RR was presented for each interquartile increase in $PM_{2.5}$ in the published paper. Dr. Qiu was requested to provide the RR for each 10 μg/m^3 increase in $PM_{2.5}$ concentration, i.e. 1.0066 as quoted above.
3. Wong et al., 2010. Part 4. Interaction between Air Pollution and Respiratory Viruses: Time Series Study of Daily Mortality and Hospital Admissions in Hong Kong. In: Public Health and Air Pollution in Asia (PAPA): Coordinated Studies of Short-Term Exposure to Air Pollution and Daily Mortality in Four Cities. HEI Research Report 154, Health Effects Institute, Boston, MA.
4. RR for respiratory diseases is obtained through the personal communications with Dr. H. Qiu. The excess risk of mortality reported in PAPA Study (Wong et al, 2010) with PM_{10} were 0.63% and 0.69% (equivalent to RRs of 1.0063 and 1.0069) and were somewhat lower than the RR for $PM_{2.5}$, as the effect of PM_{10} on health is smaller than that of $PM_{2.5}$.
5. Ko et al., 2007a. Temporal relationship between air pollutants and hospital admissions for Chronic Obstructive Pulmonary Disease in Hong Kong. Thorax *62* 779-784.

6. Ko et al., 2007b. Effects of air pollution on asthma hospitalization rates in different age groups in Hong Kong. Clinical and Experimental Allergy *37* 1312-1319.
7. Wong et al., 2006. Association between Air Pollution and General Practitioner Visits for Respiratory Diseases in Hong Kong. Thorax *61* 585-591.
8. Tam et al., 2014. Association between air pollution and general outpatient clinic consultations for upper respiratory tract infection in Hong Kong. PLOS ONE 9(1) e86913, 1-6. (Note: In Tam's study, only RR for PM_{10} was available. This is used as a proxy of RR for $PM_{2.5}$ in this study. In general, RR for PM_{10} is slightly lower in magnitude than that for $PM_{2.5}$.)
9. Tam, (2016), unpublished data. RR of all-cause, cardiovascular and respiratory mortality from Prof. W. Tam based on time series of PM2.5 on all-cause mortality between 2001 and 2010.
10. Hoek el al., 2013. Long-term air pollution exposure and cardio-respiratory mortality: a review. Environmental Health *12* 43.
11. WHO, 2013. Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide. Copenhagen: WHO Regional Office for Europe. (Note: the overlapping effect on PM has been considered. The original RR is 1.055 (1.031 – 1.080) per 10μg/m³).

B) The health impact arising from a change in air pollution is estimated by the following formula:

Attributable health outcomes = Baseline health outcome data x AF

where "AF" is the attributable fraction, RR is the relative risk estimated by the formulae below:

Equation 1: $\mathrm{AF} = (\mathrm{RR} - 1)/\mathrm{RR}$

Equation 2: $\mathrm{RR} = \mathrm{e}^{\frac{\ln(\mathrm{RR\ per\ 10\ ug/m^3})}{10} * (x-y)}$ *where "x" is referred to air pollutant concentration at a specific year (in μg/m³), and "y" as counterfactual target/desired level is referred to the WHO AQG (in μg/m³)*

Annex G

Health Benefits Attributable to the Changes in Air Quality Level Between 2015 (Base Year) and 2025 (Target Year)

<table>
<tr><th colspan="2" rowspan="2">Health Outcomes</th><th colspan="4">Air Pollutants</th><th rowspan="2">Max. Short-term Impact / Total Mortality[a]</th></tr>
<tr><th>$PM_{2.5}$</th><th>NO_2</th><th>O_3</th><th>SO_2</th></tr>
<tr><td colspan="7">Short term health outcome: Reductions in number of hospital admissions and clinic visits</td></tr>
<tr><td rowspan="4">Emergency hospital admissions saved</td><td>Cardiovascular diseases</td><td>92</td><td>704</td><td>NA</td><td>25</td><td rowspan="2">1,528</td></tr>
<tr><td>Respiratory diseases</td><td>213</td><td>824</td><td>-25 [c]</td><td rowspan="5">NA</td></tr>
<tr><td>COPD [b]</td><td>158</td><td>686</td><td>-27 [c]</td><td>--</td></tr>
<tr><td>Asthma</td><td>72</td><td>470</td><td>-17 [c]</td><td>--</td></tr>
<tr><td rowspan="2">Clinic visits saved (for new episodes of URTI)</td><td>GOPC visits</td><td>858</td><td>8,226</td><td>-293 [c]</td><td rowspan="2">262,577</td></tr>
<tr><td>GP visits</td><td>104,895</td><td>254,351</td><td>-7,921 [c]</td></tr>
<tr><td colspan="7">Long term health outcome: Reductions in number of premature deaths</td></tr>
<tr><td colspan="2">Mortality (Short-term exposure, all ages)</td><td>28</td><td>350</td><td>-3 [c]</td><td>12</td><td>d</td></tr>
<tr><td colspan="2">Mortality (Long-term, aged 30 and above)</td><td>865</td><td>983</td><td>NA</td><td>NA</td><td>1,848</td></tr>
</table>

Notes:
COPD = Chronic Obstructive Pulmonary Disease
GOPC = General Outpatient Clinic
GP = General Practitioner
URTI = Upper Respiratory Tract Infections
NA = Health outcome not assessed as the Relative Risk for the respective air pollutant is either statistically not significant or available.

a. To avoid double-counting of health effects, short-term impacts of different air pollutants are not added up. Instead, the maximum value among the air pollutants is taken.
b. COPD, influenza and pneumonia are examples of respiratory diseases. Asthma is a sub-class of COPD. While separate quantification was performed for COPD and asthma (both belong to the class of respiratory diseases), influenza and pneumonia could not be assessed due to the lack of reliable local concentration-response functions.
c. The negative (-) sign indicates the air pollutant exerts negative impact.
d. Short-term premature death is covered in the long-term premature death.

Annex H

Economic Benefits of the Health Benefits Attributable to the Changes in Air Quality Level Between 2015 (Base Year) and 2025 (Target Year)

Table 1: Economic benefits due to savings in hospital admissions, clinic visits and associated productivity loss in 2025 compared with 2015

Air Pollutants	Economic Costs Saved (HK$)			
	Hospital Admissions [a]	Clinic Visits [b]	Productivity Loss [c]	Total [d]
$PM_{2.5}$	5,510,850	26,605,560	*59,785,600*	91,902,010
NO_2	28,848,240	67,248,320	*150,004,400*	**246,100,960**
SO_2	540,750	NA	*56,000*	596,750
O_3	-413,250 [e]	-2,110,635 [e]	*-4,641,840* [e]	-7,165,725 [e]

Notes:

a. The cost of hospital admissions relates to Accidents and Emergency (A&E) attendance due to cardiovascular and respiratory diseases and cost of hospital beds.

b. The cost of clinic visits includes doctor consultation of both public and private practitioners due to new episodes of upper respiratory tract infections (URTIs).

c. The productivity loss due to hospital admission and clinic visit is estimated based on the median length of hospital stay (four days for cardiovascular illnesses and three days for respiratory illnesses) and a sick leave of one day granted by the attending doctor. The productivity loss is only a broad-brush estimate for reference only given that different estimation methods (e.g. different lengths of hospital stay, different lengths of sick leave) may yield quite different results.

d. To avoid double-counting of economic benefits, short-term impacts of different air pollutants are not added up, the maximum cost benefits among the air pollutants (i.e. NO_2) is taken as representative figures, which marked in **bold**.

e. The negative (-) sign means there could be additional costs incurred.

Table 2: Economic benefits due to avoided premature deaths in 2025 compared with 2015

Air Pollutants	Economic Costs Saved (HK$) [a]	
	Long-term premature deaths expressed in VOSL [b]	Total [c]
$PM_{2.5}$	15,659,273,600	**33,454,725,500**
NO_2	17,795,451,900	

Notes:

a. Figures are rounded to the nearest hundred.

b. The "VOSL" approach refers to the amount of money a person (or society) is willing to spend to save a life. It is derived from the trade-offs people are willing to make between fatality risk and wealth. Hence, it varies among different areas/countries and could be diverse. The measurement of monetary gain in preventing premature mortality based on the VOSL approach is only for indicative purpose. The VOSL is based on the average of VOSL from European WHO Regional Office Report and VOSL in China from a World Bank reference and then adjusted to the price in 2017, at about HK$18,103,200. These two references entailed the upper and lower bounds of the VOSL.

c. The long-term impacts can be added up as the overlapping effects of the two pollutants (i.e. $PM_{2.5}$ and NO_2) have been taken into account.