APPENDIX 3.2

Adjustment of Background NO_2, SO_2 and RSP at Black Point Power Station and Castle Peak Power Station

Adjustment of Background NO_2 at Black Point Power Station and Castle Peak Power Station

Background

An extensive set of wind tunnel tests for the Black Point Power Station was conducted as parte of the EIA of the Proposed 6000 MW Thermal Power Station at Black Point in 1993 (hereafter called BPPS EIA Study). Maximum 1-hour average nitrogen dioxide (NO_2) concentrations were modelled for a number of ASRs. However, even that the NO_x emission rates assumed in 1993 for the particular set of wind tunnel tests remain relevant for the present situation, the NO_x to NO_2 conversion rates may have had changed over the years due to the increase in background ozone concentrations. The update of such conversion rates and the re-assessment of NO_2 at the interested ASRs is summarized as below.

NO_x to NO_2 Conversion in BPPS EIA Study

The methodology for determination of NO_x to NO_2 conversion used was based on the commonly used Janssen's formula[1] that links the conversion rate to the prevailing meteorological conditions, distance to the receptor and the background ozone concentrations:

$$NO_2 / NO_x = A\left(1 - e^{-\alpha x}\right) \qquad \text{---------- (1)}$$

where A and α are coefficients depending on wind speed, ambient ozone concentration and the season of the year that can be determined; x is the distance (km) between ASR and the source.

In the BPPS EIA Study, the values of coefficients used were obtained from Janssen tables for summer conditions using linear interpolation of wind speeds. The ambient ozone concentration was assumed as 35 ppb for A and 50 ppb for α determination. The artificial increase of O_3 concentration assumed for a estimates was substantiated by the higher solar radiation in HK as compared to Holland, where the Janssen's study was conducted.

The value of A was calculated to be 0.74 and the values of α were 0.21 km^{-1} for wind speed of 8 m/s and 0.29 km^{-1} for wind speed of 12 m/s in the BPPS EIA Study.

Adjustment for NO_x / NO_2 Conversion and NO_2 Concentration

The 5-year average (2003 – 2007) of the annual average of daily hourly maximum ozone concentration measured at EPD Air Quality Monitoring Station in Yuen Long is 78.3 $\mu g/m^3$ (i.e. 40 ppb). Assuming again the summer conditions, from the *Janssen Table 4*, A will be 0.81 for wind speeds from 5 to 15 m/s.

For the α estimation, to be consistent with the BPPS EIA Study approach, the O_3 level is increased by 15 ppb i.e. the O_3 background of 55 ppb is assumed for α determination. Using again the *Janssen Table 4* and applying interpolation between the 50 and 90 ppb levels in a way consistent with the BPPS EIA Study approach, α will be 0.16 km^{-1} for 55 ppb at wind speed of 5 m/s and 0.36 km^{-1} for the wind speed of 15 m/s.

By linear interpolation for wind speeds, the values of α at wind speeds of 8m/s and 12m/s will be 0.22km^{-1} and 0.30km^{-1} respectively.

Adjustment of NO_2 can therefore be obtained from the Janssen's formula (1). Assuming C_1 be the NO_2 concentration in the BPPS EIA Study, and C_2 be the NO_2 concentration in this WENT Extension Study, the Janssen's formula will therefore be:

$$C_2 = C_1 \frac{A_2\left(1 - e^{-\alpha_2 x}\right)}{A_1\left(1 - e^{-\alpha_1 x}\right)} \qquad \text{---------- (2)}$$

In accordance with the BPPS EIA Study, Part A, Table 3.3a, the maximum hourly NO_2 was predicted based on the generating capacity of 4,800 MW of BPPS. However, with reference to the latest SP

[1] Janssen L.H.J.M. et al. A Classification of NO Oxidation Rates in Power Plant Plumes based on Atmospheric Conditions. Atmospheric Environment, 22, 43-53, 1988

Licences for BPPS, the current capacity is about 2,500 MW, which is about 50% of the BPPS EIA Study, therefore, a factor of 0.5 is applied to the hourly NO_2 concentration from BPPS contribution.

Therefore, the adjusted **1-hour** NO_2 concentrations are:

For ASRs near Ha Pak Nai :

$$C_2 = 10\frac{0.81\left(1-e^{-0.22\times3.2}\right)}{0.74\left(1-e^{-0.21\times3.2}\right)}\times 0.5$$

where x =3.2, C_1 = 10% of AQO, wind speed = 8 m/s

C_2 = 5.7% of AQO (i.e. **17.1 µg/m^3**)

For ASRs near Lung Kwu Tan:

$$C_2 = 30\frac{0.81\left(1-e^{-0.30\times2}\right)}{0.74\left(1-e^{-0.29\times2}\right)}\times 0.5$$

where x =2, C_1 = 30% of AQO, wind speed = 12 m/s

C_2 = 16.8% of AQO (i.e. **50.5 µg/m^3**)

The adjusted **24-hour** NO_2 concentrations are:

For ASRs near Ha Pak Nai :

$$C_2 = 11.3\frac{0.81\left(1-e^{-0.22\times3.2}\right)}{0.74\left(1-e^{-0.21\times3.2}\right)}$$

where x =3.2, C_1 = 11.3% of AQO, wind speed = 8 m/s

C_2 = 12.8% of AQO (i.e. **19.2 µg/m^3**)

For ASRs near Lung Kwu Tan:

$$C_2 = 12.1\frac{0.81\left(1-e^{-0.30\times2}\right)}{0.74\left(1-e^{-0.29\times2}\right)}$$

where x =2, C_1 = 12.1% of AQO, wind speed = 12 m/s

C_2 = 13.6% of AQO (i.e. **20.4 µg/m^3**)

The adjusted **Annual** NO_2 concentrations are:

For ASRs near Ha Pak Nai :

$$C_2 = 0.5\frac{0.81\left(1-e^{-0.22\times3.2}\right)}{0.74\left(1-e^{-0.21\times3.2}\right)}$$

where x =3.2, C_1 = 0.5% of AQO, wind speed = 8 m/s

C_2 = 0.57% of AQO (i.e. **0.5 µg/m^3**)

For ASRs near Lung Kwu Tan:

$$C_2 = 0.6\frac{0.81\left(1-e^{-0.30\times2}\right)}{0.74\left(1-e^{-0.29\times2}\right)}$$

where x =2, C_1 = 0.6% of AQO, wind speed = 12 m/s

C_2 = 0.67% of AQO (i.e. **0.5 µg/m^3**)

In accordance with the BPPS EIA Study, Part A, Table 3.3a, the maximum hourly NO_2 was predicted based on the generating capacity of 4,800 MW of BPPS. However, with reference to the latest SP Licences for BPPS, the current capacity is about 2,5000 MW, which is about 50% of the BPPS EIA Study, therefore, a factor of 0.5 is applied to the NO_2 concentration from BPPS contribution.

In the BPPS EIA Study, Annex B, the NO_x concentration at the source for CPA in the wind tunnel testing was 1,577 mg/m^3. However, refer to the latest SP Licence, the licence limit of NO_x for emission from CPA is 1,500 mg/m^3. Thus, a factor of *0.95* is applied to adjust the NO_2 concentration from CPA contribution.

Moreover, the NO_x concentration at the source for CPB in the wind tunnel testing was 1,578 mg/m^3. However, refer to the approved Emission Control Project to CPPS "B" Units EIA Study, new NO_x reduction technology is proposed for CPB, hence, further 80% of current NO_x emission should be reduced. However, the revised licence limit of NO_x for CPB is not confirmed, a tightened NO_x limit specified in the Best Practicable Means for Electricity Works (Coal-fired Plant, Gas-fired Plant, Gas-Turbine and Oil-fired Gas Turbine (Peak Lopping Plant) (BPM7/1)) of 670 mg/m^3 will be adopted in this assessment. Thus a factor of *0.43* is applied to adjust the NO_2 concentration from CPB contribution.

Adjusted NO_2 Concentration

The adjusted hourly, and daily/annual NO_2 concentrations from BPPS and CPPS contribution are summarised in the following **Table A-1** and **Table A-2** respectively:

Table A-1 : Adjusted Hourly NO_2 Concentration at ASRs

ASR		BPPS [1] (µg/m^3)	CPA [2] (µg/m^3)	CPB [2] (µg/m^3)	Total (µg/m^3)
Ha Pak Nai	3.2km, 232°, 252°, 8m/s	17.1 (5.7% of AQO)	56.9 (59.9 x 0.95)	20.0 (46.6 x 0.43)	94.0
Lung Kwu Tan [3]	2.0km, 330°, 12m/s	50.5 (16.8% of AQO)	-	-	50.5

Note:
[1] The maximum measured NO_2 concentration due to BPPS Emissions are referenced to BPPS EIA Report Part A, Table 3.3a
[2] The CPPS contributions are referenced to BPPS EIA Report Annex H, Table H.1
[3] For ASRs at Lung Kwu Tan, since the worst wind direction from BPPS/WNET Extension and CPPS are not at the same wind direction, no cumulative impact from CPPS is anticipated.

Table A-2 : Adjusted Daily and Annual NO_2 Concentration at ASRs

ASR	Daily NO_2 [1] (µg/m^3)	Annual NO_2 [1] (µg/m^3)
Ha Pak Nai	19.2 (12.8% of AQO)	0.5 (0.57% of AQO)
Lung Kwu Tan	20.4 (13.6% of AQO)	0.5 (0.67% of AQO)

Note:
[1] The 2nd highest daily and annual NO_2 concentrations due to BPPS and CPPS emissions are referenced to BPPS EIA Report Part B, Table 6.2b.

Adjustment of Background SO_2 at Black Point Power Station and Castle Peak Power Station

Since the BPPS is gas-fired gas turbine power plant, the SO_2 emission is very negligible in accordance with the BPPS EIA Study, Annex B (source Emissions and Characteristics – Option 3). Thus, no SO_2 concentration contributed from BPPS is considered in this assessment.

Adjustment for SO_2 Concentration

For ASRs located at Lung Kwu Sheung Tan, since the worst wind direction from BPPS/WENT Extension and CPPS are opposite, no cumulative impact from CPPS is anticipated.

Hourly SO_2 Concentration

Since there is no wind tunnel test for SO_2 concentrations performed in the BPPS EIA Study, the SSO_2 concentration from CPPS contribution are estimated based on the BPPS EIA Study Annex H, Table H1b & H1c, maximum hourly NO_x concentration at Ha Pak Nai. In accordance with the BPPS EIA Study, Annex B, the NO_x concentration at the source is 1,577 mg/m^3, and the latest licence limit of SO_2 for emission from CPA & CPB is 2,100 mg/m^3. Thus, a factor of 1.33 is applied to adjust the SO_2 concentration from both CPA and CPB contribution.

There is no flue gas desulphurization system (FGD) applied to the current CPA and CPB operation. For CPB, FGD will be installed to reduce the SO_2 emission. In accordance with the Emission Control Project to CPPS "B" Units EIA Study, Annex A, Table A.4, further 89% SO_2 reduction will be applied to the adjusted SO_2 concentration from CPB contribution for Ha Pak Nai and 88.5%.

The adjusted hourly SO_2 concentrations from CPPS contribution are summarised in **Table A-3**.

Table A-3 : Adjusted Hourly SO_2 Concentration at ASRs

ASR	CPA, NO_x (μg/m^3) [1]	CPB, NO_x (μg/m^3) [1]	Total (μg/m^3)
Ha Pak Nai	157.3 (118.3 x 1.33)	13.4 (91.7 x 1.33 x (1-0.89))	171
Lung Kwu Tan [2]	-	-	0

Note:

[1] The maximum measured NO_x concentration from CPPS contributions are reference to BPPS EIA Report Annex H, Table H.1

[2] For ASRs at Lung Kwu Tan, since the worst wind direction from BPPS/WNET Extension and CPPS are not at the same wind direction, no cumulative impact from CPPS is anticipated.

Daily and Annual SO_2 Concentration

In the BPPS EIA Study, Annex B, the SO_2 concentration at the source for CPA and CPB in the wind tunnel testing are 1,635 mg/m^3 and 1,726 mg/m^3 respectively. However, refer to the latest SP Licence, the licence limit of SO_2 for emission from both CPA and CPB are 2,100 mg/m^3. Thus, a factor of 1.28 is applied to adjust the SO_2 concentration from CPPS contribution as worst case condition. The adjusted daily and annual SO_2 concentrations from CPPS contribution are summarised in **Table A-4**.

Table A-4 : Adjusted Daily and Annual SO_2 Concentration at ASRs

ASR	Daily SO_2 [1] (μg/m^3)	Annual SO_2 [1] (μg/m^3)	Adjusted Daily SO_2 Concentration (μg/m^3)	Adjusted Annual SO_2 Concentration (μg/m^3)
Ha Pak Nai	46.6 (13.4% of AQO)	1.2 (1.5% of AQO)	60 (46.6 x 1.28)	1.5 (1.2 x 1.28)
Lung Kwu Tan	30.1 (8.6% of AQO)	0.64 (0.8% of AQO)	39 (30.1 x 1.28)	0.8 (0.64 x 1.28)

Note:

[1] The 2nd highest daily and annual SO_2 concentrations due to BPPS and CPPS emissions are referenced to BPPS EIA Report Part B, Table 6.2b.

Adjustment of Background RSP at Black Point Power Station and Castle Peak Power Station

In accordance with the BPPS EIA Study, RSP is not the dominant air pollutant in the power plant emission and not considered in its EIA Study. The predicted RSP concentrations at the ASRs are not available. Therefore, the ratio of maximum RSP to NO_x concentration stated in the Specified Process Licence for BPPS is applied to adjust the RSP concentration contributed from BPPS. Refer to the Specified Process Licence of BPPS, the maximum concentration of RSP and NO_x are listed as follows:

Source ID		C1-C6	C7-C8
Gas Firing	Maximum RSP Concentration in mg/m^3	5	5
	Maximum NO_x Concentration in mg/m^3	90	90
	Ratio of RSP/NO_x Concentration	**0.056**	**0.056**

From the above table, a factor of 0.056 is applied to calculate the RSP concentration based on the predicted NO_x concentration associated with BPPS. Same approach, the ratio of RSP to NO_x concentration licensed in the Specified Process Licence of CPPS is also applied to adjust the RSP concentration contributed from CPPS. Refer to the Specified Process Licence of CPPS, the maximum concentration of RSP and NO_2 are listed as follows:

Source ID	A1-A4	B1-B4
Maximum RSP Concentration in mg/m^3	125	125
Maximum NO_x Concentration in mg/m^3	1500	1500
Ratio of RSP/NO_x Concentration	**0.083**	**0.083**

From the above table, a factor of 0.083 is applied to adjust the RSP concentration based on the predicted NO_x concentration associated with BPPS.

Adjusted Daily and Annual RSP Concentration

ASR	Adjusted Daily NO_2 Concentration [1] ($\mu g/m^3$)	Adjusted Annual NO_2 Concentration [1] ($\mu g/m^3$)	NO_2/NO_x Ratio [2]	Ratio of RSP to NO_x Concentration [3]	Adjusted Daily RSP Concentration ($\mu g/m^3$)	Adjusted Annual RSP Concentration ($\mu g/m^3$)
Ha Pak Nai	19.2	0.5	0.4094	0.083	3.9	0.1
Lung Kwu Tan	20.4	0.5	0.3654	0.083	4.6	0.1

Note:

[1] The adjusted daily and annual NO2 concentration due to BPPS and CPPS Emissions are shown in "Adjustment of Background NO_2 at Black Point Power Station and Castle Peak Power Station".

[2] Based on the Janssen's formula of $NO_2/NO_x = A\ (1 - e^{-\alpha x})$, values of A, α and x refer to those presented in "Adjustment of Background NO_2 at Black Point Power Station and Castle Peak Power Station".

[3] The 2nd highest daily and annual average NO_2 concentration presented in BPPS EIA Report are due to both BPPS and CPPS, so for conservative assessment, the higher RSP/NO_x ratio as calculated above for BPPS and CPPS is adopted.