Stack Height Determination Report

Hamriyah IPP Sharjah UAE

11 June 2018

395137

Mott MacDonald
Mott MacDonald House
8-10 Sydenham Road
Croydon CR0 2EE
United Kingdom

T +44 (0)20 8774 2000
F +44 (0)20 8681 5706
mottmac.com

Stack Height Determination Report

Hamriyah IPP Sharjah UAE

11 June 2018

395137

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	31/05/2018	A. Bennett	C. Mills	G. Clamp	Draft report
B	11/06/2018	A. Bennett	C. Mills	G. Clamp	Final report

Document reference: 395137 | 002 | B

Information class: Standard

Contents

Table of Figures

Table of Tables

1 Introduction

1.1 Overview

This report describes the stack height determination assessment undertaken for the proposed 1800MW Hamriyah Independent Power Plant (IPP), hereafter referred to as the 'proposed Project'. The proposed Project is a combined cycle gas turbine (CCGT) and will operate on natural gas as its primary fuel and use fuel oil as back up for emergency situations.

Designing a power plant with an appropriate stack height is important to ensure that building wake effects are overcome; thereby achieving effective dispersion of pollutants. The stack height determination for the proposed Project has been undertaken using dispersion modelling, and is based on the latest plant layout and emission parameters. A stack height determination has been undertaken for both the main and bypass stacks.

Following determination of an appropriate stack height for the proposed Project, additional dispersion modelling has been undertaken (using the selected stack height) for the operation of the proposed Project on natural gas and fuel oil when operating in combined cycle. The predicted maximum ground level process contributions have been compared to national air quality standards and the results include a discussion on the likely cumulative impacts in the airshed when considering the existing baseline conditions. No additional modelling other than the stack height determination for the proposed Project operating in open cycle has been undertaken, this is because air quality impacts would be less than those predicted from combined cycle operation.

This report provides recommended stack heights based on an assessment of potential impacts on the ambient air quality only. Amongst others, it does not take account of structural requirements, safety issues or associated regulations which should be considered by those using this information to develop the stack design.

1.2 Summary project description

The proposed Project will be a combined cycle technology with a nominal capacity of 1800MW delivered by three identical power blocks. Each power block will consist of the following major equipment:

- GE 9HA.01 gas turbine
- Hydrogen cooled generator, directly cooled to the gas turbine
- Triple pressure re-heat Heat Recovery Steam Generator (HRSG) dedicated to the gas turbine. HRSG is equipped with both main and bypass stacks.
- Triple pressure re-heat steam turbine
- Air cooled generator directly cooled to the steam turbine
- Direct cooled condenser to condense steam from the steam turbine
- Usual balance of plant equipment such pumps, pipes, etc.

The gas turbines will burn either natural gas, imported Liquid Natural Gas (LNG), or fuel oil as a back-up fuel in the event of gas supply issues. The gas will be supplied directly to the plant by the Sharjah National Oil Corporation (SNOC) through a single gas pipeline.

1.3 Project location

The proposed Project will be located on the Arabian Gulf coast 5km south-west of Al Hamriyah, 6.5km north-east of Al Owan and 21.5km west-north-west of Al Zubair in the Emirate of Sharjah, United Arab Emirates (GPS location: 25° 27.649'N 55° 28.665'E) (Figure 1).

1.4 Key pollutants

The combustion of fossil fuels gives rise to emissions of nitrogen oxides (NO_x), carbon monoxide (CO), particulates (as PM_{10} and $PM_{2.5}$), carbon dioxide (CO_2) and sulphur dioxide (SO_2) emissions depending on the sulphur content of the fuel.

This stack height determination has been undertaken for emissions of nitrogen dioxide (NO_2) only as this is the main pollutant of concern for both natural gas and fuel oil. In addition, particulate matter, SO_2, carbon monoxide CO, hydrogen sulphide (H_2S) and volatile organic compounds (VOCs) have been assessed qualitatively.

Figure 1: Project location

Source: Mott MacDonald, 2018

2 Applicable standards

2.1 Limits on emissions to air

2.1.1 National requirements

Emission standards applicable to the United Arab Emirates (UAE) are set out in Federal Law No. (12) of 2006 on Air Quality and Regulation and are presented in Table 1.

Table 1: Relevant emission standards as per Federal Law No. (12) of 2006 on Air Quality and Regulation

Pollutant	UAE Max. Emission limits - stationary sources (mg/m^3)	UAE Max. Emission limits - hydrocarbon fuel combustion (mg/m^3)
NO_x (Expressed as NO_2)	Turbine combustion units: • Gas fuel: 70 • Liquid fuel: 150	Turbine combustion units: • Gas fuel: 70 • Liquid fuel: 150
SO_2	500	500
CO	500 mg/m^3	500 mg/m^3
Total suspended particulate	250	250

Source: Federal Law No. (12) of 2006

2.1.2 IFC requirements

The IFC Performance Standard 3: Resource Efficiency and Pollution Prevention [Ref 3] aims:

"To avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities" To achieve this, the IFC provides both industry-specific and general guidance on Good International Industry Practice with respect to ambient air quality and emissions to air.

The IFC Environmental Health and Safety (EHS) General Guidelines advise that, with respect to emission limits, when host country regulations differ from the levels presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. (It should be noted that the same approach does not apply to ambient concentrations, as described below).

Relevant IFC standards for emissions to air applicable for gas turbines over 50 MWth using natural gas, and fuels other than natural gas, are presented in the IFC EHS Guidelines for Thermal Power Plants 2008

The IFC standards are presented in Table 2 below. Emission limits for CO are not prescribed by the EHS Guidelines for Thermal Power Plants.

Table 2: Pollutant emissions limit values for all turbine units > 50MWth input

Fuel	Pollutant	IFC Guidelines	
		Non-Degraded airshed	Degraded airshed
Natural gas	NO_x	51 mg/Nm^3	51 mg/Nm^3
Fuels other than natural gas	NO_x	152 mg/Nm^3	152 mg/Nm^3
	PM	50 mg/Nm^3	30 mg/Nm^3
	SO_2	Use 1% sulphur fuels or less	Use 0.5% sulphur fuels or less

Notes: Environmental, Health and Safety Guidelines for Thermal Power Plants, IFC 2008.
Reference conditions: dry, 0^{o}C, 1 atmosphere, 15% O_2

Commented [BAT1]: Amendments made

2.2 Ambient air quality standards

2.2.1 National Standards

Ambient air quality standards applicable to the United Arab Emirates (UAE) are set out in Federal Law No. (12) of 2006 on Air Quality and Regulation and are presented in Table 3

2.2.2 IFC requirements

Relevant IFC standards for ambient air quality are presented in the IFC EHS Guidelines for Air Emissions and Ambient Air Quality.

The IFC EHS Guidelines advise that 'relevant standards' with respect to ambient air quality are national legislated standards or, in their absence, the current World Health Organisation (WHO) Air Quality Guidelines or other internationally recognised sources such as the EU. WHO standards are presented alongside national requirements in Table 3

Where a host country's legislated standards are less stringent than either the WHO or other internationally recognised sources, the IFC acknowledge that it is acceptable to use the national legislated standards as the principal standards that the Project is assessed against.

The current WHO Guidelines for NO_2, SO_2 and particulate matter are provided in the Air Quality Guidelines Global Update 2005. These guidelines are intended to support actions for air quality at the optimal achievable level for public health protection in different contexts. The WHO does not formally prescribe how guidelines should be used in air quality management. However, the Air Quality Guidelines Global Update does provide 'Interim Targets' to aid the progression of policy development to bring air quality in line with the proposed guideline values.

The IFC EHS Guidelines suggest that, as a general rule, emissions should not contribute more than 25 percent of the relevant air quality standards to allow additional, future sustainable development in the same airshed. It also states that projects located within poor quality airsheds (if the nationally legislated standards are exceeded significantly), should ensure that any increase in pollution is as small as feasible, and amounts to a fraction of the applicable short term and annual average air quality guidelines established in the project-specific environmental assessment.

The impacts of the Project has been discussed in the context of this approach.

2.2.3 Summary

Table 3 provides a summary of the ambient air quality standards that have been applied to the proposed Project.

The standards related to short term averaging periods (one hour and 24 hour) are maximum values. In many jurisdictions, such as the United States and Europe, short term standards are not set as having maximum values but rather include a threshold of tolerance to account for exceptional, worst case episodes. In practice this means defining a number of allowable occurrences greater than the prescribed value to account for potential abnormal or infrequent pollutions episodes - these are often referred to the guideline values being applied as percentiles. For example, in the EU the standard for the one hour NO_2 allows for 18 exceedances within a calendar year and therefore the objective level is expressed as the 99.79th percentile. When analysing one hour NO_2 results, which is the primary pollutant of concern, the maximum result have been presented to compared against national standards as maximum values and using the 99.79th percentile to provide additional context around the results to account for outliers and results which are influenced by infrequent meteorological conditions.

Table 3: Ambient air quality standards relevant to the project

Pollutant	Averaging Period	UAE Standards [a]	UAE Dubai [b] Standards	WHO Air Quality [c] Guidelines
		($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)
NO_2	1 hour	400	290	200
	24 hour	150	110	-
	Annual	-	-	40
SO_2	10 minute	-	-	500
	1 hour	350	350	-
	24 hour	150	150	125 (interim target 1) 50 (interim target 2) 20 (interim target 3) 20 (guideline)
	Annual	60	50	-
PM_{10}	24 hour[c]	150	150	150 (interim target 1) 100 (interim target 2) 75 (interim target 3) 50 (guideline)
	1 hour	-	300	-
	Annual	-	-	70 (interim target 1) 50 (interim target 2) 30 (interim target 3) 20 (guideline)
$PM_{2.5}$	24 hour[c]	-	-	75 (interim target 1) 50 (interim target 2) 37.5 (interim target 3) 25 (guideline)
	Annual	-	-	35 (interim target 1) 25 (interim target 2) 15 (interim target 3) 10 (guideline)
CO	1 hour	30 mg/Nm³	23 mg/Nm³	-
	8 hour	10 mg/Nm³	10 mg/Nm³	-

Note:
(a) The UAE standards are the applicable standards for the project.
(b) Dubai standards are indicated for reference purposes as these are regional standards based on the UAE standards however some have been set more stringently.
(c) In the absence of applicable UAE standards, IFC/WHO standards can be adopted in alignment with best practice

Source: Federal Law No. (12) of 2006, as amended, WBG EHS Guidelines

Commented [BAT2]: Added footnote on standards

3 Method

3.1 Principles of stack height determination

The purpose of a stack height calculation is to determine the height necessary to ensure that emissions from a stack do not result in excessive ground level concentrations of air pollutants because of atmospheric downwash, eddies or wakes which may be created by nearby structures or terrain.

Nearby structures are normally the dominant causes of any atmospheric downwash, eddies, or wake effects. For proper dispersion to occur, it is necessary for the emissions to be released well above the top of nearby structures. Dispersion of emissions from a stack is also determined by the emission characteristics of the source, particularly their temperature and emissions velocity when they exit the stack.

Many methods are available to determine an appropriate stack height, including simple equations and air dispersion modelling. In this case, the stack height has been determined by air dispersion modelling.

3.2 Dispersion model

Many commercially available air dispersion models can predict ground level concentrations arising from emissions to atmosphere from point sources such as power plants. The AERMOD air dispersion model was used to inform the basis of the stack height determination and air quality assessment.

AERMOD is considered as an advanced dispersion model because of the way it characterises the atmosphere. It was developed on behalf of the US Environmental Protection Agency (EPA) by the American Meteorological Society / EPA Regulatory Model Improvement Committee (AERMIC), which was formed to introduce state of the art modelling concepts into the US EPA's local-scale air quality models. AERMOD is designed to treat both surface and elevated emission sources in simple and complex terrain.

There are two input data processors that are important components of the AERMOD modelling system; AERMAP and AERMET. AERMET is the meteorological pre-processor for AERMOD, its outputs include surface meteorological conditions and parameters and vertical profiles of several atmospheric parameters. AERMAP is a terrain pre-processor designed to simplify and standardise the input of terrain data for AERMOD. The output includes a location and height scale, which is an elevation used for the computation of air-flow around hills.

AERMOD is classed by the US EPA as their "preferred model" for regulatory dispersion applications. The model is used and recognised by regulators worldwide, and is acknowledged by the International Finance Corporation (IFC) Environmental, Health, and Safety (EHS) Guidelines as an appropriate tool for predicting potential impacts from air emission sources.

3.3 Emissions Data

Emissions data are based on information provided by GE who are the proposed gas turbine suppliers. The emissions data used within the stack height determination for the main stack and the bypass stack are presented in Table 4.

The stack height determination for the proposed Project operating in open and combined cycle has been carried out for natural gas only, this is because it is the primary fuel for the Project, and the emission parameters for temperature and exit velocity when firing on fuel oil are more favourable for dispersion (temperature and exit velocity are both higher) which means that a higher stack height would be required for natural gas compared to fuel oil.

The same emissions data has been used for the stack height determination and when assessing the proposed Projects maximum predicted process. Modelling of the maximum predicted impacts from the proposed Project in combined cycle has been based on the operating scenario with the highest calculated pollutant mass emissions and its corresponding efflux temperature and velocity.

Table 4: Emissions data

Parameter (d)	Natural gas		Fuel oil
	Emissions used for the HSRG stack height determination (a)	Emissions used for the By-pass stack height determination (b)	Emissions used for the HSRG stack operating on Fuel oil
	Combined Cycle	Simple Cycle	Combined Cycle
Normalised volumetric flow (Nm^3/s) (c)	855.31	857.7	890.04
Efflux temperature (°C)	81.1	633.7	121.1
Efflux velocity (m/s)	17.17	40.96	19.58
Stack diameter (m)	8	8.3	8
NO_x emission concentration (mg/Nm^3)	51	51	152
NO_x emission rate (g/s)	44	44	135

Notes:
(a) Emissions based on operating scenario with lowest exhaust gas temperatures and exhaust gas exit velocity
(b) Emissions based on operating scenario with maximum pollutant mass emissions
(c) Normalised flows referenced to 15% O_2, dry, 0°C, 1 atm

Source: Sumitomo Corporation, 2018

3.4 Meteorological data

The most important meteorological parameters governing atmospheric dispersion of pollutants are wind direction, wind speed and atmospheric stability as described below:

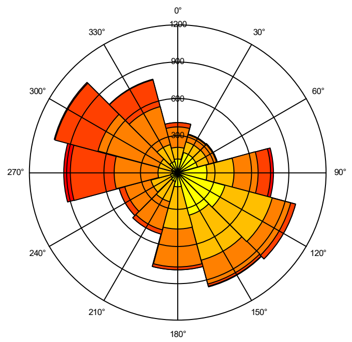
- Wind direction determines the sector of the compass into which the plume is dispersed
- Wind speed affects the distance which the plume travels over time and can affect plume dispersion by increasing the initial dilution of pollutants and inhibiting plume rise
- Atmospheric stability is a measure of the turbulence of the air, and particularly of its vertical motion. It therefore affects the spread of the plume as it travels away from the source. New generation dispersion models, such as AERMOD, use a parameter known as the Monin-Obukhov length that, together with the wind speed, describes the stability of the atmosphere

For meteorological data to be suitable for dispersion modelling purposes, several meteorological parameters are measured on an hourly basis. These parameters include wind speed, wind direction, cloud cover and temperature.

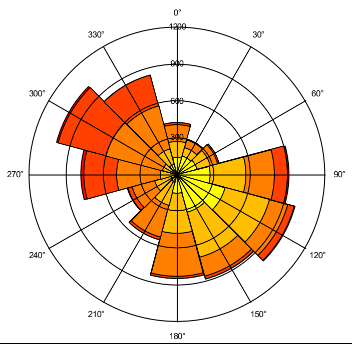
The closest meteorological station to the proposed Project with suitable available data is at Sharjah International Airport approximately 15 kilometres to the south-east of the project site. The data is considered representative of conditions expected at the proposed project site due to the short distance between them and there's no significant topographical differences between them which may influence the predominant meteorological conditions.

Figure 2 presents wind roses of the meteorological data for the monitoring period of 2013 to 2017. The wind roses illustrate that the meteorology in the area is nominated by land and sea breezes. Predominant wind directions are from the north-westerly sector (onshore breeze with increased average wind velocities in comparison to the offshore breezes) and south-easterly sector (offshore breeze).

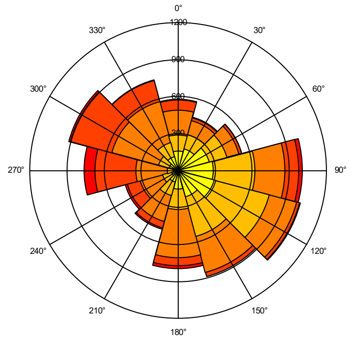
Figure 2: Meteorological data used within the assessment



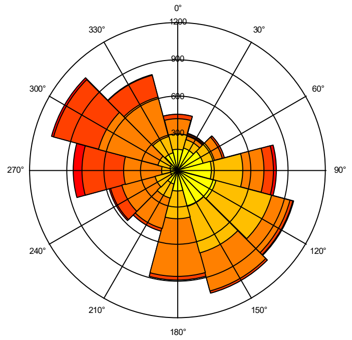
2013



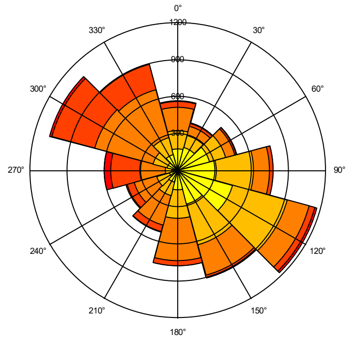
2014



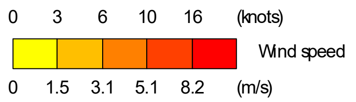
2015



2016



2017



Scale bar

Source: Sharjah International Airport Meteorological Station, 2013-2017

3.5 Terrain and surface roughness

The presence of elevated terrain can significantly affect (usually increase) ground level concentrations of pollutants emitted from elevated sources, such as stacks, by reducing the distance between the plume centre line and ground level. Conversely, terrain can increase turbulence and plume mixing, which may reduce ground level concentrations.

Terrain data has not been included in the dispersion model as the area surrounding the proposed Project can be described as flat as there are no hills with gradients greater than 1 in 10.

Roughness of terrain over which a plume passes can have a significant effect on dispersion by altering the velocity profile with height and the degree of atmospheric turbulence. Surface parameters have been accounted for within the processing of the meteorological data for land use around the meteorological station used in the assessment.

3.6 Buildings and plant layout

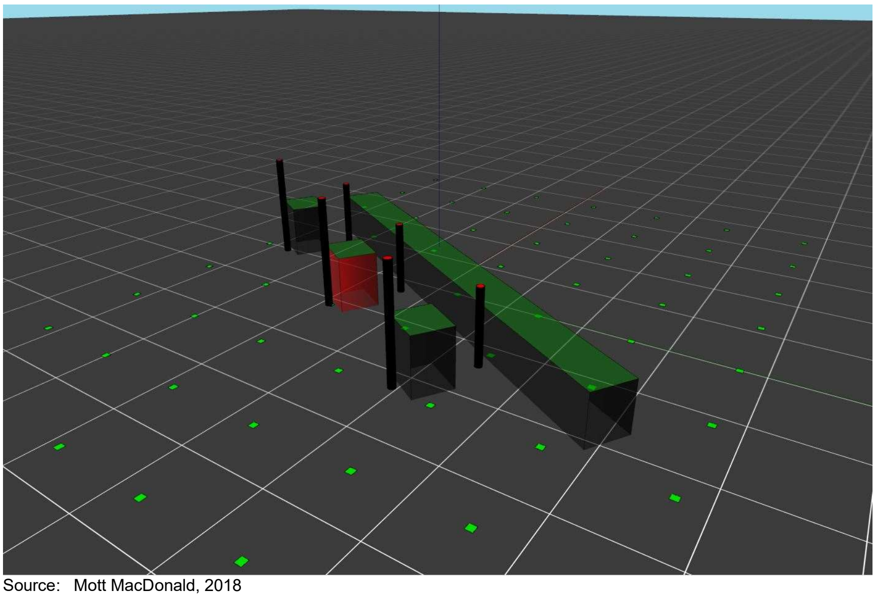
The movement of air over and around buildings generates areas of flow circulation, which can lead to increased ground level concentrations in the building wakes. The buildings likely to have the dominant effect (i.e. with the greatest dimensions likely to promote turbulence) are the generation turbine building (housing the Gas Turbines and Steam Turbines) and the heat recovery steam generators (HRSGs) are listed in Table 5 and illustrated in Figure 3.

Table 5: Buildings included within dispersion modelling

Building	X (UTM)	Y (UTM)	Height (m)	Length (m)	Width (m)
GT Building	347042.7	2816978.5	25.5	280	23
HRSG #3	346998.6	2816993.8	30.6	23.7	20.6
HRSG #2	346951.0	2816914.5	30.6	23.7	20.6
HRSG #1	346903.4	2816835.2	30.6	23.7	20.6

Source: Mott MacDonald, 2018

Figure 3: Buildings included within dispersion modelling



Source: Mott MacDonald, 2018

3.7 NO_x to NO_2 conversion

NO_x emissions associated with combustion sources such as boilers/turbines will typically comprise approximately 90-95% nitric oxide (NO) and 5-10% NO_2 at source. The NO oxidises in the atmosphere in the presence of sunlight, ozone, and volatile organic compounds to form NO_2, which is the principal pollutant of concern with respect to environmental and health effects.

There are various techniques available for estimating the proportion of NO_x that is converted to NO_2. A 50% conversion of NO_x to NO_2 has been assumed for short term averaging periods (20 minute and 1 hour), and 70% conversion for long term averages (24 hour and annual). This approach is considered appropriate based on guidance from the United States Environmental Protection Agency (US EPA) (United States Environmental Protection Agency, Part 3, 40 CFR Part 51, 2005).

3.8 Modelled grids

A modelled receptor grid centred on the centre stack has been used with a receptor spacing of 50m to capture the worst case ground level contributions.

4 Baseline Air Quality

4.1 Overview

Ambient air quality monitoring data was obtained from the Hamriyah Free Zone Authority (HFZA). Data for one year was made available the HFZA and has used this available data to characterise the baseline conditions.

The data provided by the HFZA is considered sufficient to robustly determine existing concentrations in the study area and the use of this data is in alignment with the requirements of the IFC EHS Guidelines.

4.2 Baseline ambient air quality

The Hamriyah Free Zone Authority (HFZA) provided the project with daily averaged data from the HFZA Hamriyah air quality monitoring station for the 2017 monitoring period. Pollutants measured include PM_{10}, $PM_{2.5}$, SO_2, NO, NO_2, NO_x and CO (Table 6).

Table 6: Averaged data for the Hamriyah HFZA ambient air quality monitoring for 2017

Month	Monthly averages based on daily averaged data (µg/m³)					
	$PM_{2.5}$	PM_{10}	SO_2	NO	NO_2	NO_x	CO (mg/m³)
Jan-17	36.2	129.9	4.6	17.2	21	37.7	0.8
Feb-17	47.2	322.2	4.7	11.3	18.6	30	0.7
Mar-17	32.1	95.9	4.9	34.6	33.4	67.9	0.7
Apr-17	67.6	158.4	8.6	34.3	33.4	67.8	0.5
May-17	55.8	198.3	5.3	19.1	27.4	46.5	0.5
Jun-17	51.7	170	9.4	9.8	20.4	30.2	0.4
Jul-17	89.3	260.5	7.8	13.9	20.7	34.7	0.5
Aug-17	48.3	170.3	5.7	11.1	20.9	32	1.2
Sep-17	99.1	160.1	8.2	17.2	23.7	40.9	1.2
Oct-17	56.1	157.1	8	17.2	22.6	39.9	1
Nov-17	47.9	121	9.8	22.6	24.6	47.2	1.1
Dec-17	44.1	106.2	8.9	29	27.6	56.7	1.1
Annual Average	**56.3**	**170.8**	**7.2**	**19.8**	**24.5**	**44.3**	**0.8**

Source: Hamriyah Free Zone Authority, 2018

Based on the available data, PM_{10} concentrations exceed the respective UAE daily average standard of 150µg/m³. Although there are no applicable national standards for PM_{10} and $PM_{2.5}$ the monitored values are in exceeds of the WHO guideline values. Exceedances of the PM_{10} and $PM_{2.5}$ standards is not unexpected due to the arid environment, the close proximity to the sea and associated contribution of marine salts to the atmosphere and the presence of nearby industrial sources.

Daily and annual exceedances were not monitored for any of the other pollutants monitored (i.e. SO_2, NO_2, and CO). Considering the monitored annual mean NO_2 concentrations it can be concluded that there are unlikely to be exceedances of the national standards which are set for one hour and 24-hour averaging periods. In addition, the annual average is well below the WHO standard which is applicable in the absence of a suitable national standard.

5 Results

5.1 Stack height determination

5.1.1 Main stack

Table 7 presents the results of the stack height determination for the main stack operating on natural gas and Figure 4 presents a graph of results. The results of the stack height determination are based on one unit operating at full load continuously all year. These results have been used to determine the appropriate stack height for the project based on maximum predicted process contributions and how this changes with increased stack heights.

Modelled results indicate that building wake effects influence dispersion when the main stack height is below 70m. Figure 4 shows that, for heights above 70m, any additional improvement in ground level concentrations is small and not significant. With a stack height of 60m, the modelling indicates that building wake effects are experienced as the maximum 1-hour process contributions are 78.5μg/m^3 compared to 23.1 μg/m^3 for a 70m stack height. With a stack height of less than 60m, significant building wake effects are experienced as elevated one hour process contributions are predicted.

The results indicate that when looking at the maximum one hour impacts a stack height of 70 metres is optimum. However, considering the annual mean concentrations and the 1 hour 99.79th percentile a shorter stack of 60 metres may also be considered acceptable.

The results for the one hour 99.79th percentiles indicate that a lower stack height of 70 metres would be appropriate as the number of hours where the largest one hour concentrations are predicted is limited.

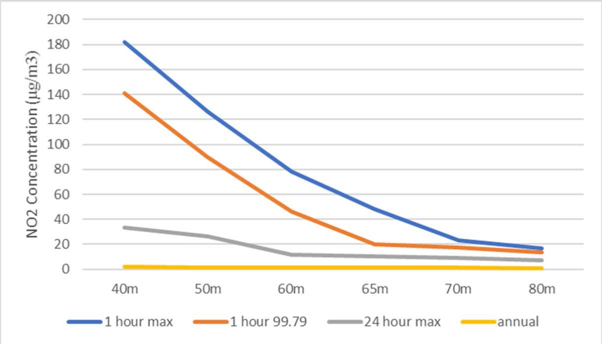
Section 5.2 presents results of both 60 and 70 metres considering all three units operating and the existing baselines concentrations for both natural gas and fuel oil firing.

Table 7: Maximum modelled NO_2 process contributions (one unit in operation) per stack height (μg/m^3)

Averaging period	Stack height						UAE standard
	40m	50m	60m	65m	70m	80m	
1-hour max	181.8	126.5	78.5	48.0	23.1	17.1	400
1 hour 99.79 percentile	141.0	89.7	46.1	20.1	17.5	13.5	400
24-hour max	33.5	26.1	11.9	10.4	9.1	7.3	150
Annual	2.0	1.6	1.3	1.2	1.1	1.0	40 (WHO standard)

Source: Mott MacDonald, 2018

Figure 4: Maximum modelled NO_2 process contributions (one unit in operation) per stack height



Source: Mot MacDonald, 2018

5.1.2 Bypass Stack

The Project is not expected to operate in open cycle for long periods of time once fully operational. However, an appropriate stack height for open cycle operation is still required to allow effective dispersion. Modelling has been undertaken with a by-pass stack height of 35m to 55m. Table 8 shows the maximum process contribution from the proposed Project and Figure 5 presents a graph of results.

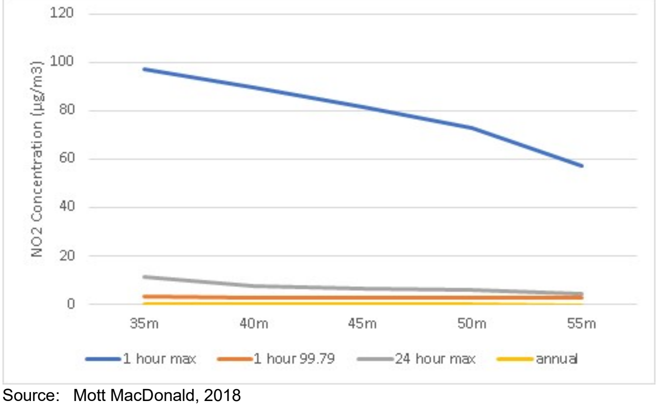
Modelled results indicate that building wake effects are having limited effects on dispersion and there is no significant reduction in maximum ground level NO_2 concentrations with increased height. Therefore. the proposed stack height of 45 metres is considered appropriate.

Table 8: Maximum modelled NO_2 process contributions (one unit in operation) per stack height (µg/m³)

Averaging period	Stack height					UAE standard
	35m	40m	45m	50m	55m	
1-hour max	97.2	89.6	81.3	72.6	57.0	400
1 hour 99.79 percentile	3.3	3.0	2.9	2.8	2.7	400
24-hour max	11.3	7.8	6.8	5.8	4.5	150
Annual	0.14	0.12	0.11	0.11	0.11	40 (WHO standard)

Source: Mott MacDonald, 2018

Figure 5: Maximum modelled NO_2 process contributions (one unit in operation) per stack height



Source: Mott MacDonald, 2018

5.2 Operational impacts

5.2.1 Main stack – natural gas

Table 9 presents the results of all three units operating continuously all year on natural gas and compares the maximum results from the modelled area for 60m and 70m stack heights.

The modelling with a 60m stack height demonstrates that, the maximum process contributions predicted based on five years of meteorological data is 127.0µg/m^3 which, is approximately 32% of the national standard and results in a predicted environmental concentration of 176.0µg/m^3 which is below 50% of the national standard (Table 9).

The results show that the 1-hour 99.79th percentile process contribution is 64.1µg/m^3 which, is approximately 16% of the national standard and results in predicted environmental concentration of 113.1µg/m^3. This indicates that the highest predicted one hour impacts would be limited to a small number of hours a year.

The maximum 24-hour process contribution concentration is approximately 22% of the daily average standard. No exceedances of the annual standard are expected as the annual process contributions are very minimal (i.e. less than 10% of the national standard).

The modelling with a 70m stack height demonstrates that, the maximum process contributions predicted based on five years of meteorological data is 60.6µg/m^3 which, is approximately 17% of the national standard and results in a predicted environmental concentration of 109.6µg/m^3 (Table 9).

The results show that the 1-hour 99.79th percentile process contribution is 49.0µg/m^3 which, is approximately 12% of the national standard and results in a predicted environmental concentration of 98.0µg/m^3. The maximum 24-hour process contribution concentration is approximately 17% of the daily standard and the predicted environmental concentration is less than 50% of the national standard.

No exceedances of the annual mean standard applied to the proposed Project are expected as the annual process contributions are less than 10% of the applicable standard.

Table 9: Modelled Ground Level Contributions from the Project – Scenario 1 (gas, 100% load) (µg/m^3)

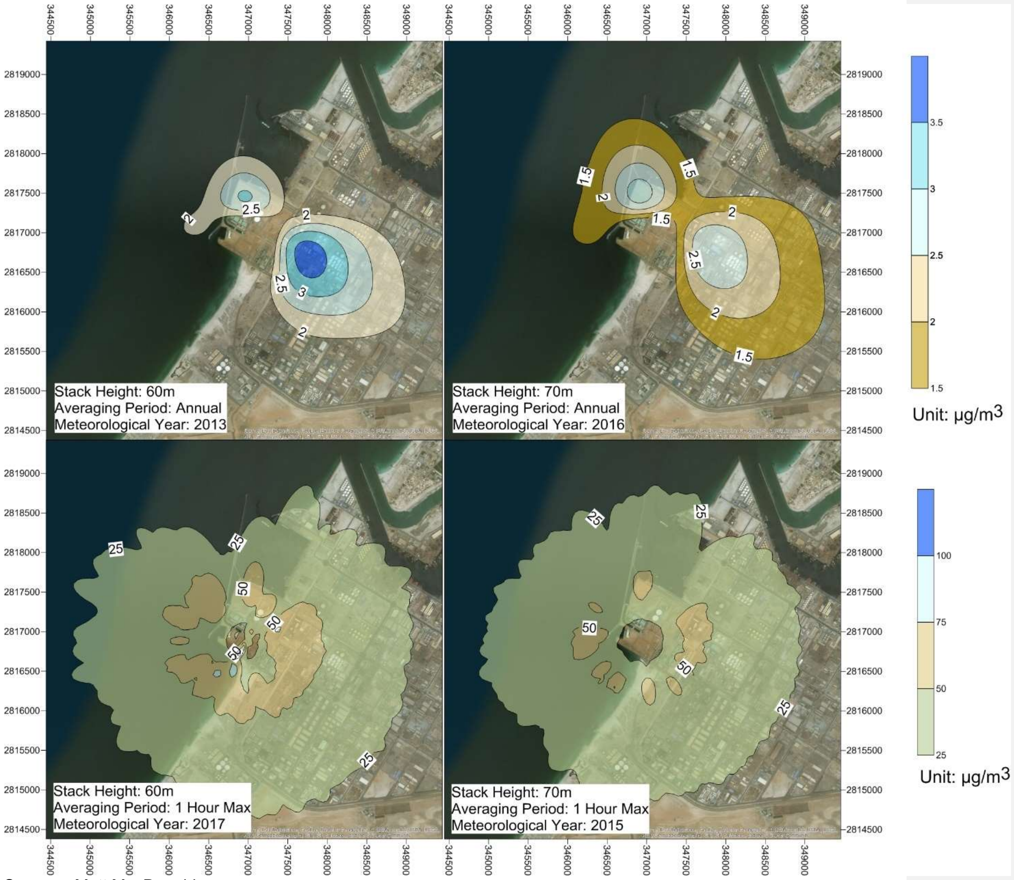
Averaging period	Process contribution per stack height		Ambient concentration	Predicted environmental concentration per stack height		UAE standards
	60m	70m		60m	70m	
1 hour max	127.0	60.6	49[(a)]	176.0	109.6	400.00
1 hour 99.79	64.1	49.0	49[(a)]	113.1	98.0	400.00
24 hour max	33.6	26.0	49[(a)]	82.6	75.0	150.00
annual	3.7	3.3	24.5	28.2	27.8	40 (WHO standard)
Note:	[(a)] The stations annual average NO_2 concentration is doubled under the precautionary principle to allow for comparison with other short-term averaged concentration data.					

Source: Mott MacDonald, 2018

Figure 6 presents contour plots for the one hour and annual mean process contributions for both 60m and 70m stack heights. The plots show that with a stack height of 60m the maximum one hour concentrations are limited to a very small area which is located over the sea where there would be no relevant human exposure.

Considering the air quality impacts, a stack height of 60m is considered appropriate.

Figure 6: One hour and annual mean contour plots



Source: Mott MacDonald

5.2.2 Main stack - fuel oil

Table 9 presents the results of all three units operating continuously all year on fuel oil and compares the maximum results from the modelled area for 60 and 70metres stack heights. Predicted annual mean concentrations have not been presented as fuel oil firing would only be used in emergency situation, and for testing purposes, and therefore would not occur for a period of a year or more.

The modelling with a 60m stack height demonstrates that, the maximum process contributions predicted based on five years of meteorological data is 280.1µg/m^3 which, is approximately 70% of the national standard and results in a predicted environmental concentration of 329.1µg/m^3 which below the national standards (Table 10). The 1-hour 99.79th percentile is considerably lower, with a process contribution of 134.2µg/m^3. This demonstrates that the highest one hour contributions are not expected to occur frequently and therefore the likelihood of fuel oil operation coinciding with the worst case meteorological conditions which would result in the highest process contributions occurring is unlikely.

The maximum 24-hour process contribution concentration is approximately 47% of the daily average standard although it is unlikely that the proposed Project would operate for 24 consecutive hours of fuel oil firing unless there was an emergency situation with gas supply.

The modelling with a 70m stack height demonstrates that, the maximum process contributions predicted based on five years of meteorological data is 156.1µg/m^3 which, is approximately 39% of the national standard and results in a predicted environmental concentration of 205.1µg/m^3 (Table 10). The 1-hour 99.79th percentile is considerably lower, with a process contribution of 106.1µg/m^3 which, is approximately 27% of the national standard and results in a predicted environmental concentration of 155.1µg/m$^{3.}$

The maximum 24-hour process contribution concentration is approximately 38% of the daily average and as with the 60m stack height it is unlikely that the proposed Project would operate for 24 consecutive hours of fuel oil firing unless there was an emergency situation with gas supply.

The predicted results for the 60 m and 70m stack heights do not change the conclusions when assessing the proposed Project when firing on natural gas and a 60m stack height is considered appropriate.

Table 10: Modelled Ground Level Contributions from the Project – Scenario 2 (Fuel oil, 100% load)

Averaging period	Process contribution per stack height		Ambient concentration	Predicted environmental concentration per stack height		UAE standards
	60m	70m		60m	70m	
1 hour max	280.1	156.1	49[(a)]	329.1	205.1	400.00
1 hour 99.79	134.2	106.1	49[(a)]	183.2	155.1	400.00
24 hour max	71.3	57.1	49[(a)]	120.3	106.1	150.00
Annual	7.1	6.3	24.5	31.6	30.8	40 (WHO standard)
Note:	[(a)] The stations annual average NO_2 concentration is doubled under the precautionary principle to allow for comparison with other short-term averaged concentration data.					

Source: Mott MacDonald, 2018

5.3 Qualitative assessment of other trace gas pollutants

5.3.1 Particulates ($PM_{2.5}$ and PM_{10})

Ambient baseline concentration of particulates within the Emirate of Sharjah are observed as exceeding the respective daily average standards. The exceedances are due to the arid environment. Based on the projects location, there are several sources of particulates in the near vicinity of the proposed Project including nearby industries, combustion emissions from vehicle traffic, mobile and fixed machinery, the Sharjah international airport, marine vessels, and exposed areas of arid land prone to wind erosion.

The project will also not lead to emissions of particulate matter. This is confirmed by the European Commission's Best Available Technique Reference (BREF) document for large combustion plants which states "The efficient combustion of gaseous fuels does not generate particulates".

Emissions of particulates when firing on fuel oil will be low as the turbine is guaranteed to meet the IFC emission guidelines for degraded airsheds. Considering fuel oil firing is expected to be for emergency use or during testing only emissions of particulates are not considered to have a significant effect on air quality.

5.3.2 Sulphur Dioxide (SO_2)

SO_2 is a gas primarily emitted from fossil fuel combustion at power plants and other industrial facilities, as well as fuel combustion in mobile sources such as locomotives, ships, and other equipment. Based on the projects location, there are several sources of SO_2 in the near vicinity of the proposed Project including nearby industries, combustion emissions from vehicle traffic, mobile and fixed machinery, the Sharjah international airport and marine vessels.

Ambient baseline concentration of SO_2 within the Emirate of Sharjah are observed as being very low and no exceedances of the standards are observed.

The natural gas will contain at most trace levels of hydrogen sulphide or sulphur and it is required that any fuel oil used during emergency periods or testing periods is required to be low sulphur. Therefore, emissions of SO_2 will be negligible and are not considered to have a significant effect on air quality.

5.3.3 Carbon monoxide (CO)

CO is a colourless, odourless, tasteless gas that is produced during incomplete combustion of any fuel like natural gas, charcoal, gasoline, kerosene, wood, gas, oil, or coal. CO is one of the most common and widely distributed air pollutants. Based on the projects location, there are several sources of CO in the near vicinity of the proposed Project including nearby industries, combustion emissions from vehicle traffic, mobile and fixed machinery, the Sharjah international airport and marine vessels.

Emissions of CO are expected to be low as high emissions are related to poor combustion and therefore will be mitigated through the efficient operation of the Project. Additionally, the relevant ambient standards for CO are significantly higher than those for NO_2 and therefore project impacts are not considered to have the potential for a significant impact.

The combustion processes will be monitored and emissions will be monitored by the proposed Projects CEMS system to monitor compliance with the guaranteed emissions levels.

5.3.4 Hydrogen sulphide (H_2S)

H_2S is a toxic, flammable gas, which has an odour of rotten eggs. H_2S occurs in the gases emanating from volcanoes, springs, swamps, and stagnant bodies of water, as well as in crude petroleum and natural gas. H_2S also is associated with municipal sewers and sewage treatment plants, and pulp and paper operations. Industrial sources of H_2S include petroleum refineries, natural gas plants, petrochemical plants, coke oven plants, food processing plants, and tanneries. Based on the projects location, there are several sources of H_2S in the near vicinity of the proposed Project including nearby industries, the storage of liquid and gaseous fossil fuels.

The natural gas used for the proposed Project will at most contain trace amounts of H_2S, as the gas will be combusted and there is not expected to be fugitive emissions contribution of H_2S is anticipated to be negligible.

5.3.5 Volatile Organic Compounds (VOCs)

VOCs are organic compounds that easily vaporise at room temperature and are colourless. VOCs are released from vehicle exhaust gases either as unburned fuels or as combustion products, and are also emitted by the evaporation of solvents and motor fuels. Based on the projects location, there are several sources of H_2S in the near vicinity of the proposed Project including nearby industries, the storage of liquid and gaseous fossil fuels, emissions from incomplete combustion from vehicle traffic, mobile and fixed machinery, the Sharjah international airport and marine vessel.

The contribution of VOC is anticipated to be negligible as the combustion processes will be carefully monitored so ensure complete combustion.

6 Conclusion

The stack height determination undertaken has demonstrated that main stack height of 60m and a by-pass stack of 45m are appropriate and allow effective dispersion of pollutants from the proposed Project and don not result in exceedances of the national air quality standards.

7 References

1. European Union (November 2010), *"Directive on Industrial Emissions (Integrated Pollution Prevention and Control) (Recast)",* Directive 2010/75/EU Official Journal, vol. 334, pp. 0017-0119.
2. European Commission (2017), *"Reference Document on Best Available Techniques for Large Combustion Plants"* (Integrated Pollution Prevention and Control) (BREF), EUR 28836 EN
3. The International Finance Corporation (IFC) (2007). 'Environmental Health and Safety (EHS) Guidelines for Thermal Power Plants.'
4. Commission Implementing Decision (EU) 2017/1442 of 31 July 2017, Establishing Best Available Techniques (BAT) Conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for large combustion plants
5. Federal Competitiveness and Statistics Authority (FCSA): Statics by Subject (n.d.). Retrieved May 21, 2017, from http://fcsa.gov.ae/en-us/Pages/Statistics/Statistics-by-Subject.aspx

mottmac.com