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Kemps Creek Data Centre

Nitrogen Dioxide Monitoring Procedure

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Final Authority

This report must be regarded as draft until the above study components have been each marked as final, and the document has been signed and dated below. A draft report is a working document, is issued without prejudice and is subject to change.



G. Graham

8 April 2025

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1. INTRODUCTION

ARUP Pty Ltd (ARUP) has commissioned Northstar Air Quality Ltd Pty (Northstar) to prepare a Nitrogen Dioxide Monitoring Procedure (NDMP) and Back-up Generator Incident Report (BGIR) for the operation of the first two stages of the data centre (the Project) situated at 706-769 Mamre Road, Kemps Creek NSW (the Project Site) as required to comply with the Conditions of Approval for the Project (SSD-10101987).

Specifically, the NDMP and BGIR for this report will address the operations for Stage 1 (SYD05) and Stage 2 (SYD06). The NDMP and BGIR will be updated to include Stage 3 (SYD07) following the construction and operation of that stage in accordance with Condition of Approval A11 (refer Section 1.1.1).

Please refer to Appendix A for common abbreviations and terminology used in this report.

1.1. Conditions of Approval

This report has been prepared to address the requirements in Conditions of Approval B18 and C13. As mentioned, these have been addressed for Stage 1 (SYD05) and Stage 2 (SYD06) of the Project in accordance with Condition of Approval A11.

1.1.1. Staging, Combining and Updating Strategies, Plans or Programs

Condition of Approval (CoA) A11 of SSD-10101987 provide the requirements for staging, combining and updating strategies, plans or programs:

Staging, Combining and Updating Strategies, Plans or Programs

A11 With the approval of the Planning Secretary, the Applicant may:

- (a) prepare and submit any strategy, plan or program required by this consent on a staged basis (if a clear description is provided as to the specific stage and scope of the development to which the strategy, plan or program applies, the relationship of the stage to any future stages and the trigger for updating the strategy, plan or program);*
- (b) combine any strategy, plan or program required by this consent (if a clear relationship is demonstrated between the strategies, plans or programs that are proposed to be combined); and*
- (c) update any strategy, plan or program required by this consent (to ensure the strategies, plans and programs required under this consent are updated on a regular basis and incorporate additional measures or amendments to improve the environmental performance of the development).*

1.1.2. Nitrogen Dioxide Monitoring Procedure (NDMP)

CoA B18 provides the requirements for the development of an NDMP:

Nitrogen Dioxide Monitoring Procedure

B18 Prior to the commencement of operation of the development, the Applicant must prepare a Nitrogen Dioxide Monitoring Procedure (NDMP) to the satisfaction of the Planning Secretary. The NDMP must:

- (a) be prepared by a suitably qualified and experienced person(s);*
- (b) identify the contemporary impact assessment criteria for nitrogen dioxide emissions;*
- (c) describe the control measures which would be implemented to minimise the duration of each power outage event;*
- (d) outline the monitoring procedure which would be implemented during each power outage event, in accordance with the most recent version of the Approved Methods for the sampling and analysis of air pollutants in NSW (EPA, 2022); and*
- (e) describe the management actions which would be taken to address any exceedances of the impact assessment criteria identified in condition B18(b)*

1.1.3. Back-up Generator Incident Reporting (BGIR)

CoA C13 provides the requirements for the 'Back-up Generator Incident Report':

Back-up Generator Incident Reporting

C13. Within 30 days of the back-up generator system being used to power the development during a power outage event (or as otherwise agreed to in writing by the Planning Secretary), the Applicant must prepare and submit a Back-up Generator Incident Report for the development to the satisfaction of the Planning Secretary. The report must include:

- (a) details regarding the:*
 - (i) date and time of the power outage event;*
 - (ii) total number of back-up generators used to power the development;*
 - (iii) total number of hours the back-up generators were operated for;*
 - (iv) total quantity of diesel fuel used by the back-up generators; and*
 - (v) total amount of electricity produced by the back-up generators;*
- (b) if relevant, confirmation regarding whether neighbouring properties were made aware that the development's back-up generator system was operating (see condition B20)*
- (c) an assessment of any air quality impacts resulting from the operation of the back-up generators; and*

(d) *an assessment and consideration of any additional measures which could be implemented to reduce future air quality impacts.*

Note: Additional measures to reduce air quality impacts could include, but are not limited to, measures to reduce the likelihood of the back-up generators being operated and retrofitting of emission controls to the back-up generators.

1.2. Reporting Requirements

The requirements are outlined in Section 1.1.2 and 1.1.3. Table 1 below provides a summary of where each MCoA requirement has been addressed in this document.

Table 1 Reporting Requirements

MCoA Condition	Requirement	Section(s)
B18	Nitrogen Dioxide Monitoring Procedure Prior to the commencement of operation of the development, the Applicant must prepare a Nitrogen Dioxide Monitoring Procedure (NDMP) to the satisfaction of the Planning Secretary. The NDMP must:	2
(a)	be prepared by a suitably qualified and experienced person(s);	2.1
(b)	identify the contemporary impact assessment criteria for nitrogen dioxide emissions;	2.2
(c)	describe the control measures which would be implemented to minimise the duration of each power outage event;	2.3
(d)	outline the monitoring procedure which would be implemented during each power outage event, in accordance with the most recent version of the Approved Methods for the sampling and analysis of air pollutants in NSW (EPA, 2022); and	2.4
(e)	describe the management actions which would be taken to address any exceedances of the impact assessment criteria identified in condition B18(b)	2.5 Appendix B
C13	Back-up Generator Incident Reporting Within 30 days of the back-up generator system being used to power the development during a power outage event (or as otherwise agreed to in writing by the Planning Secretary), the Applicant must prepare and submit a Back-up Generator Incident Report for the development to the satisfaction of the Planning Secretary. The report must include:	3
(a)	details regarding the: (i) date and time of the power outage event; (ii) total number of back-up generators used to power the development; (iii) total number of hours the back-up generators were operated for; (iv) total quantity of diesel fuel used by the back-up generators; and (v) total amount of electricity produced by the back-up generators;	3.1
(b)	if relevant, confirmation regarding whether neighbouring properties were made aware that the development's back-up generator system was operating (see condition B20);	3.2

MCoA Condition	Requirement	Section(s)
(c)	an assessment of any air quality impacts resulting from the operation of the back-up generators; and	3.3
(d)	an assessment and consideration of any additional measures which could be implemented to reduce future air quality impacts.	3.4 Appendix B

1.3. Agreed Scope

For the objectives of Condition B18 and C13 to be met, a Predictive Emission Monitoring System (PEMS) has been proposed to inform emissions from the use of back-up generators and using best-practice dispersion modelling techniques to predict the NO₂ impacts that may occur during a specific outage event.

This approach has been agreed by the NSW Department of Planning, Housing and Infrastructure (DPHI) and forms the basis of the NDMP.

2. NITROGEN DIOXIDE MONITORING PROCEDURE (NDMP)

2.1. Authority (CoA B18[a])

CoA B18(a) requires that the NDMP is prepared by a suitably qualified and experienced person. This NDMP and the associated components of the BGIR have been prepared by Northstar Air Quality Pty Ltd (ABN: 52 609 741 728). The principal authors of this document, including the NDMP and the supporting BGIR, are Certified Air Quality Professionals (CAQP) as administered by the Clean Air Society of Australia and New Zealand (CASANZ).

2.2. Impact Assessment Criteria for Nitrogen Dioxide (CoA B18[b])

CoA B18(b) requires the identification of the contemporary nitrogen dioxide (NO₂) criteria. These criteria are specified in the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (the Approved Methods (NSW EPA, 2022)), which are the defining ambient air quality criteria for NSW. The standards adopted to protect members of the community from health impacts in NSW for NO₂ are presented in Table 2.

Table 2 NSW EPA nitrogen dioxide impact assessment criteria

Pollutant	Averaging period	Criterion $\mu\text{g}\cdot\text{m}^{-3}$ (a)
Nitrogen dioxide (NO ₂)	1 hour	164
	Annual	31

Notes: (a): micrograms per cubic metre of air

2.3. Nitrogen Dioxide Control Measures (CoA B18[c])

2.3.1. Controls to Minimise Nitrogen Dioxide Emissions

Critically, the potential for NO₂ emissions is linked to the operation of the back-up generators. As the frequency and duration of power outage events is highly disruptive to the operation of the datacentre, the Proponent has embedded multiple layers of controls to manage this operational risk. It is not in the business interest of the proponent to run generators more frequently or for longer duration than is absolutely required.

The proponent is a Global datacentre operator with multiple datacentres worldwide. They are at the forefront of datacentre design and share experience across operational teams through training and standardised procedures to minimise downtime during power outage events.

In the event of a power outage event, the proponent relies upon the training of its 24-hr operational staff and on-call contractors to manage the duration of the power outage event. All datacentres have standard operating procedures which prompt immediate contact with the Electricity Service Provider.

The datacentre is critical infrastructure, requiring uninterrupted power 24/7 to provide services to key government and private clients operations that the community relies on to function.

Multiple levels of redundancy have been designed into the datacentre to manage the frequency and duration of power outages. Critically, parallel power feeders are provided on different areas of the substation and different switchboards to mitigate against failure.

There is advanced control programming to ensure that the back-up generators will only operate when required (i.e. in the event of a power outage event and for routine maintenance testing).

This PEM system described in this document is an advanced and practical solution to understand the impact of emissions from the operation of the generators during a power outage event.

2.3.2. Duration of Power Outage Events

The risk of a power outage event occurring at the Project Site is low. To predict the likelihood of a power outage event, the reliability of the power network was considered against the latest information supplied by Endeavour Energy regarding the Distribution Annual Planning Report (DAPR) (Endeavour Energy, 2023).

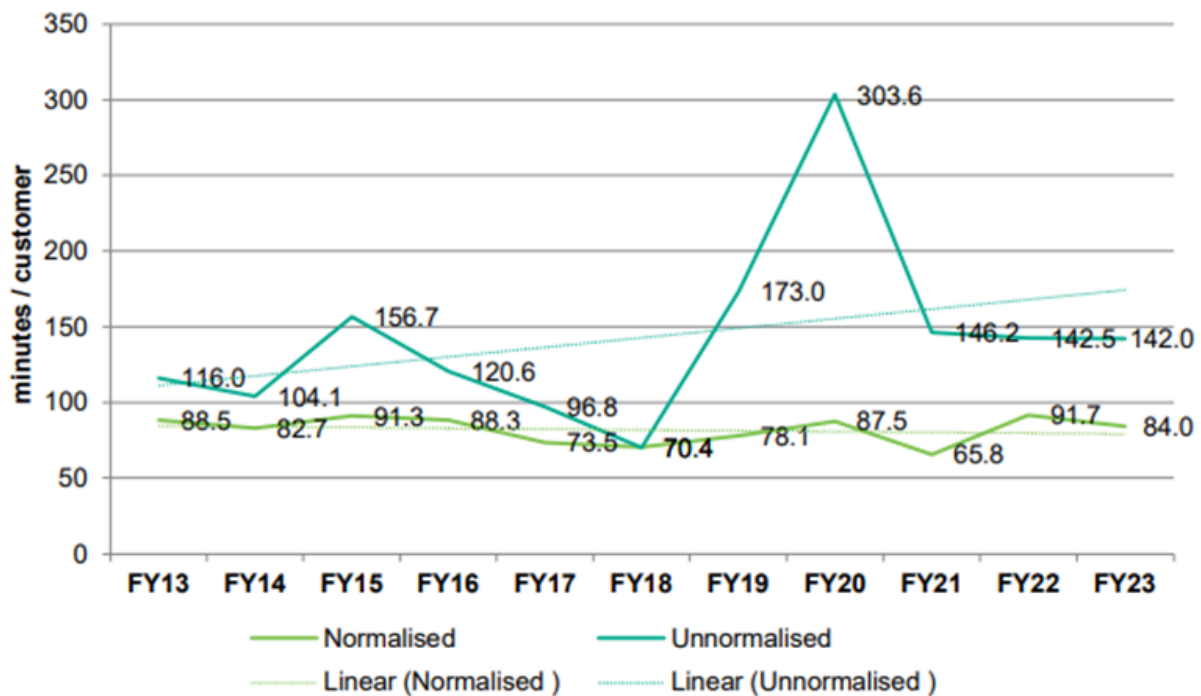
Based on the DAPR (Endeavour Energy, 2023) the average unplanned outage duration per year per customer from 2013 to 2023 equates to approximately 74.7 minutes, although exact duration of power outage events requiring standby generators cannot be determined.

Correspondingly, the likelihood of power interruptions occurring is approximately 0.014 % of the time per year ($74.7 / (8\,760 \times 60)$) or have a probability (p) of $p=0.00014$.

Over the period 2013 to 2023 the maximum unplanned outage duration per year per customer was 91.7 minutes, which would equate to a probability (p) of ($91.7 / (8\,760 \times 60)$) of $p=0.00017$.

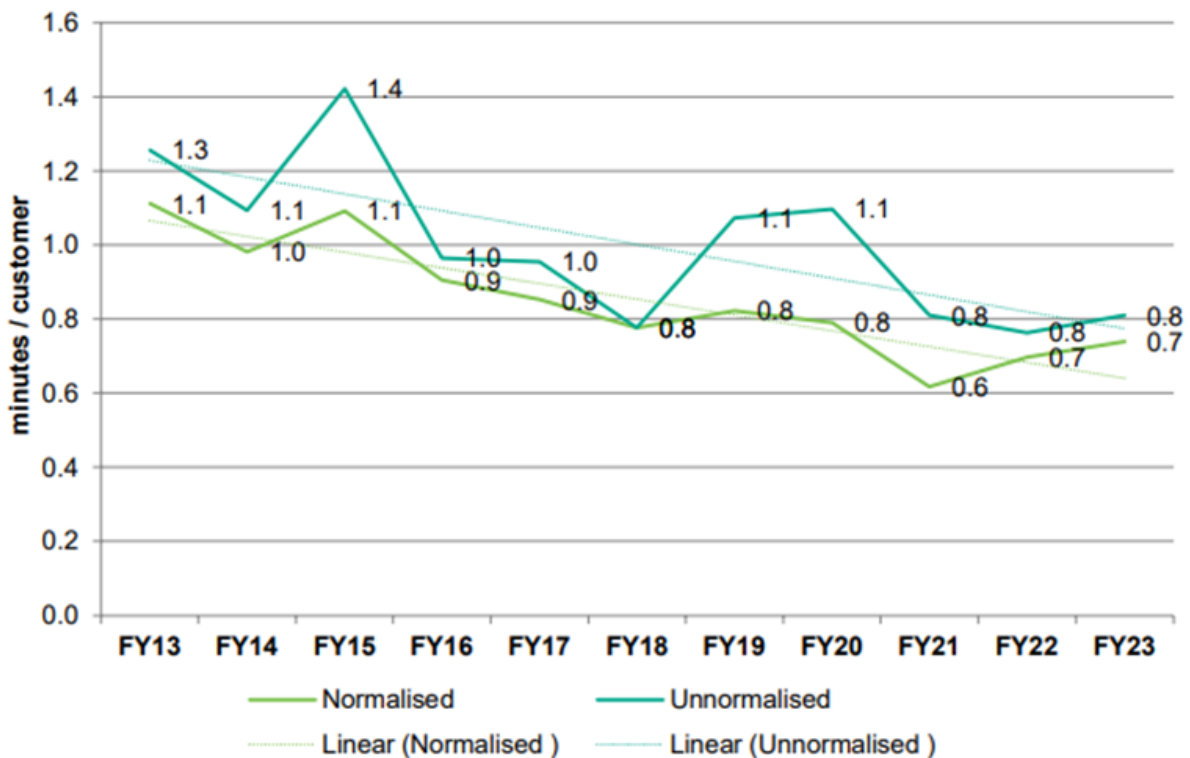
Figure 1 depicts the trends regarding system average interruption duration index (SAIDI, in minutes) and presents the system average interruption frequency index (SAIFI, interruptions per customer) over an eleven financial-year period from 2012/2013 to 2022/2023.

Figure 1 Endeavour Energy SAIDI Performance Information



Source: (Endeavour Energy, 2023)

Figure 2 Endeavour Energy SAIFI Performance Information



Source: (Endeavour Energy, 2023)

2.3.3. Other Controls

CoA C13(d) outlines the requirement for an assessment of additional measures that could be implemented as part of the Project to reduce the potential of future air quality impacts. A summary of how the assessment has been performed is provided in Section 3.4, while the full assessment is provided in Appendix B.

2.4. Nitrogen Dioxide Monitoring Procedure (CoA B18[d])

The approach to monitoring NO_x emissions from the back-up emergency generators is to perform a NATA-Accredited program of emissions monitoring during routine testing at the generator discharge stacks to measure generator performance during the operational performance testing schedule. The measurement of generator performance will demonstrate compliance with Condition B18(d), and also provide inputs to the BGIR, and as triggers for additional controls, as required in Condition B18(e).

Over time, that actual source-specific monitoring data will be used to replace specification data in a dispersion model, which creates the source ⇒ pathway ⇒ receptor (SPR) linkage from actual generator performance to impacts at receptors.

2.4.1. Testing Procedure

The emission testing schedule outlined in Table 3 will be sequentially performed on generators during the operational performance testing program.

There is limited potential for emissions testing due to (a) the operational testing program performed by the operator; and (b) a driver to reduce the number of operational hours per year to minimise air emission loads.

To facilitate the required emissions testing within the constraints outlined above, it is proposed to perform the NO_x emissions testing for less than the 1-hour duration specified in the Approved Methods (NSW EPA, 2022b), and the justification for this is:

- **Limited availability for testing for the 1-hour duration.** The annual operational testing schedule allows for one test per year for each generator operating at 100 % load for a 1-hour duration.
- **Measurement of realistic emission loads during emergency power generation.** The proponent has advised that during an emergency power outage event, the generators would not be operated at 100 % load. It is advised that a more realistic operating load during a power outage event would be around 70 % load, which is the upper bound of the target range during quarterly testing (see Figure 5). This would mean that quarterly testing represents a more representative load for the testing than reliance upon the annual 100 % load.
- **Ability to generate NO_x emission curves.** Emissions Testing during the quarterly testing (30 % to 70 % load) and annual testing (100 % load) would facilitate the derivation of emissions curves for

the generator stock. An example NO_x emissions curve derived from the technical specification documents for the COLO engine is provided in Figure 3 below. It is an objective of the NDMP to validate this emission curve with actual site-specific emissions data.

- Stability of emissions.** It is considered likely (although undemonstrated at the time of preparing the NDMP) that the emissions from a generator operating at a constant load would be very stable. The purpose of the 1-hour testing in the Approved Methods is to allow for inherent variability in emissions, either due to a batch process or emissions from combustion sources that will naturally vary over time as the feedstock is consumed. Diesel-fuelled generators are designed to provide very stable electrical output, as peaks / troughs in output will have significant impact on plant and machinery relying upon that power. The diesel consumption rate is constant at a stabilised operating load, and correspondingly the NO_x emissions will also be stable. It is considered reasonable to assume that a 30-minute test would derive reliable data to represent generator emissions and correspondingly the NDMP would derogate from the 1-hour test prescribed in the Approved Methods.

Figure 3 Example NO_x curve (C175-20 generator specification)

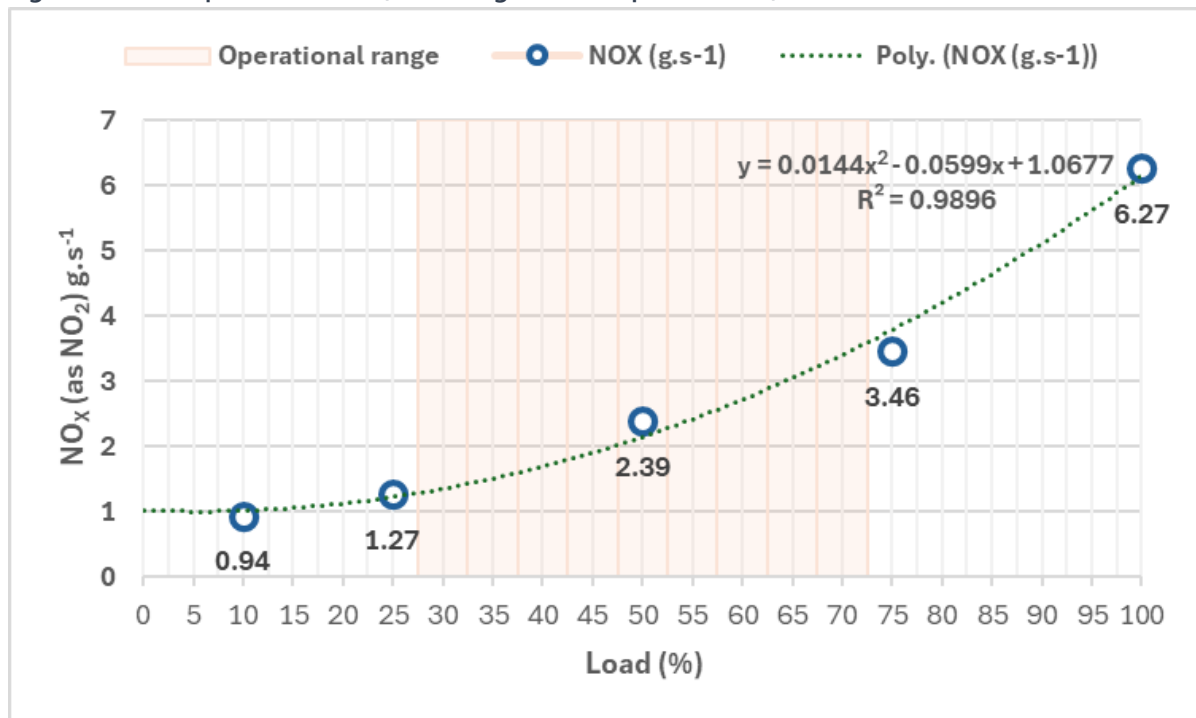


Table 3 Generator emission testing schedule

Operation	Parameter	Test Method	Duration
Operating load (typically 30 % to 70 %)	Velocity, volumetric flow, temperature	TM-2	Simultaneous during testing period
	Moisture	TM-22	30-mins / 1-hour (depending upon quarterly or annual testing)
	Nitrogen dioxide (NO ₂) or nitric oxide (NO) (NO _x expressed as NO ₂)	TM-11	30-mins / 1-hour (depending upon quarterly or annual testing)
Cold start to operating load cycle	Velocity, volumetric flow, temperature	TM-2	Simultaneous during testing period
	Moisture	TM-22	Cycle duration (expected to be < 2 mins)
	Nitrogen dioxide (NO ₂) or nitric oxide (NO) (NO _x expressed as NO ₂)	TM-11	Cycle duration (expected to be < 2 mins)

Emissions testing will be performed from sampling ports installed on the discharge stacks of each generator, located between the point of emission output from the generator and prior to the point of discharge to atmosphere, and positioned in accordance with AS/NZS 4323.1 (as far as practicable). The maintenance testing utilised during the air quality impact assessment (AQIA) (ARUP, 2021) is reproduced as Table 4..

It is noted that the estimated operating time (7 810 mins per year, or 131 total hours per year) includes the bi-monthly 0 % load tests (i.e. testing during no power generation). With reference to the Protection of the Environment Operations (Clean Air) Regulation 2022, Part 5, Division 6, Clause 73, the limitation of operation for emergency power generation is limited to 200 hours per year. In actuality, the period of power generation during testing is 7 810 mins per year, or 131 total hours per year, excluding the testing under 0 % load (refer to the right-hand side column in Table 4).

Further to the above, the following emissions testing plan would be implemented:

- Emissions testing: perform the cold start to operating load test (assumed <2 min) and then continue with the testing for the duration of the 30-minute test (in the case of quarterly testing) or 60-minute test (in the case of annual testing).

The annual emissions testing commitment would be to complete a minimum of 11 generator emission tests per year (approximately 25 % of the generator stock), until such time that 41 emission tests have been performed. It is not envisaged that it would be necessary to test each of the installed 41 no generators to avoid unnecessary provision of access platforms / ports etc, but a minimum requirement of 50 % of all generators would be tested.

The emission tests would also cover the range of operational loads, including 30 % load (minimum operation load), 70 % load (maximum operation load) and 100 % load (maximum capacity) to derive emission curves (i.e. load (%) versus measured value) for:

- Temperature (as °C);
- Flow (as $\text{Am}^3\cdot\text{s}^{-1}$ and $\text{Nm}^3\cdot\text{s}^{-1}$);
- Water vapour (as % vol);
- Oxygen (% vol);
- NO_x (as $\text{mg}\cdot\text{Nm}^{-3}$ and $\text{g}\cdot\text{s}^{-1}$); and
- NO_2 (as $\text{mg}\cdot\text{Nm}^{-3}$ and $\text{g}\cdot\text{s}^{-1}$)

Upon completion of the emission tests and the preparation of emission curves the NDMP (i.e. the monitoring commitment) would cease and the BGIR would wholly rely upon the derived source-specific emission curves.

Table 4 Maintenance testing schedule

Month	Test	Duration (min)		Colo Gen Testing		Admin Gen Testing		Total Gens Tested	Total Mins	Total Operational Mins ^(b)
		Run	Cooldown	Number of tests	Gens run per test ^(a)	Number of tests	Gens run per test ^(a)			
1	Bi-monthly, no load	10	0	20	2	1	1	41	210	0
2	No test							0	0	0
3	Quarterly (nominally 30-70 % load)	30	5	40	1	1	1	41	1 435	1 435
4	Bi-monthly, no load	10	0	20	2	1	1	41	210	0
5	No test							0	0	0
6	Quarterly (nominally 30-70 % load)	30	5	40	1	1	1	41	1 435	1 435
7	Bi-monthly, no load	10	0	20	2	1	1	41	210	0
8	No test							0	0	0
9	Quarterly (nominally 30-70 % load)	30	5	40	1	1	1	41	1 435	1 435
10	Bi-monthly, no load	10	0	20	2	1	1	41	210	0
11	No test							0	0	0
12	Annual, 100 % load	60	5	40	1	1	1	41	2 665	2 665
Total minutes per year									7 810	6 970
Total hours per year									130.2	116.2

Notes: (a) Data centre generator testing will be conducted separately from the admin generator testing

(b) Excluding testing under 0 % load i.e. testing during no power generation (refer below)

2.4.2. Utilisation of Data in PEMS

The emissions data will be utilised in a Predictive Emission Monitoring System (PEMS) as a component of the BGIR, so that the potential NO₂ impacts resulting from emissions from specific generators at surrounding land uses can be predicted under time-specific conditions (i.e. the period of a power outage).

Specifically, the PEMS is a predictive modelling tool using 5 years of meteorological data (43 800 hourly predictions) compiled into a database that can be interrogated to return data for a specific set of parameters, such as:

- Generators operating during the outage (affects total emission to air);
- Meteorological conditions during the outage (affects direction and distance of dispersion);
- Time of day during the power outage (affects vertical dispersion); and
- Season (to account for seasonal weather patterns).

The PEMS will initially utilise emissions data from the generator specifications (used in the AQIA), and over time that will be supplemented with the data obtained from NATA-accredited monitoring during the routine testing, as outlined above. The proposed PEMS methodology is outlined in Section 3 which also outlines the procedure to be implemented following an actual power outage event to provide the required input to the BGIR to comply with Condition C13.

2.5. Management Actions to Manage Exceedances (CoA B18[e])

The Project has considered proactive management practices to reduce the risk of NO₂ exceedances resulting from the operation of the back-up generators including:

- Selecting generator models with low emission rates; and
- Designing discharge points to be directed above roof height to enhance plume dispersion and reduce the effects of building downwash.

Additionally, the utilisation of the PEMS (refer Section 2.4) will provide the tool for the Project to predict how emissions from the back-up generators are dispersed in the local area surrounding the Project site during a power outage event under specific conditions during the power outage event.

In the event that exceedances are predicted to occur at surrounding land uses, a number of additional management measures are provided in Section 3.3 that could be implemented at the Project site to reduce the risk of adverse NO₂ impacts at sensitive receptor locations.

3. BACK-UP-GENERATOR INDICENT REPORTING (BGIR)

CoA C13 requires that

“Within 30 days of the back-up generator system being used to power the development during a power outage event (or as otherwise agreed to in writing by the Planning Secretary), the Applicant must prepare and submit a Back-up Generator Incident Report for the development to the satisfaction of the Planning Secretary”

The following sections describe the how the requirements of the CoA C13 are achieved.

3.1. Reporting Requirements (CoA C13[a])

CoA C13(a)(i)-(iv) provides the information required to be provided by the Applicant within a BGIR during a power outage event including:

- Date and time of the power outage event;
- Total number of back-up generators used to power the development;
- Total number of hours the back-up generators were operated for;
- Total quantity of diesel fuel used by the back-up generators; and
- Total amount of electricity produced by the back-up generators.

The PEMS has functionality to output this information in the BGIR (see Section 3.3). Figure 5 presents an example of the output that is generated using the PEMS to inform the BGIR.

3.2. Neighbouring Properties (CoA C13[b])

The final assessment report by the Department of Planning and Environment (DPE, now DPHI) for SSD 10101987 recommended a condition of consent requiring the Applicant to prepare a Power Outage Notification Protocol (PONP) prior to operation to inform neighbouring properties of emergency operations in the event of a power outage. This would ensure that neighbour properties were made aware that the development's back-up generator system was operating.

3.3. Air Quality Assessment (CoA C13[c])

3.3.1. Overview

CoA C13(c) requires an assessment of air quality impacts during a power outage event to be performed and summarised in a BGIR. The utilisation of the PEMS as introduced in Section 2.4 will provide the opportunity

to identify whether there was the potential for NO₂ impacts to be experienced at surrounding land uses under specific conditions representative of those during the power outage event.

The NDMP is implemented to measure emission parameters (see Table 6 and Table 7) during controlled and planned testing of generator performance. That measured data (see Table 6 and Table 7) would subsequently be used to update the modelling input parameters for the PEMS on a periodic basis so that, over time, the data in the PEMS is derived from source-specific measurements rather than specification data.

Table 5 presents a succinct summary of the modelling performed to generate the data used in the PEMS, while Figure 4 presents the sensitive receptor locations used to predict potential NO₂ impacts.

Table 5 PEMS inputs and data extraction

Data source	Comments	
Inputs		
Meteorology	AERMOD-ready meteorological data generated using TAPM and AERMET	5 years (43 824 hours)
Emissions	Equipment provider data (as adopted in the AQIA)	41 generators
Receptors	In all directions and distances from the Project Site	320 receptors
Dispersion Modelling	AERMOD	26 031 456 hourly NO _x predictions stored in a database
Other	• Date and time of outage; • Number of generators operating during the outage; • Number of hours operating; • Quantity of diesel used; and • Electricity generated.	As required by CoA C13(a)
Database		
Data extraction	1-hour average NO ₂ concentrations at surrounding land uses. Dataset filterable by: • Meteorological conditions (wind speed, wind direction, temperature); • Time of year (hour, month, season); and • Generators operating during outage.	Database queried by user
Reporting		
Background air quality	Background NO ₂ and O ₃ conditions	User defined
NO to NO ₂ conversion	NSW EPA Approved Methods 1-3	All outputs provided
Summary	BGIR summary	Formatted report

3.3.2. Emission Assumptions

Atmospheric dispersion modelling of the NO_x emissions from each of the 62 no generators has been performed based upon the following assumptions as outlined in Table 6 and Table 7 for the admin generator and data centre generators respectively.

Table 6 Summary of emission estimation (admin generators)

Parameter	Units	Value	Data source	Notes
Number	no.	2	AQIA	
Stack height	m AGL	20	AQIA	
Stack diameter	m ID	0.203	AQIA	
Discharge temperature	°C	571.1	AQIA	
Volumetric flow rate	Am ³ ·s ⁻¹	1.71	AQIA	
Discharge velocity	m·s ⁻¹	52.8	Calculated	Based upon the presented values
NO _x ER	g·s ⁻¹	1.484	Specification	

Table 7 Summary of emission estimation (data centre generators)

Parameter	Units	Value	Data source	Notes
Number	no.	60	AQIA	
Stack height	m AGL	20	AQIA	
Stack diameter	m ID	0.500	AQIA	
Discharge temperature	°C	460.7	Specification	Exhaust Stack Temp at 3 120 ekW
Volumetric flow rate	Am ³ ·s ⁻¹	11.74	AQIA	
Discharge velocity	m·s ⁻¹	59.8	Calculated	Based upon the presented values
NO _x ER	g·s ⁻¹	6.274	Specification	

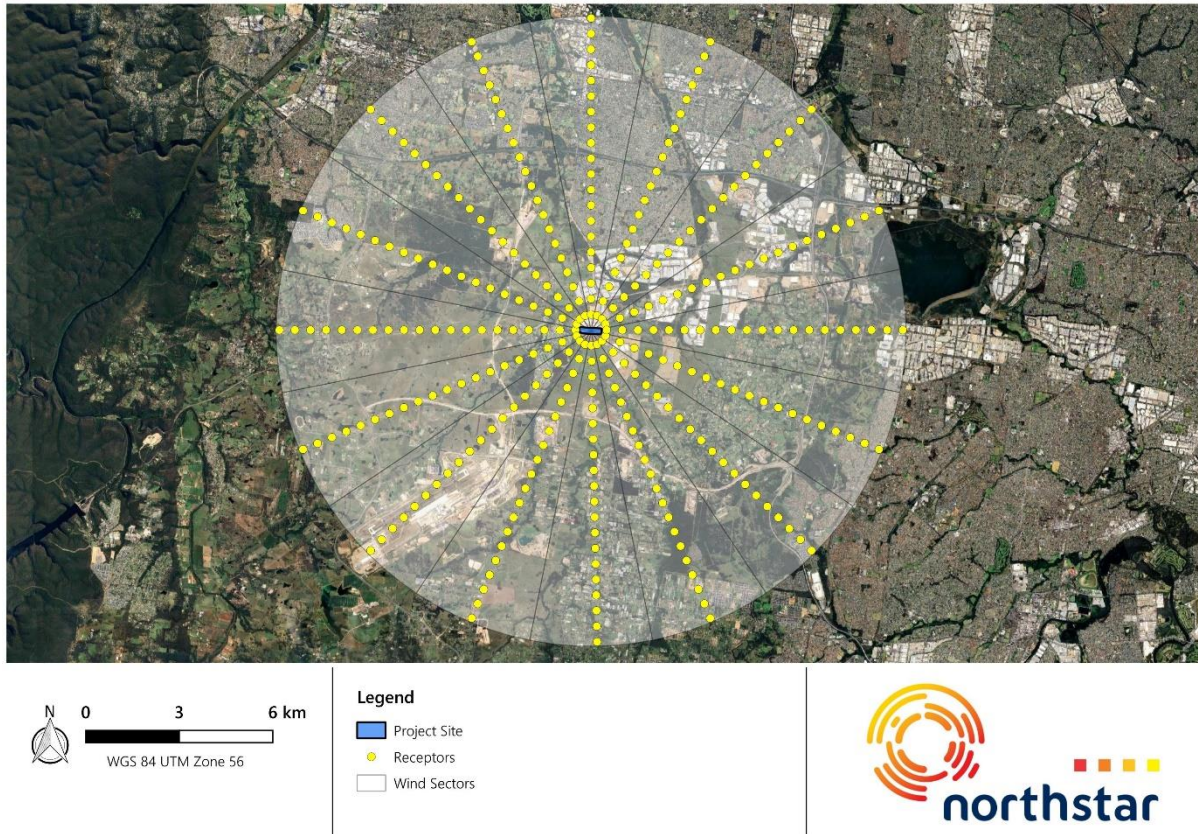
3.3.3. Dispersion Modelling Database

Atmospheric dispersion has been performed for a full 5-year meteorological period (5 × 8 760 hours, plus additional day for leap year = 43 824 hours). The dispersion modelling has been performed in accordance with the Approved Methods (NSW EPA, 2022) including building downwash utilising BPIP-Prime, to predict hourly NO_x concentrations at each receptor location. That modelling provides over 26 million data points which are held within a database (due to size restrictions). That database can then be interrogated to 'filter' the results by generator and by various prevailing conditions (see Section 3.3.5).

3.3.4. Receptors

To facilitate reporting, the utilised 320 receptors are grouped into 16 vector-specific groupings. An example of which is provided in illustrated in Figure 4.

Figure 4 Sensitive receptor groups



Source: Northstar

3.3.5. Database Interrogation

In the event of a power outage event that requires a BGIR, the PEMS tool allows the user to interrogate (i.e. 'filter') the database for outage-specific conditions, including:

- Time of day (start, end), which accounts for variations in mixing height;
- Month, which accounts for variations in seasonal conditions); and
- Prevailing meteorology, including:
 - Wind direction (range, by cardinal wind vector);
 - Wind speed (range, in units of km·hr⁻¹); and
 - Ambient temperature (range, in units of °C).

Meteorological conditions are defined by the user in units accessible from the online records maintained by the Bureau of Meteorology (BoM). An example of the dataset at St Marys automatic weather station (AWS)¹ is presented in Figure 5, which provides wind direction by cardinal vector, wind speed (km·hr⁻¹) and temperature (°C) to minimise any transcription errors.

Figure 5 Example background meteorology dataset accessed for user-defined data

Latest Weather Observations for Horsley Park													
IDN60901													
Issued at 3:01 pm EDT Tuesday 29 October 2024 (issued every 10 minutes, with the page automatically refreshed every 10 minutes)													
About weather observations Map of Sydney area stations Latest observations for Sydney area Other Formats													
Station Details ID: 067119 Name: HORSLEY PARK EQUESTRIAN CENTRE AWS Lat: -33.85 Lon: 150.86 Height: 100.0 m Data from the previous 72 hours. See also: Recent months at Horsley Park													
Date/Time EDT	Temp °C	App Temp °C	Dew Point °C	Rel Hum %	Delta-T °C	Wind				Press QNH hPa	Press MSL hPa	Rain since Sam mm	
						Dir	Spd km/h	Gust km/h	Spd kts	Gust kts			
29/03:00pm	24.6	23.6	9.0	37	8.5	ESE	4	9	2	5	-	-	0.0
29/02:30pm	24.2	22.8	9.4	39	8.1	NE	7	11	4	6	-	-	0.0
29/02:00pm	23.6	22.5	8.5	38	8.1	NNW	4	9	2	5	-	-	0.0
29/01:30pm	22.9	21.1	9.3	42	7.4	W	9	19	5	10	-	-	0.0
29/01:00pm	22.9	21.8	10.0	44	7.1	NW	6	15	3	8	-	-	0.0
29/12:30pm	22.7	21.3	10.8	47	6.6	NNW	9	15	5	8	-	-	0.0
29/12:00pm	20.5	18.3	9.4	49	5.9	NNW	11	17	6	9	-	-	0.0
29/11:30am	21.4	19.9	10.6	50	5.9	NNW	9	15	5	8	-	-	0.0
29/11:00am	19.9	18.7	10.3	54	5.2	NW	7	19	4	10	-	-	0.0
29/10:30am	19.1	18.0	10.6	58	4.6	NW	7	15	4	8	-	-	0.0
29/10:00am	18.9	17.4	10.7	59	4.5	NW	9	17	5	9	-	-	0.0
29/09:30am	18.2	17.5	11.3	64	3.8	NW	6	15	3	8	-	-	0.0
29/09:00am	17.3	16.2	10.7	65	3.5	NNW	7	9	4	5	-	-	0.0
29/08:30am	16.6	16.6	11.3	71	2.9	NW	2	7	1	4	-	-	0.0
29/08:00am	16.9	16.8	12.2	74	2.6	WSW	4	7	2	4	-	-	0.0
29/07:30am	16.1	16.1	12.3	78	2.1	SW	4	7	2	4	-	-	0.0
29/07:00am	15.2	15.2	12.3	83	1.6	SSW	4	6	2	3	-	-	0.0
29/06:30am	15.1	15.0	12.1	82	1.6	SW	4	4	2	2	-	-	0.0
29/06:00am	15.0	14.9	12.1	83	1.6	SSW	4	6	2	3	-	-	0.0
29/05:30am	15.0	14.9	12.0	82	1.6	SW	4	6	2	3	-	-	0.0
29/05:00am	15.0	14.8	11.8	81	1.7	SW	4	6	2	3	-	-	0.0
29/04:30am	15.1	15.3	11.7	80	1.8	WSW	2	4	1	2	-	-	0.0
29/04:00am	15.2	15.7	11.6	79	1.9	CALM	0	0	0	0	-	-	0.0
29/03:30am	15.2	15.6	11.4	78	2.0	CALM	0	0	0	0	-	-	0.0
29/03:00am	15.3	15.4	11.5	78	2.1	SW	2	4	1	2	-	-	0.0
29/02:30am	15.3	15.7	11.3	77	2.2	CALM	0	2	0	1	-	-	0.0
29/02:00am	15.4	15.1	11.4	77	2.2	SSW	4	6	2	3	-	-	0.0
29/01:30am	15.3	15.3	11.1	76	2.3	SSW	2	6	1	3	-	-	0.0
29/01:00am	15.4	14.6	11.2	76	2.3	SSW	6	9	3	5	-	-	0.0
29/12:30am	15.6	14.8	11.0	74	2.5	S	6	9	3	5	-	-	0.0
29/12:00am	15.6	14.7	11.2	75	2.4	SSE	7	13	4	7	-	-	0.0

¹ <http://www.bom.gov.au/products/IDN60901/IDN60901.94760.shtml>

Similarly, the user defines prevailing background air pollutant concentrations of NO₂ and O₃ during the power outage event. That data is input as units of parts per hundred million (pphm) which is consistent with the online resources maintained by NSW DCCEEW², as illustrated in Figure 6.

Figure 6 Example background air quality dataset accessed for user-defined data

Collapse all		Air quality Station rating Hourly	Particles (PM2.5) µg/m ³ Hourly average	Particles (PM10) µg/m ³ Hourly average	Ozone pphm Hourly average	Ozone pphm 4hr rolling avg	Carbon monoxide ppm 8hr rolling avg	Nitrogen dioxide pphm Hourly average
North West Sydney		GOOD						
Station data								
Penrith		GOOD	● 4.8	● 13.2	● 3.2	● 3.0	● 0.0	● 0.1
Richmond		GOOD	● 4.6	● 16.4	● 3.1	● 3.1		● 0.1
St Marys		GOOD	● 3.4	● 16.6	● 3.6	● 3.3		● 0.2

Once the relevant user-defined data has been selected, the user runs the query to generate the data set of concentration predictions from the PEMS that are reflective of the conditions during the power outage event.

3.3.6. BGIR Report

The BGIR Tool interrogates the data in the database and performs a series of three NO_x to NO₂ conversions on the dataset (in NSW), as per the NSW Approved Methods (NSW EPA, 2022), including:

- Method 1: 100 % conversion of NO to NO₂;
- Method 2: NO to NO₂ conversion limited by ambient ozone concentration (OLM); and
- Method 3: NO to NO₂ conversion using empirical relationship (Janssen).

As described in Section 3.3.4, the data is grouped into 16 vector-groups, to present the output from the tool and automatically generates a BGIR report to be provided to DPHI within 30 days of a power outage event.

The BGIR will be formed by:

- This report; and
- The output report from the BGIR Tool.

² <https://www.airquality.nsw.gov.au/air-quality-in-my-area/concentration-data?rn=north-west-sydney>

3.4. Assessment of Additional Management Measures (CoA C13[d])

CoA C10(c) requires an assessment of additional measures which may be implemented as part of the Project to reduce future air quality impacts. In the event that the results of the PEMS indicates that exceedances are predicted to occur resulting from the operation of back-up generators during a power outage, additional management measures may need to be implemented, through discussions with the relevant regulatory authorities.

The source ⇒ pathway ⇒ receptor (SPR) model has been considered to provide an assessment of additional management measures to reduce the risks of adverse NO₂ impacts (if indicated by the PEMS) from being experienced at surrounding land uses.

The SPR model is useful for understanding the hypothetical relationships between contributing factors to create exposure linkages and also how controls may be applied to manage the risk of exposure from those linkages. Each component of the SPR model is defined below, as relates to the context of this study:

- **Source** – the origin of air emissions, which in this case is the discharge points from the back-up generators;
- **Pathway** – the route through which pollutants disperse from source to receptor. In this case the pathway assessed is through atmospheric dispersion which can be influenced by various parameters such as meteorological conditions, terrain, and characteristics of the emission source(s); and
- **Receptor** – The presence of receptors that could be adversely affected by a contaminant.

For air emissions to have an impact on the receiving environment, there needs to be a connection through the SPR model. This means that the source of pollution, the way it travels (pathway), and the affected area (receptor) must all be linked for there to be a potential risk.

An assessment of potential additional management measures with consideration of the SPR model is provided in Appendix B. The identified management measures have been ranked to provide recommendations regarding the order in which each measure should be considered for implementation. The ranked order of additional management measures is provided in Table 8.

Table 8 Ranked additional management measures

	Ranking	ID	Management measure
More Desirable ⇕	1=	P1	Establish green infrastructure barriers
	1=	S4	Increase stack heights (see P3)
	1=	S5	Increase stack velocities
	1=	S7	Increase stack temperature
	1=	P3	Increase stack heights (see S4)
	6=	S2	Install low NO _x burners
	6=	S6	Install dilution fans
	6=	S8	Utilise multi-stack configuration
	9	S11	Install electrostatic precipitation devices
Least Desirable ⇕	10=	P2	Establish structural barriers
	10=	S3	Utilise alternative fuels
	12	S1	Select alternate generators
	13=	S10	Install non-selective catalytic reduction devices
	13=	S9	Install selective catalytic reduction devices
	13=	R1	Controls at receptors

4. REFERENCES

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APPENDIX A

Common Abbreviations and Terminology

Units Used in the Report

Units presented in the report follow the International System of Units (SI) conventions, unless derived from references using non-SI units.

Commonly used SI units

The following units are commonly used in Northstar reports.

Symbol	Name	Quantity
SI base units		
K	Kelvin	thermodynamic temperature
kg	kilogram	mass
m	metre	length
mol	mole	amount of substance
s	seconds	time
Non-SI units mentioned in the SI or accepted for use		
°	degree	plane angle
d	day	time
h	hour	time
ha	hectare	area
J	joule	energy
L	litre	volume
min	minute	time
N	newton	force or weight
t	tonne	mass
V	volt	electrical potential
W	watt	power

Multiples of SI and non-SI units

The following prefixes are added to unit names to produce multiples and sub-multiples of units:

Prefix	Symbol	Factor	Prefix	Symbol	Factor
T	tera-	10^{12}	p	pico-	10^{-12}
G	giga-	10^9	n	nano-	10^{-9}
M	mega-	10^6	μ	micro-	10^{-6}
k	kilo-	10^3	m	milli-	10^{-3}
h	hecto-	10^2	c	centi-	10^{-2}
da	deca-	10^1	d	deci-	10^{-1}

In this report, units formed by the division of SI and non-SI units are expressed as a negative exponent, and do not use the solidus (/) symbol. For example:

- 50 micrograms per cubic metre would be presented as $50 \mu\text{g}\cdot\text{m}^{-3}$ and not $50 \mu\text{g}/\text{m}^3$; and,

Commonly used SI-derived and non-SI units

$\text{g}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	gram per square metre per second	rate of mass deposition per unit area
$\text{g}\cdot\text{s}^{-1}$	gram per second	rate of mass emission
$\text{kg}\cdot\text{ha}^{-1}\cdot\text{hr}^{-1}$	kilogram per hectare per hour	rate of mass deposition per unit area
$\text{kg}\cdot\text{m}^{-3}$	kilogram per cubic metre	density
$\text{L}\cdot\text{s}^{-1}$	litres per second	volumetric rate
m^2	square metre	area
m^3	cubic metre	volume
$\text{m}\cdot\text{s}^{-1}$	metre per second	speed and velocity
$\text{mg}\cdot\text{m}^{-3}$	milligram per cubic metre	mass concentration per unit volume
$\text{mg}\cdot\text{Nm}^{-3}$	milligram per normalised cubic metre (of air)	mass concentration per unit volume
$\mu\text{g}\cdot\text{m}^{-3}$	microgram per cubic metre	mass concentration per unit volume
$\text{mg}\cdot\text{m}^{-3}$	milligram per cubic metre	mass concentration per unit volume
Pa	pascal	pressure
ppb	parts per billion (1×10^{-9})	volumetric concentration
pphm	parts per hundred million (1×10^{-5})	volumetric concentration
ppm	parts per million (1×10^{-6})	volumetric concentration

Abbreviations used in the report

Abbreviation	Term
AQIA	air quality impact assessment
BGIR	back-up generator incident reporting
CAQP	Certified Air Quality Professional
CASANZ	Clean Air Society of Australia and New Zealand
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAPR	distribution annual planning report
DPHI	department of Planning, Housing and Infrastructure
ER	emission rate
MCoA	Ministers Conditions of Approval
NATA	National Authorities Testing Australia
NDMP	nitrogen dioxide monitoring procedures
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
O_3	ozone
OLM	ozone limiting method
PEMS	predictive emissions monitoring system
POEO Act	Protection of the Environment Operations Act
POEO CAR	Protection of the Environment Operations (Clean Air) regulation
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index

Abbreviation	Term
SPR	source - pathway - receptor
SSD	State Significant Development
TAPM	The Air Pollution Model
TM	test method
%	percent

APPENDIX B

Additional Mitigation Measures

As outlined in Section 3.4, an assessment of additional management measures that could be implemented as part of the Project is required to be performed in accordance with COA C13(d).

A number of management measures considered to be Best Available Technology (BAT) have been reviewed and discussed below. For clarity, it is not recommended that the following management measures are currently required for the Project, however, a number of additional measures have been outlined to provide context for how air quality impacts may be further reduced if exceedances are indicated by the PEMS.

To prevent or minimise emissions during operation, BAT ensures through proper design, operation, and maintenance, that emission control techniques are utilised at their optimal capacity and availability.

Source – Pathway – Receptor Model

The source-pathway-receptor (SPR) model is useful for understanding the hypothetical relationships between contributing factors to create exposure linkages and also how controls may be applied to manage the risk of exposure from those linkages. Each component of the SPR model is defined below, as relates to the context of this study:

- **Source** – the origin of air emissions, which in this case is the discharge points from the back-up generators;
- **Pathway** – the route through which pollutants disperse from source to receptor. In this case the pathway assessed is through atmospheric dispersion which can be influenced by various parameters such as meteorological conditions, terrain, and characteristics of the emission source(s); and
- **Receptor** – The presence of receptors that could be adversely affected by a contaminant.

For air emissions to have an impact on the receiving environment, there needs to be a connection through the SPR model. This means that the source of pollution, the way it travels (pathway), and the affected area (receptor) must all be linked for there to be a potential risk.

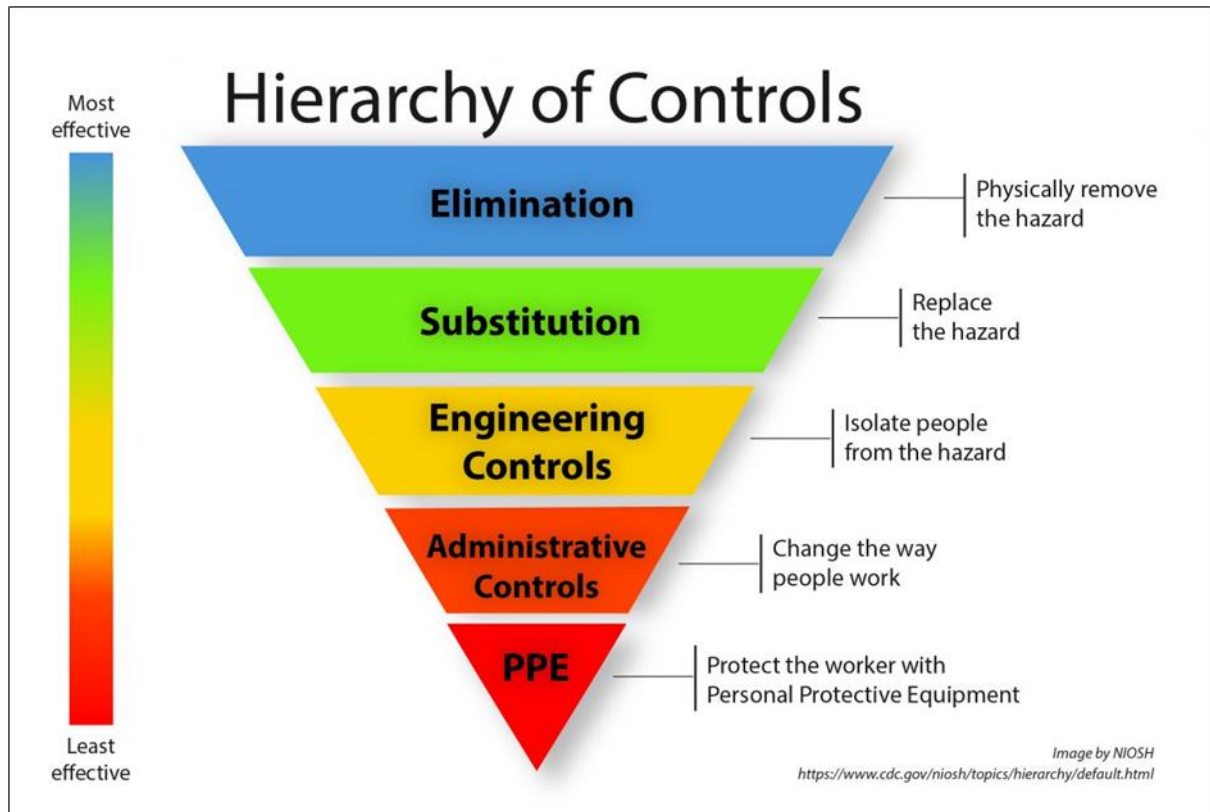
Identification of the SPR model allows for targeted management interventions to manage the environmental risks and prevent pollution from reaching sensitive areas.

Hierarchy of Controls

The hierarchy of controls are a well-documented and utilised tool for evaluating the efficacy and reliability for the control of hazards. An example of the hierarchy is presented in Figure B1.

The hierarchy of controls shows 'elimination' of the hazard as the most desirable control, through 'substitution', 'engineering' and 'administrative controls' to 'PPE' (i.e. protection from the hazard at the point of exposure) being the least effective.

Figure B1 Hierarchy of controls



Source: Centres for Disease Control and Prevention (CDC) / National Institute for Occupational Safety & Health (NIOSH)

For each identified potential control that is subsequently evaluated below, each control has been given a unique identifier that is [Sx], [Px] or [Rx] relating to how they fit into the SPR model and *x* being a sequential number (e.g. [S1], [S2], [S3]... for identified controls at source).

It is noted that these references may occur in multiple places in the following sections.

Controls at Source

Air pollution controls at the source may involve the installation of emission control devices and adoption of efficient power generation techniques to minimise pollutant releases from the Project Site.

The use of computer-based combustion control systems allows the control of fuel and combustion efficiency, reducing the generation of products of combustion.

Selection of Generators

The capacity, number, and configuration of the back-up generators at the Project Site will have been dependant on the requirements sought by the Proponent during the detailed design phase of the development.

Key factors which may have influenced the selection of generators at the Project Site include (in no order) fuel efficiency, reliability, capabilities to retrofit air pollution control (APC) techniques, start-up times and compliance with appropriate emissions limit values as specified in legislative and regulatory requirements.

The UK Environment Agency's working draft guide on the approach to the permitting and regulatory aspects for Data Centres (UK Environment Agency, 2018) notes that:

"It is generally accepted that the BAT for data centre back-up generation is presently a set of diesel generators – this allows for an on-site store of fuel for reliability and a scalable provision of MWelec."

Other technologies identified for standby power generation purposes include the Diesel Rotary Uninterruptible Power Supply engine (DRUPS) and natural gas-fuelled back-up generators utilising either combined-cycle or open-cycle gas turbine technologies or employing spark ignition.

In terms of generator selection for the Project Site:

- Diesel engines can offer a faster response speed relative to the demanded load; making them a crucial component for datacentre operations which require fast response times. Rapid start-up of back-up generators is essential where a near instantaneous supply of electricity is imperative in the event of a power outage;
- Diesel engines typically have lower maintenance costs compared to gas-fired generators; and,
- Ensuring a reliable fuel supply, particularly diesel, is essential for maintaining dependability. Use of a natural gas generator for example would necessitate reliance on an off-site supply network.

In terms of pollutants, NO_x is a predominant byproduct produced during the combustion process. The adoption of low NO_x engine technology would aid in reducing emissions at source. It is acknowledged that gas engines are known to emit lower amounts of NO_x in comparison to diesel fired engines.

As each generator has a unique specification for operating conditions (such as fuel consumption rate, operating temperature, and resultant emission specifications), the selection of generators to account for the different emission specification is a consideration for control [S1].

In Chapter 3 of the BAT Reference Document (BREF) for Large Combustion Plants (LCP BREF) (Lecomte, et al., 2017) low NO_x burners are described as employing a combination of air staging, fuel staging and internal flue-gas recirculation techniques to achieve low NO_x emission from combustion. The control efficiency can vary depending on the specific design of the burner, the combustion technology applied and fuel type, with low NO_x burners generally achieving between 20 % and 70 % of a reduction of NO_x emissions (Lecomte, et al., 2017) [S2].

Emissions Standards

In NSW, standby generators are not required to comply with standards of concentration, as specified under Schedule 2 of the Protection of the Environment (Clean Air) Regulation 2022, as long as their operation does not exceed a specific annual 200-hour limit or if the site on which they are located has a diesel fuel storage capacity not exceeding 2 000 tonnes, as specified in Schedule 1, Part 1 of the *Protection of the Environment Operations Act* (1997).

Standby generators in Australia commonly adhere to either United States (US) emissions standards (Tier 1 to Tier 4) or European Union (EU) emissions standards (Stage I to Stage V) due to the prevalent manufacturing of diesel engines in these regions.

The US non-road emissions standards are categorized by engine horsepower and model year, regulated by the US EPA. Tier 1 standards were phased in from 1996 to 2000, followed by more stringent Tier 2 from 2001 to 2006, and Tier 3 from 2006 to 2008 (applicable to engines from 37 kW to 560 kW).

Current Tier 4 standards, implemented from 2008 to 2015, require around a 90 % reduction in NO_x emissions, achieved through exhaust gas aftertreatment technologies like SCR catalysts. The California Air Resources Board (CARB) is developing Tier 5 standards to be in place between 2028 and 2030, aiming to further reduce NO_x emissions by between 50 %-90 %, which currently under consideration by the US EPA for adoption into their respective non-road engine regulations.

An air information report published by NSW EPA on the reduction of emissions from non-road diesel engines (NSW EPA, 2014) notes that:

Tier 4 emission standards make provision for the following reductions compared to Tier 1 emission standards:

- 95 % reduction in NO_x for engines less than 560 kW and 60% reduction for larger engines

Table B1 provides details of the corresponding US EPA Tier 1 to Tier 3 emissions standards for engines rated above 560 kW and Table B2 outlines the respective requirements under US EPA Tier 4 emissions standards.

Table B1 US EPA Tier 1 to Tier 3 emissions standards – engines above 560 kW

Rated power	Tier	Model year	Emissions standards	
			Units	NO _x
≥ 560 kW (≥ 750 hp)	Tier 1	2000	g·kW ⁻¹	9.2
			g·bhp·hr ⁻¹	6.9
	Tier 2	2006	g·kW ⁻¹	-
			g·bhp·hr ⁻¹	-

Note: NMHC – non-methane hydrocarbon

Table B2 US EPA Tier 4 emissions standards – engines above 560 kW

Model year	Category	Emissions standards	
		Units	NO _x
2011 - 2014	Generator sets > 900 kW	g·kWh ⁻¹	0.67
		g·bhp·hr ⁻¹	0.50
	All engines except gensets > 900 kW	g·kWh ⁻¹	3.5
		g·bhp·hr ⁻¹	2.6
2015	Generator sets	g·kWh ⁻¹	0.67
		g·bhp·hr ⁻¹	0.5
	All engines except gensets	g·kWh ⁻¹	3.5
		g·bhp·hr ⁻¹	2.6

Note: NMHC – non-methane hydrocarbon

European emissions standards follow a tiered approach, akin to the US, driven by EU parliamentary directives. EU Directive 2015/2193 on Medium Combustion Plant (MCPD) establishes requirements for stationary combustion plants with a thermal rating of equal to or more than 1 MW and less than 50 MW with limits for NO_x.

According to MCPD Article 6, emergency plants operating less than 500 hours per year, as a five-year rolling average, are exempt from emission limit values. Each generator with its own discharge stack, under MCPD provisions, can operate for testing or emergencies for up to 500 hours per calendar year without emission limit values under the MCPD. If generators share a common discharge stack, the set can be tested and maintained without emissions limit values for up to 500 hours per year.

Other non-road engine emissions in Europe adhere to EU Directive 2016/1628, known as the NRMM Regulation. This regulation sets emission limits for various power ranges and applications, outlining procedures for engine manufacturers to obtain type-approval. European Stage V standards, derived from Directive 2016/1628, mandates stringent limits on PM emissions, necessitating diesel particulate filters (DPFs) for non-road engines rated between 19 kW and 560 kW. Stage V emissions limits are also established for engines above 560 kW.

Table B3 provides the EU Stage V emissions limits for generators set engines rated above 560 kW.

Table B3 EU Stage V emissions limits by engine category

Engine category	Ignition type	Net power	Date	Emission limit (g·kWh ⁻¹)
		(kW)		NO _x
NRG-v-1 NRG-c-1	All	P > 560	2019	0.67

While the standby generators for the Project have already been determined, ensuring that the selected generators are compliant with the abovementioned emissions standards has been considered in this review [S1].

Selection of Fuel

The Project Site utilises diesel for the purposes of standby power generation. Diesel is typically the fuel used for emergency generators, and reciprocating engines fuelled by low-sulphur diesel are the most common choice for other developments of this nature.

Diesel fuel in Australia is subject to specified parameters governing environmental factors like sulphur and hydrocarbons (HC), as well as operational considerations such as carbon residue and sediments, which can impact engine performance.

Part 9 of the POEO CAR specifies limits on sulphur content within liquid fuel, whereby clause 159(2) states:

“A person must not operate fuel burning equipment powered by a reciprocating internal combustion engine using diesel, if the fuel has a sulfur content of more than the sulfur content specified for diesel—

(a) in a fuel standard determined under the Fuel Quality Standards Act 2000 of the Commonwealth, section 21, or

(b) in an approval granted under the Fuel Quality Standards Act 2000 of the Commonwealth, section 13.”

The Fuel Standard (Automotive Diesel) Determination 2001, as authorised by the Fuel Quality Standard Act 2000 denotes that diesel fuels must not contain more than 10 mg·kg⁻¹ (ppm) from 1 January 2009.

In the US, non-road engine emission regulations allowed higher sulphur content (up to 0.5 %) at Tier 1 to Tier 3 stages. However, to accommodate sulphur-sensitive control technologies in Tier 4 engines, like catalytic particulate filters, the US EPA mandated a reduction in sulphur content to 15 ppm for non-road diesel fuels.

Alternative fuel types identified through the desktop review include natural gas, propane, gasoline, liquefied natural gas (LNG). These fuels may provide gas engines with higher thermal efficiencies when compared to use over diesel generators. However, it is important to note that gas engines may come with relatively higher levels of investment, operating and maintenance costs. Additionally, whilst the use of gas engines may have the potential for lower NO_x emissions compared to diesel engines, there would be a reliance on the national gas grid for an uninterruptable supply, which may not provide the Proponent with fuel security [S3].

Discharge Design

According to (UK Environment Agency, 2018), datacentres can have short, below roof level emissions stacks, which can impact on the efficiency of dispersion of emissions. With reference to BAT, the following techniques are noted for the adequate dispersion of exhaust emissions:

1. Increased stack height
2. Vertical ports
3. Increased distances from buildings to be above roof line
4. 'Common windshield' combining several individual flues.

Stack Height

By raising the stack height, this can facilitate a higher level of dispersion of exhaust gases as they mix with the surrounding air beyond the stack plume. Although this does not decrease the pollutant concentration at source, this does aid in reducing pollutant concentrations at ground level. Elevating the stack height serves to mitigate the impact of building wake and the entrainment of emissions in the locality of the emission source.

When wind interacts with buildings or structures, turbulent eddies form on the downwind side, potentially forcing a stack plume down to the ground if it's located within approximately five times the height of the nearby structure. This turbulence, known as building downwash, can lead to increased ground-level pollutant concentrations downstream of the building or structure.

Elevating the stack height above the highest point of the building in which it is located (or nearby buildings) will help mitigate building downwash effects and reduce air quality impacts beyond the Project Site, where feasible [S4].

Discharge Velocity

Decreases in ground-level pollutant concentrations can be accomplished through improved mixing with the surrounding air once the exhaust gas plume terminates from the stack. A higher emission velocity generates increased momentum, increasing the height of the plume in the atmosphere beyond the stack exit point. This increased vertical mixing contributes to lower pollutant concentrations at surrounding receptors.

Any increase in discharge velocity should be considered alongside any improvements to the stack height to optimise plume dispersion conditions.

Increasing discharge velocities associated with the standby generators may be achieved by:

- Increasing the air extraction rate from the discharge point; and / or
- Decreasing the physical dimensions of the discharge point; and / or
- The addition of dilution air into the exhaust stream prior to discharge.

Exhaust stack restriction devices can regulate the corresponding exhaust flow through adjustment of the cross-sectional area of the stack at point of discharge [S5]

Enhanced discharge velocity may also be gained through the use of dilution fans (for example³). They operate by drawing in additional air below the point of discharge to increase volumetric flow and increasing discharge velocity. The effect of this is to significantly increase vertical momentum, which can increase the effective discharge height to conditions that are less affected by turbulent air flows over buildings and enhance dispersion.

They can be configured by multiple inlet manifold and variable speed drive fans to serve multiple discharge points, and as such may offer a practical solution for data centres that are designed with nested discharge points and have highly variable discharge flows.

Such devices have been used on other developments in the Greater Sydney region to good effect [S6].

Discharge Temperature

High stack exhaust temperatures can increase both buoyancy and plume rise dispersion conditions. Plumes tend to rise more rapidly when the associated gases are warmer compared to the atmospheric temperature, which in turn contributes to a higher plume rise which can affect the dispersion pattern.

Combustion modification such as changes to the flame temperature and O₂ content of the air-fuel (stoichiometric) mixture aim to reduce NO_x pollution by ensuring that the fuel is burned completely, or reducing the amount of nitrogen from the air that is burnt in the combustion process. Such approaches include lean burn, water injection, exhaust gas recirculation or low-NO_x boiler designs that reduce the flame temperature.

Secondary abatement technologies such as SCR operated within a narrow temperature range. Operating at lighter loads typically results in emissions at lower temperature, resulting in poorer performance of SCR aftertreatment [S7].

Multi-Stack Configuration

By physically bringing together the exhaust streams for multiple engines, it is possible to improve the mixing of flue gases with the surrounding air. This plume aggregation does not decrease the absolute quantities of pollutants being emitted however it can lead to enhanced plume dispersion which results in lower concentration at ground level.

A multi-flue stack configuration pertains to a chimney or exhaust system that contains several flues, where each generator can discharge independently through its own flue but is constrained within that stack. Multi-

³ https://www.criticalairflow.com/site/assets/files/1080/critical_airflow_tristactech.pdf

flue stacks are common in facilities with multiple combustion processes. Each flue may lead to a specific emission control system or stack gas treatment unit.

A combined flue stack configuration involves the use of a single exhaust stack system for the collective discharge of combustion byproducts from various power generation sources. This serves as the termination point with each flue feeding into the shared exhaust system [S8].

Air Pollution Control

Air pollution control (APC) encompasses a range of technologies and strategies aimed at eliminating or minimising the release of pollutants into the atmosphere. With regard to standby power generation from diesel combustion, the application of exhaust aftertreatment technologies is common.

Known air pollution control technologies that are available to reduce NO₂ emissions include:

- **Selective Catalytic Reduction (SCR)** – emissions control method that reduces NO_x emissions within exhaust gases by injecting a reducing agent which initiates a chemical reaction that converts NO_x into N₂, water, and small amounts of CO₂; and,
- **Non-selective Catalytic Reduction (NSCR)** – use of a catalyst reaction to simultaneously reduce NO_x, CO, and hydrocarbon (HC) to water, CO₂, and N₂.

Selective catalytic reduction (SCR) control devices are considered to be one of the most effective abatement techniques for NO_x releases. SCRs induce a chemical reduction via a reducing agent and catalyst to convert NO_x to molecular nitrogen (N₂) and water in the presence of a catalyst. In mobile source applications, an aqueous urea solution is typically preferred as the reductant. The LCP BREF (Lecomte, et al., 2017) notes that, *“A higher NO_x reduction is achieved with the use of several layers of catalyst. The technique design can be modular; a special catalyst and / or preheating can be used to cope with low loads or with a wide flue-gas temperature window.”*

Conversion of NO_x occurs on the catalyst surface with an ideal temperature range of between 300 °C and 450 °C, and less effectively over a wider temperature range of 170 °C and 510 °C depending on the catalyst type and/or configuration employed.

SCR can typically reduce NO_x emissions between 75 % and 90 %, HC emissions by up to 80 %, and PM emissions between 20 % and 30 %⁴. SCR requires the engine and exhaust system to reach operating temperature to be effective, requiring special pre-heaters for NO_x reduction in standby generators, which may reflect a higher cost for implementation [S9].

Selective Non-Catalytic Reduction (SNCR) involves reducing NO_x to N₂ through the reaction with ammonia (NH₃) or urea (CH₄N₂O) at a temperature between 800 °C and 1 100 °C for optimal reaction. The LCP BREF

⁴ https://archive.epa.gov/international/air/web/pdf/default-file_dieselfact_0106.pdf

(Lecomte, et al., 2017) provides a technical description for SNCR, whereby, *"Using ammonia as a reagent, the following chemical reactions take place more or less at the same time. At the lower temperature, both reactions are too slow; at the higher temperature, the unwanted by-reaction dominates with an increase in NO_x emissions."*

In contrast to SCR technology, a catalyst is not required, which lowers investment and maintenance costs, and less space is required to house the SNCR technology at the generator location. The LCP BREF (Lecomte, et al., 2017) notes that SNCR cannot be applied to gas engines or turbines due to the residence time and temperature window required for operation. SNCR processes can typically achieve a NO_x reduction level of between 30 % and 50 % (Lecomte, et al., 2017).

In NSCR technology, the engine exhaust flows through a catalyst bed where NO_x is converted to N₂. Simultaneously, VOCs and CO undergo oxidation, resulting in the formation of water and CO₂ under optimal conditions.

A technical progress report on reciprocating engine emissions control (Chapman, 2004) notes that, *"For an NSCR system to operate optimally (i.e., to minimize NO_x emissions), the inlet exhaust stream must have very low oxygen content, as well as proper concentrations of NO_x, hydrocarbons, and carbon monoxide. This requires initial engine adjustments, followed by careful monitoring of oxygen content in the exhaust."*

The catalyst demands exhaust with less than 0.5 % O₂ content. Although employing a fuel-rich mixture increases engine fuel consumption due to back pressure, it enables effective NO_x control, typically achieving levels between 90 % and 98 %⁵ [S10].

Various standby generator manufacturers have developed retrofit emission control device (RECD) systems⁶ based on electrostatic precipitation (ESP) fundamentals for use with diesel generator sets. The RECD is installed after the standby generator exhaust and no modifications to the exhaust are required. However, the RECD would have additional spacing requirements which may be constrained at the Project Site [S11].

Each air pollution control device identified in this section requires retrofitting to each standby generator (or each discharge point in the event of co-vented discharges), incurring associated costs. Retrofitting involves integrating or adding these devices to existing plant to enhance their emission control capabilities. The costs associated with this process include expenses for purchasing the control devices, installation, and potentially ongoing maintenance [S9-11].

⁵ <https://www3.epa.gov/ttn/catc1/dir1/fnoxdoc.pdf>

⁶ http://www.jnmachineries.com/cummins_retrofit_emission_control_device.php

Controls in the Pathway

Enhancing the dilution and dispersion of a pollutant plume during its journey from the source to the receptor will lower the concentration at the receptor, subsequently minimising exposure. For instance, extending the pathway, such as by emitting emissions from a tall stack, will generally, under constant conditions, increase both dilution and dispersion conditions.

Green Infrastructure

The integration of Green Infrastructure (GI) in the environment has the potential to reduce the effectiveness of the pathway from the emission source to the receptor. Introducing natural elements, like vegetation or green spaces, as contiguous barriers can disrupt the usual flow of pollutants, creating obstacles that impede the direct transmission of emissions. This interference promotes dispersion, dilution, and absorption of pollutants by greenery, which can aid in lowering the concentration of pollutants reaching the receptor.

Strategically placed Vegetative Environment Buffers (VEB) along the perimeter of industrial areas, abutting sensitive areas such as residential, child-care and educational facilities can aid in mitigation human exposure to air pollution.

According to recent research (Barwise & Kumar, 2020), the optimal configuration and plant composition of GI are unclear. Furthermore, the effectiveness of GI depends on factors such as the condition of the built environment, as well as the type, location, and configuration of GI (Kumar, et al., 2019) [P1].

Structural Barriers

Structural barriers such as sound walls or shelterbelts can influence the exposure pathway by obstructing the pollutant plume. These barriers can induce turbulence in the airflow, leading to enhanced dispersion and are used in industrial settings to reduce direct exposure to emissions at receptors. These methods may be more feasible in comparison to GI which would also require additional considerations with regard to establishment and maintenance activities.

The land uses surrounding the Project Site is generally industrial and residential in nature. While the discharges are released at a height, the implementation of structural barriers may be limited to the immediate vicinity of the Project Site due to the distance to sensitive land uses and the magnitude of the discharge and structural constraints due to the increased loads of such structures [P2].

Stack Height Optimisation

Increasing the stack height can influence the dispersion pattern of pollutants emitted from a stack. A taller stack emits the discharge at greater height and into atmospheric conditions which can enhance more effective dispersion.

Stack heights may be increased through retrofitting, noting that the increased height may have an effect of duct pressure which may affect performance of APC devices.

Often, planning restrictions may also impose limitations on stack heights to limit other environmental effects such as visual impact and design aesthetics **[S4, P3]**.

Controls at Receptors

Controls implemented at receptors are typically considered as the least favourable option, as those controls rely upon the acceptance of third-parties to accept risk and co-operate by utilising the controls, which in this instance may be at any time 24/7 with short notice.

Controls at receptors are at the point of risk exposure and can be considered to be equivalent to the reliance of PPE for worker protection (see Figure B1).

Examples of controls at receptors may include:

- Provision of ongoing support and education to understand risk. Increased community engagement, through mediums such as public forums, community advisory boards and meetings can help educate the local community to understand the Project Site's procedures for standby power generation and the potential implications on air quality. The associated costs of implementing automated warning systems may not be viable given the unlikelihood of the Project Site suffering a catastrophic power outage.
- Provision of methods to remove individuals to safer locations, such as enclosure within buildings and the provision of air filtration systems. This control is by definition, only of value inside engineered airtight buildings and of limited value in non-airtight buildings (such as residential properties), and of no value in outdoor locations.
- Implementation of alerts and alarms. Implementation of early warning systems can assist in safeguarding sensitive receptors in proximity to the Project Site. These systems can detect pollutant levels in real-time and can issue timely alerts, which can alert the local community to any potential pollution episodes.

Controls at receptors should only be realistically considered when controls at source, and then controls in the pathway have been exhausted **[R1]**.

Summary

The feasibility of implementing the identified control options in the SPR model have been evaluated by considering the following factors:

- Implementations cost;
- Regulatory requirements;

- Environmental impacts;
- Safety implications; and
- Compatibility with current processes.

This summary assesses the measures that may constrain the implementation of the control measures outlined above. Each measure is provided a risk rating (**low**, **medium**, or **high**) which identifies the constraints which may result in the implementation of the measure not being practical at the Project Site.

It is noted that for the assessment of implementation costs, this review has adopted a relative and qualitative approach as follows:

- Low = \$
- Medium = \$\$
- High = \$\$\$

Table B4 provides a summary of the additional management measures and the feasibility of implementing each measure at the Project Site.

Following the evaluation of feasibility as outlined above, the identified management measures have been ranked to provide recommendations regarding the order in which each measure should be implemented. This is presented in Section 3.4 and Table 8.

Table B4 Practicality of implementing management measures at the Project Site

Control measure	Potential Constraints					Conclusion of evaluation
	Implementation costs	Regulatory requirements	Environmental impacts	Safety implications	System compatibility	
Source						
S1 – Select alternate generators	\$\$\$	Medium	Low	Low	High	Selecting alternative generator sets would be a high-cost option, and would be very difficult to implement once the facility is operating.
S2 - Install low NO _x burners	\$\$	Low	Low	Medium	Low	- Change in designed operational conditions (combustion stability, heat exchange) represents some safety issues that would require due consideration. - May offer additional air pollution control however would require extensive retrofitting to each standby generator.
S3 - Utilise alternative fuels	\$\$	Low	Low	High	High	Compatibility, storage and handling capabilities and combustion characteristics. Standby generators utilise diesel fuel and would require significant modification, and/or re-specification.
S4 - Increase stack heights	\$	Low	Medium	Low	Low	- Compatibility with clearance requirements to negate building downwash effects, stability, and structural integrity considerations. - May be considered a feasible for implementation.
S5 - Increase stack velocities	\$	Low	Low	Medium	Low	- Change in designed operational conditions which may then require structural integrity considerations to stack configuration. - May be feasible for implementation.
S6 - Install dilution fans	\$\$	Low	Low	Low	Medium	- Higher capital cost but reduced operating cost due to inlet manifolds serving multiple discharges and variable drives. - Retrofitting may require load considerations. - May be considered a feasible for implementation.

Control measure	Potential Constraints					Conclusion of evaluation
	Implementation costs	Regulatory requirements	Environmental impacts	Safety implications	System compatibility	
S7 - Increase stack temperature	\$\$	Low	Low	Low	Low	May be considered a feasible for implementation.
S8 - Utilise multi-stack configuration	\$\$	Low	Low	Low	Medium	- Structural and maintenance considerations required from design perspective. - Additional works required to combine flues into a multi-stack configuration. - Separating exhaust into multiple stacks may aide in optimizes airflow, reducing backpressure, and enhancing generator performance.
S9 - Install selective catalytic reduction devices	\$\$\$	High	Low	Medium	High	- Require additional design considerations. - May offer additional air pollution control, requires retrofitting to each standby generator.
S10 – Install non-selective catalytic reduction devices	\$\$\$	High	Low	Medium	High	- Require additional design considerations. - May offer additional air pollution control, would require retrofitting to each standby generator.
S11 - Install electrostatic precipitation devices	\$\$	Low	Low	Medium	Medium	- Require additional design considerations. - May offer additional air pollution control, would require retrofitting to each standby generator.
Pathway						
P1 - Establish green infrastructure barriers	\$	Low	Low	Low	Medium	Given the lack of available open space between the emission sources and sensitive receptors to establish a green infrastructure barrier, it is not considered feasible for implementation.

Control measure	Potential Constraints					Conclusion of evaluation
	Implementation costs	Regulatory requirements	Environmental impacts	Safety implications	System compatibility	
P2 - Establish structural barriers	\$\$	Medium	Low	Medium	High	- Require compliance with building codes and planning policies. - Choice, design, and stability capabilities for type of barrier used. - Strategic use of barriers may provide airflow restriction from source to receptor. - Similar to P2, given the lack of available open space between the emission sources and sensitive receptors, it is not considered feasible for implementation.
P3 - Increase stack heights (see S4)	\$\$	Low	Low	Medium	Low	Compatibility with clearance requirements to negate building downwash effects, stability, and structural integrity considerations.
Receptor						
R1 – Controls at receptors	\$\$\$	Medium	Medium	Medium	High	- Typically ineffective control due to the infrequency of actual use due to the low probability of power outage and the reliance of third-party to understand the risk and co-operate through the implementation of those controls. - Potentially very high capital and maintenance costs as controls may need to be implemented at many locations. - Unlikely to be effective given the lack of notice of power outage events.

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