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THERMAL PLUME MODELLING OF PROPOSED EQUINIX DB8 ON-SITE POWER GENERATION

Technical Report Prepared For

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EXECUTIVE SUMMARY

This report, prepared by AWN Consulting Ltd, provides an assessment of the potential impact of the plumes associated with the operational phase of the proposed Equinix DB8 on-site power generation (OSPG) facility adjacent to the DB8 data centre site located off the Nangor Road, Grangecastle, Co. Dublin on aircraft in the vicinity of Casement Aerodrome. Both aeroplanes and helicopters will be likely to use Casement Aerodrome. However, it is helicopters which are at most risk from industrial plumes due to the risk of reduced oxygen and high temperatures and vertical velocities.

The issue of plume characteristics and the effect on the operation of helicopters in particular in the region of the site and Casement Aerodrome has been assessed below. An assessment has been undertaken to determine the region surrounding the facility where levels of excess temperature, turbulence (vertical velocity) and reduced oxygen could potentially be encountered. Studies undertaken by the MITRE Corporation (MITRE, 2012) and outlined in the user manual for the "Exhaust-Plume-Analyzer" model detail the likely impact of an exhaust plume on aircraft based on a range of parameters / criteria including the thermal buoyancy and temperature of the plume.

The current study is based on detailed site-specific information. The site-specific study, using the Cambridge Environmental Research Consultants (CERC) AMDS-5 model for oxygen, temperature and vertical velocity, allows the actual emission data for the facility to be used as input into the model. In addition, meteorological data for the region, based on 3 years of data from Casement Aerodrome meteorological station (2019 – 2021) and building data also forms part of the inputs to the model to allow an accurate representation of the impact of the facility in the surrounding environment. As discussed in detail below, the site-specific risk heights have been found to be limited to a distance of 9 metres from the stack top. As the diesel generators have a greater stack height, the maximum height above ordnance datum is 104.2 m Ordnance Datum (OD) (based on a base elevation of 95.2 m OD, a stack height of 20 m and the temperature exclusion zone of 9 m above stack top) and this defines the relevant exclusion zone due to these emission points.

Conclusion

Thus, in summary the results of the analysis are as follows:

- **Oxygen Content –** within 1 metre of the stack top the oxygen concentration will increase above the 12% risk level for oxygen for both gas engines (89 m OD) and diesel generators (96.2 m OD).
- **Temperature –** the temperature of the plume will drop to less than 50°C beyond 10 metres (99 m OD) of the stack top for the gas engines and beyond 9 metres (104.2 m OD) of the stack top for the diesel generators.
- **Vertical Velocity –** the critical vertical velocity of 4.3 m/s will not be exceeded beyond 14 metres (103 m OD) from the stack top of the gas engines and beyond 1 metre (96.2 m OD) from the stack top of the diesel generators.

Thus, the maximum extent of the risk zone of the plume for each parameter is shown below based on a full year of meteorological data covering all meteorological conditions including pressure/temperature inversions:

- Risk Zone for Oxygen **– < 1 metre (96.2 m OD)**
- Risk Zone for Temperature **– 9 metres (104.2 m OD)**
- Risk Zone for Vertical Velocity **– 14 metres (103 m OD)**

- **COMBINED RISK ZONE – within 9 metres above stack top and 104.2 m OD.**

In summary, beyond 9 m above the stack top (104.2 m OD), the levels of oxygen, temperature and vertical velocity will have returned to accepted/ambient levels.

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1.0 INTRODUCTION

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The issue of plume characteristics and the effect on the operation of helicopters in particular in the region of the site and Casement Aerodrome has been assessed below. An assessment has been undertaken to determine the region surrounding the facility where levels of excess temperature, turbulence (vertical velocity) and reduced oxygen could potentially be encountered. Studies undertaken by the MITRE Corporation (MITRE, 2012) and outlined in the user manual for the "Exhaust-Plume-Analyzer" model detail the likely impact of an exhaust plume on aircraft based on a range of parameters / criteria including the thermal buoyancy and temperature of the plume.

The current study is based on detailed site-specific information. The site-specific study, using the Cambridge Environmental Research Consultants (CERC) AMDS-5 model for oxygen, temperature and vertical velocity, allows the actual emission data for the facility to be used as input into the model. In addition, meteorological data for the region, based on 3 years of data from Casement Aerodrome (2019 – 2021) and building data also forms part of the inputs to the model to allow an accurate representation of the impact of the facility in the surrounding environment.

2.0 METHODOLOGY

The parameters of the plume which are most relevant to helicopters has been investigated by the Mitre Corporation as part of the development of the "*Expanded Model For Determining The Effects Of Vertical Plumes On Aviation Safety*" (MITRE, 2012). These parameters have been reviewed below.

2.1 Oxygen

The Mitre Corporation report confirms that oxygen levels below 12% are potentially hazardous to helicopters (MITRE, 2012) and thus the oxygen content of the plume with distance from the stack has been investigated.

In relation to the gas engines, the oxygen content of the plume at stack top will typically be 9.9% and has been assumed in the assessment. In relation to the diesel generators, the oxygen content of the plume at stack top will typically be 5.5% and has been assumed in the assessment.

2.2 Temperature

The Mitre Corporation report confirms that temperatures in excess of 50°C are potentially hazardous to helicopters (MITRE, 2012) and thus the temperature of the plume with distance from the stack has been investigated.

In relation to the gas engines, the temperature of the plume at stack top is 707.15K (434°C). In relation to the diesel generators, the temperature of the plume at stack top is 736.15K (463°C).

2.3 Vertical Velocity

High vertical velocities are also a concern when considering helicopter / plume interactions as they can lead to increased turbulence in the atmosphere. The literature (CASA, 2012) suggests that the critical level for vertical velocities is 4.3 m/s. Thus, modelling has been undertaken to understand the worst-case vertical velocities of both the gas engine plume and diesel generator plume with distance from the stack.

The change in each of these parameters with distance from the stack has been reviewed below. The ADMS-5 model has the capability to process calm conditions by setting the wind speed to 0.3 m/s and allowing an equal probability for all wind directions. This option has been used in this assessment for oxygen assessment, temperature assessment and the vertical velocity assessment. The model was also run with a receptor grid based on 25m horizontal spacing and 40m vertical spacing, with an overall size of approx. 2.36 km x 2.85 km, shown in Figure 1.

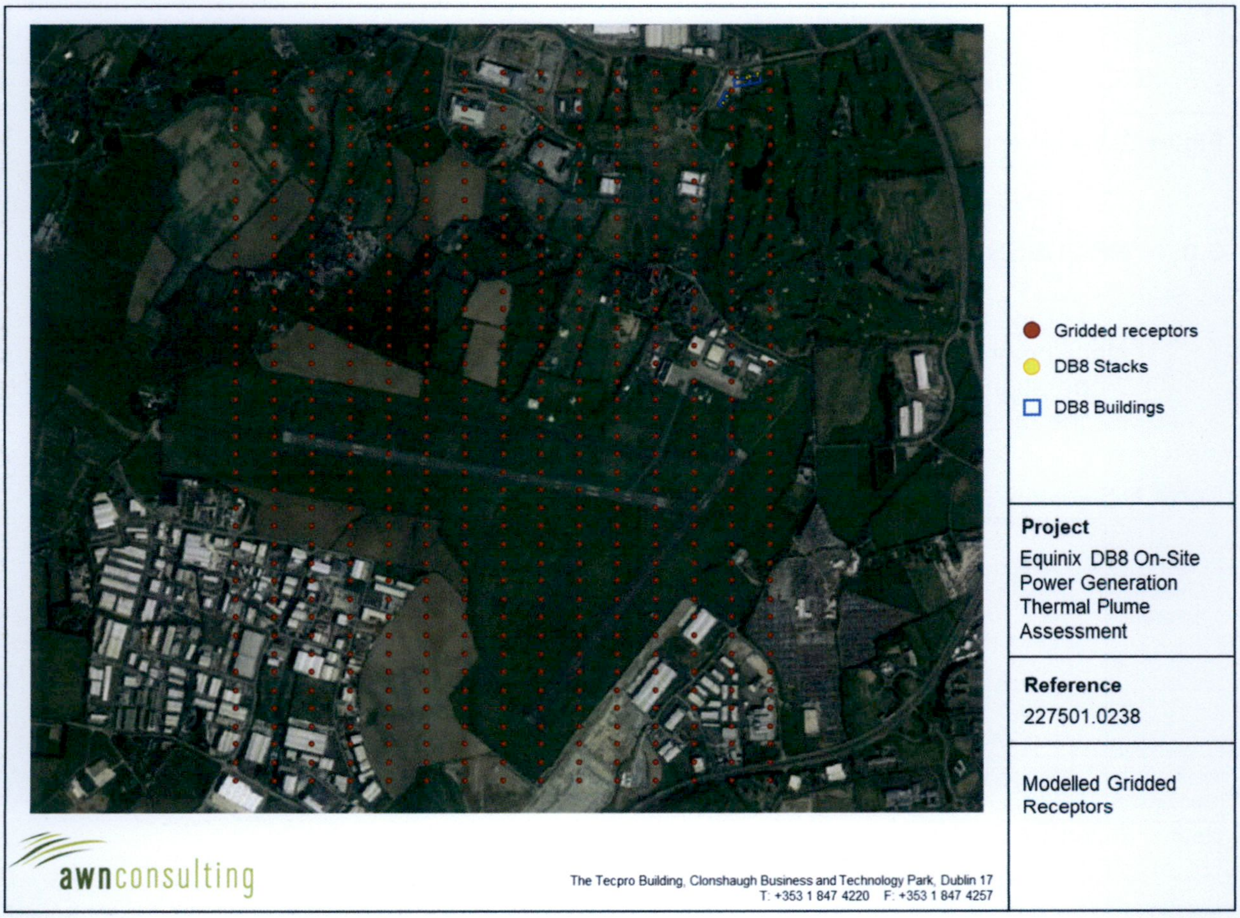

Figure 1. Study area – modelled gridded receptors

2.4 Meteorology

For each of the model parameters, 3 full years of meteorological conditions have been used in the analysis including periods of atmospheric pressure/temperature inversions. Meteorological data for the years 2019 – 2021 for Casement Aerodrome meteorological station has been used in the analysis for all scenarios outlined.

Casement Aerodrome meteorological station, which is located approximately 1.5 km south of the site, collects data in the correct format and has a data collection of greater than 90% (Met Eireann, 2022). Long-term hourly observations at Casement Aerodrome meteorological station provide an indication of the prevailing wind conditions for the region (see Figure 2). Results indicate that the prevailing wind direction is westerly to south-westerly in direction over the period 2019 – 2021. The mean wind speed is approximately 5.5 m/s over the period 2019 - 2021.

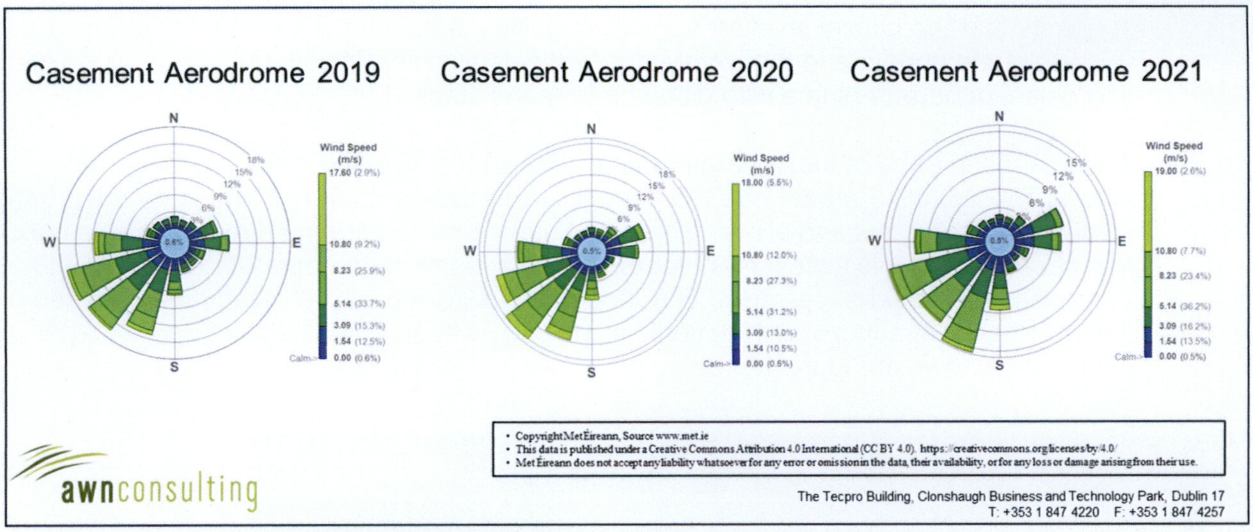

Figure 2. Casement Aerodrome Wind Roses 2019 -2021

3.0 PROCESS EMISSIONS

The proposed energy centre facility will have 8 operational gas engines which will have a stack height of 14 m. The proposed emergency diesel generators will have a maximum of 7 operational generators at which will have a stack height of 20 m. The source information for the modelled emission points has been summarised in Table 1.

Table 1. Summary of Source Information For The Gas Engine & Diesel Generator Plumes

Stack Reference	Height Above Ground Level (m)	Exit Diameter (m)	Cross-Sectional Area (m^2)	Temp (K)	Max Volume Flow (Nm^3/hr)	Exit Velocity (m/sec actual)	NO_2	
							Concentration (mg/Nm^3)	Mass Emission (g/s)
Gas Engines	14 (89 m OD)	0.4	0.13	707.15	14,790	50.4	95	0.38
Diesel Generators	20 (95.2 m OD)	0.6	0.28	736.15	19,396	20.8	1,355	7.30

Note Reference conditions are 273.15K, dry gas, 15% O_2.

4.0 RESULTS & DISCUSSION

4.1 Oxygen / Plume Interaction

The Mitre Corporation report (MITRE, 2012) confirms that depleted oxygen is generally of greatest concern when considering helicopter / plume interactions. The Mitre Corporation report confirms that at an oxygen content below 12% oxygen there is a risk of engine cut-out whilst above this level there is no risk to helicopter engines. Thus, modelling has been undertaken to determine the oxygen percentage of both the gas engines and diesel generators plume with distance from the stacks.

The following equation is used to model the % of oxygen in the plume with distance from the stack top. For a given emission concentration of any pollutant *e* (in $\mu g/m^3$), the oxygen content *O* (%), is related to the plume concentration *c* (in $\mu g/m^3$) by the following relationship (9.9 is the worst-case plume oxygen percentage at release for the gas engines):

$$c / e = (20.95 - O) / (20.95 - 9.9)$$

Thus, the calculation can be re-arranged to determine the oxygen content (%) of the plume as a function of distance from the stack top. The re-arranged equation is:

$$O (\%) = 20.95 - [(c/e) * (9.75)]$$

AMDS-5 was thus run to calculate the pollutant concentration and identify the distance from the plume centreline where the 12% oxygen level was exceeded for both the gas engines and diesel generators. Modelling was undertaken using Casement Aerodrome meteorological data for 2019 – 2021 with the worst-case year reported. Shown in Figure 3 is the result for the full year for the gas engines and in Figure 4 is the result for the full year for the diesel generators.

For the gas engines, within 1 m the oxygen content is greater than 12% oxygen. This analysis is based on every hour of the year for 2020 (worst-case year) and includes all meteorological conditions including pressure / temperature inversions.

For the diesel engines, within a distance of 1 m from the stack top, the oxygen content of the diesel generator plume will be 12% or greater. This analysis is based on every hour of the year for 2020 (worst-case year) and includes all meteorological conditions including pressure/temperature inversions.

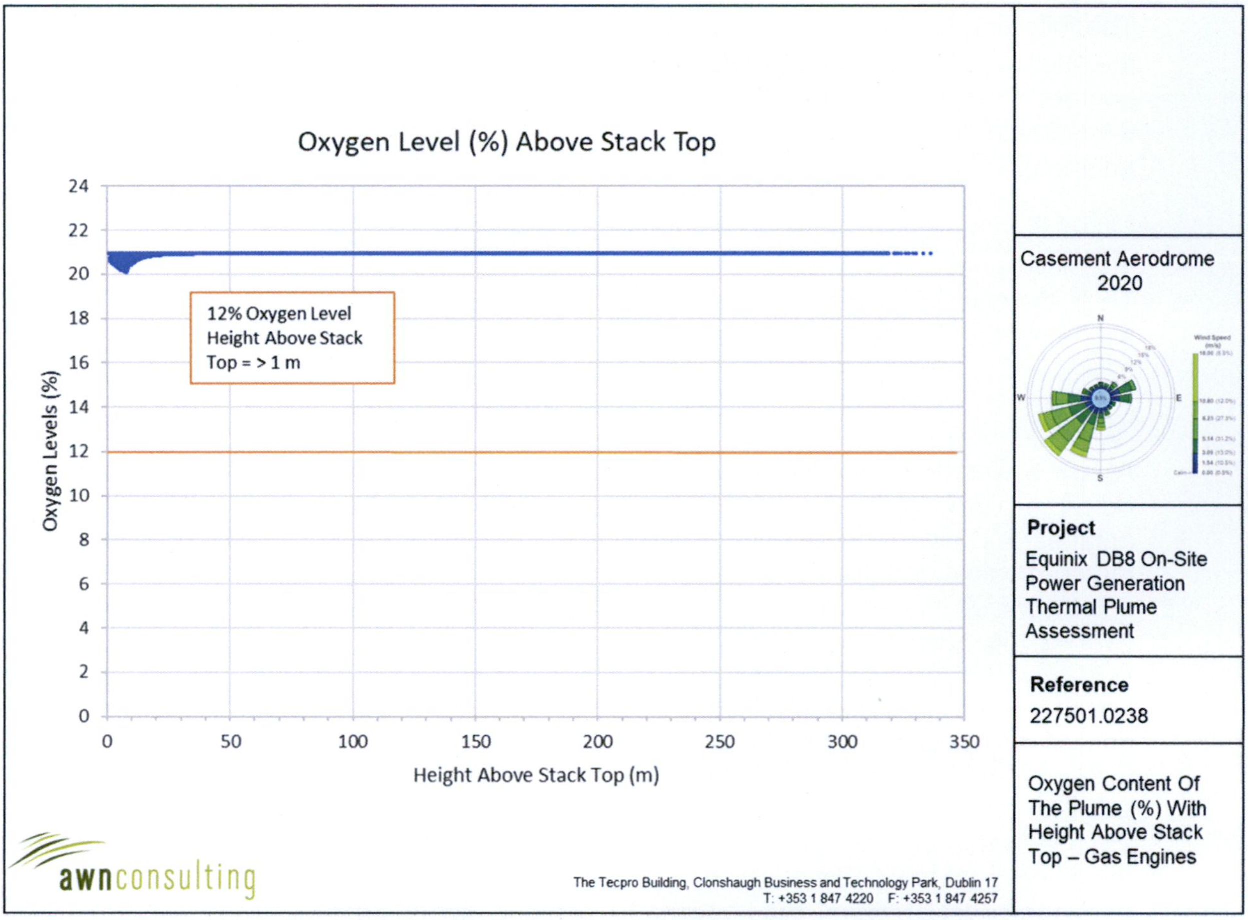

Figure 3. Oxygen Content Of The Plume (%) With Height Above Stack Top – Gas Engines

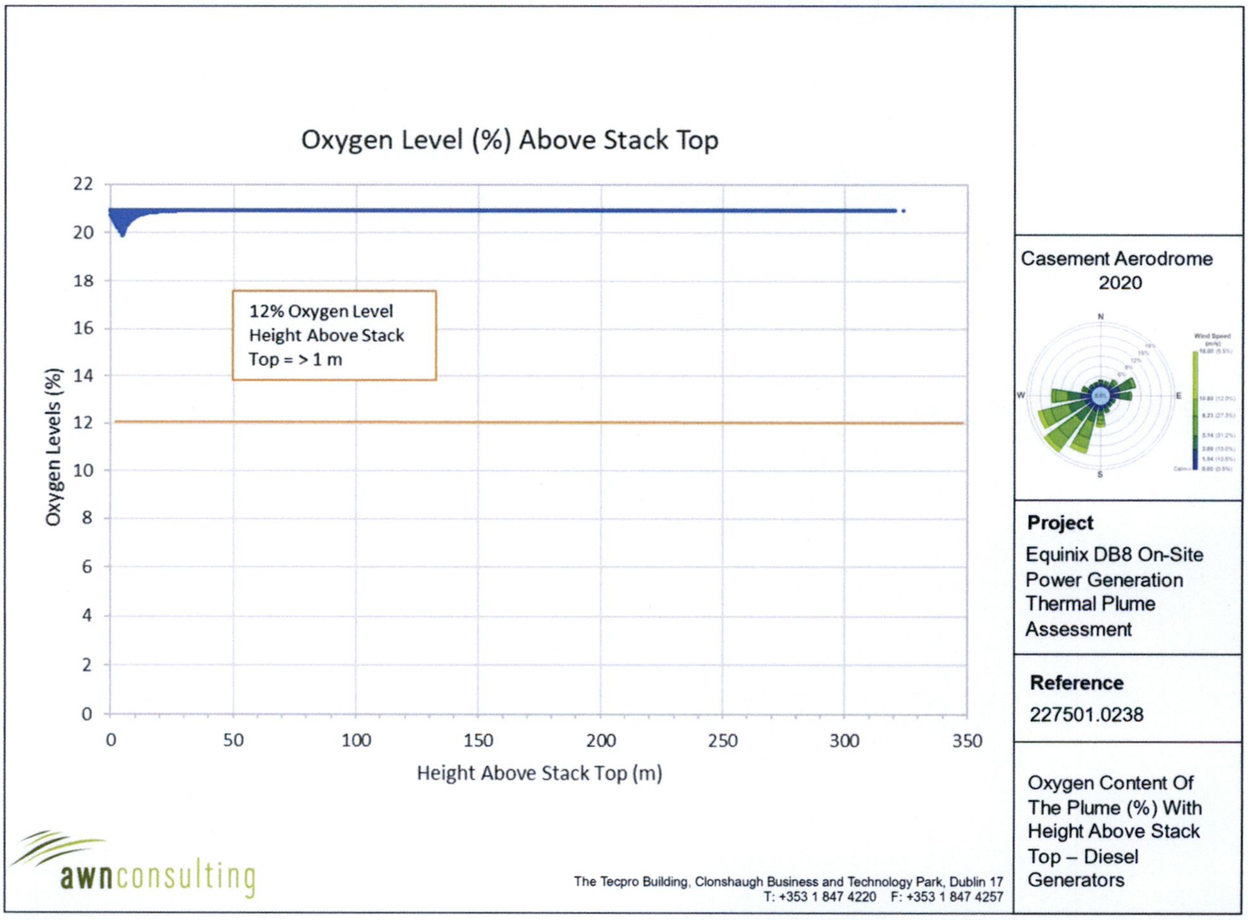

Figure 4. Oxygen Content Of The Plume (%) With Height Above Stack Top – Diesel Generators

4.2 Temperature / Plume Interaction

Temperatures in excess of 50°C are potentially hazardous to helicopters and thus the decrease in the initial temperature of both the gas engines plume (434°C) and the diesel generators plume (463°C) with distance from the stack has been investigated. Modelling of the temperature of the plume with distance from the stack has been undertaken using the CERC ADMS-5 model for every hour of the year based on Casement Aerodrome 2019 – 2021 meteorological data. The model has a specific temperature module which can, as part of the model output, give the temperature of the plume centreline with distance from the stack top.

The results are outlined below in Figure 5 and Figure 6 for 2020 (worst-case year) for the gas engines and in Figure 7 and Figure 8 for the diesel generators.

The results confirm that the plume will be below 50°C within 10 metres of the stack top and within 5 metres of the stack itself for every hour over the year for the gas engines and the plume will be below 50°C beyond 9 metres above the stack top and beyond 9 metres above the stack itself for every hour over the year for the diesel generators, including all meteorological conditions including pressure/temperature inversions for the worst-case year of 2020.

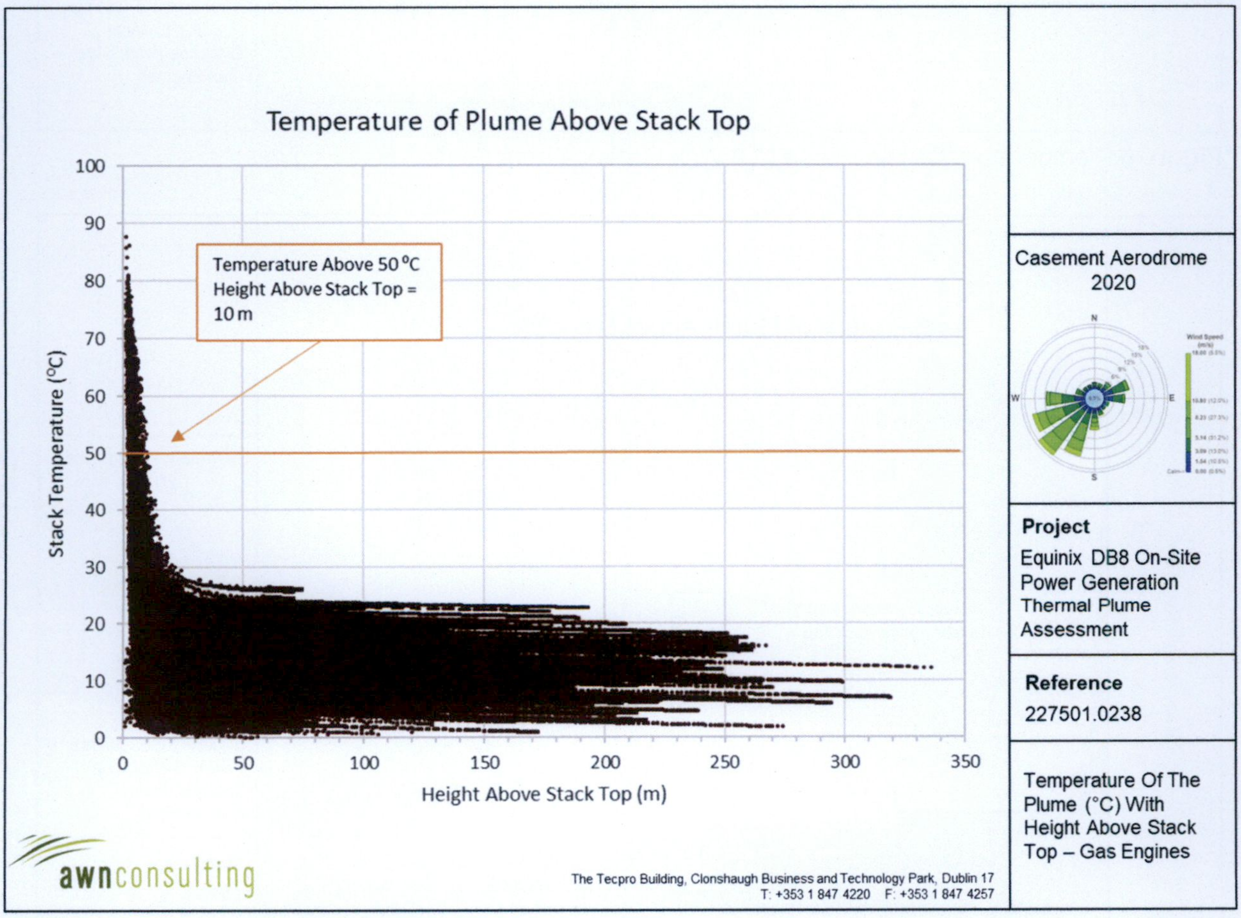

Figure 5. Temperature Of The Plume (°C) With Height Above Stack Top – Gas Engines

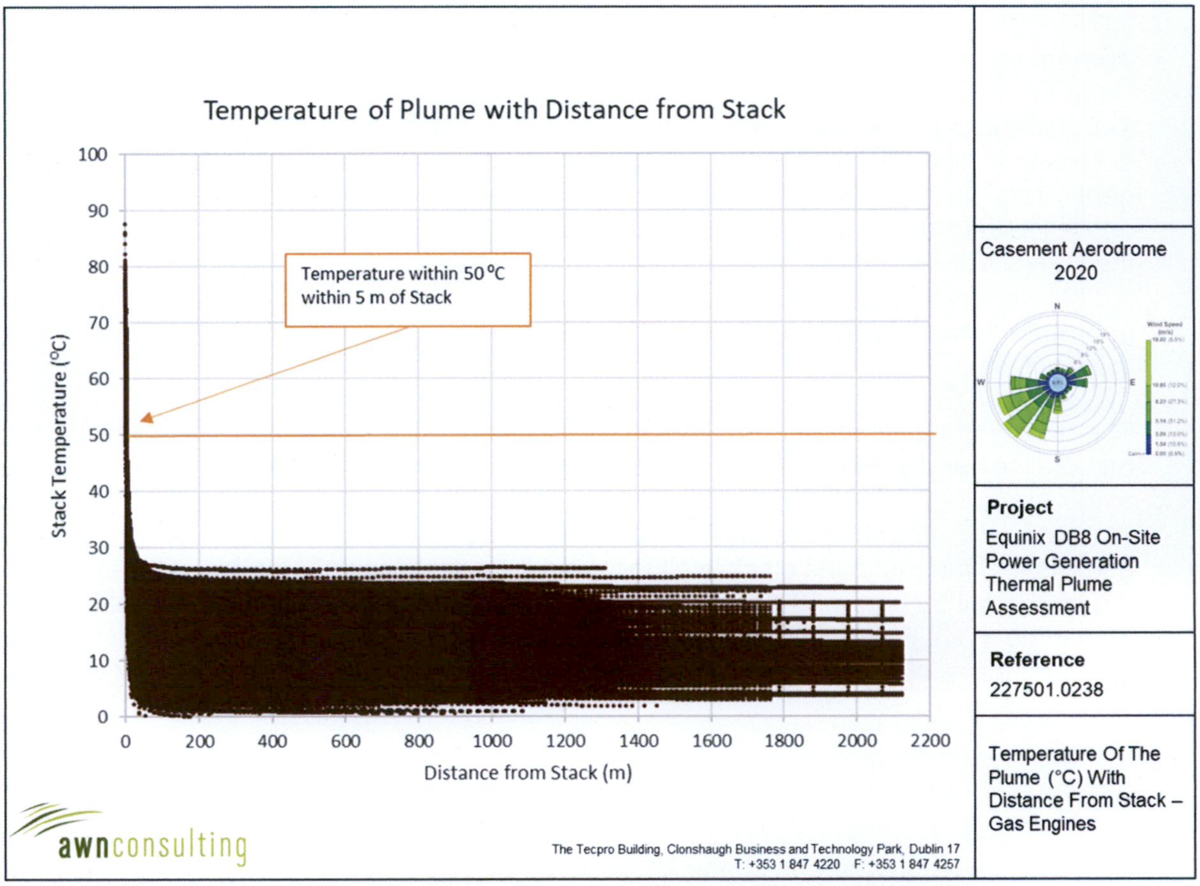

Figure 6. Temperature Of The Plume (°C) With Distance from Stack – Gas Engines

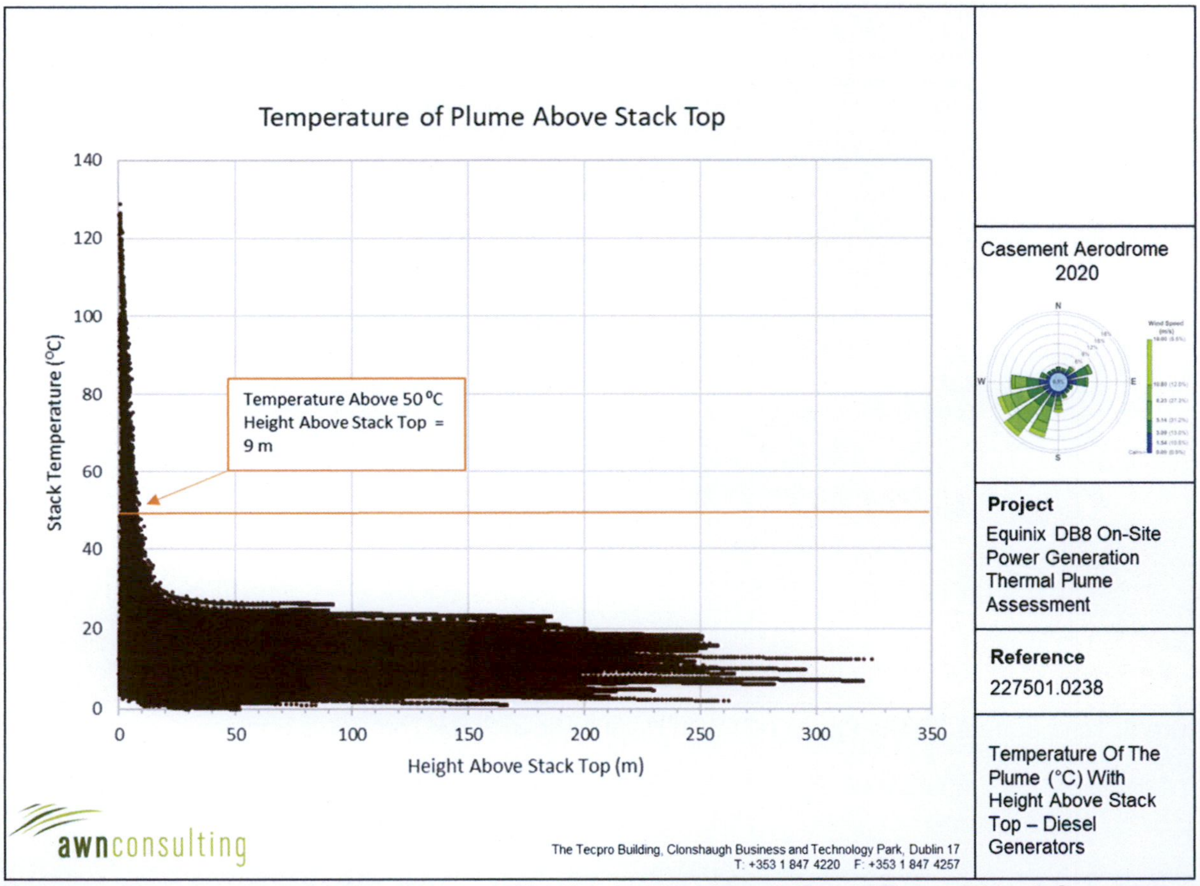

Figure 7. Temperature Of The Plume (°C) With Height Above Stack Top – Diesel Generators

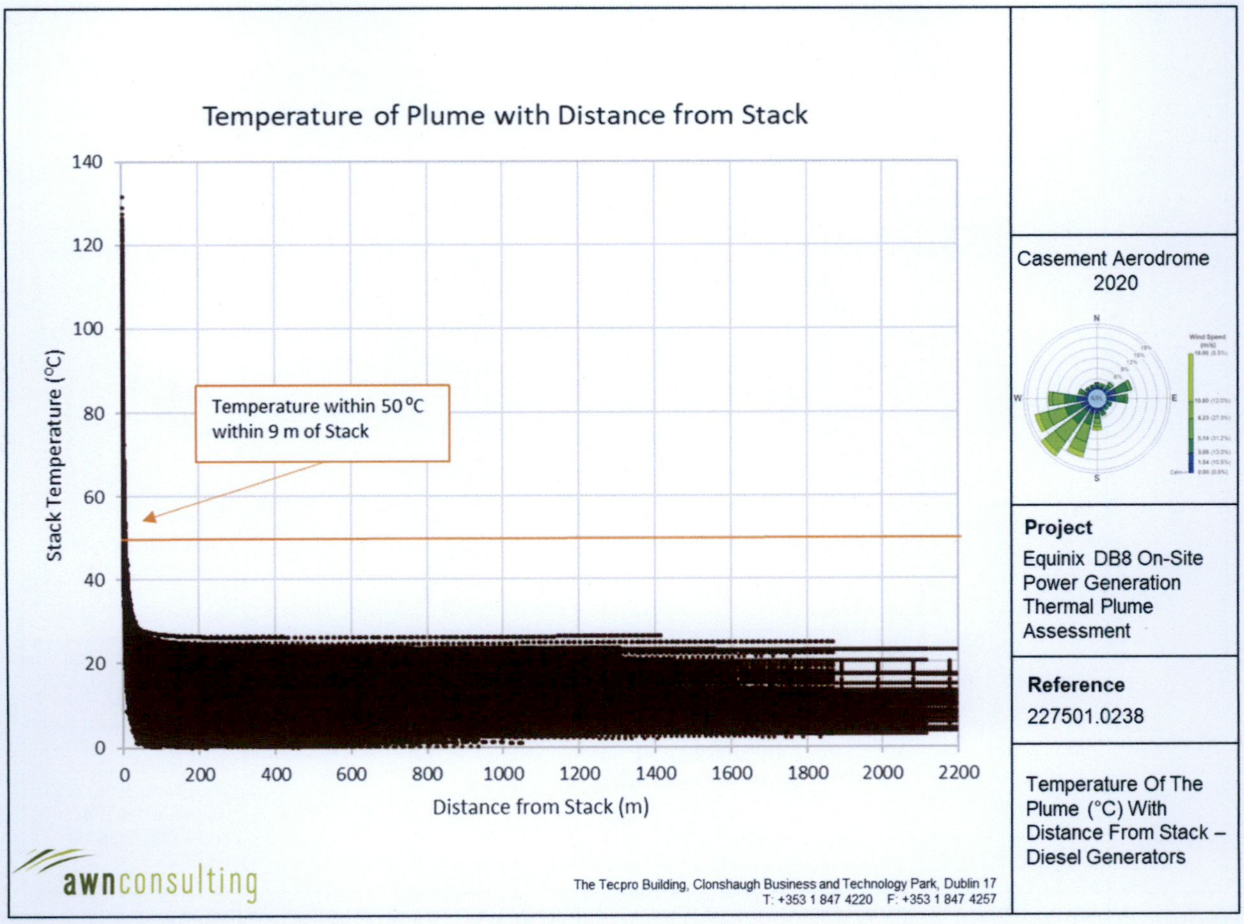

Figure 8. Temperature Of The Plume (°C) With Distance from Stack – Diesel Generators

4.3 Vertical Velocity / Plume Interaction

High vertical velocities are also relevant when considering helicopter / plume interactions. The Australian CASA (CASA, 2012) consider that the critical level for vertical velocity is 4.3 m/s. Thus, modelling has been undertaken to understand the vertical velocity of the plume with distance from the stack.

Cambridge Environmental Research Consultants (CERC), the developers of the EPA approved AMDS-5 model, were contacted to determine whether vertical velocity could be derived indirectly from the travel time of the plume with distance from the stack. CERC confirmed that the vertical velocity (in m/s) could be derived from an analysis of the plume centreline height (in metres) and the plume travel time (in seconds). The vertical velocity has been calculated for every hour of the year using Casement Aerodrome meteorological data for the period 2019 – 2021 as presented in Figure 9 and Figure 10 below for the gas engines and in Figure 11 and Figure 12 for the diesel generators for the worst-case year assessed (2020).

The results confirm that the vertical velocity of the plume will be below 4.3 m/s within 14 metres of the stack top and within 5 metres of the stack itself for every hour over the year for the gas engines and the plume will be below 4.3 m/s beyond 1 metre above the stack top and beyond 1 metre above the stack itself for every hour over the year for the diesel generators, including all meteorological conditions including pressure/temperature inversions for the worst-case year of 2020.

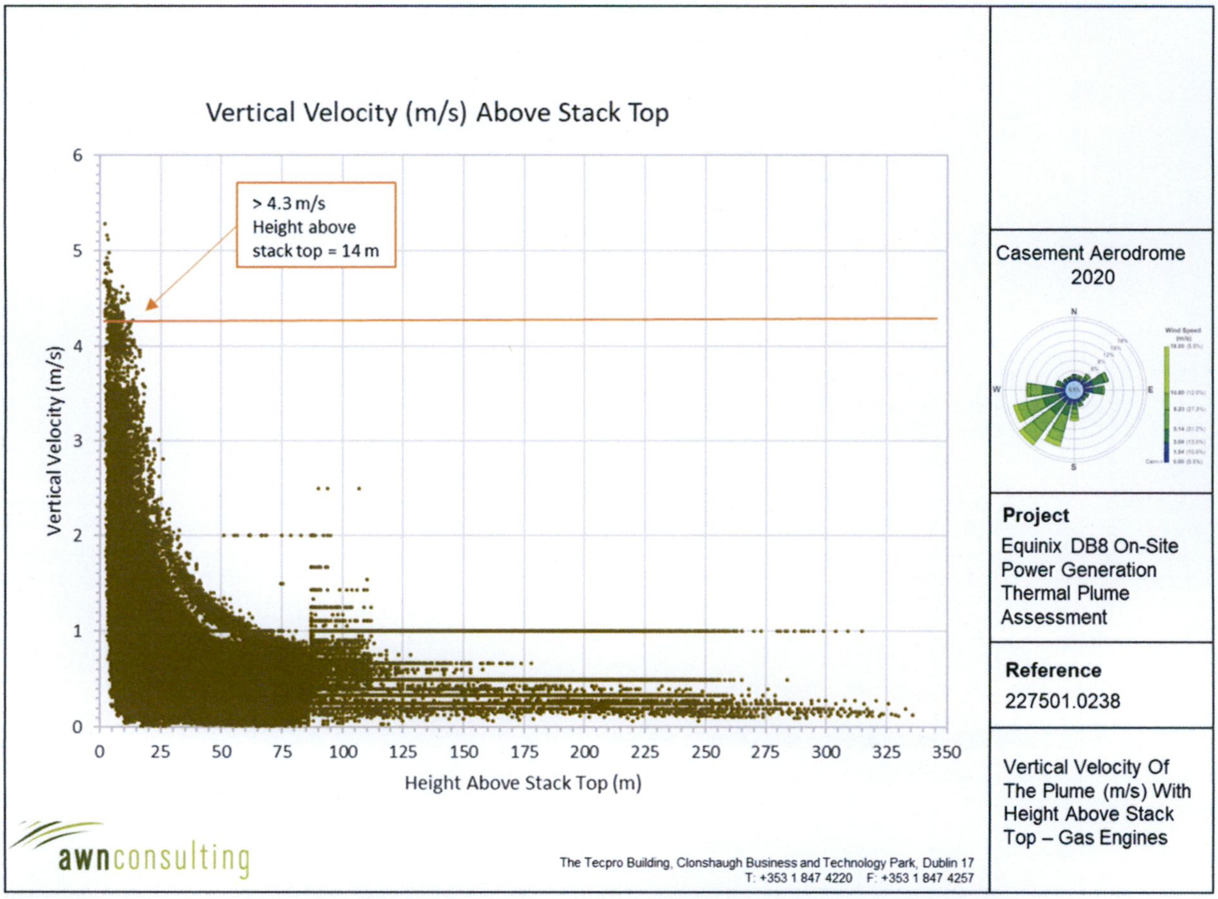

Figure 9. Vertical Velocity Of The Plume (m/s) With Height Above Stack Top – Gas Engines

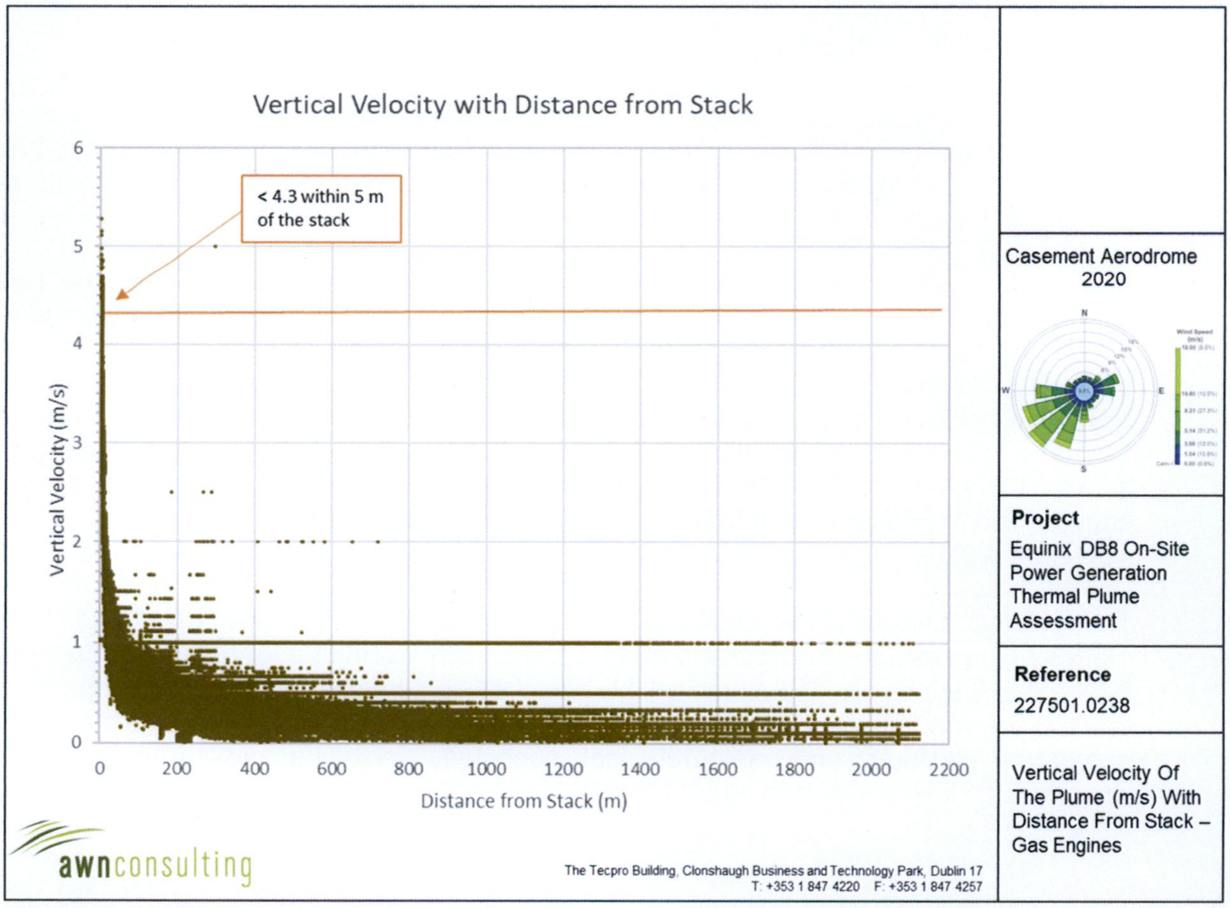

Figure 10. Vertical Velocity Of The Plume (m/s) With Distance from Stack – Gas Engines

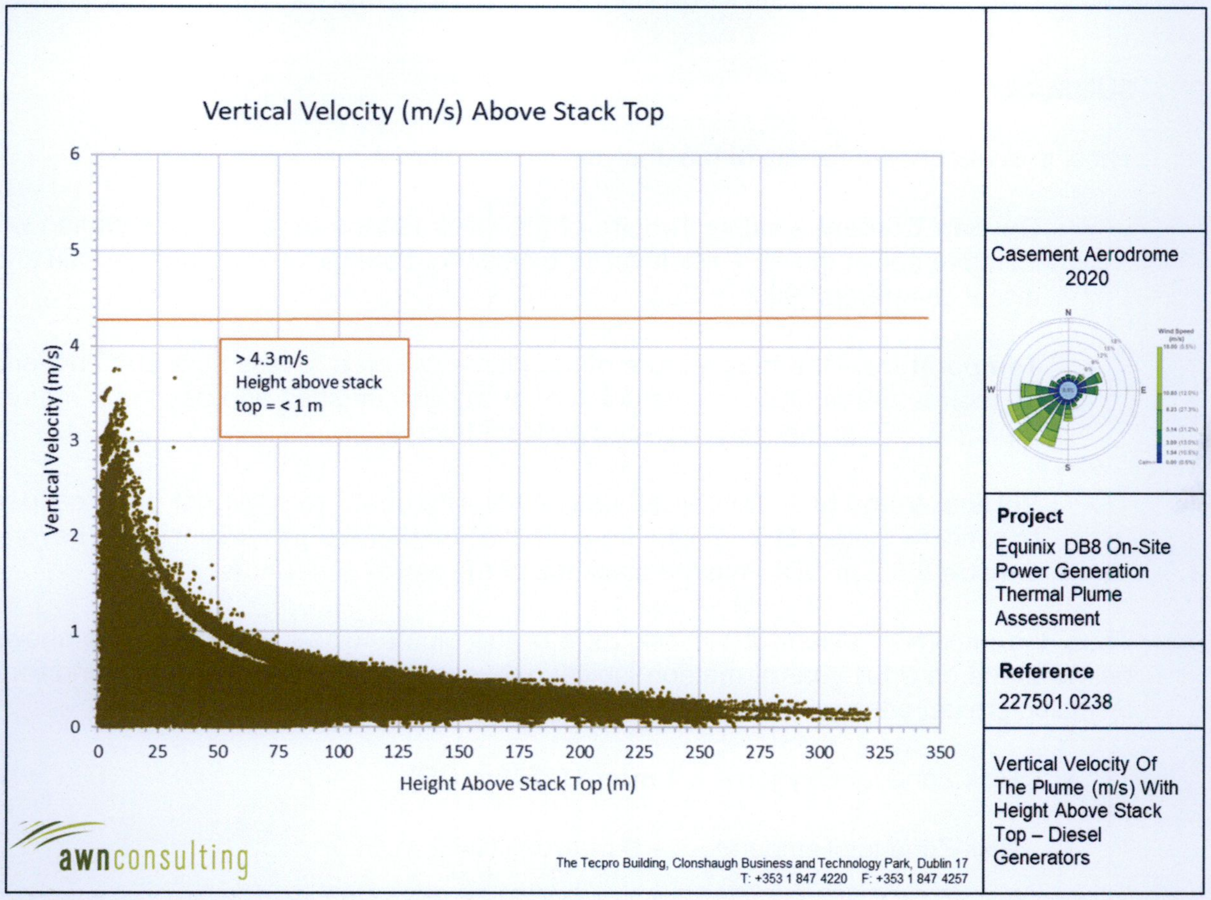

Figure 11. Vertical Velocity Of The Plume (m/s) With Height Above Stack Top – Diesel Generators

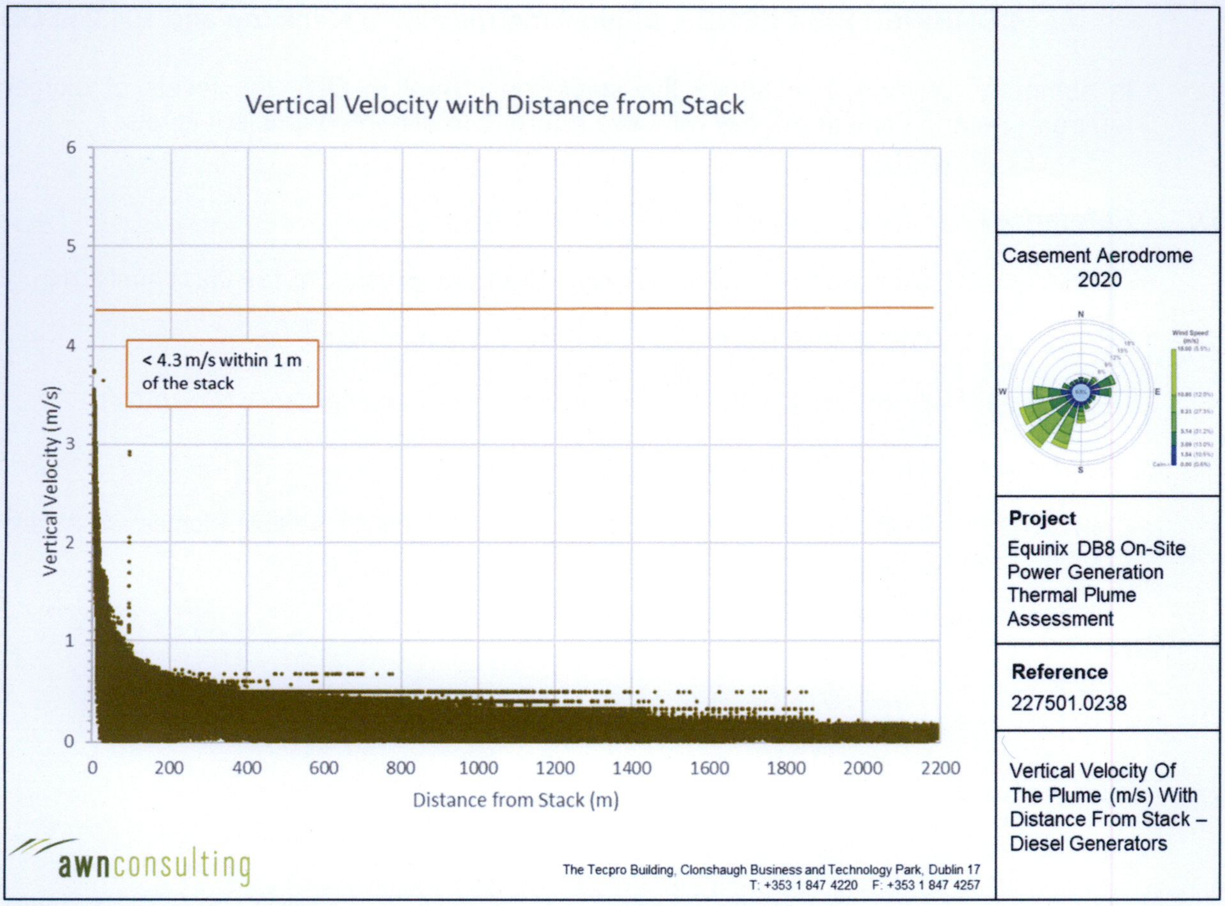

Figure 12. Vertical Velocity Of The Plume (m/s) With Distance from Stack – Diesel Generators

5.0 SUMMARY

Thus, in summary the results of the analysis are as follows:

- **Oxygen Content** – within 1 metre of the stack top the oxygen concentration will increase above the 12% risk level for oxygen for both gas engines (90 m OD) and diesel generators (96.2 m OD).
- **Temperature** – the temperature of the plume will drop to less than 50°C beyond 10 metres (99 m OD) of the stack top for the gas engines and beyond 9 metres (104.2 m OD) of the stack top for the diesel generators.
- **Vertical Velocity** – the critical vertical velocity of 4.3 m/s will not be exceeded beyond 14 metres (103 m OD) from the stack top of the gas engines and beyond 1 metre (96.2 m OD) from the stack top of the diesel generators.

Thus, the maximum extent of the risk zone of the plume for each parameter is shown below based on a full year of meteorological data covering all meteorological conditions including pressure/temperature inversions:

- Risk Zone for Oxygen **– < 1 metre (96.2 m OD)**
- Risk Zone for Temperature **– 9 metres (104.2 m OD)**
- Risk Zone for Vertical Velocity **– 14 metres (103 m OD)**
- **COMBINED RISK ZONE – within 9 metres above stack top and 104.2 m OD.**

In summary, beyond 9 m above the stack top (104.2 m OD), the levels of oxygen, temperature and vertical velocity will have returned to accepted/ambient levels.

6.0 References

CASA (2012) Guidelines For Conducting Plume Rise Assessments AC139-05(1) April 2012

CERC (2016) ADMS-5 User Guide

EPA (2020) Air Dispersion Modelling from Industrial Installations Guidance Note (AG4)

Met Éireann (2022) Met Éireann Website: www.met.ie

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USEPA (2018) AERMOD Description of Model Formulation