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EQUINIX DB8 DATA CENTER AIR QUALITY AND CLIMATE ASSESSMENT

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EXECUTIVE SUMMARY

This report presents an air quality and climate assessment for a proposed Equinix DB6 data centre development at a site located off the Nangor Road, Grangecastle, Co. Dublin. This assessment was carried out to determine the potential air quality impacts for the proposed development. There will be a total of 8 no. diesel generators on site, with a maximum of 7 no. diesel generators in operation at any one time, which will provide power to the site when power from the grid is not available or there is a requirement to reduce the load on the grid. Air dispersion modelling of nitrogen dioxide (NO_2) emissions was carried out using the United States Environmental Protection Agency's regulated model AERMOD. The modelling of air emissions from the site was carried out to assess concentrations of NO_2 at a variety of locations beyond the site boundary.

Air Quality

The assessment was carried out the determine the ambient air quality impact of the site and any air quality constraints that may be present. It was determined that as the proposed diesel generators will be used solely for emergency operation (i.e. less than 500 hours per year) the emission limit values outlined in the Medium Combustion Plant Directive are not applicable to the diesel generators on site.

A number of modelling scenarios were investigated for the purposes of this assessment. Both normal day-to-day testing operations were considered as well as emergency operations. Normal testing operations involved the diesel generators operating for up to 1-hour on a weekly basis at 100% load with no more than one generator tested at the same time. Emergency operation was based on 200 emergency hours modelled according to the USEPA methodology.

An iterative stack height assessment was undertaken to determine the minimum stack height required for dispersion purposes. It was found that a stack height of 20m above local ground level was sufficient for dispersion of pollutants.

The results indicate that the ambient ground level concentrations are in compliance with the relevant air quality standards for NO_2. For the worst-case year, emissions from the site lead to an ambient NO_2 concentration (including background) which is 85% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 91% of the annual limit value at the worst-case off-site receptor. The UK EA assessment methodology determined that in any year, the diesel generators can operate for the full year with no likelihood of an exceedance at the nearest residential receptor (at a 98th percentile confidence level). This is based on the emergency operation of 7 of the 8 no. diesel generators.

Results are similar for the cumulative scenario with emissions from the site and nearby licenced facilities leading to an ambient NO_2 concentration (including background) which is 85% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 92% of the annual limit value at the worst-case off-site receptor. The UK EA assessment methodology determined that in any year, the diesel generators, under the cumulative scenario, can operate for the full year with no likelihood of an exceedance at the nearest residential receptor (at a 98th percentile confidence level). This is based on the emergency operation of 7 of the 8 no. diesel generators.

Climate

The existing climate baseline can be determined by reference to data from the EPA on Ireland's total greenhouse gas (GHG) emissions and compliance with European Union's Effort Sharing Decision "EU 2020 Strategy" (Decision 406/2009/EC). Data from the EPA in 2020 estimates that Ireland had total GHG emissions for 2019 of 59.9 million tonnes carbon dioxide equivalent (Mt CO_2eq). This is 6.98 Mt higher than Ireland's emission ceiling for 2019 as set under the EU's Effort Sharing Decision (ESD), 406/2009/EC. Emissions are predicted to continue to exceed the targets in future years.

Based on the scale and temporary nature of the construction works, the potential impact on climate change and transboundary pollution from the construction of the Proposed Development is deemed to be short-term and imperceptible in relation to Ireland's obligations under the EU 2020 target.

No significant on-site CO_2 emissions will occur as a result of the Proposed Development. Whilst the use of electricity for the Proposed Development would indirectly result in emissions, these will be regulated under the Emission Trading Scheme (ETS) and thus the overall impact to climate is deemed indirect, negative, long-term and slight.

Conclusion

The modelling study has concluded that provided the stacks are built to a height of 20m and the emission enveloped assumed for this study is complied with then emissions from the diesel generators will be in compliance with the ambient air quality standards which are based on the protection of the environment and human health.

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1.0 INTRODUCTION

This report presents an air quality and climate assessment for a proposed Equinix DB6 data centre development at a site located off the Nangor Road, Grangecastle, Co. Dublin. This assessment was carried out to determine the potential air quality impacts for the proposed development. There will be a total of 8 no. main diesel generators on site, with a maximum of 7 no. diesel generators in operation at any one time, which will provide power to the site when power from the grid is not available or there is a requirement to reduce the load on the grid. In addition, a front-of-house (FOH) generator will also be in operation. Air dispersion modelling of nitrogen dioxide (NO_2) emissions was carried out using the United States Environmental Protection Agency's regulated model AERMOD. The modelling of air emissions from the site was carried out to assess concentrations of NO_2 at a variety of locations beyond the site boundary.

The assessment was carried out to determine the ambient air quality impact of the site and any air quality or climate constraints that may be present. It was determined that as the proposed diesel generators will be used solely for emergency operation (i.e. less than 500 hours per year) the emission limit values outlined in the Medium Combustion Plant Directive are not applicable to the diesel generators on site.

Information supporting the conclusions has been detailed in the following sections. The assessment methodology and study inputs are presented in Section 2 and Section 3. Background pollutant concentrations are summarised in Section 4. The process emissions and modelling inputs for on-site plant are presented in Section 5. The dispersion modelling results are presented in Section 6 and the assessment summaries are presented in Section 7. The model formulation is detailed in Appendix I and a review of the meteorological data used is detailed in Appendix II.

2.0 ASSESSMENT CIRTERIA

2.1 Ambient Air Quality Standards

In order to reduce the risk to health from poor air quality, national and European statutory bodies have set limit values in ambient air for a range of air pollutants. These limit values or "Air Quality Standards" are health or environmental-based levels for which additional factors may be considered. The applicable standards in Ireland include the Air Quality Standards Regulations 2011, which incorporate EU Directive 2008/50/EC (see Table 1). The ambient air quality standards applicable for NO_2 are outlined in this Directive.

Air quality significance criteria are assessed on the basis of compliance with the appropriate standards or limit values. The standards outlined in Table 1 have been used in the current assessment to determine the potential impact of NO_2 emissions from the facility on ambient air quality.

Pollutant	Regulation Note 1	Limit Type	Value
Nitrogen Dioxide (NO_2)	2008/50/EC	Hourly limit for protection of human health - not to be exceeded more than 18 times/year	200 μg/m^3
		Annual limit for protection of human health	40 μg/m^3

Note 1 EU 2008/50/EC – Clean Air For Europe (CAFÉ) Directive replaces the previous Air Framework Directive (1996/30/EC) and daughter directives 1999/30/EC and 2000/69/EC

Table 1 Ambient Air Quality Standards

2.2 Climate Agreements

Ireland is party to both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The Paris Agreement, which entered into force in 2016, is an important milestone in terms of international climate change agreements and includes an aim of limiting global temperature increases to no more than 2°C above pre-industrial levels with efforts to limit this rise to 1.5°C. The aim is to limit global GHG emissions to 40 gigatonnes as soon as possible whilst acknowledging that peaking of GHG emissions will take longer for developing countries. Contributions to GHG emissions will be based on Intended Nationally Determined Contributions (INDCs) which will form the foundation for climate action post 2020. Significant progress was also made in the Paris Agreement on elevating adaption onto the same level as action to cut and curb emissions.

In order to meet the commitments under the Paris Agreement, the EU enacted *Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No. 525/2013* (the Regulation). The Regulation aims to deliver, collectively by the EU in the most cost-effective manner possible, reductions in GHG emissions from the Emission Trading Scheme (ETS) and non-ETS sectors amounting to 43% and 30%, respectively, by 2030 compared to 2005. Ireland's obligation under the Regulation is a 30% reduction in non-ETS greenhouse gas emissions by 2030 relative to its 2005 levels.

In 2015, the Climate Action and Low Carbon Development Act 2015 (No. 46 of 2015) (Government of Ireland, 2015) was enacted (the Act). The purpose of the Act was to enable Ireland '*to pursue, and achieve, the transition to a low carbon, climate resilient and environmentally sustainable economy by the end of the year 2050*' (3.(1) of No.

46 of 2015). This is referred to in the Act as the '*national transition objective*'. The Act makes provision for a national mitigation plan, and a national adaptation framework. In addition, the Act provided for the establishment of the Climate Change Advisory Council with the function to advise and make recommendations on the preparation of the national mitigation and adaptation plans and compliance with existing climate obligations.

The *Climate Action Plan* (CAP) (Government of Ireland, 2019), published in June 2019, outlines the current status across key sectors including Electricity, Transport, Built Environment, Industry and Agriculture and outlines the various broadscale measures required for each sector to achieve ambitious decarbonisation targets. The CAP also details the required governance arrangements for implementation including carbon-proofing of policies, establishment of carbon budgets, a strengthened Climate Change Advisory Council and greater accountability to the Oireachtas. The CAP has set a built environment sector reduction target of 40 - 45% relative to 2030 pre-NDP (National Development Plan) projections.

Following on from Ireland declaring a climate and biodiversity emergency in May 2019 and the European Parliament approving a resolution declaring a climate and environment emergency in Europe in November 2019, the Government approved the publication of the General Scheme for the Climate Action (Amendment) Bill 2019 in December 2019 (Government of Ireland, 2020a). The General Scheme was prepared for the purposes of giving statutory effect to the core objectives stated within the CAP. It is expected that the new Climate Action (Amendment) Bill (the Bill) will be published before the end of 2021.

In October 2020, the Climate Action and Low Carbon Development (Amendment) Bill 2020 (Government of Ireland, 2020b) was published in draft format (draft 2020 Climate Act) which amends and enhances the 2015 Climate Act. Once approved, the purpose of the 2020 Climate Act is to provide for the approval of plans '*for the purpose of pursuing the transition to a climate resilient and climate neutral economy by the end of the year 2050*'. The 2020 Climate Act will also '*provide for carbon budgets and a decarbonisation target range for certain sectors of the economy*'. The 2020 Climate Act removes any reference to a national mitigation plan and instead refers to both the Climate Action Plan, as published in 2019, and a series of National Long Term Climate Action Strategies. In addition, the Environment Minister shall request each local authority to make a 'local authority climate action plan' lasting five years and to specify the mitigation measures and the adaptation measures to be adopted by the local authority.

Individual county councils in Ireland have also published their own Climate Change Strategies which outline the specific climate objectives for that local authority and associated actions to achieve the objectives. The South Dublin County Council (SDCC) Climate Action Plan (SDCC and Codema 2019) outlines SDCC's goals to mitigate GHG emissions and plans to prepare for and adapt to climate change. The SDCC Climate Action Plan highlights the risks that climate change poses to transportation network with risks mainly associated with extreme weather events and sea level rise. The SDCC Climate Action Plan, in relation to energy and built environment, has a target of a 33% improvement in energy efficiency by 2020 and a 40% reduction in council's GHG emissions by 2030. Additional measures include an energy master plan for the Dublin region and upgrades in buildings using Energy Performance Contracts.

3.0 ASSESSMENT METHODOLOGY

Emissions from the facility have been modelled using the AERMOD dispersion model (Version 19191) which has been developed by the U.S. Environmental Protection Agency (USEPA)[1] and following guidance issued by the EPA[2]. The model is a steady-state Gaussian plume model used to assess pollutant concentrations associated with industrial sources and has replaced ISCST3[3] as the regulatory model by the USEPA for modelling emissions from industrial sources in both flat and rolling terrain[4-6]. The model has more advanced algorithms and gives better agreement with monitoring data in extensive validation studies[6-10]. An overview of the AERMOD dispersion model is outlined in Appendix I.

The air dispersion modelling input data consisted of information on the physical environment (including building dimensions and terrain features), design details from all emission points on-site and five years of appropriate hourly meteorological data. Using this input data the model predicted ambient ground level concentrations beyond the site boundary for each hour of the modelled meteorological years. The model post-processed the data to identify the location and maximum of the worst-case ground level concentration. This worst-case concentration was then added to the background concentration to give the worst-case predicted environmental concentration (PEC). The PEC was then compared with the relevant ambient air quality standard to assess the significance of the releases from the site.

The modelling aims to achieve compliance with the guidance outlined within Appendix K of the EPA document *AG4 Guidance for Air Dispersion Modelling*[2]

Throughout this study a worst-case approach was taken where possible. This will most likely lead to an over-estimation of the levels that will arise in practice. The worst-case assumptions are outlined below:

- Maximum predicted concentrations were reported in this study, even if no residential receptors were near the location of this maximum;
- Conservative background concentrations were used in the assessment;
- The effects of building downwash, due to on-site buildings, has been included in the model.

3.1 Air Dispersion Modelling Methodology

The United States Environmental Protection Agency (USEPA) approved AERMOD dispersion model has been used to predict the ground level concentrations (GLC) of compounds emitted from the principal emission sources on-site.

The modelling incorporated the following features:

- Three receptor grids were created at which concentrations would be modelled. Receptors were mapped with sufficient resolution to ensure all localised "hot-spots" were identified without adding unduly to processing time. The receptor grids were based on Cartesian grids with the site at the centre. An outer grid measured 10 x 10 km with the site at the centre and with concentrations calculated at 500m intervals. A middle grid measured 5 x 5 km with the site at the centre and with concentrations calculated at 250m intervals. A smaller denser grid measured 1.5 x 1.5 km with the site at the centre and concentrations calculated at 125m intervals. Boundary receptor locations were also placed along the boundary of the site, at 25m intervals, giving a total of 4,072 calculation points for the model.

- Discrete receptors were also added to the model to represent nearby residential receptors.
- All on-site buildings and significant process structures were mapped into the computer to create a three dimensional visualisation of the site and its emission points. Buildings and process structures can influence the passage of airflow over the emission stacks and draw plumes down towards the ground (termed building downwash). The stacks themselves can influence airflow in the same way as buildings by causing low pressure regions behind them (termed stack tip downwash). Both building and stack tip downwash were incorporated into the modelling.
- Detailed terrain has been mapped into the model using SRTM data with 30m resolution. The site is located in an area of complex terrain. All terrain features have been mapped in detail into the model using the terrain pre-processor AERMAP[(11)].
- Hourly-sequenced meteorological information has been used in the model. Meteorological data over a five year period (Casement Aerodrome 2016 – 2020) was used in the model (see Figure 2 and Appendix II)[(12)].
- The source and emissions data, including stack dimensions, gas volumes and emission temperatures have been incorporated into the model.

3.2 Terrain

The AERMOD air dispersion model has a terrain pre-processor AERMAP[(11)] which was used to map the physical environment in detail over the receptor grid. The digital terrain input data used in the AERMAP pre-processor was obtained from SRTM. This data was run to obtain for each receptor point the terrain height and the terrain height scale. The terrain height scale is used in AERMOD to calculate the critical dividing streamline height, H_{crit}, for each receptor. The terrain height scale is derived from the Digital Elevation Model (DEM) files in AERMAP by computing the relief height of the DEM point relative to the height of the receptor and determining the slope. If the slope is less than 10%, the program goes to the next DEM point. If the slope is 10% or greater, the controlling hill height is updated if it is higher than the stored hill height.

In areas of complex terrain, AERMOD models the impact of terrain using the concept of the dividing streamline (H_c). As outlined in the AERMOD model formulation[(1)] a plume embedded in the flow below H_c tends to remain horizontal; it might go around the hill or impact on it. A plume above H_c will ride over the hill. Associated with this is a tendency for the plume to be depressed toward the terrain surface, for the flow to speed up, and for vertical turbulent intensities to increase.

AERMOD model formulation states that the model "captures the effect of flow above and below the dividing streamline by weighting the plume concentration associated with two possible extreme states of the boundary layer (horizontal plume and terrain-following). The relative weighting of the two states depends on: 1) the degree of atmospheric stability; 2) the wind speed; and 3) the plume height relative to terrain. In stable conditions, the horizontal plume "dominates" and is given greater weight while in neutral and unstable conditions, the plume traveling over the terrain is more heavily weighted"[(7)].

3.3 Meteorological Data

The selection of the appropriate meteorological data has followed the guidance issued by the USEPA[1]. A primary requirement is that the data used should have a data capture of greater than 90% for all parameters. 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%. Long-term hourly observations at Casement Aerodrome meteorological station provide an indication of the prevailing wind conditions for the region (see Figure 1 and Appendix II)[12]. Results indicate that the prevailing wind direction is westerly to south-westerly in direction over the period 2016 – 2020. The mean wind speed is approximately 5.5 m/s over the period 2016 - 2020.

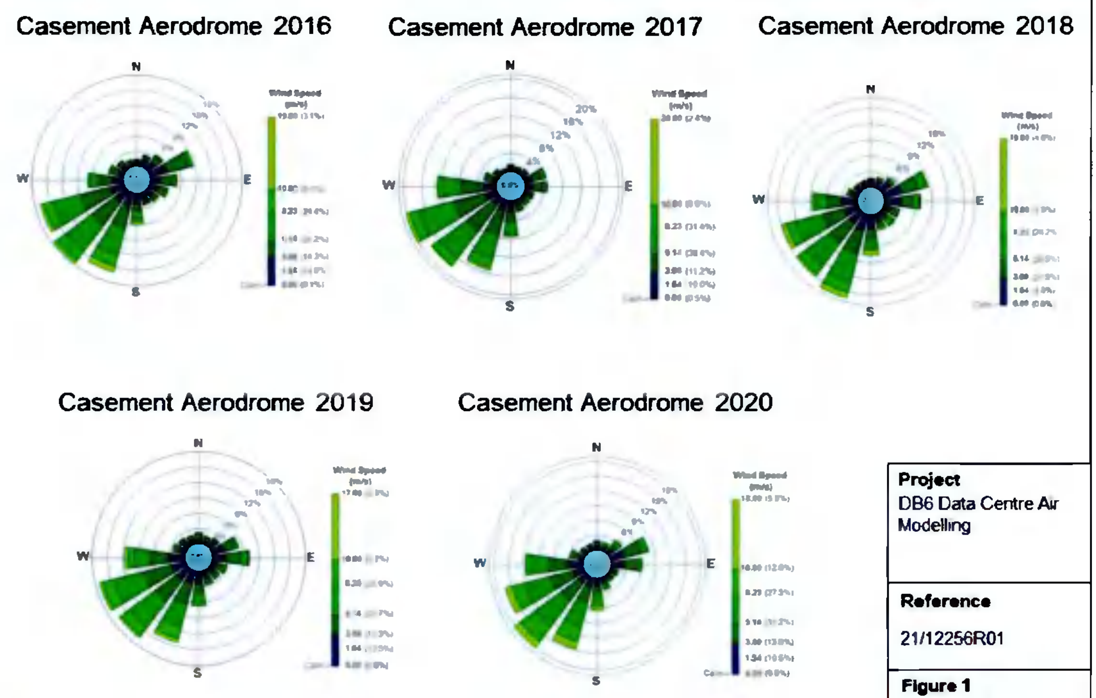

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Figure 1
Casement Aerodrome Windrose 2016 - 2020

3.4 Geophysical Considerations

AERMOD simulates the dispersion process using planetary boundary layer (PBL) scaling theory[1]. PBL depth and the dispersion of pollutants within this layer are influenced by specific surface characteristics such as surface roughness, albedo and the availability of surface moisture. Surface roughness is a measure of the aerodynamic roughness of the surface and is related to the height of the roughness element. Albedo is a measure of the reflectivity of the surface whilst the Bowen ratio is a measure of the availability of surface moisture.

AERMOD incorporates a meteorological pre-processor AERMET[13] to enable the calculation of the appropriate parameters. The AERMET meteorological preprocessor requires the input of surface characteristics, including surface roughness (z_0), Bowen Ratio and albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. The values of albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type was carried out to a distance of 10km from the meteorological station for Bowen Ratio and albedo and to a distance of 1km for surface roughness in line with USEPA recommendations[13,14] as outlined in Appendix II.

In relation to AERMOD, detailed guidance for calculating the relevant surface parameters has been published[14]. The most pertinent features are:

- The surface characteristics should be those of the meteorological site (Casement Aerodrome) rather than the installation;
- Surface roughness should use a default 1km radius upwind of the meteorological tower and should be based on an inverse-distance weighted geometric mean. If land use varies around the site, the land use should be sub-divided by sectors with a minimum sector size of 30°;
- Bowen ratio and albedo should be based on a 10km grid. The Bowen ratio should be based on an un-weighted geometric mean. The albedo should be based on a simple un-weighted arithmetic mean.

AERMOD has an associated pre-processor, AERSURFACE[14] which has representative values for these parameters depending on land use type. The AERSURFACE pre-processor currently only accepts NLCD92 land use data which covers the USA. Thus, manual input of surface parameters is necessary when modelling in Ireland. Ordnance survey discovery maps (1:50,000) and digital maps such as those provided by the EPA, National Parks and Wildlife Service (NPWS) and Google Earth® are useful in determining the relevant land use in the region of the meteorological station. The Alaska Department of Environmental Conservation has issued a guidance note for the manual calculation of geometric mean for surface roughness and Bowen ratio for use in AERMET[15]. This approach has been applied to the current site with full details provided in Appendix II.

3.5 Building Downwash

When modelling emissions from an industrial installation, stacks which are relatively short can be subjected to additional turbulence due to the presence of nearby buildings. Buildings are considered nearby if they are within five times the lesser of the building height or maximum projected building width (but not greater than 800m).

The USEPA has defined the “Good Engineering Practice” (GEP) stack height as the building height plus 1.5 times the lesser of the building height or maximum projected building width. It is generally considered unlikely that building downwash will occur when stacks are at or greater than GEP[16].

When stacks are less than this height, building downwash will tend to occur. As the wind approaches a building it is forced upwards and around the building leading to the formation of turbulent eddies. In the lee of the building these eddies will lead to downward mixing (reduced plume centreline and reduced plume rise) and the creation of a cavity zone (near wake) where re-circulation of the air can occur. Plumes released from short stacks may be entrained in this airflow leading to higher ground level concentrations than in the absence of the building.

The Plume Rise Model Enhancements (PRIME)[8,9] plume rise and building downwash algorithms, which calculates the impact of buildings on plume rise and dispersion, have been incorporated into AERMOD. The building input processor BPIP-PRIME produces the parameters which are required in order to run PRIME. The model takes into account the position of each stack relative to each relevant building and the projected shape of each building for 36 wind directions (at 10° intervals). The model determines the change in plume centreline location with downwind distance based on the slope of the mean streamlines and coupled to a numerical plume rise model[9].

Given that the stacks are less than 2.5 times the lesser of the building height or maximum projected building width, building downwash will need to be taken into account and the PRIME algorithm run prior to modelling with AERMOD. The dominant building for each relevant stack will vary as a function of wind direction and relative building heights.

4.0 BACKGROUND CONCENTRATIONS OF POLLUTANTS

Air quality monitoring programs have been undertaken in recent years by the EPA and Local Authorities[17,18]. The most recent annual report on air quality "*Air Quality in Ireland 2019*"[18], details the range and scope of monitoring undertaken throughout Ireland. As part of the implementation of the Framework Directive on Air Quality (1996/62/EC), four air quality zones have been defined in Ireland for air quality management and assessment purposes[17]. Dublin is defined as Zone A and Cork as Zone B. Zone C is composed of 23 towns with a population of greater than 15,000. The remainder of the country, which represents rural Ireland but also includes all towns with a population of less than 15,000 is defined as Zone D. In terms of air monitoring, Grangecastle is categorized as Zone A[17].

With regard to NO_2, continuous monitoring data from the EPA[17,18], at suburban Zone A background locations in Rathmines, Swords and Ballyfermot show that current levels of NO_2 are below both the annual and 1-hour limit values, with annual average levels ranging from 15 - 22 µg/m³ in 2019 (see Table 2). Sufficient data is available for the station in Swords, a location outside of the M50, to observe long-term trends since 2015[17], with annual average results ranging from 13 – 16 µg/m³. The 1-hour concentrations, measured as a 99.8th percentile were also in compliance with the 1-hour limit value of 200 µg/m³. Based on these results, an estimate of the current background NO_2 concentration in the region of the proposed development is 15 µg/m³.

In relation to the annual average background, the ambient background concentration was added directly to the process concentration with the short-term peaks assumed to have an ambient background concentration of twice the annual mean background concentration.

The methodology for converting NO_X to NO_2 was based on the ozone limiting method (OLM) approach based on an initial NO_2/NO_X ratio of 0.1 and a background ozone level of 55 µg/m³ based on a review of EPA data for similar Zone A locations[18].

Year	Ballyfermot	Rathmines	Swords
2015	16	18	13
2016	17	20	16
2017	16	17	14
2018	17	20	16
2019	20	22	15
Average	**17**	**19**	**15**

Table 2 Annual Mean NO_2 Concentrations In Zone A Locations (µg/m³)

4.1 Climate Baseline

Anthropogenic emissions of greenhouse gases in Ireland included in the EU 2020 strategy are outlined in the most recent review by the EPA which details provisional emissions up to 2019[19]. The data published in 2020 states that Ireland will exceed its 2019 annual limit set under the EU's Effort Sharing Decision (ESD), 406/2009/EC1 by an estimated 6.98 Mt. For 2019, total national greenhouse gas emissions are estimated to be 59.90 million tonnes carbon dioxide equivalent (Mt CO_2eq) with 45.71 MtCO_2eq of emissions associated with the ESD sectors for which compliance with the EU targets must be met. Agriculture is the largest contributor in 2019 at 35.3% of the total, with the transport sector accounting for 20.3% of emissions of CO_2.

GHG emissions for 2019 are estimated to be 4.5% lower than those recorded in 2018. Emission reductions have been recorded in 6 of the last 10 years. However, compliance with the annual EU targets has not been met for four years in a row. Emissions from 2016 – 2019 exceeded the annual EU targets by 0.29 $MtCO_2eq$, 2.94 $MtCO_2eq$, 5.57 $MtCO_2eq$ and 6.98 $MtCO_2eq$ respectively. Agriculture is consistently the largest contributor to emissions with emissions from the transport and energy sectors being the second and third largest contributors respectively in recent years.

The EPA 2019 GHG Emissions Projections Report for 2018 – 2040[20] notes that there is a long-term projected decrease in greenhouse gas emissions as a result of inclusion of new climate mitigation policies and measures that formed part of the National Development Plan (NDP) which was published in 2018. Implementation of these are classed as a "*With Additional Measures scenario*" for future scenarios. A change from generating electricity using coal and peat to wind power and diesel vehicle engines to electric vehicle engines are envisaged under this scenario. While emissions are projected to decrease in these areas, emissions from agriculture are projected to grow steadily due to an increase in animal numbers. However, over the period 2013 – 2020 Ireland is projected to cumulatively exceed its compliance obligations with the EU's Effort Sharing Decision (Decision No. 406/2009/EC) 2020 targets by approximately 10 Mt CO_2eq under the "*With Existing Measures*" scenario and 9 Mt CO_2eq under the "*With Additional Measures*" scenario[20].

5.0 OPERATIONAL EMISSIONS

It is proposed to have a total of 8 no. diesel generators on site. In addition, a front-of-house (FOH) generator will also be in operation. An iterative stack height assessment was conducted in order to determine the minimum stack height required for optimum dispersion.

5.1 Construction Phase

Air Quality

The current assessment focused firstly on identifying the existing baseline levels of NO_2, PM_{10} and $PM_{2.5}$ in the region of the proposed facility by an assessment of EPA monitoring data. Thereafter, the impact of the construction phase on air quality was determined by a qualitative assessment of the nature and scale of dust generating construction activities associated with the proposed facility.

When appropriate dust mitigation measures are implemented, fugitive emissions of dust and particulate matter from the site will be negative, short-term and imperceptible in nature, posing no nuisance at nearby receptors.

Climate

The impact of the construction phase of the proposed facility on climate was determined by a qualitative assessment of the nature and scale of greenhouse gas generating construction activities associated with the Proposed Development.

The Institute of Air Quality Management document '*Guidance on the Assessment of Dust from Demolition and Construction*'[(21)] states that site traffic and plant is unlikely to make a significant impact on climate. Based on the scale and temporary nature of the construction works and the intermittent use of equipment, the potential impact on climate change and transboundary pollution from the proposed facility is deemed to be negative, short-term and imperceptible in nature in relation to Ireland's obligations under the EU 2030 target.

5.2 Air Quality - Emergency Operations

The diesel generators will operate in an emergency scenario when there is a power outage in the area. In addition, testing of the generators at reduced load will be required. It has been assumed that this will occur weekly with one generator tested within any one hour. In reality, testing will be of less frequency than this.

There are two methodologies used to determine the impact from the operation of the diesel generators on ambient air quality. Both methodologies from the USEPA and UK EA have been used in this assessment, this follows the guidance outlined in Appendix K of the Irish EPA document AG4[(2)]. Emission details can be seen in Table 3.

USEPA Guidance suggests that for emergency operations, an average hourly emission rate should be used rather than the maximum hourly rate[(22)]. As a result, the maximum hourly emission rates from the diesel generators were reduced by $\frac{200}{8760}$ and the diesel generators were modelled over a period of one full year.

A second methodology has been published by the UK Environment Agency. The consultation document is entitled "*Diesel Generator Short-Term NO_2 Impact Assessment*"[(23)]. The methodology is based on considering the statistical likelihood of an exceedance of the NO_2 hourly limit value (18 exceedances are allowable per year before the air standard is deemed to have been exceeded). The assessment assumes a hypergeometric distribution to assess the likelihood of exceedance hours coinciding with the emergency operational hours of the diesel generators. The cumulative hypergeometric distribution of 19 and more hours per year is computed and the probability of an exceedance determined. The guidance suggests that the 95th percentile confidence level should be used to indicate if an exceedance is likely. More recent guidance[24] has recommended this probability should be multiplied by a factor of 2.5 and therefore the 98th percentile confidence level should be used to indicate if an exceedance is likely. The guidance suggests that the assessment should be conducted at the nearest residential receptor or at locations where people are likely to be exposed and that there should be no running time restrictions on these generators when providing power on site during an emergency.

Both the methodology advised in the USEPA guidance as well as the approach described in the UK EA guidance have been applied for the emergency scenario modelled in this study to ensure a robust assessment of predicted air quality impacts from the diesel generators. This also follows the guidance outlined in Appendix K of the EPA AG4 guidance[2] which includes the methodology for assessing emissions of air pollutants from nearby licenced facilities by means of a cumulative assessment.

Stack Reference	Exit Diameter (m)	Cross Sectional Area (m^2)	Temp (K)	Volume Flow Rate (Nm^3/hr at 15% Ref. O_2)	Exist Velocity (m/sec actual)	NO_x Concentration (mg/Nm^3 at 15% O_2 Ref.)	Mass Emission (g/s)
Diesel generators – Testing	0.6	0.28	736.15	19,396	20.8	1355	7.30
Diesel generators – Emergency Operations	0.6	0.28	736.15	19,396	20.8	1355	7.30 Note 2 / 0.167 Note 3
Front of House generator	0.5	0.20	778.25	10,062	11.4	510	1.42

Note 1 For the purposes of this assessment normalised conditions are 273.15 K, 101.3 Pa, dry gas and 15% O_2
Note 2 Maximum emission rate used to model the hypergeometric distribution at the 98th%ile confidence level
Note 3 Reduced emission rates based on USEPA protocol used to model emissions during emergency operation based on 200 hours of operation

Table 2 Emission Details – DB6 Diesel Generators

5.3 Climate

On-site emissions of greenhouse gases will mainly derive from infrequent standby emissions due to the diesel generators. However, the main emissions will be indirect emissions from the use of electricity which forms part of the EU-wide Emission Trading Scheme (ETS) and thus greenhouse gas emission from electricity generation are not included when determining compliance with the targeted 30% reduction in the non-ETS sector. Thus, any necessary increase in electricity generation due to data centre demand will have no impact on Ireland's obligation to meet the EU Effort Sharing Decision.

6.0 AIR MODELLING RESULTS

An iterative stack height assessment was undertaken in order to determine the minimum stack height required for dispersion purposes. This assessment found that a stack height of 20m is required for all stacks. Modelling proceeded on the basis of a 20m stack height for all diesel generators on site.

6.1 Emergency Operations Scenario (USEPA Methodology)

This scenario involved modelling 7 of the 8 diesel generators for 200 emergency hours as per the USEPA guidance(22).

The NO_2 modelling results at the worst-case off-site receptor are detailed in Table 4. The results indicate that the ambient ground level concentrations are in compliance with the relevant air quality standards for NO_2. For the worst-case year, emissions from the site lead to an ambient NO_2 concentration (including background) which is 85% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 91% of the annual limit value at the worst-case off-site receptor.

The geographical variations in ground level NO_2 concentrations beyond the facility boundary for the worst-case years modelled are illustrated as concentration contours in Figures 2 and 3. The locations of the maximum concentrations for NO_2 are close to the boundary of the site with concentrations decreasing with distance from the facility.

Pollutant / Year	Background (µg/m^3)	Averaging Period	Process Contribution (µg/m^3)	Predicted Environmental Concentration (µg/m^3)	Standard (µg/m^3) Note 1
NO_2 / 2016	30	99.8th%ile of 1-hr means	136.6	166.6	200
	15	Annual Mean	18.4	33.4	40
NO_2 / 2017	30	99.8th%ile of 1-hr means	139.8	169.8	200
	15	Annual Mean	21.5	36.5	40
NO_2 / 2018	30	99.8th%ile of 1-hr means	122.6	152.6	200
	15	Annual Mean	19	34	40
NO_2 / 2019	30	99.8th%ile of 1-hr means	133.3	163.3	200
	15	Annual Mean	19	34	40
NO_2 / 2020	30	99.8th%ile of 1-hr means	131.6	161.6	200
	15	Annual Mean	20.9	35.9	40

Note 1 Air Quality Standards 2011 (from EU Directive 2008/50/EC and S.I. 180 of 2011)

Table 4 Dispersion Model Results for Nitrogen Dioxide (NO_2) – Emergency Operations Scenario

6.2 Emergency Operations Scenario (UK EA Methodology)

This assessment involved modelling the continuous operation of 7 of the 8 no. diesel generators at their maximum emission rate for a full year based on the UK EA methodology[(23)]. The methodology, based on considering the statistical likelihood of an exceedance of the NO_2 hourly limit value assuming a hypergeometric distribution, has been undertaken at the worst-case residential / sensitive receptor. The cumulative hypergeometric distribution of 19 and more hours per year was computed and the probability of an exceedance determined. The results have been compared to the 98th percentile confidence level to indicate if an exceedance is likely at various operational hours for the diesel generators. The results (Table 5 and Figure 4) indicate that in the worst-case year, the diesel generators can operate for the full year with no likelihood of an exceedance of the ambient air quality standard (at a 98th percentile confidence level).

Pollutant / Year / Scenario	Hours of operation (Hours) (98th%ile) Allowed Prior To Exceedance Of Limit Value	UK Guidance – Probability Value = 0.02 (98th%ile)[Note 1]
NO_2 / 2016	8760	0.02
NO_2 / 2017	8760	
NO_2 / 2018	8760	
NO_2 / 2019	8760	
NO_2 / 2020	8760	

Note 1 Guidance Outlined In UK EA publication "Diesel Generator Short-term NO_2 Impact Assessment" (EA, 2016)

Table 5 Hypergeometric Statistical Results at Worst-case Residential Receptor – Emergency Operations Scenario

6.3 Cumulative Operations Scenario (USEPA Methodology)

This scenario involved modelling 7 of the 8 diesel generators for 200 emergency hours as per the USEPA guidance(22) in addition to licenced emissions from Takeda, Pfizer and Grange Backup Power.

The NO_2 modelling results at the worst-case off-site receptor are detailed in Table 6. The results indicate that the ambient ground level concentrations are in compliance with the relevant air quality standards for NO_2. For the worst-case year, emissions under the cumulative scenario lead to an ambient NO_2 concentration (including background) which is 85% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 92% of the annual limit value at the worst-case off-site receptor.

The geographical variations in ground level NO_2 concentrations beyond the facility boundary for the worst-case years modelled are illustrated as concentration contours in Figures 5 and 6. The locations of the maximum concentrations for NO_2 are close to the boundary of the site with concentrations decreasing with distance from the facility.

Pollutant / Year	Background (µg/m^3)	Averaging Period	Process Contribution (µg/m^3)	Predicted Environmental Concentration (µg/m^3)	Standard (µg/m^3) Note 1
NO_2 / 2016	30	99.8th%ile of 1-hr means	136.6	166.6	200
	15	Annual Mean	18.7	33.7	40
NO_2 / 2017	30	99.8th%ile of 1-hr means	139.8	169.8	200
	15	Annual Mean	21.7	36.7	40
NO_2 / 2018	30	99.8th%ile of 1-hr means	122.6	152.6	200
	15	Annual Mean	19.2	34.2	40
NO_2 / 2019	30	99.8th%ile of 1-hr means	133.3	163.3	200
	15	Annual Mean	19.2	34.2	40
NO_2 / 2020	30	99.8th%ile of 1-hr means	131.6	161.6	200
	15	Annual Mean	21.1	36.1	40

Note 1 Air Quality Standards 2011 (from EU Directive 2008/50/EC and S.I. 180 of 2011)

Table 6 Dispersion Model Results for Nitrogen Dioxide (NO_2) – Cumulative Operations Scenario

6.4 Cumulative Operations Scenario (UK EA Methodology)

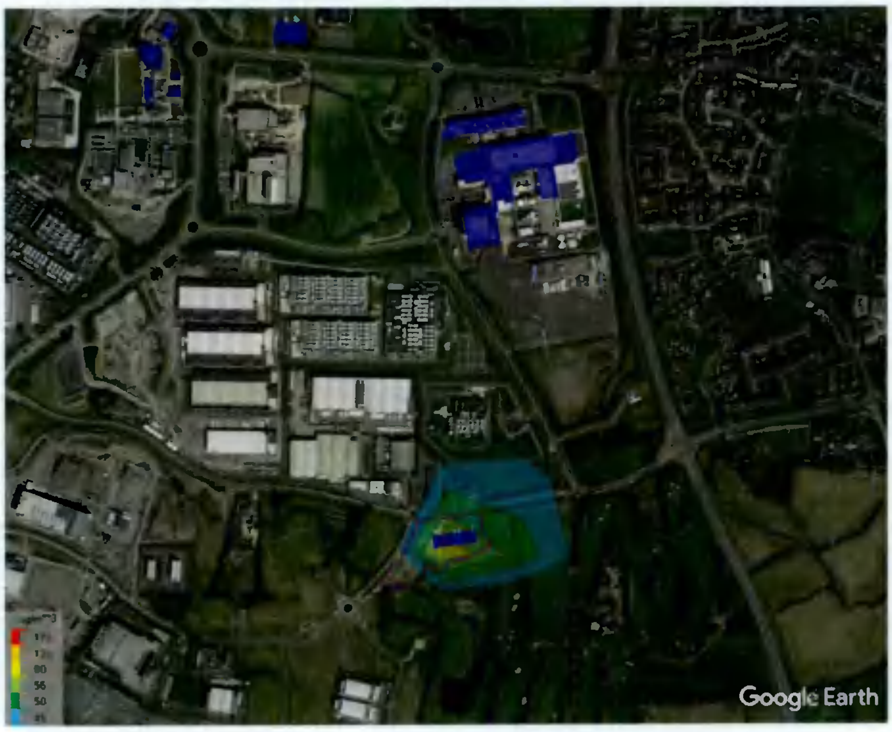
This assessment involved modelling the continuous operation of 7 of the 8 no. diesel generators at their maximum emission rate for a full year based on the UK EA methodology[(23)] in addition to licenced emissions from Takeda, Pfizer and Grange Backup Power.

The methodology, based on considering the statistical likelihood of an exceedance of the NO_2 hourly limit value assuming a hypergeometric distribution, has been undertaken at the worst-case residential / sensitive receptor. The cumulative hypergeometric distribution of 19 and more hours per year was computed and the probability of an exceedance determined. The results have been compared to the 98th percentile confidence level to indicate if an exceedance is likely at various operational hours for the diesel generators. The results (Table 7 and Figure 7) indicate that in the worst-case year, the diesel generators can operate for the full year with no likelihood of an exceedance of the ambient air quality standard (at a 98th percentile confidence level).

Pollutant / Year / Scenario	Hours of operation (Hours) (98th%ile) Allowed Prior To Exceedance Of Limit Value	UK Guidance – Probability Value = 0.02 (98th%ile)[Note 1]
NO_2 / 2016	8760	0.02
NO_2 / 2017	8760	
NO_2 / 2018	8760	
NO_2 / 2019	8760	
NO_2 / 2020	8760	

Note 1 Guidance Outlined In UK EA publication "Diesel Generator Short-term NO_2 Impact Assessment" (EA, 2016)

Table 7 Hypergeometric Statistical Results at Worst-case Residential Receptor – Cumulative Operations Scenario



Site boundary

Maximum concentration: 139.8 µg/m³

N

Background mapping from Google Earth

Project
DB6 Data Centre Air Modelling

Reference
21/12256R01

Figure 2
Max 1-Hour NO_2 Concentrations 2017 (as 99.8%ile) (µg/m³) (Excluding background)

awnconsulting

The Teopro Building Clonshaugh Business and Technology Park, Dublin 17
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Site boundary

Maximum annual mean concentration: 21.5 µg/m³

N

Background mapping from Google Earth

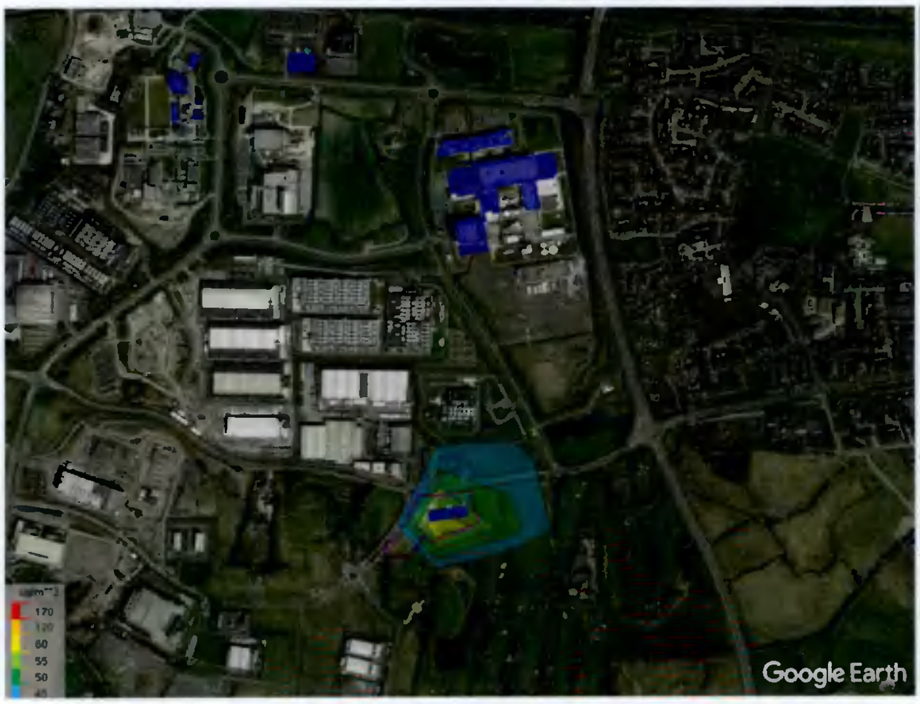
Project
DB6 Data Centre Air Modelling

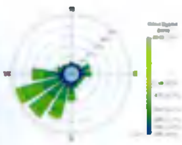
Reference
21/12256R01

Figure 3
Annual Mean NO_2 Concentrations 2017 (µg/m³) (Excluding background)

awn consulting

The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T +353 1 847 4220 F +353 1 847 4257





Site boundary

Maximum concentration: 139.8 µg/m³

N

Background mapping from Google Earth

Project
DB6 Data Centre Air Modelling

Reference
21/12256R01

Figure 4
Cumulative Max 1-Hour NO_2 Concentrations 2017 (as 99.8%ile) (µg/m³) (Excluding background)

awnconsulting

The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T: +353 1 847 4220 F: +353 1 847 4257

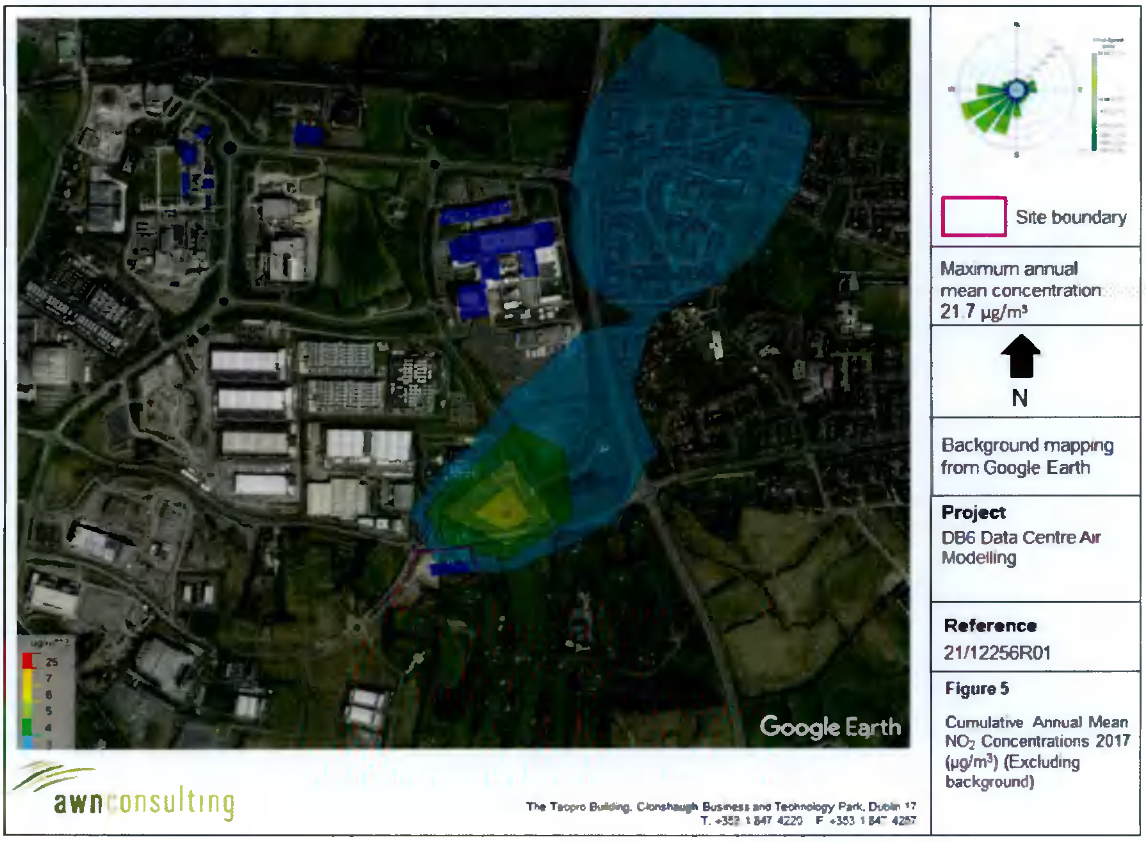


Figure 5

Cumulative Annual Mean NO_2 Concentrations 2017 ($\mu g/m^3$) (Excluding background)

7.0 ASSESSMENT SUMMARY

The assessment was carried out the determine the ambient air quality impact of the site and any air quality constraints that may be present. It was determined that as the proposed diesel generators will be used solely for emergency operation (i.e. less than 500 hours per year) the emission limit values outlined in the Medium Combustion Plant Directive are not applicable to the diesel generators on site.

A number of modelling scenarios were investigated for the purposes of this assessment. Normal day-to-day testing operations were considered as well as emergency operations. Normal testing operations involved the diesel generators operating for up to 1-hour on a weekly basis at 100% load with no more than one generator tested at the same time. Emergency operations was based on 200 emergency hours modelled according to the USEPA methodology.

An iterative stack height assessment was undertaken to determine the minimum stack height required for dispersion purposes. It was found that a stack height of 20m was sufficient for dispersion of pollutants.

Air Quality

This scenario involved the testing of the 8 no. diesel generators associated with the data centre on a weekly basis in addition to 200 emergency hours of operation averaged over the year as per the USEPA methodology.

The results indicate that the ambient ground level concentrations are in compliance with the relevant air quality standards for NO_2. For the worst-case year, emissions from the site lead to an ambient NO_2 concentration (including background) which is 85% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 91% of the annual limit value at the worst-case off-site receptor.

The UK EA assessment methodology determined that in any year, the diesel generators can operate for the full year with no likelihood of an exceedance at the nearest residential receptor (at a 98th percentile confidence level). This is based on the emergency operation of 7 of the 8 no. diesel generators.

Results are similar for the cumulative scenario with emissions from the site and nearby licenced facilities leading to an ambient NO_2 concentration (including background) which is 85% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 92% of the annual limit value at the worst-case off-site receptor.

The UK EA assessment methodology determined that in any year, the diesel generators, under the cumulative scenario, can operate for the full year with no likelihood of an exceedance at the nearest residential receptor (at a 98th percentile confidence level). This is based on the emergency operation of 7 of the 8 no. diesel generators.

Climate

The existing climate baseline can be determined by reference to data from the EPA on Ireland's total greenhouse gas (GHG) emissions and compliance with European Union's Effort Sharing Decision "EU 2020 Strategy" (Decision 406/2009/EC). Data from the EPA in 2020 estimates that Ireland had total GHG emissions for 2019 of 59.9 million tonnes carbon dioxide equivalent (Mt CO_2eq). This is 6.98 Mt higher than Ireland's emission ceiling for 2019 as set under the EU's Effort Sharing Decision (ESD), 406/2009/EC. Emissions are predicted to continue to exceed the targets in future years.

Based on the scale and temporary nature of the construction works, the potential impact on climate change and transboundary pollution from the construction of the Proposed Development is deemed to be short-term and imperceptible in relation to Ireland's obligations under the EU 2020 target.

No significant on-site CO_2 emissions will occur as a result of the facility. Whilst the use of electricity for the facility would indirectly result in emissions, these will be regulated under the Emission Trading Scheme (ETS) and thus the overall impact to climate is deemed indirect, negative, long-term and slight.

Conclusion

The modelling study has concluded that provided the stacks are built to a height of 20m and the emission enveloped assumed for this study is complied with then emissions from the diesel generators will be in compliance with the ambient air quality standards which are based on the protection of the environment and human health.

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APPENDIX I

Description of the AERMOD Model

The AERMOD dispersion model has been developed in part by the U.S. Environmental Protection Agency (USEPA)[1,6]. The model is a steady-state Gaussian model used to assess pollutant concentrations associated with industrial sources. The model is an enhancement on the Industrial Source Complex-Short Term 3 (ISCST3) model which has been widely used for emissions from industrial sources.

Improvements over the ISCST3 model include the treatment of the vertical distribution of concentration within the plume. ISCST3 assumes a Gaussian distribution in both the horizontal and vertical direction under all weather conditions. AERMOD with PRIME, however, treats the vertical distribution as non-Gaussian under convective (unstable) conditions while maintaining a Gaussian distribution in both the horizontal and vertical direction during stable conditions. This treatment reflects the fact that the plume is skewed upwards under convective conditions due to the greater intensity of turbulence above the plume than below. The result is a more accurate portrayal of actual conditions using the AERMOD model. AERMOD also enhances the turbulence of night-time urban boundary layers thus simulating the influence of the urban heat island.

In contrast to ISCST3, AERMOD is widely applicable in all types of terrain. Differentiation of the simple versus complex terrain is unnecessary with AERMOD. In complex terrain, AERMOD employs the dividing-streamline concept in a simplified simulation of the effects of plume-terrain interactions. In the dividing-streamline concept, flow below this height remains horizontal, and flow above this height tends to rise up and over terrain. Extensive validation studies have found that AERMOD (precursor to AERMOD with PRIME) performs better than ISCST3 for many applications and as well or better than CTDMPLUS for several complex terrain data sets[7].

Due to the proximity to surrounding buildings, the PRIME (Plume Rise Model Enhancements) building downwash algorithm has been incorporated into the model to determine the influence (wake effects) of these buildings on dispersion in each direction considered. The PRIME algorithm takes into account the position of the stack relative to the building in calculating building downwash. In the absence of the building, the plume from the stack will rise due to momentum and/or buoyancy forces. Wind streamlines act on the plume leads to the bending over of the plume as it disperses. However, due to the presence of the building, wind streamlines are disrupted leading to a lowering of the plume centreline.

When there are multiple buildings, the building tier leading to the largest cavity height is used to determine building downwash. The cavity height calculation is an empirical formula based on building height, the length scale (which is a factor of building height & width) and the cavity length (which is based on building width, length and height). As the direction of the wind will lead to the identification of differing dominant tiers, calculations are carried out in intervals of 10 degrees.

In PRIME, the nature of the wind streamline disruption as it passes over the dominant building tier is a function of the exact dimensions of the building and the angle at which the wind approaches the building. Once the streamline encounters the zone of influence of the building, two forces act on the plume. Firstly, the disruption caused by the building leads to increased turbulence and enhances horizontal and vertical dispersion. Secondly, the streamline descends in the lee of the building due to the reduced pressure and drags the plume (or part of) nearer to the ground, leading to higher ground level concentrations. The model calculates the descent of the plume as a function of the building shape and, using a numerical plume rise model, calculates the change in the plume centreline location with distance downwind.

The immediate zone in the lee of the building is termed the cavity or near wake and is characterised by high intensity turbulence and an area of uniform low pressure. Plume mass captured by the cavity region is re-emitted to the far wake as a ground-level volume source. The volume source is located at the base of the lee wall of the building, but is only evaluated near the end of the near wake and beyond. In this region, the disruption caused by the building downwash gradually fades with distance to ambient values downwind of the building.

AERMOD has made substantial improvements in the area of plume growth rates in comparison to ISCST3[(3,7)]. ISCST3 approximates turbulence using six Pasquill-Gifford-Turner Stability Classes and bases the resulting dispersion curves upon surface release experiments. This treatment, however, cannot explicitly account for turbulence in the formulation. AERMOD is based on the more realistic modern planetary boundary layer (PBL) theory which allows turbulence to vary with height. This use of turbulence-based plume growth with height leads to a substantial advancement over the ISCST3 treatment.

Improvements have also been made in relation to mixing height[(3,7)]. The treatment of mixing height by ISCST3 is based on a single morning upper air sounding each day. AERMOD, however, calculates mixing height on an hourly basis based on the morning upper air sounding and the surface energy balance, accounting for the solar radiation, cloud cover, reflectivity of the ground and the latent heat due to evaporation from the ground cover. This more advanced formulation provides a more realistic sequence of the diurnal mixing height changes.

AERMOD also has the capability of modelling both unstable (convective) conditions and stable (inversion) conditions. The stability of the atmosphere is defined by the sign of the sensible heat flux. Where the sensible heat flux is positive, the atmosphere is unstable whereas when the sensible heat flux is negative the atmosphere is defined as stable. The sensible heat flux is dependent on the net radiation and the available surface moisture (Bowen Ratio). Under stable (inversion) conditions, AERMOD has specific algorithms to account for plume rise under stable conditions, mechanical mixing heights under stable conditions and vertical and lateral dispersion in the stable boundary layer.

AERMOD also contains improved algorithms for dealing with low wind speed (near calm) conditions. As a result, AERMOD can produce model estimates for conditions when the wind speed may be less than 1 m/s, but still greater than the instrument threshold.

APPENDIX II

Meteorological Data - AERMET

AERMOD incorporates a meteorological pre-processor AERMET (version 19191)[13]. AERMET allows AERMOD to account for changes in the plume behaviour with height. AERMET calculates hourly boundary layer parameters for use by AERMOD, including friction velocity, Monin-Obukhov length, convective velocity scale, convective (CBL) and stable boundary layer (SBL) height and surface heat flux. AERMOD uses this information to calculate concentrations in a manner that accounts for changes in dispersion rate with height, allows for a non-Gaussian plume in convective conditions, and accounts for a dispersion rate that is a continuous function of meteorology.

The AERMET meteorological preprocessor requires the input of surface characteristics, including surface roughness (z_0), Bowen Ratio and albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. A morning sounding from a representative upper air station, latitude, longitude, time zone, and wind speed threshold are also required.

Two files are produced by AERMET for input to the AERMOD dispersion model. The surface file contains observed and calculated surface variables, one record per hour. The profile file contains the observations made at each level of a meteorological tower, if available, or the one-level observations taken from other representative data, one record level per hour.

From the surface characteristics (i.e. surface roughness, albedo and amount of moisture available (Bowen Ratio)) AERMET calculates several boundary layer parameters that are important in the evolution of the boundary layer, which, in turn, influences the dispersion of pollutants. These parameters include the surface friction velocity, which is a measure of the vertical transport of horizontal momentum; the sensible heat flux, which is the vertical transport of heat to/from the surface; the Monin-Obukhov length which is a stability parameter relating the surface friction velocity to the sensible heat flux; the daytime mixed layer height; the nocturnal surface layer height and the convective velocity scale which combines the daytime mixed layer height and the sensible heat flux. These parameters all depend on the underlying surface.

The values of albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use types was carried out in line with USEPA recommendations[3] and using the detailed methodology outlined by the Alaska Department of Environmental Conservation[15]. AERMET has also been updated to allow for an adjustment of the surface friction velocity (u*) for low wind speed stable conditions based on the work of Qian and Venkatram (BLM, 2011). Previously, the model had a tendency to over-predict concentrations produced by near-ground sources in stable conditions.

<u>Surface roughness</u>

Surface roughness length is the height above the ground at which the wind speed goes to zero. Surface roughness length is defined by the individual elements on the landscape such as trees and buildings. In order to determine surface roughness length, the USEPA recommends that a representative length be defined for each sector, based on an upwind area-weighted average of the land use within the sector, by using the eight land use categories outlined by the USEPA. The inverse-distance weighted surface roughness length derived from the land use classification within a radius of 1km from Casement Aerodrome Meteorological Station is shown in Table A1.

Sector	Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter[Note 1]
0-360	100% Grassland	0.050	0.100	0.010	0.010

Note 1: Winter defined as periods when surfaces covered permanently by snow whereas autumn is defined as periods when freezing conditions are common, deciduous trees are leafless and no snow is present (Iqbal, 1983). Thus for the current location autumn more accurately defines "winter" conditions at the proposed facility.

Table A1 Surface Roughness based on an inverse distance weighted average of the land use within a 1km radius of Casement Aerodrome Meteorological Station.

Albedo

Noon-time albedo is the fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. Albedo is used in calculating the hourly net heat balance at the surface for calculating hourly values of Monin-Obuklov length. A 10km x 10km square area is drawn around the meteorological station to determine the albedo based on a simple average for the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Casement Meteorological Station is shown in Table A2.

Area-weighted Land Use Classification	Spring	Summer	Autumn	Winter[1]
0.5% Water, 30% Urban, 0.5% Coniferous Forest 38% Grassland, 19% Cultivated Land	0.155	0.180	0.187	0.187

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.

Table A2 Albedo based on a simple average of the land use within a 10km × 10km grid centred on Casement Aerodrome Meteorological Station.

Bowen Ratio

The Bowen ratio is a measure of the amount of moisture at the surface of the earth. The presence of moisture affects the heat balance resulting from evaporative cooling which, in turn, affects the Monin-Obukhov length which is used in the formulation of the boundary layer. A 10km x 10km square area is drawn around the meteorological station to determine the Bowen Ratio based on geometric mean of the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Casement Meteorological Station is shown in Table A3.

Geometric Mean Land Use Classification	Spring	Summer	Autumn	Winter[1]
0.5% Water, 30% Urban, 0.5% Coniferous Forest 38% Grassland, 19% Cultivated Land	0.549	1.06	1.202	1.202

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.

Table A3 Bowen Ratio based on a geometric mean of the land use within a 10km × 10km grid centred on Casement Aerodrome Meteorological Station.