H2Teesside Project

Environmental Permit Application Reference: [EPR/AP3328SQ/A001]

Land at and in the vicinity of the former Redcar Steel Works site, Redcar and in Stockton-on-Tees, Teesside

Document Reference: [AP3328SQ-APP-CO2] CO_2 Dispersion Modelling Report

Environmental Permitting (England and Wales) Regulations 2016

Applicants: H2 Teesside Ltd

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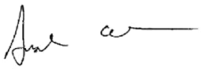
Signed		Date	09/10/2024
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1 INTRODUCTION

1.1 Overview

1.1.1 H2 Teesside Limited has submitted an Environmental Permit application for a proposed Hydrogen Production Facility with Carbon Capture (the 'Proposed Installation') (Environment Agency Reference EPR/AP3328SQ/A001) in June 2024.

1.1.2 As part of the Environmental Permit determination for the Proposed Installation, the Environment Agency (EA) issued a notice requesting further information before the application can be considered to be Duly Made. Point 12 of this notice requires a CO_2 Venting Assessment to be undertaken, and states:

1.1.3 "Provide a risk assessment for emissions associated with venting of concentrated/pressurised carbon dioxide inventories, according to scope, methodology and advice provided during the pre-application."

1.1.4 AECOM Limited has been commissioned to undertake dispersion modelling of the carbon dioxide (CO_2) emissions from the Proposed Installation.

1.1.5 The emissions of CO_2 from the Proposed Installation do present a risk to human health at offsite locations if released in sufficient quantities or from vents without sufficient dispersion. This assessment has identified a number of scenarios where CO_2 can be released during the process, and dispersion modelling has been undertaken to confirm potential offsite impacts where members of the public may be present.

1.1.6 This report sets out the scope of works, methodology and results from the dispersion modelling carried out.

1.2 Scope of Works

1.2.1 AECOM have undertaken an assessment of CO_2 emissions from a selection of release scenarios to assess the potential of impacts at offsite locations. The assessment includes the following tasks:

- Review of published CO_2 exposure levels and reported effects levels
- Review of potential release scenarios
- Sensitivity testing on the following parameters:
  - Model Selection – GASTAR and ADMS 6
  - Wind Speed and direction
  - Choice of meteorological year
  - Magnitude of release
  - Release height

- Inclusion of modelled buildings if appropriate

- Detailed dispersion modelling of CO_2 releases

1.2.2 The reports details the methodology used to assess the potential impacts of CO_2 releases from the Proposed Installation, and their associated effects on receptors in the vicinity of the site.

1.3 Exposure Criteria

1.3.1 There are no air quality objectives, targets or Environmental Assessment Levels (EALs) set for CO_2 for the protection of human health at locations where members of the public may be present. Therefore, in order to determine an appropriate assessment level to ensure the protection of human health, available workplace exposure limits have been reviewed.

1.3.2 CO_2 has been recognised as a potential risk in workplaces for over a century, and Workplace Exposure Limits (WELs) have been set in order to protect worker health. The Health and Safety Executive (HSE) published WELs to be used in UK workplaces in their document EH40 . This sets an 8-hour Time Weighted Average (TWA) of 5,000 ppm (or 9,150 mg/m^3), and a 15-minute Short Term Exposure Limit (STEL) of 15,000 ppm (or 27,400 mg/m^3). These values are for the protection of workers, and assume an individual that is relatively healthy and has access to areas of clean air. The values given are not considered relevant to public exposure where members of the public may be present occasionally or permanently (e.g. public rights of way or residential properties) where potentially more vulnerable individuals such as the elderly or children are likely to be present.

1.3.3 In addition, the HSE has published guidance on exposure to substances during major accidents, and introduce the concept of Specified Level of Toxicity (SLOT) and Significant likelihood of Death (SLOD). These use a Dangerous Toxic Load (DTL) and a specified period of time to calculate a concentration that would represent a specific risk.

1.3.4 The SLOT represents the dose at which highly susceptible people would be killed (a fatality rate of 1-5%) and cause severe medical distress to a large proportion of the remaining population. The SLOD represents the dose which would results in a fatality rate of 50% within the exposed population. The SLOT and SLOD DTL's are related in the following equation:

$$C^n t = A$$

- Where:
- • C = Concentration in ppm
- • t = exposure time in minutes
- • n = the toxic exponent of C (for CO_2, a value of 8 is used)
- • A = DTL, which is given as:

- For SLOT, a value of 1.5×10^{40}
- For SLOD, a value of 1.5×10^{41}

1.3.5 Given the above parameters, SLOT and SLOD concentrations for given periods of time can be derived for CO_2. These concentrations are shown in Table 2 1 (rounded to the nearest 1,000), and indicated that significant effects, including death, can be experienced at concentration of 6.3% for a one hour exposure time.

Table 1-1: CO_2 SLOT and SLOD Concentrations

EXPOSURE TIME (MINUTES)	CO_2 CONCENTRATION IN AIR			
	SLOT		SLOD	
	%	PPM	%	PPM
1440 (24 hour)	4.2%	42,000	5.7%	57,000
60	6.3%	63,000	8.4%	84,000
30	6.9%	69,000	9.2%	92,000
20	7.2%	72,000	9.6%	96,000
10	7.9%	79,000	10.5%	105,000
5	8.6%	86,000	11.5%	115,000
1	10.5%	105,000	14.0%	140,000

1.3.6 The United States Centre for Disease Control and Prevention (CDC), through their National Institute for Occupational Safety and Health (NIOSH) has published a number of maximum concentrations for substances within the workplace from which a worker could escape within a 30-minute period without any impairing symptoms or permanent health effects. These are referred to the Immediate Dangerous to Life or Health (IDHL) concept, and gives a value of 40,000 ppm (4%) for CO_2.

1.3.7 Public Health England (PHE, now the UK Health Security Agency (UK HSA) has published a Compendium of Chemical Hazards[1], including CO_2, which provides a range of concentrations at which health effects can occur. At CO_2 concentrations of 2-5%, people can experience headaches, dizziness, sweating and shortness of breath. The HSE report on the Assessment of the major hazard potential of carbon dioxide supports these values, noting that health effects can be reported from concentrations in the order of 3% over an hour.

1.3.8 It is proposed that a maximum 1 hour concentration of 2% (or 20,000ppm) presents a very low risk to the health of the general population, as any health effects at this concentration should be reversible and temporary in nature. This concentration has been used in this assessment as an Upper Exposure Criteria. It should be noted that the reported values discussed above provide a concentration at which health effects can occur in an exposed population, but no commentary on the sensitivity and overall health of the exposed population, and do not provide a level of safety

[1] Public Health England, Compendium of Chemical Hazards: Carbon dioxide, url: https://www.gov.uk/government/publications/carbon-dioxide-properties-and-incident-management, accessed: 17/07/2023

to ensure the protection of sensitive members of the public from possible health effects. It is therefore proposed that a maximum 1 hour concentration of 1% (or 10,000 ppm) CO_2 is used in this assessment as a Lower Exposure Criteria, as being protective of more sensitive members of the public from harm before the likely onset of symptoms.

2 METHODOLOGY

2.1.1 This section sets out the methodology to assess potential impacts of CO_2 releases from the Proposed Installation on sensitive receptors within the vicinity of the facility.

Study Area

2.1.2 The Proposed Installation is located in the Borough of Redcar and Cleveland, on the east bank of the River Tees. The Cleveland Links golf course is approximately 1 km to the east, with the Warrenby Industrial Estate approximately 1.3km. The area to the north forms part of the Teesmouth and Cleveland coast Special Protection Area (SPA), RAMSAR and Site of Special Scientific Interest (SSSI) and is publicly accessible. The area is shown in Figure A1.

Discrete Receptors

2.1.3 Ground-level concentrations of CO_2 have been predicted at discrete air quality sensitive receptors, as detailed in Table 2-1Error! Reference source not found.. The locations of these receptors are also shown in Figure A1 in Appendix A. The receptors are selected to be representative of residential dwellings, recreational areas and schools in the area around the Proposed Installation.

Table 2-1: Human Receptor Locations

RECEPTOR REFERENCE	RECEPTOR DESCRIPTION	GRID REFERENCE		DISTANCE AND DIRECTION FROM THE PROPOSED INSTALLATION
		X	Y	
$R1_{a-az}$	Breakwater South Gare access road (site boundary North)	456905* 456429*	525850* 526033*	0 m north
$R2_{a-co}$	Proposed Installation site boundary East (Net Zero Teeside)	456905* 456579*	525850* 525000*	0 m east
R3	Houses at Warrenby	457950	525045	1.3 km east
R4	Cleveland Golf Links	458090	525550	1.3 km east
R5	South Gare Fishermans Association	455680	527395	1.5 km northwest
R6	Marine Club	455550	527345	1.5 km northwest
R7	Caravan Park	458675	525415	1.7 km east

RECEPTOR REFERENCE	RECEPTOR DESCRIPTION	GRID REFERENCE		DISTANCE AND DIRECTION FROM THE PROPOSED INSTALLATION
		X	Y	
R8	Houses at Dormanstown	457895	523735	1.8 km southeast
R9	Houses at Coatham	458900	525060	2.2 km east
R10	Dormanstown Primary School	458250	523585	202 km southeast
R11	Coatham C of E School	459195	524980	2.5 km east
$R12_{a-az}$	Proposed Installation site boundary West (Hygreen)	456327* 456144*	525679* 525202*	0 m west
$R13_{a-ay}$	Proposed Installation site boundary West (Hygreen)	456327* 455860*	525679* 525858*	0 m west

* first and last coordinates from a transect of receptor points along the industrial site boundary, maximum value at any model output location are shown in results tables for receptors R1, R2, R12 and R13.

2.1.4 Ecological receptors have not been included in this assessment as plant life is not considered to be sensitive to short term releases of CO_2, and it has not been determined what such a release would have on animal life. It has been assumed that concentrations which present a risk to human health present the same risk to animal life.

Model Selection

2.1.5 CO_2 is a dense gas, meaning that it is heavier than air and a pure release of CO_2 does not disperse in the same manner as other typical industrial releases. There is a significant risk that CO_2 releases can travel along the ground, representing a greater risk to public exposure than might otherwise be the case and therefore the choice of model needs to be able to model dense gas releases. This limits the number of commercially available models for such purposes.

2.1.6 For this assessment, two models have been used – ADMS (v6.0) and GASTAR (v3.2.2), both produced by Cambridge Environmental Research Consultants (CERC). A sensitivity analysis has been undertaken to compare the models output to determine the appropriate selection for assessment of CO_2 releases at offsite locations (see Appendix B sensitivity analysis).

2.1.7 ADMS comes with extensive verification studies for the dispersion of gas phase emissions[2], and is currently accepted by the Environment Agency as an appropriate model for air dispersion of typical gaseous emissions from industrial sources for regulatory purposes. ADMS allows for modelling of grounded plumes where the gas is too dense, and treats the modelled plume as passive from the point it hits the ground. For gaussian plume models, where the plume becomes passive within a relatively short distance and the inputs are known to a high degree of certainty, there is evidence that such models perform similarly to dense gas models over

[2] CERC, 2023, Model Validation, url: https://www.cerc.co.uk/environmental-software/model-validation.html

distance of up to 5km from the source[3]. Over greater distances (up to 25km), gaussian plume models can predict concentrations 2 to 3 times greater than dense gas models, and can be shown to be conservative when undertaking environmental assessments.

2.1.8 The initial release conditions for each scenario have been provided as steady-state, so as to present a conservative assessment of CO_2 emissions (see Appendix C). Initial release conditions have been derived from the current process design data and are considered to be conservative estimates of release conditions. The use of steady-state emissions data and the proximity of receptors to the source means that ADMS can be considered to be suitable for modelling dense gas emissions in such scenarios.

2.1.9 GASTAR is a consequence model optimised for process safety risk assessments under complex near field conditions, and therefore is less well suited to more typical environmental impact assessment work. For scenarios where ADMS is unable to model the movement and dispersion of the CO_2 plume due to the complex near field conditions, GASTAR is used instead.

Release Scenarios

2.1.10 The Proposed Installation is currently in the Front-End Engineering Design (FEED) process, and the release scenarios have been identified and assessed based on preliminary estimates, in order to determine those which are considered to represent the highest and lowest predicted releases of CO_2 during the operation of the Proposed Installation, and therefore considered to represent the highest potential risk to offsite receptors. The data will be refined as the project progresses, and this assessment is based on current conservative estimates. The parameters used in scenario selection and the justification for selection are given in greater detail in Appendix C.

2.1.11 Fourteen potential CO_2 release scenarios per phase have been identified and are detailed in Table 2-2.

2.1.12 In detailed design, the nature and frequency of these released will be further defined. There may also be other vents added to the selected design that will be investigated.

2.1.13 The modelled release scenarios have considered a release over a period of an hour, to align with the Exposure Criteria used. A 24 hour release period has been considered for Scenarios which include Start-up, Commissioning, and Operation. For Emergency release scenarios, it is anticipated that a release can only occur for a maximum of 20 minutes due to the quantity of CO_2 stored within the system. Modelled results have therefore been factored to take this into account and allow comparison to the Exposure Criteria.

[3] Health and Safety Executive, 2021, Review of dense-gas dispersion for industrial regulation and emergency preparedness and response, June 2021

Table 2-2: Modelled Scenarios

SCENARIO ID	PHASE	TYPE	DESCRIPTION	JUSTIFICATION FOR SCENARIO SELECTION
Scenario 1	1	Start-up	Commissioning & Start-up prior to exporting CO_2 to NEP (Initial System Setup and Testing)	Highest predicted release of CO_2 during start-up – both phases
	2	Start-up	Commissioning & Start-up prior to exporting CO_2 to NEP (Initial System Setup and Testing)	
Scenario 2	1	Start-up	Commissioning & Start-up prior to exporting CO_2 to NEP (Initial System Setup and Testing)	Highest predicted release of CO_2 during start-up (P1) and operation (P2)
	2	Operational	PCV on CO_2 Separator (21-V-08003)	
Scenario 3	1	Start-up	Commissioning & Start-up prior to exporting CO_2 to NEP (Initial System Setup and Testing)	Highest predicted release of CO_2 during start-up (P1) and blocked outlet emergency (P2)
	2	Emergency 1	Blocked outlet at CO_2 compression discharge.	
Scenario 4	1	Operational	PCV on CO_2 Separator (21-V-08003)	Highest predicted release of CO_2 during operation (P1) and Start-up (P2)
	2	Start-up	Commissioning & Start-up prior to exporting CO_2 to NEP (Initial System Setup and Testing)	
Scenario 5	1	Operational	PCV on CO_2 Separator (21-V-08003)	Highest predicted release of CO_2 during operation – both phases
	2	Operational	PCV on CO_2 Separator (21-V-08003)	
Scenario 6	1	Operational	PCV on CO_2 Separator (21-V-08003)	Highest predicted

	2	Emergency 1	Blocked outlet at CO_2 compression discharge.	release of CO_2 during operation (P1) and blocked outlet emergency (P2)
Scenario 7	1	Emergency 1	Blocked outlet at CO_2 compression discharge.	Highest predicted release of CO_2 during blocked outlet emergency (P1) and start up (P2)
	2	Start-up	Commissioning & Start-up prior to exporting CO_2 to NEP (Initial System Setup and Testing)	
Scenario 8	1	Emergency 1	Blocked outlet at CO_2 compression discharge.	Highest predicted release of CO_2 during blocked outlet emergency (P1) and operation (P2)
	2	Operational	PCV on CO_2 Separator (21-V-08003)	
Scenario 9	1	Emergency 1 & 2	Blocked outlet at CO_2 compression discharge. Reverse flow from CO_2 pipeline at MAOP (44 barg).	Highest predicted emergency scenario, blocked outlet emergency (both phases) and reverse flow (p1)
	2	Emergency 1	Blocked outlet at CO_2 compression discharge.	
Scenario 10	1	Commissioning	Commissioning & Start-up Plant Performance Testing Phase (incl the LCHA Performance Test) if NEP is unavailable.	Highest predicted commissioning scenario
	2	Commissioning	Commissioning & Start-up Plant Performance Testing Phase (incl the LCHA Performance Test) if NEP is unavailable.	
Scenario 11	1	Commissioning	Commissioning & Start-up Plant Performance Testing Phase (incl the LCHA	Highest predicted release of CO_2

			Performance Test) if NEP is unavailable.	during commissioning (P1) and operation (P2)
	2	Operational	PCV on CO_2 Separator (21-V-08003)	
Scenario 12	1	Commissioning	Commissioning & Start-up Plant Performance Testing Phase (incl the LCHA Performance Test) if NEP is unavailable.	Highest predicted release of CO_2 during commissioning (P1) and operation (P2)
	2	Emergency 1	Blocked outlet at CO_2 compression discharge.	
Scenario 13	1	Operational	PCV on CO_2 Separator (21-V-08003)	Highest predicted release of CO_2 during operation (P1) and commissioning (P2)
	2	Commissioning	Commissioning & Start-up Plant Performance Testing Phase (incl the LCHA Performance Test) if NEP is unavailable.	
Scenario 14	1	Emergency 1	Blocked outlet at CO_2 compression discharge.	Highest predicted release of CO_2 during emergency (P1) and commissioning (P2)
	2	Commissioning	Commissioning & Start-up Plant Performance Testing Phase (incl the LCHA Performance Test) if NEP is unavailable.	

**Final plant layout design and vent location to be confirmed.*

General Model Parameters

2.1.14 The general model conditions used in the assessment are summarised in Table 2-3. Other scenario specific parameters are set out in the following sections.

Table 2-3: General Model Inputs

VARIABLE	INPUT
Surface roughness at source	0.3
Surface roughness at meteorological site	0.3
Receptors	Selected discrete receptors (see Table 2-1) Regular grid, up to 2km from source. Resolution of 20m.

Receptor location	X-Y co-ordinates determined by GIS (see Table 2-4) z = 0m
Source location	X-Y co-ordinates determined by GIS (see Table 2-4)
Emissions	Data provided from FEED (see Table 2-4)
Sources	See Table 2-4
Meteorological data	5 years of meteorological data, Durham Tees Valley Meteorological Station (2018-2022)
Terrain data	See Section 0
Modelled Buildings that may cause building downwash effects	See Section 0

Source Parameters

2.1.15 The emission source parameters used in this assessment are set out in Table 2-4.

Table 2-4: Source Emission Parameters

SCENARIO	PHASE	SOURCE DESCRIPTION	MODELLED COORDINATES* (X,Y)	RELEASE HEIGHT (M)	INTERNAL DIAMETER (M)	EXIT VELOCITY (M/S)	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	COMPOSITION
Scenario 1	1	Start-up Vent (upstream of CO_2 metering)	456466, 525372	31	0.91	31.3	2	145,000	21.2	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
	2	Start-up Vent (upstream of CO_2 metering)	456621, 525722	31	0.91	31.3	2	145,000	21.2	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
Scenario 2	1	Start-up Vent (upstream of CO_2 metering)	456466, 525372	31	0.91	31.3	2	145,000	21.2	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	456576, 525700	31	0.91	36.2	34	147,000	1.7	35	96.36 mol% CO_2, 3.19 mol% H2O, 0.19 mol% methanol, 0.15 mol% H2, 0.01 mol% NH3

SCENARIO	PHASE	SOURCE DESCRIPTION	MODELLED COORDINATES* (X,Y)	RELEASE HEIGHT (M)	INTERNAL DIAMETER (M)	EXIT VELOCITY (M/S)	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	COMPOSITION
Scenario 3	1	Start-up Vent (upstream of CO_2 metering)	456466, 525372	31	0.91	31.3	2	145,000	21.2	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
	2	Blocked outlet at CO_2 compression discharge.	456624, 525737	55	0.76	41.6	-18	145,000	30	20 - 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.
Scenario 4	1	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	456451, 252425	31	0.91	31.3	2	145,000	1.7	35	99.84 mol% CO_2; 0.15% Hydrogen
	2	Start-up Vent (upstream of CO_2 metering)	456621, 525722	31	0.91	31.3	2	145,000	21.2	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
Scenario 5	1	Overpressure control downstream of CO_2 separator,	456451, 525425	31	0.91	31.3	2	145,000	1.7	35	99.84 mol% CO_2; 0.15% Hydrogen

SCENARIO	PHASE	SOURCE DESCRIPTION	MODELLED COORDINATES* (X,Y)	RELEASE HEIGHT (M)	INTERNAL DIAMETER (M)	EXIT VELOCITY (M/S)	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	COMPOSITION
		upstream of CO_2 compression.									
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	456576, 525700	31	0.91	36.2	34	147,000	1.7	35	96.36 mol% CO_2, 3.19 mol% H2O, 0.19 mol% methanol, 0.15 mol% H2, 0.01 mol% NH3
Scenario 6	1	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	456451, 252425	31	0.91	31.3	2	145,000	1.7	35	99.84 mol% CO_2; 0.15% Hydrogen
	2	Blocked outlet at CO_2 compression discharge.	456624, 525737	55	0.76	41.6	-18	145,000	30	20 - 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.

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Scenario 7	1	Blocked outlet at CO_2 compression discharge.	456442, 525367	55	0.76	41.6	-18	145,000	30	20 - 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.
	2	Start-up Vent (upstream of CO_2 metering)	456621, 525722	31	0.91	31.3	2	145,000	21.1	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
Scenario 8	1	Blocked outlet at CO_2 compression discharge.	456442, 525367	55	0.76	41.6	-18	145,000	30	20 - 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	456576, 525700	31	0.91	36.2	34	147,000	1.7	35	96.36 mol% CO_2, 3.19 mol% H2O, 0.19 mol% methanol, 0.15 mol% H2, 0.01 mol% NH3

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Scenario 9	1	Blocked outlet at CO_2 compression discharge.	456442, 525367	55	0.76	41.6	-18	145,000	30	20 - 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.
		Reverse flow from CO_2 pipeline at MAOP (44 barg).	456466, 525372	16.5	0.25	20	-87.5	10,700	30	-13.5	99.84 mol% CO_2; 0.15% Hydrogen
	2	Blocked outlet at CO_2 compression discharge.	456624, 525737	55	0.76	41.6	-18	145,000	30	20 - 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.
Scenario 10	1	Commissioning Vent (downstream of CO_2 metering)	456466, 525372	31	0.91	31.3	2	145,000	21.1	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen

SCENARIO	PHASE	SOURCE DESCRIPTION	MODELLED COORDINATES* (X,Y)	RELEASE HEIGHT (M)	INTERNAL DIAMETER (M)	EXIT VELOCITY (M/S)	EXIT TEMPERATURE (°C)	EFFLUX RATE (KG/HR)	UPSTREAM PROCESS SYSTEM PRESSURE (BARG)	UPSTREAM PROCESS SYSTEM TEMP. (°C)	COMPOSITION
	2	Commissioning Vent (downstream of CO_2 metering)	456621, 525722	31	0.91	31.3	2	145,000	21.1	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
Scenario 11	1	Commissioning Vent (downstream of CO_2 metering)	456466, 525372	31	0.91	31.3	2	145,000	21.1	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
	2	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	456576, 525700	31	0.91	36.2	34	147,000	1.7	35	96.36 mol% CO_2, 3.19 mol% H2O, 0.19 mol% methanol, 0.15 mol% H2, 0.01 mol% NH3
Scenario 12	1	Commissioning Vent (downstream of CO_2 metering)	456466, 525372	31	0.91	31.3	2	145,000	21.1	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
	2	Blocked outlet at CO_2 compression discharge.	456624, 525737	55	0.76	41.6	-18	145,000	30	20 – 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.

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Scenario 13	1	Overpressure control downstream of CO_2 separator, upstream of CO_2 compression.	456451, 252425	31	0.91	31.3	2	145,000	1.7	35	99.84 mol% CO_2; 0.15% Hydrogen
	2	Commissioning Vent (downstream of CO_2 metering)	456621, 525722	31	0.91	31.3	2	145,000	21.1	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen
Scenario 14	1	Blocked outlet at CO_2 compression discharge.	456442, 525367	55	0.76	41.6	-18	145,000	30	20 – 25	99.08 mol% CO_2, 0.15 mol% H2, 0.52 mol% water, 0.25 mol% methanol.
	2	Commissioning Vent (downstream of CO_2 metering)	456621, 525722	31	0.91	31.3	2	145,000	21.1	26 - 36	99.84 mol% CO_2; 0.15% Hydrogen

Meteorological Data

2.1.16 Actual measured hourly-sequential meteorological data is available for input into dispersion models, and it is important to select data as representative as possible for the site that will be modelled. This is usually achieved by selecting a meteorological station as close to the site as possible, although other stations may be used if the local terrain and conditions vary considerably, or if the station does not provide sufficient data.

2.1.17 The meteorological site that was selected for the assessment is Durham Tees Valley Airport, located approximately 22 km southwest of the Proposed Installation, at a flat airfield in a principally agricultural area, and therefore a surface roughness of 0.3 m (representative of an agricultural area) has been selected for the meteorological site.

2.1.18 The modelling for this assessment has utilised 5 years of meteorological data for the period 2018 – 2022. Wind roses for each of the years within this period are shown in Figure 1.

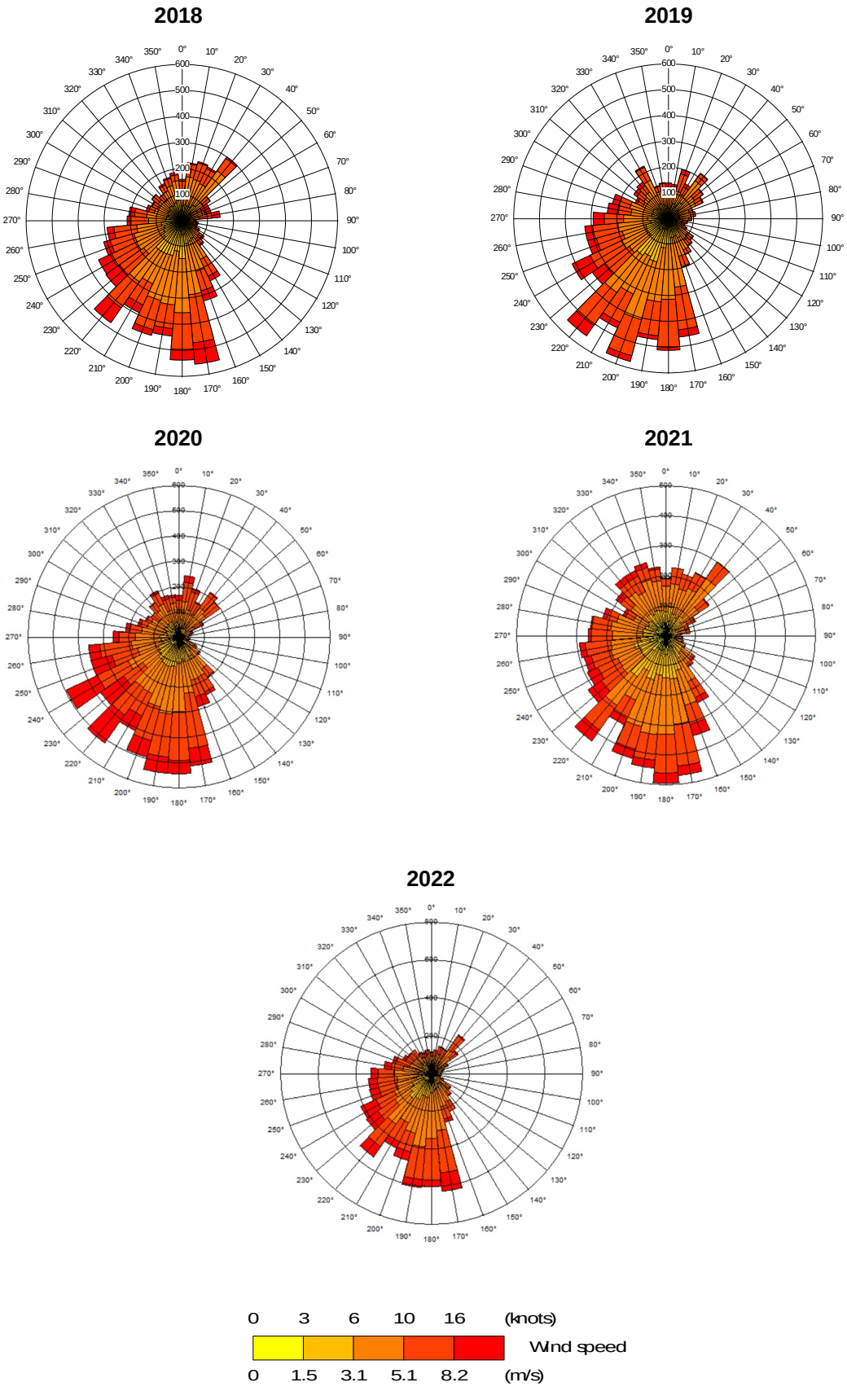

Figure 1: Wind roses for Durham Tees Valley airport, 2018 to 2022

Model Domain

2.1.19 Emissions from the release sources have been modelled on a receptor grid in order to determine:

- The location and magnitude of the maximum offsite ground level impacts; and
- To enable the generation of CO_2 isopleth plots.

2.1.20 The modelled grid extends 2km from a centre point of 456477, 525580 with a resolution of 20m.

Modelled Buildings

2.1.21 The buildings that make up the Proposed development have the potential to affect the dispersion of emissions from the modelled emission sources. The ADMS buildings effect module incorporates building downwash effects as part of the modelling procedure.

2.1.22 The building downwash module in ADMS is detailed in the ADMS User Guide[4]. For each line in the meteorological data, ADMS creates a virtual building perpendicular to the wind direction, of a size determined by the extents of the building. A main building is determined for each source, and building downwash is then calculated for the main building. Downwash is calculated by creating a region downwind of the building into which a proportion of the plume is entrained. This entrained proportion is then homogenised within this region, and emitted as another plume with a height proportional to the building height with plume rise. The result is that concentrations close to the source are likely to be higher than without building downwash, but receptors further from the source would be lower.

2.1.23 For a standard emission, the plume has buoyancy and when it contacts the ground the model includes ground deflection and further dispersion. For a dense gas plume has no buoyancy and grounds almost immediately on release. Once it contacts the ground, ADMS models the plume as passive and does not introduce further plume rise or dispersion.

2.1.24 As emissions of CO_2 are modelled as a dense gas and ground relatively quickly, it is considered that the inclusion of building downwash in the model is not appropriate for all source building combinations. The model results reported in this assessment do not include building downwash, and are more conservative at all offsite receptor locations.

Terrain

2.1.25 In standard dispersion modelling of more typical gases of a similar or lower density to air, terrain data is used where there are large changes in height with a typical gradient of 1:10. Where such changes are not likely to occur, terrain data is not used. As the area around the Proposed Installation is relatively flat, terrain data was not used.

[4] CERC (2023), ADMS 6 Atmospheric Dispersion Modelling System, User Guide, Version 6.0, March 2023

3 RESULTS

3.1.1 This section presents the results from the dispersion modelling for each assessed scenario. Modelled Process Contributions (PCs) at each of the modelled receptors and at the point of maximum impact beyond the Proposed Installation site boundary have been presented and compared to the adopted Exposure Criteria detailed in Section 2. The presented results are as follows:

- Scenarios 1, 2, 4, 5, 10, 11, 13: The 1 hour and 24 hour mean CO_2 process contributions at each modelled receptor location have been reported, and a comparison to the Exposure Criteria.
- Scenarios 3, 6, 7, 8, 9, 12, 14: These scenarios contain an emergency release which are not expected to last for more than 20 minutes, but could last for upto 1 day. The 1 hour and 20 minute mean CO_2 process contributions at each modelled receptor location have been reported, and a comparison to the Exposure Criteria. The 20 minute release Process Contributions (PCs) is based on the 1 hour process contribution factored to account for a release duration of a maximum of 20 minutes.

Scenario 1

3.1.2 The maximum 1 hour mean and 24 hour mean CO_2 Process Contributions at each modelled receptor location for Scenario 1 are shown in Table 3-1 and Table 3-2.

Table 3-1: Maximum 1 hour CO_2 Process Contributions - Scenario 1

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	14390	72/144
$R2_z$	456815	525617	10434	52/104
R3	457950	525045	1954	10/20
R4	458090	525550	1971	10/20
R5	455680	527395	1662	8/17
R6	455550	527345	1550	8/16
R7	458675	525415	1476	7/15
R8	457895	523735	1342	7/13
R9	458900	525060	1200	6/12
R10	458250	523585	1173	6/12
R11	459195	524980	1049	5/10

$R12_v$	456252	525483	9988	50/100
$R13_a$	456327	525679	7112	36/71
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-2: Maximum 24 hour CO_2 Process Contributions - Scenario 1

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_o$	456774	525900	3425	17/34
$R2_d$	456894	525822	2033	10/20
R3	457950	525045	322	2/3
R4	458090	525550	368	2/4
R5	455680	527395	237	1/2
R6	455550	527345	246	1/2
R7	458675	525415	262	1/3
R8	457895	523735	184	1/2
R9	458900	525060	217	1/2
R10	458250	523585	150	1/2
R11	459195	524980	188	1/2
$R12_r$	456266	525520	1634	8/16
$R13_a$	456327	525679	1069	5/11
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.3 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptors R1 and R2 where predicted concentrations are above the Lower Exposure Criteria. The values above the lower exposure threshold occur over a small area, as shown in Figure A2, Appendix A.

3.1.4 The predicted CO_2 concentrations of 14,390 ppm (R1v) and 10,434 ppm (R2z)are above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it

is considered unlikely that members of the public at this location would experience any health effects.

3.1.5 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2. The isopleth plot is shown in Figure A3, Appendix A.

Scenario 2

3.1.6 The maximum 1 hour mean and 24 hour mean CO_2 Process Contributions at each modelled receptor location for Scenario 2 are shown in Table 3-1 and Table 3-2.

Table 3-3: Maximum 1 hour CO_2 Process Contributions - Scenario 2

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_{ab}$	456653	525947	10308	52/103
$R2_{bn}$	456676	525253	9615	48/96
R3	457950	525045	1782	9/18
R4	458090	525550	1850	9/18
R5	455680	527395	1504	8/15
R6	455550	527345	1364	7/14
R7	458675	525415	1339	7/13
R8	457895	523735	1284	6/13
R9	458900	525060	1071	5/11
R10	458250	523585	1093	5/11
R11	459195	524980	940	5/9
$R12_v$	456252	525483	9988	50/100
$R13_a$	456327	525679	6827	34/68
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-4: Maximum 24 hour CO_2 Process Contributions - Scenario 2

	GRID REFERENCE	24 HR PC	

RECEPTOR ID	X	Y	(PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
$R1_q$	456756	525907	2392	12/24
$R2_{be}$	456708	525337	1646	8/16
R3	457950	525045	280	1/3
R4	458090	525550	302	2/3
R5	455680	527395	218	1/2
R6	455550	527345	217	1/2
R7	458675	525415	220	1/2
R8	457895	523735	171	1/2
R9	458900	525060	184	1/2
R10	458250	523585	136	1/1
R11	459195	524980	160	1/2
$R12_r$	456266	525520	1634	8/16
$R13_a$	456327	525679	1073	5/11
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.7 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptor R1 where predicted concentrations are above the Lower Exposure Criteria. The values above the lower exposure threshold occur over a small area, as shown in Figure A4, Appendix A.

3.1.8 A predicted CO_2 concentration of 10,308 ppm (R1ab) is above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.9 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2. The isopleth plot is shown in Figure A5, Appendix A.

Scenario 3

3.1.10 The maximum 1 hour mean and 20 minute mean CO_2 Process Contributions at each modelled receptor location for Scenario 3 are shown in Table 3-1 and Table 3-2.

Table 3-5: Maximum 1 hour CO_2 Process Contributions - Scenario 3

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	10499	52/105
$R2_{bn}$	456676	525253	9615	48/96
R3	457950	525045	1540	8/15
R4	458090	525550	1555	8/16
R5	455680	527395	1351	7/14
R6	455550	527345	1215	6/12
R7	458675	525415	1214	6/12
R8	457895	523735	1139	6/11
R9	458900	525060	983	5/10
R10	458250	523585	977	5/10
R11	459195	524980	867	4/9
$R12_v$	456270	525530	9988	50/100
$R13_a$	456327	525679	6827	34/68
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-6: Maximum 20 minute CO_2 Process Contributions - Scenario 3

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	3500	17/35
$R2_{bn}$	456676	525253	3205	16/32
R3	457950	525045	513	3/5
R4	458090	525550	518	3/5
R5	455680	527395	450	2/5

R6	455550	527345	405	2/4
R7	458675	525415	405	2/4
R8	457895	523735	380	2/4
R9	458900	525060	328	2/3
R10	458250	523585	326	2/3
R11	459195	524980	289	1/3
$R12_v$	456270	525530	3329	17/33
$R13_a$	456327	525679	2276	11/23
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.11 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptor R1 where predicted concentrations are above the Lower Exposure Criteria. The values above the lower exposure threshold occur over a small area, as shown in Figure A6, Appendix A.

3.1.12 A predicted CO_2 concentration of 10,499 ppm (R1v) is above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.13 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2.

Scenario 4

3.1.14 The maximum 1 hour mean and 24 hour mean CO_2 Process Contributions at each modelled receptor location for Scenario 4 are shown in Table 3-1 and Table 3-2.

Table 3-7: Maximum 1 hour CO_2 Process Contributions - Scenario 4

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	13414	67/134
$R2_z$	456815	525617	10434	52/104
R3	457950	525045	1797	9/18
R4	458090	525550	1908	10/19
R5	455680	527395	1494	7/15

R6	455550	527345	1386	7/14
R7	458675	525415	1363	7/14
R8	457895	523735	1206	6/12
R9	458900	525060	1112	6/11
R10	458250	523585	1083	5/11
R11	459195	524980	982	5/10
$R12_y$	456241	525455	8618	43/86
$R13_a$	456327	525679	7112	36/71
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-8: Maximum 24 hour CO_2 Process Contributions - Scenario 4

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_o$	456774	525900	3415	17/34
$R2_q$	456848	525701	1649	8/16
R3	457950	525045	247	1/2
R4	458090	525550	334	2/3
R5	455680	527395	221	1/2
R6	455550	527345	229	1/2
R7	458675	525415	233	1/2
R8	457895	523735	167	1/2
R9	458900	525060	183	1/2
R10	458250	523585	138	1/1
R11	459195	524980	159	1/2
$R12_z$	456237	525446	1137	6/11
$R13_a$	456327	525679	1092	5/11
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.15 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptors R1 and R2 where predicted concentrations are above the Lower Exposure Criteria. The values above the lower exposure threshold occur over a small area, as shown in Figure A7, Appendix A.

3.1.16 The predicted CO_2 concentrations of 13,414 ppm (R1v) and 10,434 ppm (R2z)are above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.17 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2. The isopleth plot is shown in Figure A8, Appendix A.

Scenario 5

3.1.18 The maximum 1 hour mean and 24 hour mean CO_2 Process Contributions at each modelled receptor location for Scenario 5 are shown in Table 3-1 and Table 3-2.

Table 3-9: Maximum 1 hour CO_2 Process Contributions - Scenario 5

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_{ac}$	456644	525950	9969	50/100
$R2_q$	456848	525701	7075	35/71
R3	457950	525045	1750	9/17
R4	458090	525550	1795	9/18
R5	455680	527395	1337	7/13
R6	455550	527345	1199	6/12
R7	458675	525415	1230	6/12
R8	457895	523735	1148	6/11
R9	458900	525060	990	5/10
R10	458250	523585	1003	5/10
R11	459195	524980	881	4/9
$R12_y$	456241	525455	8618	43/86
$R13_a$	456327	525679	6378	32/64

Upper Exposure Criteria	*20,000 ppm*
Lower Exposure Criteria	*10,000 ppm*

Table 3-10: Maximum 24 hour CO_2 Process Contributions - Scenario 5

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_q$	456756	525907	2412	12/24
$R2_g$	456884	525794	1203	6/12
R3	457950	525045	206	1/2
R4	458090	525550	268	1/3
R5	455680	527395	203	1/2
R6	455550	527345	201	1/2
R7	458675	525415	191	1/2
R8	457895	523735	157	1/2
R9	458900	525060	150	1/1
R10	458250	523585	126	1/1
R11	459195	524980	131	1/1
$R12_z$	456237	525446	1137	6/11
$R13_a$	456327	525679	1048	5/10
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.19 Predicted CO_2 concentrations are below the Lower and Upper Exposure Criteria at all of the selected representative receptors for Scenario 5. The isopleth plots for 1 hour and 24 hour CO_2 are shown in Figures A9 and A10, Appendix A.

Scenario 6

3.1.20 The maximum 1 hour mean and 20 minute mean CO_2 Process Contributions at each modelled receptor location for Scenario 6 are shown in Table 3-1 and Table 3-2.

Table 3-11: Maximum 1 hour CO_2 Process Contributions - Scenario 6

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_w$	456700	525929	9529	48/95
$R2_y$	456819	525626	6563	33/66
R3	457950	525045	1415	7/14
R4	458090	525550	1465	7/15
R5	455680	527395	1184	6/12
R6	455550	527345	1048	5/10
R7	458675	525415	1076	5/11
R8	457895	523735	1004	5/10
R9	458900	525060	881	4/9
R10	458250	523585	888	4/9
R11	459195	524980	788	4/8
$R12_y$	456241	525455	8618	43/86
$R13_a$	456327	525679	5808	29/58
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-12: Maximum 20 minute CO_2 Process Contributions - Scenario 6

Receptor ID	Grid Reference		24 Hr PC (ppm) *Assuming 24 hour release*	Proportion of Exposure Criteria (Lower/Upper, %)
	X	Y		
$R1_w$	456700	525929	3176	16/32
$R2_y$	456819	525626	2188	11/22
R3	457950	525045	472	2/5

R4	458090	525550	488	2/5
R5	455680	527395	395	2/4
R6	455550	527345	349	2/3
R7	458675	525415	359	2/4
R8	457895	523735	335	2/3
R9	458900	525060	294	1/3
R10	458250	523585	296	1/3
R11	459195	524980	263	1/3
$R12_y$	456241	525455	2873	14/29
$R13_a$	456327	525679	1936	10/19
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.21 Predicted CO_2 concentrations are below the Lower and Upper Exposure Criteria at all of the selected representative receptors for Scenario 6. The isopleth plot for 1 hour CO_2 is shown in Figure A11, Appendix A.

Scenario 7

3.1.22 The maximum 1 hour mean and 20 minute mean CO_2 Process Contributions at each modelled receptor location for Scenario 7 are shown in Table 3-1 and Table 3-2.

Table 3-13: Maximum 1 hour CO_2 Process Contributions - Scenario 7

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	12823	64/128
$R2_z$	456815	525617	10434	52/104
R3	457950	525045	1522	8/15
R4	458090	525550	1683	8/17
R5	455680	527395	1368	7/14
R6	455550	527345	1268	6/13
R7	458675	525415	1230	6/12
R8	457895	523735	1071	5/11

R9	458900	525060	990	5/10
R10	458250	523585	966	5/10
R11	459195	524980	878	4/9
$R12_a$	456327	525679	7112	36/71
$R13_a$	456327	525679	7112	36/71
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-14: Maximum 20 minute CO_2 Process Contributions - Scenario 7

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	4274	21/43
$R2_z$	456815	525617	3478	17/35
R3	457950	525045	507	3/5
R4	458090	525550	561	3/6
R5	455680	527395	456	2/5
R6	455550	527345	423	2/4
R7	458675	525415	410	2/4
R8	457895	523735	357	2/4
R9	458900	525060	330	2/3
R10	458250	523585	322	2/3
R11	459195	524980	293	1/3
$R12_a$	456327	525679	2371	12/24
$R13_a$	456327	525679	2371	12/24
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.23 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptors R1 and R2 where

predicted concentrations are above the Lower Exposure Criteria. This exceedance occurs over a small area, as shown in Figure A12, Appendix A.

3.1.24 The predicted CO_2 concentrations of 12,843 ppm (R1v) and 10,434 ppm (R2z)are above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.25 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2.

Scenario 8

3.1.26 The maximum 1 hour mean and 20 minute mean CO_2 Process Contributions at each modelled receptor location for Scenario 8 are shown in Table 3-1 and Table 3-2.

Table 3-15: Maximum 1 hour CO_2 Process Contributions - Scenario 8

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_y$	456681	525936	8888	44/89
$R2_{ae}$	456798	525570	7075	35/71
R3	457950	525045	1412	7/14
R4	458090	525550	1458	7/15
R5	455680	527395	1210	6/12
R6	455550	527345	1080	5/11
R7	458675	525415	1068	5/11
R8	457895	523735	1013	5/10
R9	458900	525060	868	4/9
R10	458250	523585	886	4/9
R11	459195	524980	777	4/8
$R12_a$	456327	525679	6378	32/64
$R13_a$	456327	525679	6378	32/64
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-16: Maximum 20 minute CO_2 Process Contributions - Scenario 8

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_y$	456681	525936	2963	15/30
$R2_{ae}$	456798	525570	2358	12/24
R3	457950	525045	471	2/5
R4	458090	525550	486	2/5
R5	455680	527395	403	2/4
R6	455550	527345	360	2/4
R7	458675	525415	356	2/4
R8	457895	523735	338	2/3
R9	458900	525060	289	1/3
R10	458250	523585	295	1/3
R11	459195	524980	259	1/3
$R12_a$	456327	525679	2126	11/21
$R13_a$	456327	525679	2126	11/21
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.27 Predicted CO_2 concentrations are below the Lower and Upper Exposure Criteria at all of the selected representative receptors for Scenario 8. The isopleth plot for 1 hour CO_2 is shown in Figure A13, Appendix A.

Scenario 9

3.1.28 The maximum 1 hour mean and 20 minute mean CO_2 Process Contributions at each modelled receptor location for Scenario 9 are shown in Table 3-1 and Table 3-2.

Table 3-17: Maximum 1 hour CO_2 Process Contributions - Scenario 9

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_y$	456681	525936	9621	48/96

$R2_{bo}$	456672	525243	7590	38/76
R3	457950	525045	1291	6/13
R4	458090	525550	1357	7/14
R5	455680	527395	1156	6/12
R6	455550	527345	1029	5/10
R7	458675	525415	1057	5/11
R8	457895	523735	967	5/10
R9	458900	525060	827	4/8
R10	458250	523585	842	4/8
R11	459195	524980	736	4/7
$R12_x$	456245	525464	7662	38/77
$R13_a$	456327	525679	5535	28/55
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-18: Maximum 20 minute CO_2 Process Contributions - Scenario 9

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	3207	16/32
$R2_{bo}$	456672	525243	2530	13/25
R3	457950	525045	430	2/4
R4	458090	525550	452	2/5
R5	455680	527395	385	2/4
R6	455550	527345	343	2/3
R7	458675	525415	352	2/4
R8	457895	523735	322	2/3
R9	458900	525060	276	1/3
R10	458250	523585	281	1/3
R11	459195	524980	245	1/2

$R12_x$	456245	525464	2554	13/26
$R13_a$	456327	525679	1845	9/18
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.29 Predicted CO_2 concentrations are below the Lower and Upper Exposure Criteria at all of the selected representative receptors for Scenario 9. The isopleth plot for 1 hour CO_2 is shown in Figure A14, Appendix A.

Scenario 10

3.1.30 The maximum 1 hour mean and 24 hour mean CO_2 Process Contributions at each modelled receptor location for Scenario 10 are shown in Table 3-1 and Table 3-2.

Table 3-19: Maximum 1 hour CO_2 Process Contributions - Scenario 10

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
R1v	456709	525925	14390	72/144
R2z	456815	525617	10434	52/104
R3	457950	525045	1954	10/20
R4	458090	525550	1971	10/20
R5	455680	527395	1662	8/17
R6	455550	527345	1550	8/16
R7	458675	525415	1476	7/15
R8	457895	523735	1342	7/13
R9	458900	525060	1200	6/12
R10	458250	523585	1173	6/12
R11	459195	524980	1049	5/10
R12v	456252	525483	9988	50/100
R13a	456327	525679	7112	36/71
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-20: Maximum 24 hour CO_2 Process Contributions - Scenario 10

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_o$	456774	525900	3425	17/34
$R2_d$	456894	525822	2033	10/20
R3	457950	525045	322	2/3
R4	458090	525550	368	2/4
R5	455680	527395	237	1/2
R6	455550	527345	246	1/2
R7	458675	525415	262	1/3
R8	457895	523735	184	1/2
R9	458900	525060	217	1/2
R10	458250	523585	150	1/2
R11	459195	524980	188	1/2
$R12_r$	456266	525520	1634	8/16
$R13_a$	456327	525679	1069	5/11
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.31 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptors R1 and R2 where predicted concentrations are above the Lower Exposure Criteria. The values above the lower exposure threshold occur over a small area, as shown in Figure A15, Appendix A.

3.1.32 The predicted CO_2 concentrations of 14,390 ppm (R1v) and 10,434 ppm (R2z)are above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.33 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2. The isopleth plot for the 24 hour CO_2 is shown in Figure A16, Appendix A.

Scenario 11

3.1.34 The maximum 1 hour mean and 24 hour mean CO_2 Process Contributions at each modelled receptor location for Scenario 11 are shown in Table 3-1 and Table 3-2.

Table 3-21: Maximum 1 hour CO_2 Process Contributions – Scenario 11

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_{ab}$	456653	525947	10308	52/103
$R2_{bn}$	456676	525253	9615	48/96
R3	457950	525045	1782	9/18
R4	458090	525550	1850	9/18
R5	455680	527395	1504	8/15
R6	455550	527345	1364	7/14
R7	458675	525415	1339	7/13
R8	457895	523735	1284	6/13
R9	458900	525060	1071	5/11
R10	458250	523585	1093	5/11
R11	459195	524980	940	5/9
$R12_v$	456252	525483	9988	50/100
$R13_a$	456327	525679	6827	34/68
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

Table 3-22: Maximum 24 hour CO_2 Process Contributions - Scenario 11

RECEPTOR ID	GRID REFERENCE		24 HR PC (PPM) *ASSUMING 24 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_q$	456756	525907	2392	12/24
$R2_{be}$	456708	525337	1646	8/16

R3	457950	525045	280	1/3
R4	458090	525550	302	2/3
R5	455680	527395	218	1/2
R6	455550	527345	217	1/2
R7	458675	525415	220	1/2
R8	457895	523735	171	1/2
R9	458900	525060	184	1/2
R10	458250	523585	136	1/1
R11	459195	524980	160	1/2
$R12_r$	456266	525520	1634	8/16
$R13_a$	456327	525679	1073	5/11
Upper Exposure Criteria			*20,000 ppm*	
Lower Exposure Criteria			*10,000 ppm*	

3.1.35 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for 1 hour mean CO_2, except receptor R1 where predicted concentrations are above the Lower Exposure Criteria. This exceedance occurs over a small area, as shown in Figure A17, Appendix A.

3.1.36 A predicted CO_2 concentration of 10,308 ppm (R1ab) is above the Lower Exposure Criteria (10,000 ppm) for the onset of symptoms, and it is considered unlikely that members of the public at this location would experience any health effects.

3.1.37 Predicted CO_2 concentrations are below the Exposure Criteria at all of the selected representative receptors for the 24 hour mean CO_2. The isopleth plot for 24 hour CO_2 is shown in Figure A18, Appendix A.

Scenario 12

3.1.38 The maximum 1 hour mean and 20 minute mean CO_2 Process Contributions at each modelled receptor location for Scenario 12 are shown in Table 3-1 and Table 3-2.

Table 3-23: Maximum 1 hour CO_2 Process Contributions - Scenario 12

RECEPTOR ID	GRID REFERENCE		1 HR PC (PPM) *ASSUMING 1 HOUR RELEASE*	PROPORTION OF EXPOSURE CRITERIA (LOWER/UPPER, %)
	X	Y		
$R1_v$	456709	525925	10499	52/105
$R2_{bn}$	456676	525253	9615	48/96