Midia Gas Development FEED Study

Offshore and Onshore Atmospheric Dispersion Modelling Report

Black Sea Oil & Gas SRL

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ABBREVIATIONS

BSOG	Black Sea Oil & Gas S.R.L.
CERC ADMS	Cambridge Environmental Research Consultants Atmospheric Dispersion Modelling System
CO	Carbon monoxide
EBRD	European Bank for Reconstruction and Development
EHC	Electro-hydraulic-chemical
EIA	Environmental impact assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union
g	Gram
GTP	Gas Treatment Plant
J	Joule
K	Kelvin
kg	Kilogram
km	Kilometre
LAT	Lowest astronomical tide
m	Metre
m^3	Cubic metre
MEG	Monoethylene glycol
mg	milligram
MGD / MGD Project	Midia Gas Development / Midia Gas Development Project
MMSCMD	Million standard cubic metres per day
NO_2	Nitrogen dioxide
PM10	Particulate matter with a diameter between 2.5 and 10 µm
RSV	Rig supply vessel
s	Second
SO_2	Sulphur dioxide
TEG	Triethylene glycol
UTM	Universal Transverse Mercator
VOC	Volatile organic compounds
WGS84	World Geodetic System 1984
WHP	Wellhead platform
µg	Microgram
µm	Micrometres
%	Percent

1 INTRODUCTION

1.1 Project Overview

Black Sea Oil & Gas S.R.L. (BSOG) is the titleholder (together with Petro Ventures Resources SRL and Gas Plus International BV) and operator of the Concession Agreement for Petroleum Exploration, Development and Production in Blocks XIII Pelican and XV Midia, Contract Area B (XV Midia), located on the continental shelf of the Romanian Black Sea. The Ana and Doina reservoirs lie in Midia Block XV of the western Black Sea, some 110 km to the east of Constanta, Romania.

BSOG intends to develop the Midia Gas Development Project (MGD) to produce and process gas from the Ana and Doina discoveries and route it to export to consumers within Romania and/or the European Union (EU). The planned first gas production date for the Ana and Doina fields is Quarter 2 of 2019.

Both the Ana and Doina fields have high methane content (>99 mole%) with minimal contaminants. The fields are predicted to have an overall production life of 10 to 15 years with a predicted peak production capacity of approximately 3 million standard cubic metres per day (MMSCMD).

The selected concept is illustrated in Figure 1.1 and described below.

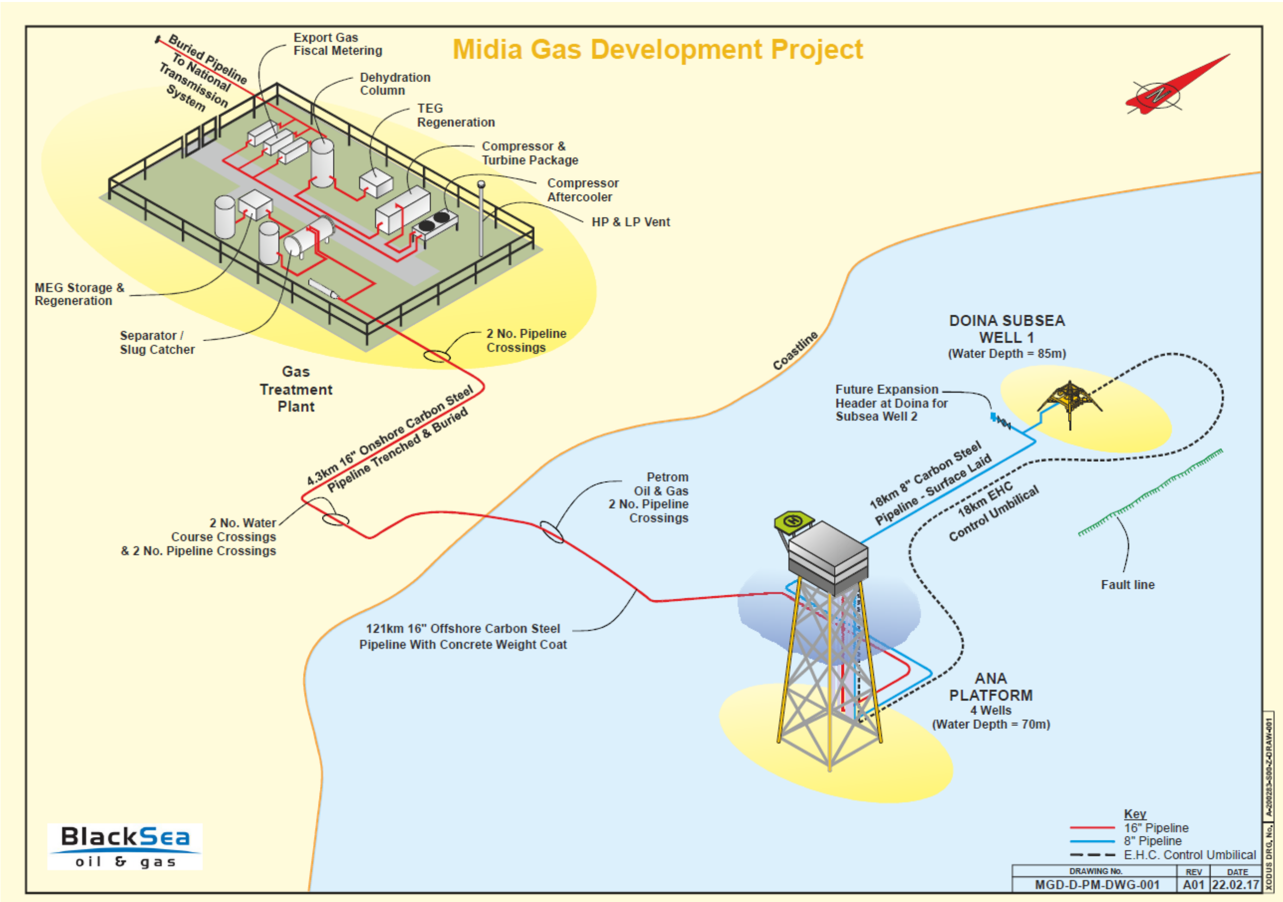


Figure 1.1: Process Schematic for Midia Gas Development

The facilities required for the development can be summarised as follows:

> Doina: Up to 2 × subsea wells in a daisy chain arrangement – wells controlled via an electro-hydraulic-chemical (EHC) umbilical from the Ana platform. The initial development is for 1 × Doina subsea well.

> Doina to Ana infield pipeline: 8-inch carbon steel pipeline with no concrete coating, continuously inhibited against hydrates with monoethylene glycol (MEG).

> Ana: Normally unmanned wellhead platform (WHP) with 4 × platform wells, pipework fully rated to well closed in tubing head pressure, cold vent, power generation, chemical storage and injection pumps for MEG, helideck, temporary refuge, boat landing facility, temporary refuge, lifeboat, facilities to enable temporary installation of pig receivers and pig launchers, crane, deck integrated fire-fighting system and minimal other facilities.

> Ana to shore pipeline: 16-inch carbon steel pipeline with concrete coating for stability, continuously inhibited against hydrates with MEG.

> Beach crossing: To be either trenched using cofferdams or achieved via horizontal directional drilling.

> Beach to onshore gas treatment plant pipeline: Trenched and buried 16-inch carbon steel pipeline, continuously inhibited against hydrates with MEG.

> Onshore gas treatment plant (GTP): Pig receiver, slug catcher/separator, single stage turbine driven compressor (with scrubber and air cooled aftercooler), triethylene glycol (TEG) dehydration of gas, fiscal metering, MEG regeneration and storage, control room, power generation, utilities, cold vent, fixed fire water system, etc.

Gas produced from MGD will be exported to the national gas transmission system.

The overall field layout for MGD is shown in Figure 1.2.

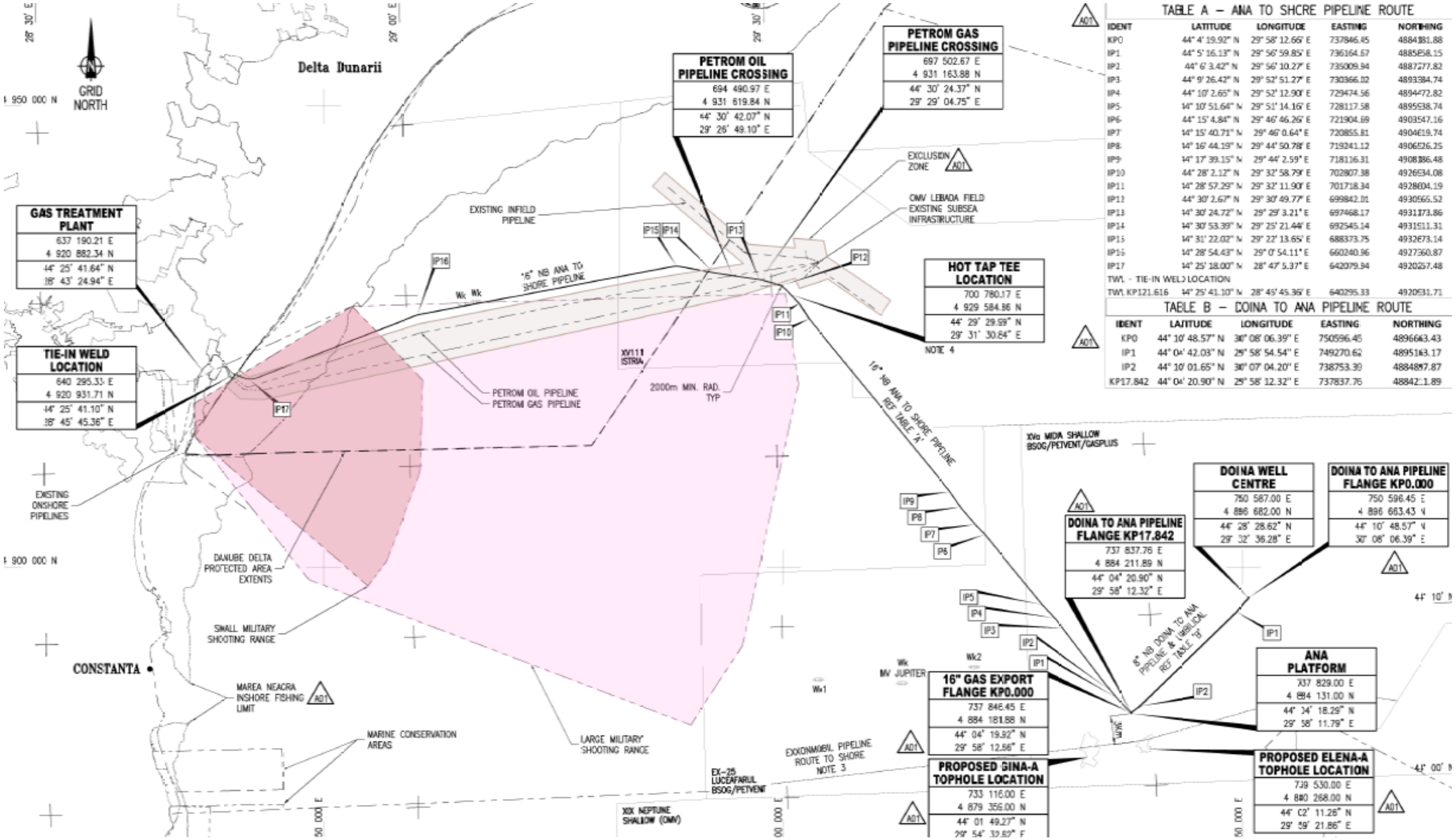


Figure 1.2: Overall Field Layout for Midia Gas Development Project

1.2 Purpose of the Modelling

Atmospheric dispersion modelling for the onshore and offshore elements of the MGD Project has been undertaken by Xodus Group on behalf of BSOG. The results from the modelling study will be used to inform environmental impact assessments (EIA) being conducted for the MGD Project both to meet Romanian permitting requirements and as part of the Environmental and Social Impact Assessment (ESIA) being undertaken to meet international finance institution requirements, particularly those of the European Bank for Reconstruction and Development (EBRD). This study is not itself an impact assessment; it should be viewed as a risk assessment exercise to be used in support of the EIA/ESIA requirements of the MGD Project.

1.3 Scope of the Modelling

The scope of the modelling was to investigate the dispersion of pollutants emitted from the onshore diesel and gas power generators, onshore compressor turbine package, and the offshore diesel power generator.

There will be small but routine/continuous emissions of hydrocarbon gas from dynamic seal leakage of the onshore compressor turbine package. There will also be a periodic requirement for the emergency disposal of hydrocarbon gas during relief or blowdown events (onshore only) or for plant depressurisation for maintenance (onshore and offshore). These emissions are all expected to be cold vented (Reference 1[1]), although the possibility exists for flaring onshore at the GTP. Such emissions are very low onshore (for either a flare or a vent) in comparison to the overall CO_2 emissions from the GTP associated with the compressor, generator and fired heaters, and offshore in comparison with the overall emissions from the diesel generator, and they are not included in the atmospheric dispersion modelling.

Three scenarios were considered in the modelling as follows:

- Scenario A - Maximum emissions from normal operation (onshore)
    - One (of two) gas engines (GP-G-60-01A/B) and one compressor turbine package (GP-Z-32-01), both at 100% load;
- Scenario B - Maximum emissions from abnormal operation (onshore)
    - One backup power generation package running on diesel (GP-Z-63-01), at 100% load;
- Scenario C - Maximum emissions from normal operation (offshore)
    - One (of two) diesel generators (AN-G-60-01A/B), at 100% load.

[1] Flaring and Venting BAT Assessment - A-200283-S00-A-REPT-005-A02

2 AIR DISPERSION MODELLING

2.1 ADMS 5.2

CERC ADMS 5.2 is a Gaussian plume atmospheric dispersion model which characterises the atmospheric turbulence by two parameters; the boundary layer depth and the Monin-Obukhov length. This method is combined with a skewed Gaussian concentration distribution to calculate dispersion of a wide range of buoyant and passive releases to the atmosphere. The model is applicable up to 60 km downwind of the source and may provide useful information for up to 100 km downwind.

ADMS 5.2 utilises hourly sequential meteorological files containing wind speed, wind direction, temperature, and cloud cover data to calculate the dispersion of the release. The boundary layer information and Monin-Obukhov length used by ADMS 5.2 is calculated using a meteorological pre-processor developed by the UK Met Office.

ADMS 5.2 was selected to conduct the onshore and offshore atmospheric dispersion modelling because it is accepted as one of the leading atmospheric models to inform assessments used for regulatory purposes.

2.2 Meteorology

Meteorological conditions have the biggest effect on the plume dispersion within the model. For this project, 5 years (2012 - 2016) of hourly sequential meteorological data from the Constanta meteorological station (44°12'50"N, 28°38'44"E WGS84) were used, provided by the UK Met Office[2]. The wind rose in Figure 2.1 plots the frequency of wind from a particular direction, and uses coloured bands to show wind speed ranges. Altogether 92% of the total number of hours for the 5 years have been used in the emission modelling, which excludes hours of calm (defined as wind speed <0.75 m/s) and unavailable data. All modelling work described in this report does not therefore include calm conditions. The wind rose shows that the majority of the time wind is blowing from the north with a smaller proportion of winds blowing from the west. Annual wind roses are given in Appendix A.

[2] This was the closest available location for both the onshore and offshore sites, about 110 km west of the WHP and 25 km south of the GTP.

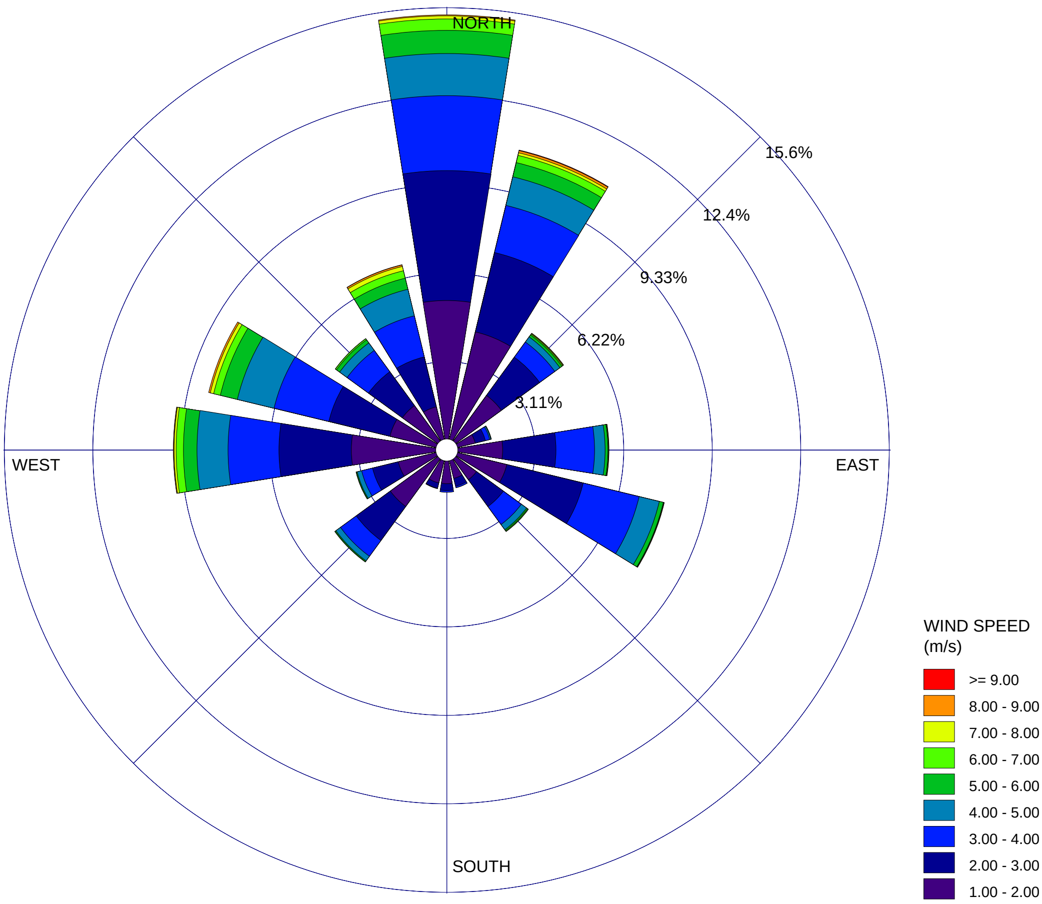


Figure 2.1 Wind rose for Constanta meteorological data (2012 - 2016)

2.3 Air Quality Standards

Onshore, air quality is measured by comparing measured or predicted concentrations against a range of health-effects based standards. Standards for air quality are concentrations over a given time period that are considered to be acceptable in the light of scientific evidence about the effects of each emission on health and on the environment. The air quality standards apply at areas of relevant public exposure which are defined as areas that are likely to be exposed for a period of time appropriate to the averaging period of the objective. Although air quality standards have been derived for onshore, rather than offshore air quality, their application offshore provides an indication of potential environmental effects from offshore atmospheric releases.

Law no. 104/2011 transposes EU Directive 2008/50/EC on ambient air quality and cleaner air for Europe and Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air into national law. The applicable air quality limits are shown in Table 2-1; these pollutants were chosen based on the emissions listed in the manufacturers' product data sheets referred to in Appendix C.

It should be noted that many of the guideline values allow for a number of exceedances to occur each year, in recognition that peak values are not necessarily good descriptors of air quality. This is represented as a percentile value (calculated by subtracting the number of allowed exceedances per year from the total number of measurements possible per year and then dividing this number by the total number of measurements possible per year). For example, in Table 2.1, the standard for SO_2 is that the average hourly value is allowed to exceed 350 µg/m^3 24 times in a year (0.27%).

Pollutant	Averaging period	Concentration	Units
Nitrogen Dioxide (NO_2)	1 hour	200 (99.79th percentile)	$\mu g/m^3$
Sulphur Dioxide (SO_2)	1 hour	350 (99.73th percentile)	$\mu g/m^3$
	24 hours	125 (99.18th percentile)	$\mu g/m^3$
	1 year	40 (annual average)	$\mu g/m^3$
Particulates (PM_{10})	24 hours	50 (annual average)	$\mu g/m^3$
	1 year	40 (annual average)	$\mu g/m^3$
Carbon Monoxide (CO)	8 hour	10 (8-hour running mean)	mg/m^3
Benzene	1 year	5 (annual average)	$\mu g/m^3$

Table 2-1 Relevant air quality standards[3]

2.4 Background Air Quality

As the GTP is located in a rural area, background air quality at the GTP is assumed to be equivalent to the nearest available rural air quality monitoring station. This is located in Calarasi (44°8'25"N, 27°16'30"E) and relevant values are shown in Table 2-2. The WHP location is in the Black Sea more than 100 km from the shore, in a highly dispersive environment and not near any sources of air pollution. Since no offshore air quality data are available, the data from Calarasi have also been applied for the WHP.

Pollutant	Concentration	Units
NO_2	14.42	$\mu g/m^3$
SO_2	12.81	$\mu g/m^3$
PM10[4]	0	$\mu g/m^3$
CO[5]	0.00008	mg/m^3
Benzene[6]	1.16	$\mu g/m^3$

Table 2-2 Background air quality for relevant pollutants[7]

2.5 Specified Receptors

A list of settlements[8], i.e. areas of relevant public exposure (Section 2.3) within 70 km of the proposed location of the GTP is given in Appendix B. The Ana WHP is located more than 100 km from the GTP, but is also included in this list for reference. In addition, the Port of Midia, although not a settlement, is also included in this list.

[3] Law no. 104/2001 on ambient air quality – which transposes the Ambient Air Quality Directive 2008/50/EC and Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. Annex No. 3, Part B - Limit values for the protection of human health.
[4] Assumed to be zero due to rural location.
[5] No data were available for benzene at the Calarasi monitoring station. Data for a Constanta monitoring station (44°10'35"N, 28°38'58"E WGS84) was selected in place.
[6] No data were available for benzene at the Calarasi monitoring station. Data for a Constanta monitoring station (44°10'35"N, 28°38'58"E WGS84) was selected in place.
[7] Most recent values available were chosen from the Airbase database available at https://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-8.
[8] Defined from aerial photographs provided by Google Earth.

2.6 Surface Roughness

For the onshore scenarios (A and B), a surface roughness considered appropriate for an agricultural area was used. The ADMS 5.2 User Guide[9] suggests a value of 0.2 or 0.3 be used and Section 4.1.1 details how the roughness of 0.3 used in this study was selected. For the offshore scenario (C), a surface roughness considered appropriate for the sea of 0.0001 was used[10].

2.7 Grid Description

A regular Cartesian grid was used for all scenarios, centred on the GTP (Scenarios A and B) or the Ana platform (Scenario C). It should be noted that the grids used for the onshore scenarios do not overlap with the offshore scenario, and that the location of the specified receptors frequently lies outside of the Cartesian grid. Table 2-3 below presents the grid set up for each scenario modelled.

Scenario	Grid spacing (m)	No. points	Maximum extent (km)
A	400	51	20 x 20
B	400	51	20 x 20
C	600	51	30 x 30

Table 2-3 Grid set up for all scenarios

[9] ADMS 5.2 User Guide, CERC, 2016
[10] ADMS 5.2 User Guide, CERC, 2016

3 INPUT ASSUMPTIONS

Emission parameters for the equipment listed in section 1.2 were calculated as shown in Appendix C based on equipment manufacturer data sheets and appropriate project specifications provided by BSOG. The values used are shown in Table 3-1.

Parameter	**Equipment**			
	Onshore			Offshore
	Gas engine	Backup power generation package (diesel)	Compressor turbine package	Diesel generator
	GP-G-9-01A/B	GP-Z-63-01	GP-Z-32-01	AN-G-60-01A/B
Easting (WGS84 UTM Zone 35 N)	638280.21	638241.21	638241.21	737829
Northing (WGS84 UTM Zone 35 N)	4921908.89	4921938.91	4921938.91	4884131
Exhaust height above sea level (m)	6.1	6.1	11.2	30.5
Exhaust diameter (m)	0.452	0.6	1.78	0.18
Mass flux (kg/s)	0.1465	0.235	22.105	0.1[11]
Specific heat capacity (J/kg/K)	1077	1041	1041	1041
Density (kg/m^3)	0.49	0.42	0.45	0.42
CO emission rate (g/s)	1.20	1241.00	1.05	0.05
Benzene emission rate (g/s)	3.30	0.09	0.30	0.001
SO_2 emission rate (g/s)[12]	-	0.001	-	0.00001[13]
NO_2 emission rate (g/s)	0.60	3.84	1.32	0.15
PM10 emission rate (g/s)[14]	-	0.04	-	-
Included in Scenario A?	Yes		Yes	
Included in Scenario B?		Yes		
Included in Scenario C?				Yes

Table 3-1 Emission parameters

[11] Minimum value available in ADMS 5.2. Actual value calculated to be 0.021 kg/s.
[12] SO_2 is not listed as an emission species in the manufacturer product data sheets. As a conservative estimate, the EU limit for sulphur content of diesel intended for vehicular use of 10 mg/kg is used to calculate the emission of SO_2, as shown in Appendix C.
[13] This value is considered negligible and is therefore excluded from the modelling.
[14] Particulate matter size was not reported in equipment data sheets so PM10 was assumed.

In all cases, the equipment data sheets did not give values for benzene emission rates. They did, however, give values for pollutants such as volatile organic compounds (VOCs) and unburnt hydrocarbons. There is no Romanian or EU air quality standard on VOCs and unburnt hydrocarbons, nor are there World Health Organisation air quality standards. Taking a conservative approach, emissions of these were combined and assessed as benzene, which is represented by the benzene emission rates displayed above.

4 RESULTS AND DISCUSSION

4.1 Onshore Scenarios A and B

4.1.1 Onshore surface roughness

Two preliminary model runs using the parameters for Scenario A showed that maximum long term average concentrations were slightly higher when a surface roughness value of 0.3 was used as opposed to when a surface roughness value of 0.2 was used. Results are shown in Table 4-1.

Pollutant	**Maximum predicted concentration when surface roughness = 0.2**	**Maximum predicted concentration when surface roughness = 0.3**
Benzene	18.1 µg/m^3	18.6 µg/m^3
CO	0.0060 mg/m^3	0.0062 mg/m^3
NO_2	17.7 µg/m^3	17.9 µg/m^3

Table 4-1 Comparison of maximum predicted concentrations for Scenario A with two possible values for surface roughness

Assumption of a surface roughness of 0.3 resulted in higher maximum predicted concentrations compared to a value of 0.2. Taking a precautionary approach, results from runs using the higher surface roughness were analysed further in this report.

4.1.2 Scenario A – onshore normal operating conditions

As there is no SO_2 or PM10 emitted in this scenario, these parameters were not modelled and are therefore omitted from all discussion.

The Romanian air quality standards for benzene, NO_2 and CO were not exceeded at any of the specified receptors. Annual mean concentrations and percentiles are shown in Table 4-2.

Maximum long-term average predicted concentrations for benzene, CO and NO_2 are shown in Table 4-3.

Receptor	Benzene	CO		NO_2	
	Annual mean concentration (µg/m^3)	Annual mean concentration (mg/m^3)	8 hour 100th percentile concentration (mg/m^3)	Annual mean concentration (µg/m^3)	1 hour 99.79th percentile concentration (µg/m^3)
GTP	1.91	0.000400	0.01731	14.62	20.14
Port of Midia	1.50	0.000219	0.00284	14.50	15.81
Vadu	1.47	0.000196	0.01679	14.48	18.31
Sacele	1.34	0.000153	0.00363	14.46	16.22
Traian	1.32	0.000143	0.00415	14.46	16.43
Navodari	1.31	0.000143	0.00205	14.46	15.41
Gura Dobrogei	1.29	0.000135	0.00187	14.45	15.33
Nuntasi	1.25	0.000114	0.00253	14.44	15.65
Tariverde	1.24	0.000109	0.00192	14.44	15.34
Istria	1.22	0.000101	0.00218	14.44	15.43
Lumina	1.27	0.000122	0.00160	14.45	15.18
Cogealac	1.24	0.000108	0.00162	14.44	15.25
Corbu	1.25	0.000120	0.00434	14.45	16.27
Palazu Mic	1.22	0.000106	0.00191	14.44	15.32
Piatra	1.21	0.000098	0.00166	14.43	15.24

Table 4-2 Air quality predictions for receptors with the 15 highest annual mean benzene concentration.

Pollutant	Reference period	Concentration units	Air quality standard	Maximum long term average predicted concentration	Percentage of limit value (>100% indicates exceedance) (%)
Benzene	1 year	µg/m^3	5	18.6	372
CO	8 hours	mg/m^3	10	0.0062	0.0620
NO_2	1 hour	µg/m^3	200	17.9	8.92

Table 4-3 Maximum predicted concentrations under Scenario A at any location in the 20 km grid

The maximum predicted concentrations for CO and NO_2 do not exceed the Romanian air quality standards. The air quality standard for the maximum predicted concentration is exceeded for benzene by 372%. However, this is a conservative estimate because, as there is no Romanian or EU air quality standard for unburnt hydrocarbons and VOCs, these emissions were combined and assessed against the benzene standard (Section 3). In addition, this is a very localised effect.

4.1.3 Scenario B – abnormal onshore operating conditions

The amount of SO_2 emitted in this scenario is extremely low (0.001 g/s), so there is no significant deviation from the background in the predicted mean or percentile SO_2 concentration for any of the specified receptors, and results for this pollutant are therefore not presented here.

The Romanian air quality standards for benzene, NO_2 and PM10 were not exceeded at any of the specified receptors (Table 4-4). The limit for CO was exceeded at two of the specified receptor sites, Vadu (three times in five years) and the GTP itself (once in five years; Table 4-4).

Receptor	Benzene	CO			NO_2		PM10	
	Annual mean conc. (µg/m^3)	Annual mean conc. (mg/m^3)	8 hour 100th percentile conc. (mg/m^3)	Exceedances per year	Annual mean conc. (µg/m^3)	1 hour 99.79th percentile conc. (µg/m^3)	Annual mean conc. (µg/m^3)	24 hour 99.79th percentile conc. (µg/m^3)
Vadu	1.18	0.081	13.71	0.6	14.68	38.76	0.0026	0.0065
GTP	1.19	0.244	12.95	0.2	15.17	48.87	0.0080	0.0239
Traian	1.17	0.038	3.47	0.0	14.54	21.36	0.0012	0.0039
Port of Midia	1.18	0.097	2.31	0.0	14.72	20.79	0.0031	0.0099
Corbu	1.17	0.024	2.27	0.0	14.49	21.09	0.0007	0.0020
Sacele	1.17	0.046	2.27	0.0	14.56	21.05	0.0014	0.0047
Nuntasi	1.17	0.023	2.03	0.0	14.49	19.64	0.0007	0.0024
Istria	1.17	0.016	1.53	0.0	14.47	19.11	0.0005	0.0016
Navodari	1.17	0.046	1.47	0.0	14.56	18.89	0.0014	0.0049
Tariverde	1.17	0.021	1.40	0.0	14.49	18.69	0.0007	0.0022
Palazu Mic	1.17	0.019	1.37	0.0	14.47	18.53	0.0006	0.0020
Gura Dobrogei	1.17	0.041	1.36	0.0	14.54	18.64	0.0012	0.0045
Cogealac	1.17	0.021	1.24	0.0	14.49	18.35	0.0007	0.0023
Lumina	1.17	0.032	1.21	0.0	14.52	18.09	0.0010	0.0034
Piatra	1.17	0.013	1.15	0.0	14.46	18.17	0.0004	0.0010
Sinoe	1.17	0.012	1.11	0.0	14.46	17.84	0.0004	0.0013
Oituz	1.17	0.017	1.09	0.0	14.47	17.81	0.0005	0.0017
Fantanele	1.17	0.014	1.07	0.0	14.47	17.58	0.0004	0.0015
Ovidiu	1.17	0.031	1.03	0.0	14.51	17.57	0.0010	0.0033
Mihail Kogalnic-eanu	1.17	0.008	1.01	0.0	14.45	17.01	0.0003	0.0007

Table 4-4 Air quality predictions for receptors with the 20 highest 100th percentile values for CO under Scenario B

Maximum long term average predicted concentrations for benzene, CO, NO_2, PM10 and SO_2 are shown in Table 4-5. There are no locations at which the air quality standards are exceeded long term.

Pollutant	Reference period (hours)	Concentration units	Air quality standard	Maximum long term average predicted concentration	Percentage of limit value (>100% indicates exceedance) (%)
Benzene	1	µg/m³	5	1.45	28.9
CO	8	mg/m³	10	3.79	37.9
NO_2	1	µg/m³	200	26.2	13.1
PM10	24	µg/m³	50	0.127	0.255
SO_2	1	µg/m³	350	12.8	3.66

Table 4-5 Maximum predicted concentrations under Scenario B for the 20 km grid

The air quality standard for CO was exceeded four times in a five year period, all within 2.5 km of the GTP. However, the maximum long term average predicted concentration (3.79 mg/m³) is only 37.9% of the air quality standard.

4.1.4 Inter-annual variability

So far, results have been presented that have been obtained using meteorological data for the five year period 2012 – 2016; however, this could mask potentially significant inter-annual variation. Table 4-6 shows the annual mean concentrations at Vadu, the nearest village to the proposed GTP (about 2.5 km north), and the settlement where the highest percentile concentrations are predicted to occur.

Year	Scenario A			Scenario B				Frequency of wind from south (%)[15]
	Benzene (µg/m³)	CO (mg/m³)	NO_2 (µg/m³)	Benzene (µg/m³)	CO (mg/m³)	NO_2 (µg/m³)	PM10 (µg/m³)	
2012	1.41	1.76E-04	14.47	1.175	0.0638	14.62	2.06E-03	2.1
2013	1.40	1.70E-04	14.47	1.174	0.0601	14.61	1.93E-03	2.8
2014	1.32	1.40E-04	14.46	1.165	0.0449	14.56	1.46E-03	1.7
2015	1.38	1.61E-04	14.46	1.174	0.0539	14.59	1.73E-03	1.4
2016	1.87	3.38E-04	14.56	1.184	0.1870	15.02	6.02E-03	6.4

Table 4-6 Annual mean concentrations of pollutants at Vadu, and frequency of southerly winds

The highest long term mean concentrations at Vadu occur in 2016, whilst the lowest long term mean concentrations occur in 2014. This is likely to be due to changes in the frequency of southerly winds which would transport pollutants from the GTP towards Vadu. These southerly winds were much more frequent in 2016 (6.4% of hourly data) than in 2012, 2013, 2014 or 2015 (1.4 to 2.8%; Table 4-6).

[15] Fraction of hourly data where winds are from the south. Data where the wind speed is less than 1 m/s is not included and southerly winds are defined at 157.5 – 202.5°.

4.2 Offshore - Scenario C

The relatively small quantities of pollutants emitted in Scenario C, together with the local conditions, mean that pollutant concentrations in the plume are low. Although the need to use the minimum value of 0.1 kg/s for the mass flux (Table 3-1) means that the values reported here are likely to be underestimates, even a five-fold increase in the mass flux does not result in a significant variation in predicted concentrations, most likely due to the relatively low input values.

Romanian air quality standards were not predicted to be exceeded at any of the specified receptors or at any location on the grid.

Maximum long term average predicted concentrations are shown in Table 4-7. The values for benzene and CO are extremely low, and represent a negligible fraction of the air quality standard. The value for NO_2 represents a larger fraction of the air quality standard (7.26%). However, the background concentration represents 7.21% of the standard, suggesting that the emissions contribute just 0.05%.

Pollutant	**Reference period**	**Air quality standard**		**Maximum long term average predicted concentration**		**Percentage of limit value (>100% indicates exceedance) (%)**	**Background concentration**	
		Value	Units	Value	Units		Value	Units
Benzene	1 year	5	µg/m³	6.16E-4	µg/m³	0.0123	1.17	µg/m³
CO	8 hours	10	mg/m³	0.00011	mg/m³	0.00110	8E-5	mg/m³
NO_2	1 hour	200	µg/m³	14.5	µg/m³	7.26	14.42	µg/m³

Table 4-7 Maximum long term predicted concentrations for Scenario C (offshore)

5 CONCLUSIONS

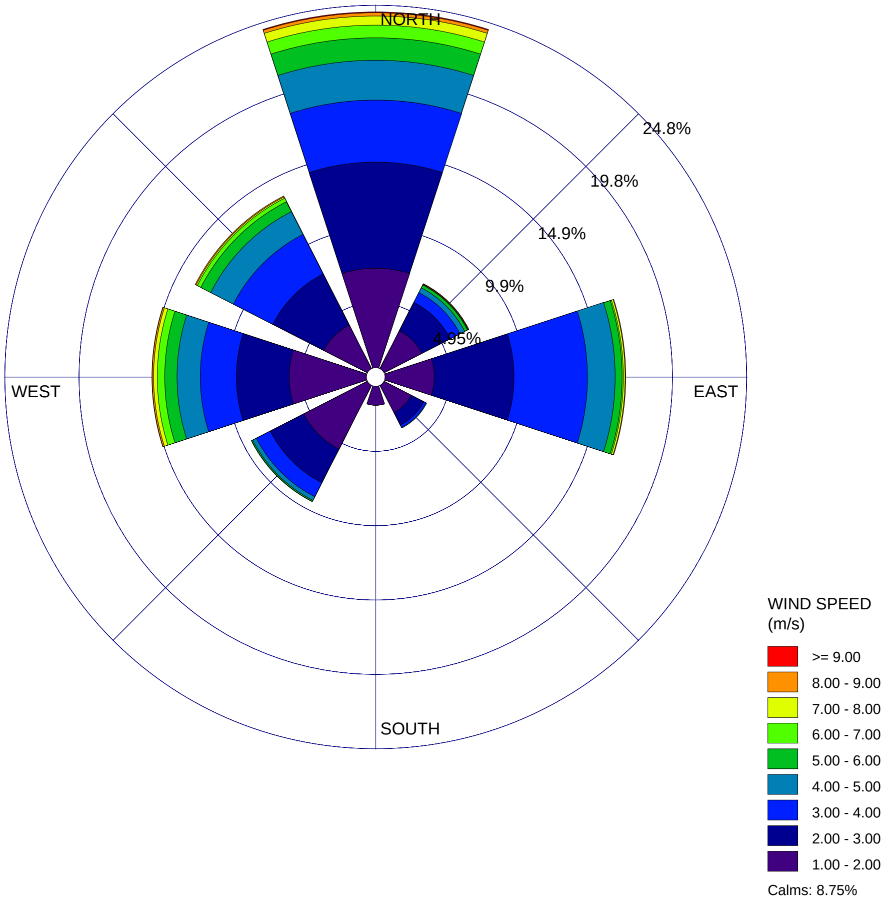
The modelling study assessed potential onshore and offshore emissions from the Midia Gas Development Project under normal and abnormal operating conditions.

- Under normal operating conditions of the GTP (use of a gas engine and compressor turbine package), no exceedances of Romanian air quality standards were predicted for emission of SO_2, benzene, PM10, NO_2 or CO.
- Under abnormal operating conditions of the GTP (use of a diesel powered backup generator), no exceedances of Romanian air quality standards were predicted for emission of SO_2, PM10, NO_2 or benzene. The air quality standard was exceeded for CO four times over a five year period, but as the back-up generator is likely to only be used occasionally for short periods, this is not considered to have a significant impact.
- No exceedances of Romanian air quality standards were predicted for the Ana platform as a result of the use of a diesel generator under normal operating conditions.

As modelling was undertaken using preliminary designs and equipment choices, further atmospheric dispersion modelling is recommended once project designs have been finalised.

APPENDIX A ANNUAL WIND ROSES

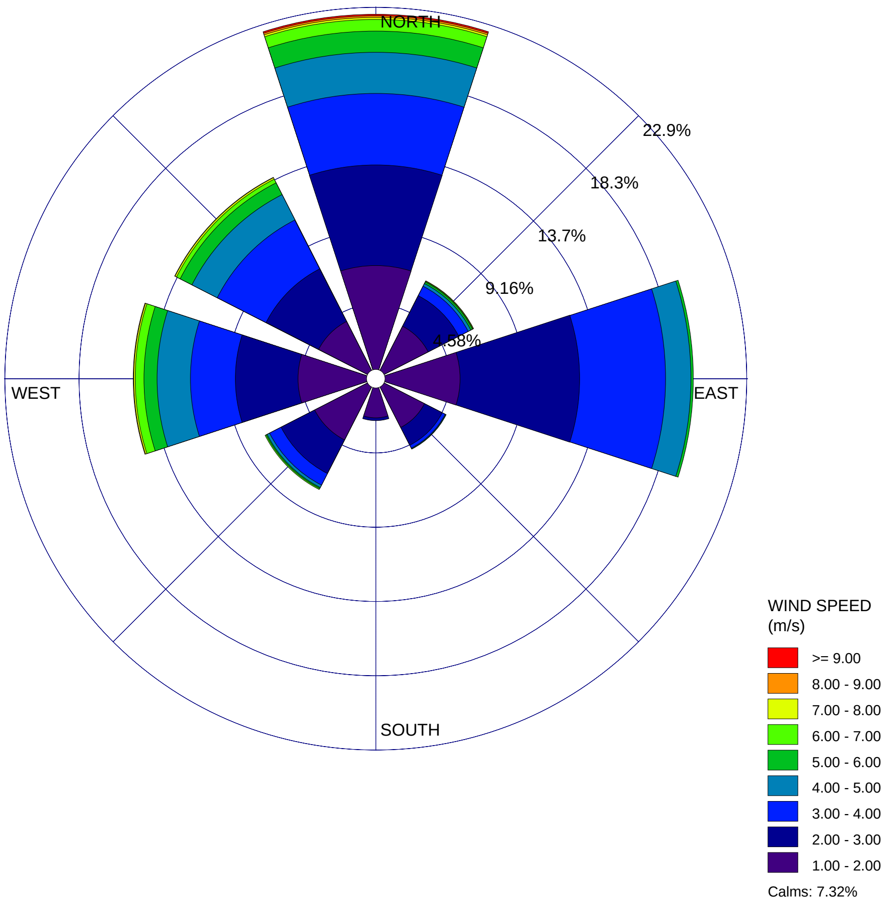
WIND ROSE PLOT:	DISPLAY:
2012	**Wind Speed** **Direction (blowing from)**



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
Station 15480 Constanta	**Start Date: 01/01/2012 - 00:00** **End Date: 31/12/2012 - 23:00**	**Xodus Group**	
		MODELER: **KM**	xodus GROUP
	CALM WINDS: **8.75%**	TOTAL COUNT: **8781 hrs.**	
	AVG. WIND SPEED: **2.15 m/s**	DATE: **16/08/2017**	PROJECT NO.: **A200283**

WRPLOT View - Lakes Environmental Software

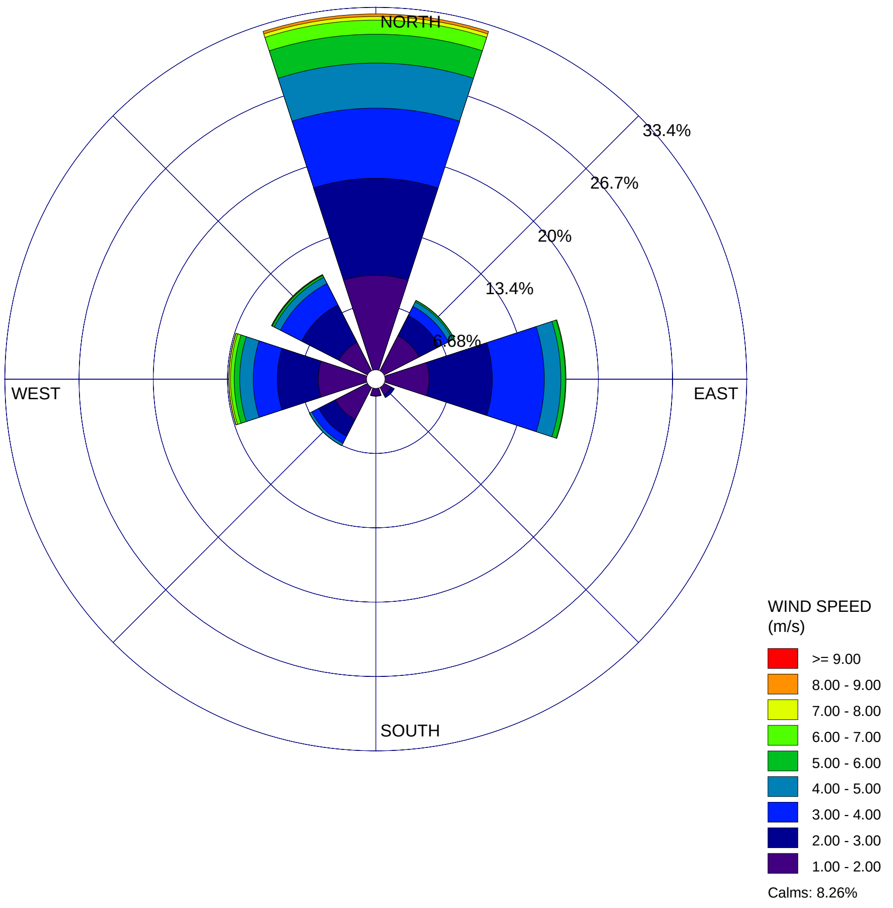
WIND ROSE PLOT: 2013	DISPLAY: Wind Speed Direction (blowing from)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
Station 15480 Constanta	**Start Date: 01/01/2013 - 00:00** **End Date: 31/12/2013 - 23:00**	**Xodus Group**	
		MODELER: **KM**	
	CALM WINDS: **7.32%**	TOTAL COUNT: **8757 hrs.**	
	AVG. WIND SPEED: **2.11 m/s**	DATE: **16/08/2017**	PROJECT NO.: **A200283**

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:	DISPLAY:
2014	**Wind Speed** **Direction (blowing from)**



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
Station 15480 Constanta	**Start Date: 01/01/2014 - 00:00** **End Date: 31/12/2014 - 23:00**	**Xodus Group**	
		MODELER: **KM**	
	CALM WINDS: **8.26%**	TOTAL COUNT: **8747 hrs.**	
	AVG. WIND SPEED: **2.11 m/s**	DATE: **16/08/2017**	PROJECT NO.: **A200283**

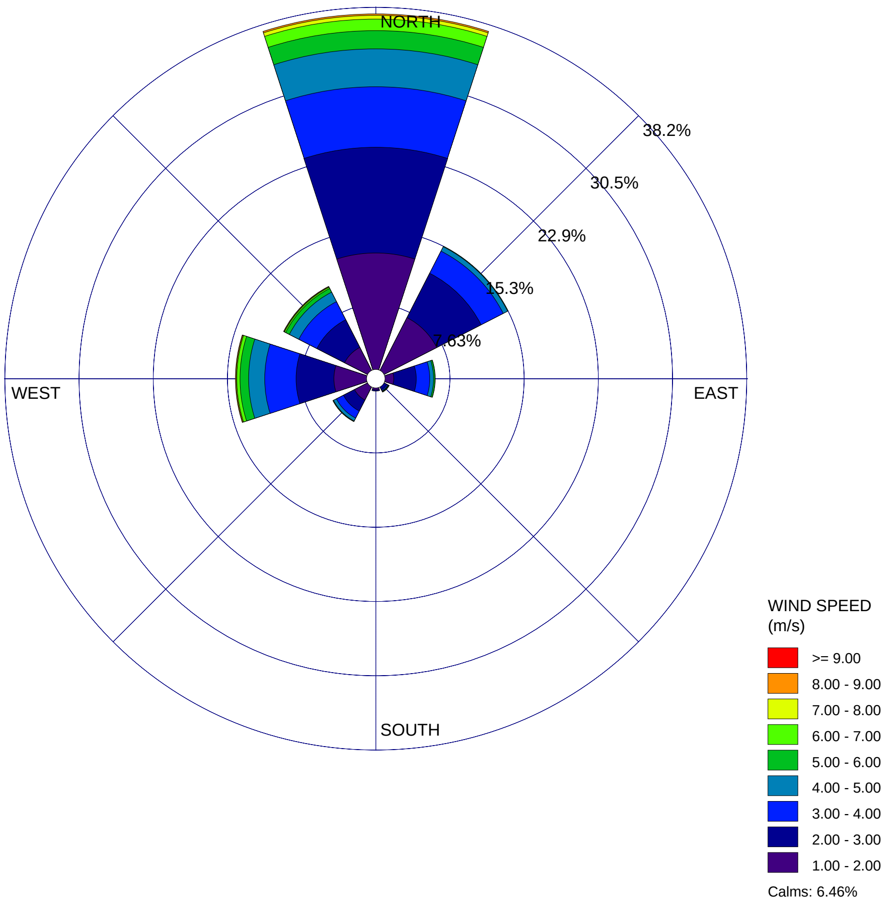
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

2015

DISPLAY:

Wind Speed
Direction (blowing from)



COMMENTS: Station 15480 Constanta	DATA PERIOD: **Start Date: 01/01/2015 - 00:00** **End Date: 31/12/2015 - 23:00**	COMPANY NAME: **Xodus Group**	
		MODELER: **KM**	xodus GROUP
	CALM WINDS: **6.46%**	TOTAL COUNT: **8582 hrs.**	
	AVG. WIND SPEED: **2.13 m/s**	DATE: **16/08/2017**	PROJECT NO.: **A200283**

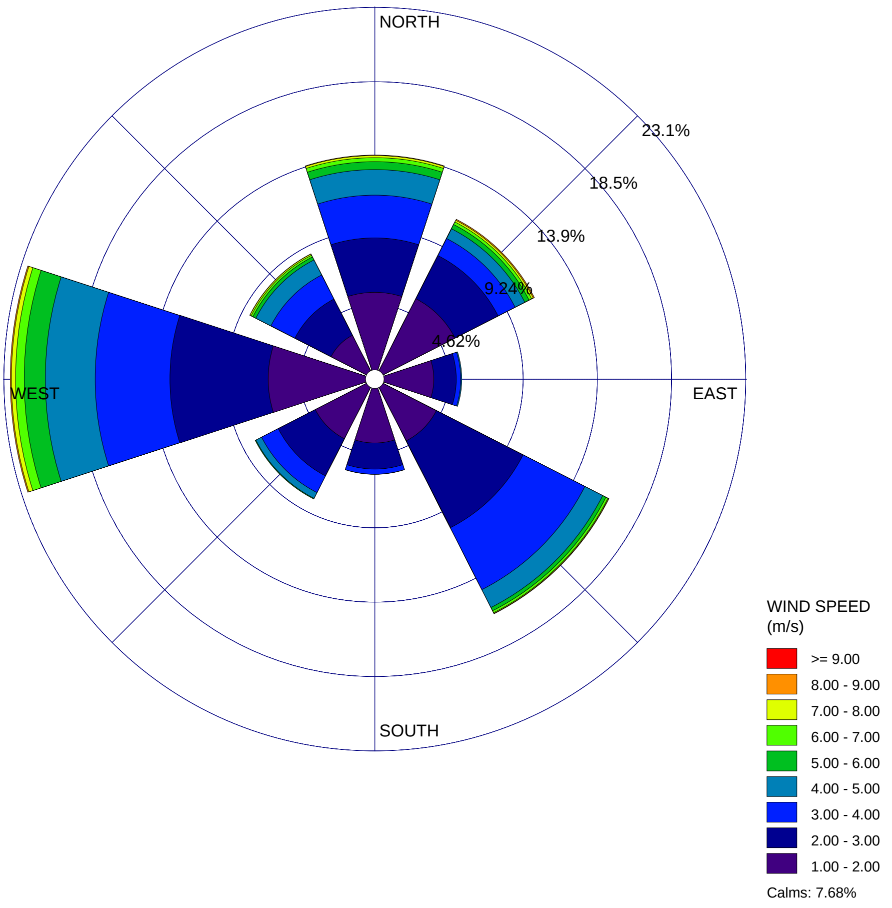
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

2016

DISPLAY:

Wind Speed
Direction (blowing from)



COMMENTS: Station 15480 Constanta	DATA PERIOD: **Start Date: 01/01/2016 - 00:00** **End Date: 31/12/2016 - 23:00**	COMPANY NAME: **Xodus Group**	
		MODELER: **KM**	
	CALM WINDS: **7.68%**	TOTAL COUNT: **8783 hrs.**	
	AVG. WIND SPEED: **2.03 m/s**	DATE: **16/08/2017**	PROJECT NO.: **A200283**

WRPLOT View - Lakes Environmental Software

APPENDIX B SPECIFIED RECEPTORS

Locations of settlements within 70 km of the Gas Treatment Plant, and the location of the Ana platform.

Name	Location (WGS84 UTM 35N)		Location (WGS84)	
	Northing	Easting	Latitude	Longitude
Ana WHP	737829	4920882	44 04' 18.29"	29 58' 11.19"
Gas Treatment Plant	638727	4884131	44 25' 41.64"	28 45' 45.36"
Vadu	632445	4923041	44°26'50.53"	28°44'36.48"
Corbu	634668	4919852	44°25'11.45"	28°39'49.47"
Port of Midia	632769	4911044	44°20'24.61"	28°41'21.74"
Constanta	632030	4892118	44°10'12.74"	28°39'38.72"
Constinesti	631483	4867261	43°56'47.87"	28°38'43.12"
Sacele	633706	4926786	44°28'56.70"	28°39'12.30"
Traian	635980	4927538	44°29'19.62"	28°40'53.61"
Istria	631464	4936258	44°34'0.55"	28°42'44.78"
Nuntasi	627600	4932210	44°31'52.44"	28°39'16.40"
Tariverde	624542	4934378	44°33'5.19"	28°36'23.33"
Cogealac	624884	4934161	44°33'0.07"	28°34'4.60"
Fantanele	601480	4940014	44°36'9.49"	28°34'25.24"
Vulturu	591979	4943948	44°38'30.21"	28°16'46.62"
Saraiu	599032	4951973	44°42'54.85"	28° 9'40.60"
Dulgheru	586833	4950543	44°42'5.12"	28°15'0.13"
Garliciu	609666	4958045	44°46'13.91"	28° 5'50.48"
Casimcea	606171	4951981	44°42'46.15"	28°23'4.29"
Corugea	600986	4954074	44°43'55.83"	28°20'27.07"
Rahman	636995	4960983	44°47'42.41"	28°16'36.32"
Sinoe	633878	4942395	44°37'18.68"	28°43'36.69"
Mihai Viteazu	629908	4944079	44°38'15.36"	28°41'16.85"
Panduru	625979	4949622	44°41'17.55"	28°38'21.82"
Beidaud	620177	4952042	44°42'38.47"	28°35'25.50"
Sarighiol de Deal	619289	4949831	44°41'30.42"	28°31'0.06"
Neatarnarea	612956	4955517	44°44'35.17"	28°30'24.48"
Cerbu	611253	4964501	44°49'29.92"	28°25'43.77"
Sambata Noua	612909	4965831	44°50'13.98"	28°24'27.31"
Razboieni	605625	4957700	44°45'49.61"	28°25'36.20"
Cismeaua Noua	633141	4961598	44°47'59.92"	28°20'7.88"

Name	Location (WGS84 UTM 35N)		Location (WGS84)	
	Northing	Easting		Northing
Baia	627935	4952786	44°42'57.89"	28°40'51.59"
Ceamurlia de Sus	636982	4957030	44°45'18.80"	28°36'58.88"
Ceamurlia de Jos	640600	4954912	44°44'4.17"	28°43'48.12"
Lunca	645436	4954055	44°43'33.87"	28°46'31.71"
Visina	647249	4957096	44°45'8.91"	28°50'14.55"
Jurilovca	624790	4957244	44°45'12.35"	28°51'37.15"
Piatra	622084	4918349	44°24'27.64"	28°34'2.11"
Palazu Mic	621756	4921752	44°26'19.57"	28°32'2.69"
Gura Dobrogei	614151	4926323	44°28'47.85"	28°31'51.73"
Cheia	614333	4929767	44°30'43.91"	28°26'10.33"
Gradina	610453	4934235	44°33'8.55"	28°26'22.11"
Pantelimon de Jos	605870	4936437	44°34'22.10"	28°23'28.01"
Runcu	594738	4938957	44°35'46.22"	28°20'2.14"
Siriu	589755	4942350	44°37'41.75"	28°11'39.57"
Horia	590965	4942776	44°37'57.85"	28° 7'53.72"
Closca	586090	4946722	44°40'5.15"	28° 8'51.18"
Miorita	579280	4948411	44°41'2.06"	28° 5'10.82"
Ciobanu	576570	4951863	44°42'56.75"	28° 0'3.44"
Harsova	582459	4948623	44°41'12.82"	27°57'58.55"
Ghindaresti	587184	4942541	44°37'53.39"	28° 2'22.52"
Tichilesti	593975	4939514	44°36'13.30"	28° 5'55.08"
Crisan	606462	4939648	44°36'14.54"	28°11'3.19"
Pantelimon	628910	4933555	44°32'50.87"	28°20'24.95"
Navodari	625371	4909063	44°19'24.21"	28°37'0.03"
Lumina	621649	4906625	44°18'7.45"	28°34'18.20"
Oituz	624511	4909597	44°19'46.01"	28°31'32.79"
Ovidiu	628337	4903078	44°16'13.06"	28°33'36.39"
Palazu Mare	620494	4899101	44°14'1.81"	28°36'25.39"
Poiana	628956	4897991	44°13'30.68"	28°30'31.03"
Lazu	625521	4886454	44° 7'11.67"	28°36'42.11"
Cumpana	628873	4886474	44° 7'14.48"	28°34'7.63"
Agigea	594219	4884163	44° 5'57.50"	28°36'36.35"
Stupina	598308	4935360	44°33'55.48"	28°11'11.40"

Name	Location (WGS84 UTM 35N)		Location (WGS84)	
	Northing	Easting		Northing
Crucea	608580	4932590	44°32'23.78"	28°14'14.83"
Mireasa	583727	4928240	44°29'57.52"	28°21'56.92"
Topalu	595059	4933190	44°32'49.84"	28° 3'14.57"
Baltagesti	600190	4926594	44°29'11.05"	28°11'43.66"
Galbiori	613516	4927712	44°29'44.78"	28°15'36.70"
Targusor	617268	4924360	44°27'49.07"	28°25'37.28"
Mihail Kogalniceanu	610227	4914546	44°22'28.95"	28°28'19.05"
Nicolae Balcescu	606164	4915470	44°23'2.87"	28°23'1.70"
Dorobantu	598738	4918464	44°24'42.06"	28°20'0.32"
Tepes Voda	589590	4922134	44°26'44.75"	28°14'27.14"
Dunarea	571285	4921281	44°26'21.40"	28° 7'32.81"
Facaeni	572828	4934299	44°33'30.61"	27°53'51.33"
Bordusani	572289	4925849	44°28'56.22"	27°54'56.95"
Cegani	585483	4923810	44°27'50.32"	27°54'31.53"
Seimeni	594495	4916098	44°23'35.25"	28° 4'23.98"
Silistea	597956	4917051	44°24'2.10"	28°11'11.89"
Tortoman	616625	4911173	44°20'49.99"	28°13'44.31"
Culmea	615218	4901487	44°15'26.22"	28°27'39.48"
Nazarcea	612201	4898479	44°13'49.55"	28°26'33.69"
Nisipari	612278	4901794	44°15'38.65"	28°24'20.28"
Poarta Alba	607252	4896087	44°12'33.70"	28°24'19.36"
Castelu	604854	4901675	44°15'37.49"	28°20'37.07"
Cuza Voda	601856	4904563	44°17'12.32"	28°18'51.01"
Medgidia	594369	4901136	44°15'22.82"	28°16'33.36"
Mircea Voda	592560	4904075	44°17'1.68"	28°10'57.72"
Tibrinu	570782	4909316	44°19'52.37"	28° 9'39.47"
Maltezi	570530	4919155	44°25'20.01"	27°53'21.08"
Stelnica	566480	4918109	44°24'46.22"	27°53'9.17"
Fetesi-Gara	567934	4918490	44°24'59.94"	27°50'6.22"
Vlasca	583126	4916159	44°23'43.92"	27°51'10.87"
Cernavoda	586090	4911047	44°20'52.56"	28° 2'34.57"
Stefan cel Mare	586999	4905957	44°18'6.36"	28° 4'45.40"
Saligny	588806	4904253	44°17'10.78"	28° 5'25.36"

Name	Location (WGS84 UTM 35N)		Location (WGS84)	
	Northing	Easting		Northing
Faclia	597099	4903828	44°16'56.21"	28° 6'46.64"
Remus Opreanu	605271	4899346	44°14'27.15"	28°12'57.70"
Valea Dacilor	613202	4894922	44°11'59.73"	28°19'2.84"
Murfatlar	618388	4892741	44°10'44.77"	28°24'58.38"
Valu lui Traian	630507	4891668	44°10'7.05"	28°28'50.99"
Eforie Nord	627810	4881409	44° 4'27.23"	28°37'47.36"
Techirghiol	632069	4879841	44° 3'38.15"	28°35'44.77"
Eforie Sud	631247	4877127	44° 2'7.50"	28°38'53.69"
Tuzla	580327	4873983	44° 0'26.16"	28°38'13.99"
Cochirleni	575764	4903065	44°16'35.03"	28° 0'23.74"
Rasova	584006	4899541	44°14'42.60"	27°56'56.09"
Ivrinezu Mic	585364	4897659	44°13'38.35"	28° 3'6.52"
Ivrinezu Mare	590712	4898041	44°13'50.15"	28° 4'7.96"
Pestera	593574	4892633	44°10'52.58"	28° 8'5.64"
Izvoru Mare	606718	4889800	44° 9'19.47"	28°10'12.67"
Ciocarlia de Sus	603712	4885834	44° 7'4.48"	28°20'1.38"
Ciocarlia	614373	4884633	44° 6'27.14"	28°17'45.34"
Baraganu	618702	4883194	44° 5'34.79"	28°25'43.63"
Potarnichea	621254	4881003	44° 4'21.30"	28°28'56.48"
Movilita	620790	4878314	44° 2'52.69"	28°30'48.95"
Biruinta	617631	4872830	43°59'55.27"	28°30'23.59"
Topraisar	611165	4875600	44° 1'26.87"	28°28'4.03"
Mereni	610657	4876576	44° 2'2.12"	28°23'14.40"
Lanurile	599611	4880700	44° 4'16.03"	28°22'54.66"
Cobadin	595956	4880069	44° 4'1.27"	28°14'37.77"
Viisoara	591106	4881510	44° 4'49.74"	28°11'54.48"
Negresti	594173	4872829	44° 0'10.65"	28° 8'11.08"
Conacu	602589	4871710	43°59'33.00"	28°10'28.06"
Ciobanita	606207	4874475	44° 0'58.52"	28°16'47.73"
Osmancea	599597	4874671	44° 1'3.03"	28°19'30.34"
Credinta	601816	4870651	43°58'56.10"	28°14'30.80"
Casicea	604558	4869156	43°58'6.56"	28°16'9.36"
General Scarisoreanu	627510	4868369	43°57'39.68"	28°18'11.81"

Name	Location (WGS84 UTM 35N)		Location (WGS84)	
	Northing	Easting		Northing
23 August	622943	4864393	43°55'17.82"	28°35'17.92"
Moseni	624680	4866259	43°56'21.06"	28°31'54.76"
Dulcesti	629257	4863120	43°54'38.32"	28°33'10.00"
Olimp	628981	4860695	43°53'16.91"	28°36'33.04"
Neptun	628859	4858291	43°51'59.19"	28°36'18.58"
Jupiter	628845	4857492	43°51'33.38"	28°36'12.41"
Cap Aurora	628314	4856472	43°51'0.32"	28°36'10.91"
Venus	627774	4855920	43°50'42.79"	28°35'46.64"
Saturn	627491	4853884	43°49'37.14"	28°35'20.72"
Mangalia	621514	4852800	43°49'2.21"	28°35'7.12"
Pecineaga	612281	4861732	43°53'55.25"	28°30'46.96"
Amzacea	611281	4868860	43°57'51.49"	28°23'58.62"
Pelinu	609487	4864657	43°55'35.83"	28°23'10.59"
Tataru	605974	4859985	43°53'5.43"	28°21'46.71"
Comana	596185	4861480	43°53'55.70"	28°19'10.41"
Plopeni	585665	4867344	43°57'10.57"	28°11'55.49"
Pietreni	649747	4883269	44° 5'51.34"	28° 4'12.88"
Salcioara	631766	4961647	44°47'33.11"	28°53'35.33"
Caugagia	639855	4961207	44°47'31.61"	28°39'56.95"
Visterna	643663	4968731	44°51'29.80"	28°46'12.36"
Enisala	646022	4970819	44°52'34.71"	28°49'7.91"
Sarichioi	648425	4977823	44°56'19.83"	28°51'2.67"
Sabangia	647807	4981594	44°58'20.18"	28°52'56.23"
Agighiol	653064	4987222	45° 1'22.94"	28°52'34.00"
Iazurile	652928	4986503	45° 0'55.65"	28°56'33.30"
Valea Nucarilor	635941	4989573	45° 2'35.19"	28°56'30.43"
Babadag	639869	4971901	44°53'15.20"	28°43'17.20"
Zebil	638091	4977656	44°56'18.90"	28°46'21.89"
Randunica	637001	4984093	44°59'48.64"	28°45'7.14"
Mihail Kogalniceanu	633528	4987877	45° 1'51.97"	28°44'21.12"
Lastuni	633352	4986972	45° 1'25.04"	28°41'41.60"
Sata Nou	630861	4979245	44°57'14.88"	28°41'26.17"
Mihai Bravu	628599	4978373	44°56'48.29"	28°39'31.74"

Name	Location (WGS84 UTM 35N)		Location (WGS84)	
	Northing	Easting		Northing
Turda	625696	4981172	44°58'20.45"	28°37'51.13"
Nicolae Balcescu	590013	4983781	44°59'46.83"	28°35'40.99"
Daeni	601507	4965563	44°50'16.08"	28° 8'19.92"
Fagarasu Nou	605066	4967820	44°51'23.65"	28°17'4.97"
Luminita	609162	4972138	44°53'41.68"	28°19'50.29"
Topolog	618729	4969557	44°52'15.85"	28°22'54.98"
Fantana Mare	627341	4968078	44°51'22.44"	28°30'9.62"
Slava Rusa	627207	4966982	44°50'41.58"	28°36'40.83"
Camena	622708	4962889	44°48'29.06"	28°36'31.04"
Stejaru	619341	4958670	44°46'15.23"	28°33'2.63"
Vasile Alecsandri	624141	4961227	44°47'40.13"	28°30'31.67"
Mina Altan-Tepe	737829	4960295	44°47'6.98"	28°34'9.24"

APPENDIX C CALCULATION OF EMISSION PARAMETERS

Assignment:	Midia Development		
Ass't Number	A200283-S03		
Unit:	-		
Client:	BSOG	**Unit Number:**	n/a
Location:	Black Sea	**Calculation No:**	A200283-SO3-CALC-001
Calculation Title:		**No. of pages :**	6

Calculation of Input Parameters for ADMS Modelling

Tagged Items to which this calculation relates:

Tag	Description
GP-G-60-01A	Power generation GTs on fuel gas
GP-G-60-01B	Power generation GTs on fuel gas

Referenced Computer Files:

Filename	Description	Checked
None		

Referenced Calculations / Standards / Drawings:

Document	Description
None	

Comments:

This is input to the ADMS modelling for Midia. Data have been provided by the project

Revision History:

Rev.	Status	By		Checked		Approved	
		Initial	Date	Initial	Date	Initial	Date
01	Initial draft	AM	24/7/2017	KM	07-Aug-17		

CALCULATION FRONT SHEET	**Xodus Group Ltd.**	
	Assignment Number:	A200283-S03

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC N^{O} REV. N^{O}	A200283-SO3-CALC-001

ASSIGNMENT	Midia Development					ASS'T No.	A200283-S03
SUBJECT	Calculation of Input Parameters for ADMS Modelling					AREA No.	n/a
PREP. BY	AM	CHKD. BY	KM	APP. BY		ITEM/TAG No.	GP-G-60-01A/B
DATE	24/7/2017	DATE	07-Aug-17	DATE		REF. DRG. No	n/a

\\xodus.local\aberdeen\Xodus\Assignments\A200283\S00\Working Files\Environment\Modelling\Atmospheric\Background to Emission rates\onshore\Fuel_gas gen\[A200283_S03_CALC_001_R01.xlsx]First Page

Rev | Ref

1 AIM

This sheet contains calculations for emissions from gas generator plant as input to ADMS

2 SUMMARY

Emissions data are calculated in this spreadsheet to allow direct input into ADMS.

Assumptions

1 Locations and sizes of equipment have been taken from FEED drawings and other client-supplied information
2 Fuel gas composition is from A200283-S00-P-DATA-009
3 Unless vendor data stated otherwise, gas turbines and engines operate with an air intake to produce an exhaust stream containing 15vol% oxygen, dry basis at NTP
4 Concentrations ofpollutants in the GT exhausts are taken from vendor data
5 Concentrations of CO2 in the GT exhausts are derived from the combustion stoichiometry
6 Particulate emissions from gas-fired combustion equipment are negligible
7 Stack diameters for all GTs and engines have been specified to generate exhaust velocities of 20 m/s
8 A200283-S03-CALC-004-R01_KM

All other minor assumptions are indicated in following calculation sheets

Constants

	Name	Value	Units
Conversion barrel to m3	b2m3	0.159	m3/bbl
Conversion ft3 to m3	ft32m3	0.02832	m3/ft3
Gas constant	RR	8.31451	J/mol.K

Legend

	Manually input value by Xodus
	Calculated value
	Value linked from another cell or sheet
	Uncertain value - on HOLD
	Data from objective source (referenced)

Revisions

3 ATTACHMENTS

None

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC N^{O} REV. N^{O}	A200283-SO3-CALC-001 0

ASSIGNMENT	Midia Development					ASS'T No.	A200283-S03
SUBJECT	Calculation of Input Parameters for ADMS Modelling					AREA No.	n/a
PREP. BY	AM	CHKD. BY	KM	APP. BY	0	ITEM/TAG No.	GP-G-60-01A/B
DATE	24/7/2017	DATE	07-Aug-17	DATE	00-Jan-00	REF. DRG. No.	n/a

\\xodus.local\aberdeen\Xodus\Assignments\A200283\S00\Working Files\Environment\Modelling\Atmospheric\Background to Emission rates\onshore\Fuel_gas gen\[A200283_S03_CALC_001_R01.xlsx]Main Power Gen (gas onshore)

Rev | Ref / assumpt

Plant Main Power Generation - Gas fuelled

Emission source

The power generation is 2 x Gas_Engine:GPG-60-01A & GPG-60-01B

Number operating machines	1	
Generated power per machine	1.2	MWe

All calculations below are per machine

Fuel Gas

Composition (Ref 1,2)

	Mol fr.	Mol fr.	MW	NCV	
	-	norm.	g/gmol	kJ/gmol	
Hydrogen		0.0000	2.016	241.72	
Water		0.0000	18.015	0.00	
Hydrogen sulfide	0.0000	0.0000	34.082	517.95	
Carbon dioxide	0.0009	0.0009	44.010	0.00	
Nitrogen	0.0010	0.0010	28.013	0.00	
Methane	0.9966	0.9966	16.043	802.69	
Ethane	0.0005	0.0005	30.070	1,428.84	
Propane	0.0001	0.0001	44.097	2,043.37	
Isobutane	0.0000	0.0000	58.123	2,648.42	
n-butane	0.0001	0.0001	58.123	2,657.60	
Isopentane	0.0001	0.0001	72.150	3,265.08	
n-Pentane	0.0000	0.0000	72.150	3,272.00	
Benzene		0.0000	78.114	3,169.56	
Toluene		0.0000	92.141	3,772.08	
Xylene		0.0000	106.167	4,376.48	
E-Benzene		0.0000	106.167	4,387.37	
C6	0.0002	0.0002	86.177	3,887.21	
C7+	0.0004	0.0004	100.204	4,501.72	Assumes heptane unless otherwise specified
TOTAL	1.0000	1.0000	16.16	804.51	

Fuel gas temperature	5	°C	ASSUMED		
	278.15	K			
Fuel gas pressure	4	kPa	fuel pressure range on cat datasheet is 4 - 35 kPag		
	4,000	Pa			
FG density at T & P	0.028	kg/am3	as perfect gas		
	0.683	kg/sm3	Note: ref 4 has fuel gas density of 0.884 kg/sm3		
Fuel gas Flowrate	1,631	te/y	297 Nm³/h @0.627 kg/Nm³		
	1,631	te/y	For single machine		
	186.2	kg/h			
	0.052	kg/s			
	1.85	am3/s			
	6,664	am3/h			
	159,948	am3/d			
	0.08	sm3/s	3	scf/s	
	273	sm3/h	9,626	scf/h	
	6,543	sm3/d	231,033	scfd	
			0.23	MMscfd	
	3.20	gmol/s			
Thermal input from fuel gas	2,576	kW(th)			
	2.6	MW(th)			
Overall efficiency	46.6%	%			
Heat rate		kJ/kWh			

INSTRUCTION **To use the fuel gas flowrate value supplied by client, use goal seek to obtain correct value in given units by changing flow in kg/s**
Or if a power is given use goal seek to obtain correct thermal input powre by changing fuel gas flow

Combustion stoichiometry

ASSUME Complete combustion

	Mol fr.	Comp. i	C no.	H no.	O2 used	CO2	H2O	
	norm.	mol/s			mol/s	mol/s	mol/s	
Hydrogen	0.0000	0.00						Assumes no combustion
Water	0.0000	0.00					0.00	
Hydrogen sulfide	0.0000	0.00						Assumes no combustion
Carbon dioxide	0.0009	0.00				0.00		
Nitrogen	0.0010	0.00						
Methane	0.9966	3.19	1	4	6.38	3.19	6.38	
Ethane	0.0005	0.00	2	6	0.01	0.00	0.00	
Propane	0.0001	0.00	3	8	0.00	0.00	0.00	
Isobutane	0.0000	0.00	4	10	0.00	0.00	0.00	
n-butane	0.0001	0.00	4	10	0.00	0.00	0.00	
Isopentane	0.0001	0.00	5	12	0.00	0.00	0.00	
n-Pentane	0.0000	0.00	5	12	0.00	0.00	0.00	
Benzene	0.0000	0.00	6	6	0.00	0.00	0.00	
Toluene	0.0000	0.00	7	8	0.00	0.00	0.00	
Xylene	0.0000	0.00	8	10	0.00	0.00	0.00	
E-Benzene	0.0000	0.00	8	10	0.00	0.00	0.00	
C6	0.0002	0.00	6	14	0.01	0.00	0.01	
C7+	0.0004	0.00	7	16	0.02	0.01	0.01	
TOTAL	1.0000	3.20			6.42	3.22	6.41	

Air Intake

Flow of air inlet

Volume flow	1.2	am3/s	<--- Calculated on basis of 3.90 Nm³/bkW-Hr at 1245 bkW air flow at 37C and 101.3 Kpa and		
Ambient air temperature	5	°C	278.15	K	converted to 5C and same pressure (Caterpillar data sheet)
Volume % N2 in air	79.054%				
Volume % O2 in air	20.946%				
Volume flow N2 in air intake	0.95	am3/s	41.55	gmol/s	
Volume flow rate O2 in air intake	0.25	am3/s	11.01	gmol/s	

Gas Exhaust

Temperature of exhaust	at engine manifold	424	°C	697	K	
Temperature drop up stack	ASSUMED	0	°C	273	K	Waste heat recovery
Temperature of exhaust	at top of stack	424	°C	697	K	

Stack diameter	0.452	m	ASSUMED	7
Stack XS area	0.16	m2		
Stack height above ground level	6.1	m		
Stack easting (ref to WGSXX UTM Zone XX)	#REF!	m		
Stack northing (ref to WGSXX UTM Zone XX)	#REF!	m		

Composition of gas exhaust

	cp (Kj/Kg K)	gmol/s	mol% wet	mol% dry	mass (kg)	Vol at T ex (am3/s)	Vol (Nm3/s)		
N2	1.04	42	74.5%	84.2%	1.16	2.38	0.93		
O2	0.919	5	8.2%	9.3%	0.15	0.26	0.10		
CO2	0.844	3.22	5.8%	6.5%	0.14	0.18	0.07		
H2O	1.93	6.41	11.5%		0.12	0.37	0.14		
TOTAL (wet gas)		56	100.0%	100.0%	1.568	3.19	1.25	28.12	Mol wt of gas
TOTAL (dry gas)		49					1.11	0.49	Actual density
								1077	Spec heat cap J/Kg/k

Data sheet exhaust mass flow	1.6	kg/s
Calculated exhaust mass flow	1.6	kg/s
Difference	0.06	kg/s

INSTRUCTION Adjust volumetric air intake flow in kg/s such that difference in exhaust mass flows is zero - use goal seek

Volume % O2 in dry gas required	15.0%	Note: GTs and engines usually 15%, burners 3%	3
Volume % O2 calculated	9.3%	Note: expected to be different from 15% as air intake calculated on data sheet value for exhuast flow	
Difference in O2 %	5.7%		

Exhaust velocity at stack exit 19.9 m/s

13

Exhaust emissions

CO2 and SO2 calculated from combustion stoichiometry above
NOx and CO from vendor data
CH4 and VOC from EEMS data

CO2 exhaust	3.22	gmol/s		5
	142	g/s		
NOx in exhaust	500	mg/Nm3		4
	0.6	g/s		
CO in exhaust	1046.0	mg/Nm3		4
	1.2	g/s		
SO2	No sulphur in fuel gas			
CH4	2499	mg/Nm3	THC of 2940 less 441for nmhc	4
	2.8	g/s		
VOCs	441	mg/Nm3		4
	0.5	g/s		

SUMMARY DATA

Input data for ADMS	*Units*	*Location* GP-G-60-01A	GP-G-60-01B			
Effective plume discharge height	m	6.1	6.1			
Effective plume discharge diameter	m	0.5	0.5			
Effective plume discharge velocity	m/s	19.9	19.9			
Effective plume discharge temperature	°C	424	424			
CO2 emission rate	g/s	142	142			
CO emission rate	g/s	1.2	1.2			
NOx emission rate	g/s	0.6	0.6			
N2O emission rate	g/s	-	-			
SO2 emission rate	g/s	-	-			
CH4 emission rate	g/s	2.8	2.8			
VOC emission rate	g/s	0.5	0.5			
Particulate emission rate	g/s	-	-			
mass flux rate	kg/s	0.146502	0.146502			
Mol wt of gas	gmol	28.12	28.1			
Actual density	kg/m³	0.49	0.5			
Spec heat cap J/Kg/k	j/kg k	1,077	1,077			
Stack easting (ref to WGSXX UTM Zone 35N)	m	638,280.21	638,280.21			8
Stack northing (ref to WGSXX UTM Zone 35N)	m	4,921,908.89	4,921,903.54			8

BlackSea oil & gas

Assignment:	ADMS: Midia Onshore Power Gen Diesel				
Ass't Number	A200283-S03				
Unit:	-				
Client:	BSOG	**Unit Number:**	n/a		
Location:	Black Sea	**Calculation No:**	A200283-S03-CALC-002		
Calculation Title:			**No. of pages :**	25	

Calculation of Input Parameters for AMDS Modelling

Tagged Items to which this calculation relates:

Tag	Description
GP-Z-63-01	Power generation diesel backup

Referenced Computer Files:

Filename	Description	Checked
None		

Referenced Calculations / Standards / Drawings:

Document	Description
None	

Comments:

This is input to the ADMS modelling for Midia. Data have been provided by the project

Revision History:

Rev.	Status	By		Checked		Approved	
		Initial	Date	Initial	Date	Initial	Date
01	Initial draft	AM	24/7/17	KM	07-Aug-17	KM	07-Aug-17

CALCULATION FRONT SHEET	**Xodus Group Ltd.**	
	Assignment Number:	A200283-S03

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC N^O^ REV. N^O^	A200283-S03-CALC-002

ASSIGNMENT	ADMS: Midia Onshore Power Gen Diesel					ASS'T No.	A200283-S03
SUBJECT	Calculation of Input Parameters for AMDS Modelling					AREA No.	n/a
PREP. BY	AM	CHKD. BY	KM	APP. BY	KM	ITEM/TAG No.	GP-Z-63-01
DATE	24/7/17	DATE	07-Aug-17	DATE	07-Aug-17	REF. DRG. No	n/a

\\xodus.local\aberdeen\Xodus\Assignments\A200283\S00\Working Files\Environment\Modelling\Atmospheric\Background to Emission rates\onshore\Diesel Gen\[A200283_S03_CALC_002__R01.xlsx]First Page

Rev | Ref

1 **AIM**

This sheet contains calculations for emissions from backup diesel generator as input to ADMS

2 **SUMMARY**

The various cases for ADMS assessment are set out in ref 3. Emissions data are calculated in this spreadsheet to allow direct input into ADMS.

Assumptions

1. Locations and sizes of equipment have been taken from FEED drawings and other client-supplied information
2. Diesel is 86. mass% carbon with the balance hydrogen http://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html/
3. Unless vendor data stated otherwise, gas turbines and engines operate with an air intake to produce an exhaust stream containing 15vol% oxygen, dry basis at NTP in this case have used value from vendor datasheet which is
4. Diesel density is 850 kg/m3
5. ambient temperature assumed to be 5C as average low temperature for operation
6. Concentrations of NOx and CO in the GT exhausts are taken from vendor data
7. Concentrations of CO2 in the GT exhausts are derived from the combustion stoichiometry
8. Concentrations of methane assumed to be zero from diesel
9. Diesel net heating value is 42.6 MJ/kg : Dukes calorific values (2015 table A1)
10. Diesel contains maximum 10 mg/kg sulphur in line with European law. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3AI28077
11. stack diameter determined to ensure exhaust velocity is 20m/s
12. A200283-S03-CALC-004-R01_KM

All other minor assumptions are indicated in following calculation sheets

Constants

	Name	Value	Units
Conversion barrel to m3	b2m3	0.159	m3/bbl
Conversion ft3 to m3	ft32m3	0.02832	m3/ft3
Gas constant	RR	8.31451	J/mol.K

Legend

(yellow)	Manually input value by Xodus
(grey)	Calculated value
(blue)	Value linked from another cell or sheet
(orange)	Uncertain value - on HOLD
(green)	Data from objective source (referenced)

Revisions

01 Initial calculation
02

BlackSea oil & gas

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC N° REV. N°	A200283-S03-CALC-002 0

ASSIGNMENT	**ADMS: Midia Onshore Power Gen Diesel**					ASS'T No.	**A200283-S03**
SUBJECT	**Calculation of Input Parameters for AMDS Modelling**					AREA No.	**n/a**
PREP. BY	AM	CHKD. BY	KM	APP. BY	KM	ITEM/TAG No.	**GP-Z-63-01**
DATE	24/7/17	DATE	07-Aug-17	DATE	07-Aug-17	REF. DRG. No.	**n/a**

\\xodus.local\aberdeen\Xodus\Assignments\A200283\S00\Working Files\Environment\Modelling\Atmospheric\Background to Emission rates\onshore\Diesel Gen\[A200283_S03_CALC_002__R01.xlsx]Onshore Power Gen (diesel)

Rev | Ref / assumption

Power Generation - diesel fuelled onshore

Emission source — 3

			Ref
Number operating machines	1		1
Generated power per machine	1.2	MWe	1

All calculations below are per machine

Calculation for emissions from diesel-fuelled combustion plant

Diesel fuel

Composition

	Mass fr.	MW	Moles	Mol fr.	Ref
	-	g/gmol	gmol/g fuel	-	
Hydrogen	0.140	1.00794	0.139	0.660	1
Carbon	0.860	12.011	0.072	0.340	2
TOTAL			0.210	1.000	

Composition — 1

	MW
	g/gmol
Water	18.015
Carbon dioxide	44.010
Nitrogen	28.013

				Ref
Diesel density	850	kg/m3		4
Diesel Flow rate	0.072911	kg/s	308.8 l/hr	1
	262	kg/h		
	0.000086	m3/s		
	0.086	L/s		
	5.1	L/min		
	15.3	gmol/s		
NHV fuel	42.6	MJ/kg		9
Thermal input from diesel	3.11	MW(th)		

Combustion stoichiometry

ASSUME Complete combustion

	Mol. Fr	Comp. i	C no.	H no.	O2 used	CO2	H2O
	-	mol/s			mol/s	mol/s	mol/s
Hydrogen	0.6598	10.13	0	1	2.5	0.0	5.1
Carbon	0.3402	5.22	1	0	5.2	5.2	0.0
TOTAL		15.35			7.8	5.2	5.1

Air Intake

					Ref
Flow of air inlet	108.3	am3/m			1
Flow of air inlet					
Volume flow	1.81	am3/s	Calculated on basis of same %O2 in exhaust as for gas fuelled		
Ambient air temperature	5	°C	278.15	K	5
Volume % N2 in air	79.054%				
Volume % O2 in air	20.946%				1
Volume flow N2 in air intake	1.43	am3/s	62.50	gmol/s	
Volume flow rate O2 in air intake	0.38	am3/s	16.56	gmol/s	

Gas Exhaust

						Ref
Temperature of exhaust	at engine manifold	570.3	°C	843	K	1
Temperature drop up stack		0	°C	273	K	
Temperature of exhaust	at top of stack	570.3	°C	843	K	
Stack diameter	0.6	m				11
Stack XS area	0.28	m2				
Stack height above datum(m)	6.1	m	assumption			

Composition of gas exhaust

	cp (Kj/Kg K)	gmol/s	mol% wet	mol% dry	mass (kg)	Vol at T ex (am3/s)	Vol (Nm3/s)		
N2	1.04	62.50	76.6%	81.7%	1.75	4.33	1.40		
O2	0.92	8.81	10.8%	11.5%	0.28	0.61	0.20		
CO2	0.84	5.22	6.4%	6.8%	0.23	0.36	0.12		
H2O	1.93	5.06	6.2%		0.09	0.35	0.11		
TOTAL (wet gas)		81.59	100.0%	100.0%	2.35	5.65	1.83	28.85	Mol wt of Ex gas
TOTAL (dry gas)		76.53					1.72	0.42	Actual density
								1041	Spec heat cap J/Kg/k

			Ref
Volume % O2 in dry gas required	11.5%	ASSUME - %O2 is correct as caluculted from datasheet	3
Volume % O2 calculated	11.5%		3
Difference in O2 %	0.0%		3

INSTRUCTION **Use goal seek: set Difference in O2% to zero by changing air intake volume flow in am3/s**

Exhaust velocity at stack exit 20.0 m/s

Exhaust emissions (per GT)

Mass flow rate diesel to GT 0.073 kg/s

CO2 exhaust	5.22	gmol/s			7
	230	g/s			
NOx in exhaust	13826	g/h			6
	3.84	g/s			
CO in exhaust	4466.0	g/h			6
	1.240556	g/s			
SO2	0.00001	kg/kg fuel	10 ppm (mg/kg)	sulphur content of fuel (Europena maximum value)	10
	0.000729	g/s		http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3AI28077	
CH4	0				8
VOCs	330	g/h			6
	0.091667	g/s			
Particulates	159	g/h			6
	0.044167	g/s			

SUMMARY DATA

Input data for ADMS	Units	Location				
		GP-Z-63-01	n/a	n/a	n/a	
Effective plume discharge height	m	6.1	n/a	n/a	n/a	
Effective plume discharge diameter	m	0.600	n/a	n/a	n/a	
Effective plume discharge velocity	m/s	20.0	n/a	n/a	n/a	
Effective plume discharge temperature	°C	570	n/a	n/a	n/a	
CO2 emission rate	g/s	230	n/a	n/a	n/a	
CO emission rate	g/s	1.241	n/a	n/a	n/a	
NOx emission rate	g/s	3.84	n/a	n/a	n/a	
N2O emission rate	g/s	-	n/a	n/a	n/a	
SO2 emission rate	g/s	0.001	n/a	n/a	n/a	
CH4 emission rate	g/s	-	n/a	n/a	n/a	
VOC emission rate	g/s	0.092	n/a	n/a	n/a	
Particulate emission rate	g/s	0.044	n/a	n/a	n/a	
mass flux rate	kg/s	0.235	n/a	n/a	n/a	
Mol wt of Ex gas	gmol	28.847	n/a	n/a	n/a	
Actual density	kg/m³	0.42	n/a	n/a	n/a	
Spec heat cap J/Kg/k	J/kg K	1,041	n/a	n/a	n/a	
Stack easting (ref to WGSXX UTM Zone 35)	m	638,241.21	n/a	n/a	n/a	12
Stack northing (ref to WGSXX UTM Zone 35)	m	4,921,938.91	n/a	n/a	n/a	12

Assignment:	ADMS: Midia Onshore Compressor Turbine Package				
Ass't Number	A200283-S03				
Unit:	-				
Client:	BSOG	**Unit Number:**	n/a		
Location:	Black Sea	**Calculation No:**	A200283-S03-CALC-002		
Calculation Title:			**No. of pages :**	4	
Calculation of Input Parameters for AMDS Modelling					

Tagged Items to which this calculation relates:

Tag	Description
GP-Z-32-01	Compressor turbine package

Referenced Computer Files:

Filename	Description	Checked
None		

Referenced Calculations / Standards / Drawings:

Document	Description
None	

Comments:

This is input to the ADMS modelling for Midia. Data have been provided by the project.

Revision History:

Rev.	Status	By		Checked		Approved	
		Initial	Date	Initial	Date	Initial	Date
01	Initial draft	AM	24/7/17	KM	07-Aug-17	KM	07-Aug-17

CALCULATION FRONT SHEET	**Xodus Group Ltd.**	
	Assignment Number:	A200283-S03

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC N^{O} REV. N^{O}	A200283-S03-CALC-002

ASSIGNMENT	ADMS: Midia Onshore Compressor Turbine Package					ASS'T No.	A200283-S03
SUBJECT	Calculation of Input Parameters for AMDS Modelling					AREA No.	n/a
PREP. BY	AM	CHKD. BY	KM	APP. BY	KM	ITEM/TAG No.	GP-Z-32-01
DATE	24/7/17	DATE	07-Aug-17	DATE	07-Aug-17	REF. DRG. No	n/a

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Rev | Ref

1 AIM

This sheet contains calculations for emissions from combustion plant as input to ADMS

2 SUMMARY

The various cases for ADMS assessment are set out in ref 3. Emissions data are calculated in this spreadsheet to allow direct input into ADMS.

Assumptions

1. Locations and sizes of equipment have been taken from FEED drawings and other client-supplied information
2. Diesel is 86. mass% carbon with the balance hydrogen http://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html/
3. Unless vendor data stated otherwise, gas turbines and engines operate with an air intake to produce an exhaust stream containing 15vol% oxygen, dry basis at NTP in this case have used value from vendor datasheet which is
4. Diesel density is 850 kg/m3
5. ambient temperature assumed to be 5C as average low temperature for operation
6. Concentrations of NOx and CO in the GT exhausts are taken from vendor data
7. Concentrations of CO2 in the GT exhausts are derived from the combustion stoichiometry
8. Concentrations of methane assumed to be zero from diesel
9. Diesel net heating value is 42.6 MJ/kg : Dukes calorific values (2015 table A1)
10. Diesel contains maximum 10 mg/kg sulphur in line with European law. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al28077
11. stack diameter determined to ensure exhaust velocity is 20m/s
12. A200283-S03-CALC-004-R01_KM

All other minor assumptions are indicated in following calculation sheets

Constants

	Name	Value	Units
Conversion barrel to m3	b2m3	0.159	m3/bbl
Conversion ft3 to m3	ft32m3	0.02832	m3/ft3
Gas constant	RR	8.31451	J/mol.K

Legend

Colour	Meaning
Yellow	Manually input value by Xodus
Grey	Calculated value
Light blue	Value linked from another cell or sheet
Orange	Uncertain value - on HOLD
Green	Data from objective source (referenced)

Revisions

01 Initial calculation

02

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC N° / REV. N°	A200283-S03-CALC-002 / 0

ASSIGNMENT	ADMS: Midia Onshore Compressor Turbine Package					ASS'T No.	A200283-S03
SUBJECT	Calculation of Input Parameters for AMDS Modelling					AREA No.	n/a
PREP. BY	AM	CHKD. BY	KM	APP. BY	KM	ITEM/TAG No.	GP-Z-32-01
DATE	#VALUE!	DATE	07-Aug-17	DATE	07-Aug-17	REF. DRG. No.	n/a

\\xodus.local\aberdeen\Xodus\Assignments\A200283\S00\Working Files\Environment\Modelling\Atmospheric\Background to Emission rates\onshore\Comp\[A200283_S03_CALC_003__R01.xlsx]Onshore compression

Rev | Ref / assumption

Compressor Turbine Package

Exhaust emissions (compression unit)

	Rate	Unit	Molar mass	Unit	cp (kj/kg K)	kj/k	Ref / assumption
argon exhaust	1004.00	kg/h	39.948	g/gmol	0.52		
	279	g/s				0.1450222	
H20 exhaust	3237.00	kg/h	18.015	g/gmol	1.93		
	899	g/s				1.7353917	
N2 exhaust	58877.00	kg/h	28.013	g/gmol	1.04		
	16,355	g/s				17.008911	
O2 exhaust	12814.00	kg/h	32	g/gmol	0.919		
	3,559	g/s				3.2711294	
CO2 exhaust	3638.00	kg/h	44.01	g/gmol	0.844		7
	1,011	g/s				0.8529089	
NOx in exhaust	41.510	te/y	46.0055	g/gmol			6
	1.32	g/s					
CO in exhaust	33.25	te/y	28.01	g/gmol			6
	1.05	g/s					
SO2			no sulphur in fuel gas				10
	0.000000						
CH4	9.52	te/y	16.04	g/gmol			8
	0.302	g/s					
VOCs		g/h					6
		g/s					
Particulates		g/h					6
		g/s					

stack height 11.2 m
stack diameter 1.78 m
stack area 2.5 m2

Diameter detemined to reduce exit velocity below 20 m/s

Mass flux 22.1 kg/s | 177822 am³/h | 19.9 m/s | temperature of exhaust 503°C

SUMMARY DATA 0.448 kg/am3 | 1041.0719 specific heat capcity of exhaust j/kg/k

Input data for ADMS	Units	Location				Ref / assumption
		GP-Z-32-01	n/a	n/a	n/a	
Effective plume discharge height	m	11.2	n/a	n/a	n/a	
Effective plume discharge diameter	m	1.780	n/a	n/a	n/a	
Effective plume discharge velocity	m/s	19.9	n/a	n/a	n/a	
Effective plume discharge temperature	°C	503	n/a	n/a	n/a	
CO2 emission rate	g/s	1,011	n/a	n/a	n/a	
CO emission rate	g/s	1.054	n/a	n/a	n/a	
NOx emission rate	g/s	1.32	n/a	n/a	n/a	
N2O emission rate	g/s	-	n/a	n/a	n/a	
SO2 emission rate	g/s	-	n/a	n/a	n/a	
CH4 emission rate	g/s	0.302	n/a	n/a	n/a	
VOC emission rate	g/s	-	n/a	n/a	n/a	
Particulate emission rate	g/s	-	n/a	n/a	n/a	
mass flux rate	kg/s	22.105	n/a	n/a	n/a	
exhaust molecular mass	gmol	28.520	n/a	n/a	n/a	
exhaust gas actual density	kg/m³	0.45	n/a	n/a	n/a	
exhaust gas spe heat capacity	J/kg K	1,041	n/a	n/a	n/a	
Stack easting (ref to WGSXX UTM Zone 35)	m	638,241.21	n/a	n/a	n/a	12
Stack northing (ref to WGSXX UTM Zone 35)	m	4,921,938.91	n/a	n/a	n/a	12

Assignment:	ADMS: Midia Onshore Power Gen Diesel			
Ass't Number	A200283-S03			
Unit:	-			
Client:	BSOG	**Unit Number:**	n/a	
Location:	Black Sea	**Calculation No:**	A200283-S03-CALC-002	
Calculation Title:			**No. of pages :**	25

Calculation of Input Parameters for AMDS Modelling

Tagged Items to which this calculation relates:

Tag	Description
GP-Z-63-01	Power generation diesel offshore

Referenced Computer Files:

Filename	Description	Checked
None		

Referenced Calculations / Standards / Drawings:

Document	Description
None	

Comments:

This is input to the ADMS modelling for Midia. Data have been provided by the project

Revision History:

Rev.	Status	By		Checked		Approved	
		Initial	Date	Initial	Date	Initial	Date
01	Initial draft	AM	08-Aug-17	KM	09-Aug-17	KM	16-Aug-17

CALCULATION FRONT SHEET	**Xodus Group Ltd.**	
	Assignment Number:	A200283-S03

BlackSea oil & gas

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC Nº REV. Nº	A200283-S03-CALC-002

ASSIGNMENT	ADMS: Midia Onshore Power Gen Diesel					ASS'T No.	A200283-S03
SUBJECT	Calculation of Input Parameters for AMDS Modelling					AREA No.	n/a
PREP. BY	AM	CHKD. BY	KM	APP. BY	KM	ITEM/TAG No.	GP-Z-63-01
DATE	08-Aug-17	DATE	09-Aug-17	DATE	16-Aug-17	REF. DRG. No	n/a

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Rev | Ref

1 **AIM**

This sheet contains calculations for emissions from combustion plant as input to ADMS

2 **SUMMARY**

The various cases for ADMS assessment are set out in ref 3. Emissions data are calculated in this spreadsheet to allow direct input into ADMS.

Assumptions

1 Locations and sizes of equipment have been taken from FEED drawings and other client-supplied information
2 Diesel is 86. mass% carbon with the balance hydrogen http://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html/
3 Unless vendor data stated otherwise, gas turbines and engines operate with an air intake to produce an exhaust stream containing 15vol% oxygen, dry basis at NTP in this case have used value from vendor datasheet which is
4 Diesel density is 850 kg/m3
5 ambient temperature assumed to be 5C as average low temperature for operation
6 Concentrations of NOx and CO in the GT exhausts are taken from vendor data
7 Concentrations of CO2 in the GT exhausts are derived from the combustion stoichiometry
8 Concentrations of methane assumed to be zero from diesel
9 Diesel net heating value is 42.6 MJ/kg : Dukes calorific values (2015 table A1)
10 Diesel contains maximum 10 mg/kg sulphur in line with European law.
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al28077
11 stack diameter determined to ensure exhaust velocity is 20m/s
12 A-200283-S00-U-LAYT-001.pdf
13 A-200283-S00-L-LAYT-004.pdf

All other minor assumptions are indicated in following calculation sheets

Constants

	Name	Value	Units
Conversion barrel to m3	b2m3	0.159	m3/bbl
Conversion ft3 to m3	ft32m3	0.02832	m3/ft3
Gas constant	RR	8.31451	J/mol.K

Legend

Colour	Meaning
(yellow)	Manually input value by Xodus
(grey)	Calculated value
(blue)	Value linked from another cell or sheet
(orange)	Uncertain value - on HOLD
(green)	Data from objective source (referenced)

Revisions

01 Initial calculation

XODUS GROUP LTD	Xodus 138 Cheapside London, EC2V 6BJ	CALC N°	A200283-S03-CALC-002
		REV. N°	0

ASSIGNMENT	ADMS: Midia Offshore Power Gen Diesel					ASS'T No.	A200283-S03
SUBJECT	Calculation of Input Parameters for AMDS Modelling					AREA No.	n/a
PREP. BY	AM	CHKD. BY	KM	APP. BY	KM	ITEM/TAG No.	GP-Z-63-01
DATE	08/08/17	DATE	09-Aug-17	DATE	16-Aug-17	REF. DRG. No.	n/a

\\xodus.local\aberdeen\Xodus\Assignments\A200283\S00\Working Files\Environment\Modelling\Atmospheric\Background to Emission rates\offshore\[A200283_S03_CALC_004__R01.xlsx]Offshore Power Gen (diesel)

Rev | Ref / assumption

Power Generation - diesel fuelled offshore

Emission source (a) - Tags AN-G-60-01A/B — 3

Number operating machines: 1 — 1
Generated power per machine: 0.099 MWe — 1

All calculations below are per machine

Calculation for emissions from diesel-fuelled combustion plant

Diesel fuel

Composition

	Mass fr.	MW	Moles	Mol fr.	Ref
	-	g/gmol	gmol/g fuel	-	
Hydrogen	0.140	1.00794	0.139	0.660	1
Carbon	0.860	12.011	0.072	0.340	2
TOTAL			0.210	1.000	

Composition — 1

	MW
	g/gmol
Water	18.015
Carbon dioxide	44.010
Nitrogen	28.013

Diesel density: 850 kg/m3 — 4
Diesel Flow rate: 0.006540 kg/s; 27.7 l/hr — 1
24 kg/h
0.000008 m3/s
0.008 L/s
0.5 L/min
1.4 gmol/s

NHV fuel: 42.6 MJ/kg — 9

Thermal input from diesel: 0.28 MW(th)

Combustion stoichiometry

ASSUME Complete combustion

	Mol. Fr	Comp. i	C no.	H no.	O2 used	CO2	H2O
	-	mol/s			mol/s	mol/s	mol/s
Hydrogen	0.6598	0.91	0	1	0.2	0.0	0.5
Carbon	0.3402	0.47	1	0	0.5	0.5	0.0
TOTAL		1.38			0.7	0.5	0.5

Air Intake Flow of air inlet: 9.7 am3/m — adjusted to match combustion calc value — 1

Flow of air inlet
Volume flow: 0.16 am3/s — Calculated on basis of same %O2 in exhaust as for gas fuelled
Ambient air temperature: 5 °C — 278.15 K — 5
Volume % N2 in air: 79.054%
Volume % O2 in air: 20.946% — 1
Volume flow N2 in air intake: 0.13 am3/s — 5.60 gmol/s
Volume flow rate O2 in air intake: 0.03 am3/s — 1.48 gmol/s

Gas Exhaust

Temperature of exhaust at engine manifold: 556.6 °C — 830 K — 1
Temperature drop up stack: 0 °C — 273 K
Temperature of exhaust at top of stack: 556.6 °C — 830 K

Stack diameter: 0.18 m — 11
Stack XS area: 0.03 m2
Stack height above datum(m): 30.5 m — 13

Composition of gas exhaust

	cp (Kj/Kg K)	gmol/s	mol% wet	mol% dry	mass (kg)	Vol at T ex (am3/s)	Vol (Nm3/s)		
N2	1.04	5.60	76.6%	81.7%	0.16	0.38	0.13		
O2	0.92	0.79	10.8%	11.5%	0.03	0.05	0.02		
CO2	0.84	0.47	6.4%	6.8%	0.02	0.03	0.01		
H2O	1.93	0.45	6.2%		0.01	0.03	0.01		
TOTAL (wet gas)		7.31	100.0%	100.0%	0.21	0.50	0.16	28.85	Mol wt of Ex gas
TOTAL (dry gas)		6.85					0.15	0.42	Actual density
								1041	Spec heat cap J/Kg/k

Volume % O2 in dry gas required: 11.5% — ASSUME - %O2 is correct as caluculted from combustion calc — 3
Volume % O2 calculated: 11.5% — 3
Difference in O2 %: 0.0% — 3

INSTRUCTION **Use goal seek: set Difference in O2% to zero by changing air intake volume flow in am3/s**

Exhaust velocity at stack exit: 19.6 m/s

Exhaustive emissions (per GT)

Mass flow rate diesel to GT	0.007	kg/s			
CO2 exhaust	0.47	gmol/s			7
	21	g/s			
NOx in exhaust	548	g/h			6
	0.15	g/s			
CO in exhaust	163.0	g/h			6
	0.05	g/s			
SO2	0.00001	kg/kg fuel	10 ppm (mg/kg)	sulphur content of fuel (Europena maximum value)	10
	0.000065	g/s		http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3AI28077	
CH4	0				8
VOCs	2	g/h			6
	0.000556	g/s			
Particulates		g/h			6
	0.000000	g/s			

SUMMARY DATA

Input data for ADMS	*Units*	*Location* GP-Z-63-01	n/a	n/a	n/a		
Effective plume discharge height	m	30.5	n/a	n/a	n/a		
Effective plume discharge diameter	m	0.180	n/a	n/a	n/a		
Effective plume discharge velocity	m/s	19.6	n/a	n/a	n/a		
Effective plume discharge temperature	°C	557	n/a	n/a	n/a		
CO2 emission rate	g/s	21	n/a	n/a	n/a		
CO emission rate	g/s	0.045	n/a	n/a	n/a		
NOx emission rate	g/s	0.15	n/a	n/a	n/a		
N2O emission rate	g/s	-	n/a	n/a	n/a		
SO2 emission rate	g/s	0.000	n/a	n/a	n/a		
CH4 emission rate	g/s	-	n/a	n/a	n/a		
VOC emission rate	g/s	0.001	n/a	n/a	n/a		
Particulate emission rate	g/s	-	n/a	n/a	n/a		
mass flux rate	kg/s	0.021	n/a	n/a	n/a		
Mol wt of Ex gas	gmol	28.847	n/a	n/a	n/a		
Actual density	kg/m³	0.42	n/a	n/a	n/a		
Spec heat cap J/Kg/k	J/kg K	1,041	n/a	n/a	n/a		
Stack easting (ref to WGSXX UTM Zone 35)	m	737,829.00	n/a	n/a	n/a	Use Anna platform location here,	12
Stack northing (ref to WGSXX UTM Zone 35)	m	4,884,131.00	n/a	n/a	n/a	no greater precision required.	12