APPENDIX 5A

Emissions Estimate Assumptions

Appendix 5A
Onshore and Offshore Atmospheric Emissions Estimates

CONTENTS

1 Introduction

This Appendix provides supplementary information to the emissions calculations presented in Chapter 5: Project Description and includes pollutant emission factors and the basis of emissions estimates for each SD2 Project phase.

Emissions were calculated using internationally accepted emission factors from the following sources:

- European Environment Agency EMEP/CORINAIR Emission Inventory Guidebook – 2007;
- United States Environmental Protection Agency AP42;
- E&P Forum Report No. 2.59/197 (Methods for Estimating Atmospheric Emissions from E&P Operations, Report No. 2.59/197; The Oil Industry International E&P Forum, September 1994); and
- EEMS Atmospheric Emission Calculations Issue 1.8 (UK Offshore Operators Association Ltd, 2008).

2 Emissions Factors

2.1 Stationary Combustion Sources, Flaring, Vessels and Helicopters

Table 1 presents emissions factors used to calculate emissions from:

- Stationary combustion emission sources including gas and/ or diesel engines, generators, turbines and heaters;
- Flares (including MODU flares); and
- Vessels and helicopters.

Table 1 Stationary Combustion Source, Flare, Vessel and Helicopter Emission Factors

Type of Source	Fuel	Unit	CO_2	CO	NO_X	SO_X	CH_4	VOC
Engine[1]	Diesel	tonnes emissions/ tonnes of fuel used	3.2	0.0157	0.0594	0.004	0.00018	0.002
Turbine[1]				0.00092	0.0135		0.0000328	0.000295
Heater[1]				0.00071	0.0028		0.00000705	0.0000282
Engine[1]	Gas		2.86	0.0076	0.0576	0.0000128	0.0198	0.0032
Turbine[1]				0.0030	0.0061		0.00092	0.000036
Heater[1]				0.0006	0.0024		0.000089	0.0000099
Vessel[2]	Diesel		3.2	0.0052	0.0125	8.00E-03	0.000087	0.0008
Helicopter[2]				0.008	0.059		0.00027	0.0024
Platform Flare[1]	Gas	tonnes emissions/ tonnes of gas flared	2.8	0.0067	0.0012	0.0000128	0.010	0.010
MODU Flare[1]			2.8	0.0067	0.0012	0.0000128	0.045	0.005

Sources:
[1] EEMS- Atmospheric Emissions Calculations, UK Department of Energy & Climate Change, 2008, Issue 1.810a
[2]E&P Forum - Report No. 2.59/197

2.2 Construction Plant

Table 2 presents emission factors used to calculate emissions forecasts from construction plant including trucks, cranes, loaders etc. These factors are dependant on the engine size of the construction plant.

Table 2 Construction Plant Emission Factors

Engine size	Species Emission Factors (g/kWhr)				
	[1]CO_2	[2]NO_x	[2]CH_4	[2]CO	[2]NMVOC
0-20	948	14.4	0.05	8.38	3.82
20-37	948	14.4	0.05	6.43	2.91
37-75	948	14.4	0.05	5.06	2.28
75-130	948	14.4	0.05	3.76	1.67
130-300	948	14.4	0.05	3	1.3
300-560	948	14.4	0.05	3	1.3
560-1000	948	14.4	0.05	3	1.3
>1000	948	14.4	0.05	3	1.3

[1] Carbon Dioxide Calculation from US EPA420-R-05-019 Exhaust Emission Factors for Nonroad Engine Modelling NR-010e
[2] EMEP/CORINAIR Emission Inventory Guidebook - 2007. Group 8: Other mobile sources and machinery. SNAP Sector 0808 Industry.

As there are no standard emission factors for Carbon Dioxide (CO_2) from non-road vehicle emissions, Table 3 below provides an emission factor calculation method based on brake specific fuel consumption (BSFC) of a diesel engine according to the US EPA AP42. The relevant parameters required to calculate the CO_2 emission factor are presented in Table 3 below.

Table 3 Brake Specific Fuel Consumption Emission Factors

CO_2 emissions factors from BSFC[1]		
1,232	g/hp-hr	gCO_2/hp/hr
948	g/kWhr	gCO_2/kWhr
Brake Specific Fuel Consumption (BSFC) of Diesel Engine		
50.0	KW	Engine size
0.4	Efficiency	Efficiency of engine
125.0	kJ/s	Engine Fuel Input
44,800.0	KJ/kg	Calorific value of Diesel
0.003	kg/s	Mass Fuel Input
26.0	hp	Power Fuel Input
0.1	g/hp/s	BSFC

[1]Using the equation CO2 = (BSFC * 453.6 - HC) * 0.87 * (44/12), where;
- CO_2 is in g/hp-hr
- Brake Specific fuel Consumption (BSFC) is the diesel fuel consumption in lb/hp-hr
- 453.6 is the conversion factor from pounds to grams
- HC is the in-use adjusted hydrocarbon emissions in g/hp-hr
- 0.87 is the carbon mass fraction of gasoline and diesel fuel
- 44/12 is the ratio of CO_2 mass to carbon mass

3 Methodology

3.1 Drilling and Completion Activities

To calculate emissions forecast from drilling and completion activities, the estimated fuel usage for each emission source and the anticipated duration of use was multiplied by the relevant emission factor provided in Table 1. Calculations were undertaken for drilling, completion and intervention activities based on the estimated number of vessels and duration of use as provided in Appendix 5F.

Emission forecasts associated with flaring were based on the estimated flowrates, duration and frequency of well test, clean up and invention flaring as described within Chapter 5 Section 5.4 of the ESIA. The volume of flaring anticipated was then multiplied by the relevant emissions factor to provide the expected emissions over the PSA.

Table 4 Estimated Drilling, Completion and Intervention Emissions

	Drilling[1]			Completion[3]		Intervention[4]		
	MODU Power Generation	Support Vessels and helicopters	Well Testing & Clean Up Flaring[2]	MODU Power Generation	Support Vessels and helicopters	MODU Power Generation	Support Vessels and helicopters	Intervention Flaring[5]
	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)
CO_2	135,680.0	330,366.2	278,008.2	52,416.0	120,640.0	41,472.0	95,451.4	341,835.3
CO	665.7	825.8	665.2	257.2	220.0	201.0	238.6	818.0
NO_x	2,518.6	6,088.8	119.1	973.0	1,543.9	85.5	1,759.9	146.5
SO_x	169.6	825.9	1.3	65.5	212.0	51.8	238.6	1.6
CH_4	7.6	27.9	4,468.0	2.9	7.0	0.3	8.1	5,493.8
NMVOC	0.0	247.7	496.4	32.8	66.0	8.6	71.6	610.4
GHG	135,840.3	330,951.4	371,836.0	52,477.9	120,787.4	41,477.4	95,620.6	457,204.7

Basis of estimate:
1. 16 wells to be drilled. Each well takes approximately 265 days to drill. Number and type of vessels provided in Appendix 5F
2. Each well to undergo clean up and 1 well test at each of the two remaining flank locations will undergo well testing. Duration and flowrate as provided within Chapter 5 Section 5.4 of this ESIA
3. 26 wells to be completed. Each well takes approximately 70 days to complete. Number and type of vessels provided in Appendix 5F
4. Up to 160 intervention events across PSA, approximately 8.9 per year, requiring 9 days of MODU and vessel support per events. Number and type of vessels provided in Appendix 5F
5. 50% of intervention events result in flaring. Duration and flowrate as provided within Chapter 5 Section 5.4 of this ESIA

3.2 Onshore Construction and Commissioning of Terminal Facilities

Terminal Construction

The estimated number of typical key construction plant and vehicles expected to be used onsite during the construction of the Terminal facilities per phase is presented in Table 2 of Appendix 5F.

Using the schedule (which shows the expected duration and overlapping of phases) presented in Figure 5.9 Chapter 5 of the ESIA, emissions for each phase were calculated by multiplying total plant operating hours and the relevant emission factors provided in Tables 2 and 3 of this Appendix, taking into account engine size.

The emissions per plant type is provided in Table 5 below.

Table 5 Estimated Onshore Construction of Terminal Facilities Emissions by Plant Type

Plant	CO_2	NO_x	CH_4	CO	NMVOC	SO_2
	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)
Bulldozer	2,553.5	38.8	0.1	8.1	3.5	1.6
Wheeled loader	38,798.4	589.3	2.0	263.2	119.1	24.2
Tracked excavator	2,285.7	34.7	0.1	12.2	5.5	1.4
Dump truck	21,510.9	326.7	1.1	145.9	66.0	13.4
Motor grader	685.1	10.4	0.0	4.6	2.1	0.4
Asphalt paver	2,342.5	35.6	0.1	7.4	3.2	1.5
Road lorry	9,136.5	138.8	0.5	62.0	28.0	5.7
Diesel generator	81,397.9	1,236.4	4.3	322.8	143.4	50.9
Mechanical water bowser	4,429.8	67.3	0.2	30.0	13.6	2.8
Mobile telescopic crane	10,924.4	165.9	0.6	74.1	33.5	6.8
Mobile telescopic crane	7,986.8	121.3	0.4	54.2	24.5	5.0
Mobile telescopic crane	2,904.7	44.1	0.2	19.7	8.9	1.8
Mobile telescopic crane	1,703.4	25.9	0.1	11.6	5.2	1.1
Mobile telescopic crane	417.6	6.3	0.0	2.8	1.3	0.3
Mobile telescopic crane	417.6	6.3	0.0	2.8	1.3	0.3
Tower Crane	2,279.5	34.6	0.1	9.0	4.0	1.4
Large lorry concrete mixer	263.0	4.0	0.0	2.3	1.1	0.2
Fork lift truck	321.0	4.9	0.0	2.8	1.3	0.2
Water pump	2,015.9	30.6	0.1	13.7	6.2	1.3
Concrete pump	2,745.2	41.7	0.1	10.9	4.8	1.7
Large rotary bored piling rig (110 t)	10,460.4	158.9	0.6	33.1	14.3	6.5
Air Compressor	1,399.3	21.3	0.1	12.4	5.6	0.9
TIG & MIG Welding Machine	15,110.2	229.5	0.8	80.7	36.3	9.4
TIG Welding Machine	30,623.9	465.2	1.6	163.5	73.7	19.1
MIG Welding Machine	31,187.0	473.7	1.6	166.5	75.0	19.5
Welding Machine (electric)	46,926.0	712.8	2.5	250.5	112.9	29.3
Welding Machine (Diesel)	31,374.7	476.6	1.7	167.5	75.5	19.6
Truck	3,083.0	46.8	0.2	20.9	9.5	1.9
Mini loader (Bobcat)	1,038.0	15.8	0.1	9.2	4.2	0.6
Man lift (cherry picker)	10,504.9	159.6	0.6	71.3	32.2	6.6
Drain Pump	1,591.7	24.2	0.1	10.8	4.9	1.0
Repair Truck	1,661.2	25.2	0.1	11.3	5.1	1.0
Lube Oil Truck	1,661.2	25.2	0.1	11.3	5.1	1.0
Vacuum Truck	553.7	8.4	0.0	3.8	1.7	0.3
Fuel bowser	1,328.9	20.2	0.1	9.0	4.1	0.8
TOTAL	**383,624**	**5,827**	**20**	**2,082**	**937**	**240**

Terminal Commissioning

Terminal commissioning activities that will result in emissions are expected to comprise:

- Testing of the turbine for SD2 power generation – run over a 21 day period over a range of power loads from idle to full load. Gas will be supplied from the existing SD1 facilities during these tests with power generated to be exported to the Azeri grid.
- Testing of export gas compression turbines – each gas compression turbine is expected to be run for up to 24 hours. Gas will be supplied from the existing SD1 facilities
- Diesel user testing – it is planned to test the following diesel users for a maximum of 24 hours:
    - Air compressor package; and
    - Firewater pumps.

In order to calculate emissions during terminal commissioning the anticipated maximum emission flowrates for each source calculated from the operations phase assessment (see Section 3.6 below) were multiplied by the duration of the activity. The emissions per type of source are provided in Table 6.

Table 6 Estimated Onshore Terminal Facilities Commissioning Emissions

Emission	Estimated Emissions During Terminal Commissioning (Turbines)	Estimated Emissions During Terminal Commissioning (Diesel Users)	Estimated Emissions During Terminal Commissioning (All)
	(tonnes)	(tonnes)	(tonnes)
SOx	0	0	0.03
CO_2	6,751.7	0.17	6,751.88
CO	7.4	0.001	7.40
NO_x	33.8	0.003	33.85
CH_4	2.3	0	2.27
NMVOC	0.1	0.0	0.09
GHG	6,799.5	0.17	6,799.62

Onshore Construction and Commissioning of Offshore and Subsea Facilities

Emission estimates during onshore jacket, bridge and topside construction were calculated based on historic fuel records from the Bibi Heybet and BDJF yards where previous ACG and SD jackets and topsides were constructed. Estimated fuel usage per month for onsite generators and engines was multiplied by the relevant emission factors provided in the Table 1.

Emissions during commissioning activities were estimated assuming the main platform generators and the diesel platform users (emergency generators, firewater pumps and cranes) will be run for frequencies and durations as described in Section 5.6.7.3 of Chapter 5. Emissions were calculated by multiplying the anticipated diesel consumption rates by these frequencies and duration and the relevant emission factors (provided in Table 1).

Emissions forecast for Onshore Construction and Commissioning of Offshore and Subsea Facilities are provided in Table 7.

Table 7 Estimated Onshore Construction and Commissioning of Offshore and Subsea Facilities Emissions

Emissions	Jacket and Bridge Construction	Topside Construction	Onshore Commissioning	TOTAL
	(tonnes)	(tonnes)	(tonnes)	(tonnes)
CO_2	24,480	22,848	11,565	**58,893**
CO	88.2	83.9	5.5	**177.6**
NO_x	355.2	336.4	55.7	**747.3**
SO_2	30.6	28.6	14.5	**73.6**
CH_4	1.1	1.0	0.1	**2.2**
NMVOC	11.6	11.0	1.3	**24.0**
GHG	24,502	22,869	11,568	**58,939**

Basis of Estimate:
- Topside and jacket estimates derived from contractor fuel consumption records during construction of DWG platforms at ATA and BDJF yards.
- Monthly diesel at topside yard estimated as 130 tonnes, monthly gasoline consumption 40 tonnes
- Monthly diesel consumption at jacket yard estimated as 206 tonnes, monthly gasoline consumption 40 tonnes
- Records indicate 65% generator usage and 35% engine usage
- Onshore commissioning estimate based on assumptions as provided by the project regarding diesel usage, frequency and duration of testing of main generators and platform diesel users
- Emission factors: EEMS Atmospheric Emission Calculations Issue 1.8 UKOOA 2008

3.3 Platform Installation, Hook Up and Commissioning

To calculate the emissions estimates for the vessels associated with platform installation, hook up and commissioning processes, the estimated fuel consumption rates of each vessel were multiplied by the expected number and duration of use for each vessel (as detailed in Appendix 5F) and applicable emission factors (provided in Table 1 of this Appendix).

Emissions associated with platform commissioning activities are expected to arise from (refer to Section 5.7.5 of Chapter 5) :

- One 1MW temporary diesel generator used for up to 6 months
- Main platform generators will be run on intermittently diesel for 6-8 months during the commissioning period. As a worst case it was assumed that the generators would be run for up to 6 months on diesel.

Emissions were calculated by multiplying the anticipated duration of use, fuel consumption rates and the relevant emissions factors (refer to Table 1 of this Appendix).

Table 8 below provides emissions forecast calculated for Platform Installation, Hook Up and Commissioning phase of SD2 Project.

Table 8 Estimated Platform Installation, Hook Up and Commissioning Emissions

	PR Jacket installation	QU Jacket installation	PR Topside Installation	QU Topside Installation	Bridge Installation	Fotel Support	Commissioning	TOTAL
	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)
CO_2	5,500.80	5,481.60	2,208.00	1,872.00	1,248.00	2,112.00	40,320.00	**58,742.40**
CO	13.75	13.70	5.52	4.68	3.12	5.28	11.59	**57.65**
NO_x	101.42	101.07	40.71	34.52	23.01	38.94	170.10	**509.76**
SO_x	13.75	13.70	5.52	4.68	3.12	5.28	50.40	**96.46**
CH_4	0.46	0.46	0.19	0.16	0.11	0.18	0.41	**1.97**
NMVOC	4.13	4.11	1.66	1.40	0.94	1.58	3.72	**17.53**
GHG	5,510.55	5,491.31	2,211.91	1,875.32	1,250.21	2,115.74	40,328.68	**58,783.72**

3.4 Installation, Hook Up and Commissioning of Subsea Export and MEG Pipelines

Installation, hook up and commissioning of MEG import and export pipelines consists of:

- **Offshore and Nearshore Pipeline Installation** – emissions during this phase will arise from vessel usage (see Table 9). Emissions were calculated based on estimated fuel consumption rates of each operated vessel multiplied by the expected number and duration of usage of each vessel (provided in Table 5 of Appendix 5F) and relevant emission factors (provided in Table 1 of this Appendix).

Table 9 Estimated Offshore and Nearshore Pipeline Installation Emissions (Vessels)

	Pipeline Installation	Pipeline Commissioning	Total
	(tonnes)	(tonnes)	(tonnes)
CO_2	282,144.0	14,016.0	296,160.0
CO	705.4	35.0	740.4
NO_x	5,202.0	258.4	5,460.5
SO_x	705.4	35.0	740.4
CH_4	23.8	1.2	25.0
NMVOC	211.6	10.5	222.1
GHG	286,587.8	14,040.8	296,684.8

- **Onshore and Nearshore Pipeline Installation** – emissions during this phase will arise from construction plant and vehicle usage (see Table 10). Emissions were calculated based on the number of plant and equipment predicted to be used (refer to Section 4 of Appendix 5F) and the relevant emissions factors (provided in Table 2 of this Appendix) taking into account engine size.

Table 10 Estimated Onshore and Nearshore Pipeline Installation Emissions (Construction Plant)

Onshore						
	CO_2	NOx	CH_4	CO	NMVOC	SO_2
	tonnes					
Tracked Excavators	2,432.6	37.0	0.13	16.50	7.5	1.5
Dump Trucks	750.8	11.4	0.04	5.09	2.3	0.5
Forklift Trucks	75.1	1.1	0.00	0.66	0.3	0.0
Mobile telescopic crane	750.8	11.4	0.04	5.09	2.3	0.5
Mechanical Water Bowser	600.7	9.1	0.03	4.07	1.8	0.4
Fuel Bowser	600.7	9.1	0.03	4.07	1.4	0.4
Mini loader (Bobcat)	150.2	2.3	0.01	1.33	0.6	0.1
Roller Compactors	1,501.6	22.8	0.08	10.19	4.6	0.9
Bulldozers	2,687.9	40.8	0.14	8.51	3.7	1.7
Side Booms	2,432.6	37.0	0.13	16.50	7.5	1.5
Nearshore						
	CO_2	NO_X	CH_4	CO	NMVOC	SO_2
	tonnes					
Mobile telescopic crane	819.1	12.4	0.04	5.56	2.514	0.5
Bulldozer	3,909.7	59.4	0.21	12.37	5.361	2.4
Tipper Trucks	1,365.1	20.7	0.07	9.26	4.190	0.9
Back Hoe	546.0	8.3	0.03	3.70	1.676	0.3
Generators	3,276.3	49.8	0.17	10.37	4.493	2.0

- **Pipeline Pre-commissioning and Dewatering** – pipeline pre-commissioning undertaken from onshore will involve usage of one air compressor supported by a diesel powered generator. Emission estimates have been calculated by multiplying estimated diesel consumption rate for the plant by the predicted duration of the activity (refer to Section 4 of Appendix 5F). Table 11 presents the estimated emissions.

Table 11 Estimated Pipeline Pre-Commissioning Emissions (Onshore)

Emission	CO_2	NOx	CH_4	CO	NMVOC	SO_2
	tonnes					
Air Compressor	1,334.8	20.3	0.1	4.2	1.8	0.8
Generators	46,154.7	701.1	2.4	146.1	63.3	28.8

3.5 Installation, Hook Up and Commissioning of Subsea Infrastructure

Emissions during installation, hook up and commissioning of subsea infrastructure will arise from vessel usage (see Table 12). Emissions were calculated based on estimated fuel consumption rates of each operated vessel multiplied by the expected number and duration of usage of each vessel (provided in Table 6 of Appendix 5F) and relevant emission factors (provided in Table 1 of this Appendix).

Table 12 Estimated Subsea Infrastructure Installation Emissions

	Subsea Installation (tonnes)	Subsea Commissioning (tonnes)	Total (tonnes)
CO_2	38,880.0	20,160.0	59,040.0
CO	97.2	50.4	147.6
NO_x	716.9	371.7	1,088.6
SO_x	97.2	50.4	147.6
CH_4	3.3	1.7	5.0
NMVOC	29.2	15.1	44.3
GHG	38,948.9	20,195.7	59,144.6

3.6 Offshore Operations

Estimated emissions to air were calculated based on a combination of emission forecasting using bespoke software and spreadsheet-based manual calculations.

The emissions forecasting software (developed by PI Ltd.) was used to calculate CO_2 and NO_X emissions from the SDB platform complex from combustion processes over the duration of the PSA. CO, CH_4, SO_2 and VOC emissions were calculated manually using the EEMS emission factors.

The source of the main data inputs were:

- Process data was obtained from the project heat and material balance
- Fuel Gas composition was taken from the project heat & material balance
- Equipment Details were obtained from the:
  - Electrical Load Summary
  - Equipment Lists
  - Equipment Load Profile
  - Electrical Load Profile
  - Electrical Load Lists
- Production Data was obtained from the latest production profile.
- Flaring scenarios (duration, frequency and flowrates) as estimated by the project.

In addition the volumes of diesel usage over the PSA both by diesel users and the main diesel generators were made based on data provided by the project engineers. The model assumed 10 days of shut down for planned maintenance activities every two years during which the main generators would be powered by diesel for 2 days and buy back gas for 8 days. An average 0.23 tonnes per day of diesel was been included in the estimate to account for cranes usage and usage of the emergency generators and diesel fire pumps during weekly testing.

The model took into account the load profile associated with the anticipated use of DEH as presented within Chapter 5 Table 5.28 and the anticipated subsea infrastructure installation schedule and 1st – 5th gases as shown in Figure 5.3.

The model was run at 15°C, in order to simulate average ambient meteorological conditions as the performance of the main emission sources are affected by the ambient air temperature.

Modelling was undertaken on an annual basis from 2018 until 2036, i.e. until the end of the PSA. Table 13 below provides emissions forecast for the SDB platform complex combustion source during Operations

Table 13 Estimated SDB Platform Complex Emissions (Combustion Sources) During Operations

OFFSHORE	CO_2				NOx				SOx				CO				CH_4				VOC			
YEAR	Power Generation	Extraneous Diesel	Flare	**All Sources**	Power Generation	Extraneous Diesel	Flare	**All Sources**	Power Generation	Extraneous Diesel	Flare	**All Sources**	Power Generation	Extraneous Diesel	Flare	**All Sources**	Power Generation	Extraneous Diesel	Flare	**All Sources**	Power Generation	Extraneous Diesel	Flare	**All Sources**
2018	67,927	40	11,340	**79,307**	247	1	5	**253**	5	0.03	0.05	**5**	69	0.20	28	**97**	21	0.00	18	**38**	1	0.03	3	**4**
2019	102,743	114	17,689	**120,547**	393	2	8	**403**	8	0.07	0.08	**9**	102	0.56	43	**146**	30	0.01	28	**58**	2	0.07	4	**7**
2020	155,977	57	33,920	**189,955**	608	1	15	**624**	12	0.04	0.16	**12**	156	0.28	83	**239**	46	0.00	53	**99**	3	0.04	9	**12**
2021	157,050	114	50,776	**207,940**	616	2	22	**641**	13	0.07	0.24	**13**	157	0.56	124	**282**	46	0.01	79	**125**	4	0.07	13	**16**
2022	156,641	114	48,279	**205,035**	612	2	21	**636**	12	0.07	0.23	**12**	157	0.56	118	**276**	47	0.01	75	**122**	4	0.07	12	**16**
2023	164,342	114	50,360	**214,816**	667	2	22	**691**	13	0.07	0.24	**14**	164	0.56	123	**288**	49	0.01	78	**127**	4	0.07	13	**16**
2024	156,496	57	47,862	**204,416**	611	1	21	**633**	12	0.04	0.22	**12**	157	0.28	117	**274**	47	0.00	74	**121**	4	0.04	12	**16**
2025	164,192	114	49,736	**214,042**	666	2	22	**690**	13	0.07	0.23	**14**	164	0.56	121	**286**	49	0.01	77	**126**	4	0.07	13	**16**
2026	156,306	57	47,238	**203,601**	610	1	21	**632**	12	0.04	0.22	**12**	157	0.28	115	**273**	47	0.00	73	**120**	4	0.04	12	**15**
2027	156,400	114	48,904	**205,418**	612	2	21	**636**	13	0.07	0.23	**13**	156	0.56	119	**276**	46	0.01	76	**122**	4	0.07	12	**16**
2028	152,781	57	46,406	**199,245**	586	1	20	**608**	12	0.04	0.22	**12**	153	0.28	113	**267**	46	0.00	72	**118**	3	0.04	12	**15**
2029	152,787	114	47,654	**200,556**	587	2	21	**610**	13	0.07	0.22	**13**	152	0.56	116	**269**	45	0.01	74	**119**	4	0.07	12	**16**
2030	152,377	57	45,366	**197,800**	583	1	20	**604**	12	0.04	0.21	**12**	153	0.28	111	**265**	45	0.00	70	**116**	3	0.04	11	**15**
2031	152,364	114	46,614	**199,092**	584	2	20	**607**	12	0.07	0.22	**13**	152	0.56	114	**267**	45	0.01	72	**118**	4	0.07	12	**15**
2032	151,178	57	38,914	**190,150**	575	1	17	**593**	12	0.04	0.18	**12**	152	0.28	95	**247**	45	0.00	60	**106**	3	0.04	10	**13**
2033	149,695	114	32,672	**182,481**	567	2	14	**584**	12	0.07	0.15	**12**	149	0.56	80	**230**	44	0.01	51	**95**	3	0.07	8	**12**
2034	149,110	57	25,389	**174,556**	562	1	11	**574**	12	0.04	0.12	**12**	149	0.28	62	**211**	44	0.00	39	**84**	3	0.04	6	**10**
2035	148,982	114	22,059	**171,155**	562	2	10	**574**	12	0.07	0.10	**12**	148	0.56	54	**203**	44	0.01	34	**78**	3	0.07	6	**9**
2036	148,756	57	19,561	**168,375**	559	1	9	**569**	12	0.04	0.09	**12**	149	0.28	48	**197**	44	0.00	30	**75**	3	0.04	5	**8**
PSA Total	2,796,103	1,643	730,740	**3,528,487**	10,812	31	320	**11,163**	222	1.03	3.42	**226**	2,794	8.11	1,788	**4,591**	831	0.09	1,136	**1,966**	63	1.03	183	**248**

Emissions during operations will also arise from:

- Fugitive emissions e.g. from fittings (refer to Annex 1 of this Appendix); and
- Supply and support vessels and non routine use of helicopters. Emissions associated with vessels and helicopters during offshore operations were estimated based on estimated fuel consumption rates multiplied by the expected number and duration of use for each vessel/helicopter (as detailed in Appendix 5F) and applicable emission factors (provided in Table 1 of this Appendix).

Table 14 presented the total estimated emissions during offshore operations.

Table 14 Total Estimated Offshore Operations Emissions

	CO_2	CO	NO_x	SO_2	CH_4	VOC	GHG
	ktonnes	**tonnes**	**tonnes**	**tonnes**	**tonnes**	**tonnes**	**ktonnes**
Combustion Sources (including Flaring)	3,528.5	4,590.6	11,162.9	226.2	1,966.4	247.7	3,569.8
Fugitive Sources	0	0	0	0	1,944.0	453.9	48.6
Helicopters/Supply Vessels	114.0	284.8	2,099.2	285.0	9.6	85.4	114.2
TOTAL	**3,642.5**	**4,875.4**	**13,262.1**	**511.2**	**3,920.9**	**786.9**	**3,724.8**
Note: SO_2 assumed to be equivalent to SO_x							

3.7 Onshore Operations

As for the offshore operations estimated emissions to air were calculated based on a combination of emission forecasting using bespoke software and spreadsheet-based manual calculations.

The emissions forecasting software (developed by PI Ltd.) was used to calculate CO_2 and NO_x emissions from the onshore combustion sources over the duration of the PSA. CO, CH_4, SO_4 and VOC emissions were calculated manually using the EEMS emission factors.

The source of the main data inputs were:

- Process data was obtained from the project heat and material balance
- Fuel Gas composition was taken from the project heat & material balance
- Equipment Details were obtained from the:
  - Electrical Load Summary
  - Equipment Lists
  - Equipment Load Profile
  - Electrical Load Profile
  - Electrical Load Lists
- Production Data was obtained from the latest production profile.
- Flaring scenarios (duration, frequency and flowrates) as estimated by the project.

As for offshore the model assume a 91% availability (i.e. 9% for downtime). However, it is assumed that the electrical power required by the SD2 facilities during production downtime will be provided by the existing Sangachal Terminal utilities. It was therefore assumed that the facilities would be operated for 332 days per year on gas and 0 days on diesel. Flaring scenarios (including frequency, duration and flowrate) were provided by the project team.

The model was run at 15°C, in order to simulate average ambient meteorological conditions as the performance of the main emission sources are affected by the ambient air temperature.

Modelling was undertaken on an annual basis from 2018 until 2036, i.e. until the end of the PSA. Table 15 below provides emissions forecast for the onshore combustion sources during Operations

Table 15 Estimated SD2 Onshore Facility Emissions (Combustion Sources) During Operations

ONSHORE	CO2					NOx					SOx					CO					CH_4					VOC				
YEAR	Power Generation	Turbine Driven Compressors	Process Heaters	Flare	**All Sources**	Power Generation	Turbine Driven Compressors	Process Heaters	Flare	**All Sources**	Power Generation	Turbine Driven Compressors	Process Heaters	Flare	**All Sources**	Power Generation	Turbine Driven Compressors	Process Heaters	Flare	**All Sources**	Power Generation	Turbine Driven Compressors	Process Heaters	Flare	**All Sources**	Power Generation	Turbine Driven Compressors	Process Heaters	Flare	**All Sources**
2018	80,726	96,976	10,570	38,062	**226,334**	358	285	9.3	16.7	**669.0**	0.4	0.5	0.0	0.2	**1.1**	88.5	106	2.3	93.5	**290.3**	27.2	32.6	0.3	60.8	**120.9**	1.1	1.3	0	8.1	**10.5**
2019	82,309	124,196	17,163	38,812	**262,480**	374	570	15.1	17.1	**976.2**	0.4	0.6	0.1	0.2	**1.3**	90.3	136	3.8	95.3	**325.4**	27.7	41.8	0.6	62	**132.1**	1.1	1.6	0.1	8.2	**11.0**
2020	87,037	205,562	23,756	36,374	**352,729**	424	1073	20.8	16	**1533.8**	0.4	1	0.1	0.2	**1.7**	95.5	225	5.2	89.3	**415.0**	29.3	69.1	0.8	58.1	**157.3**	1.2	2.7	0.1	7.7	**11.7**
2021	87,593	208,307	19,219	36,374	**351,493**	430	1108	16.9	16	**1570.9**	0.4	1	0.1	0.2	**1.7**	96.1	228	4.2	89.3	**417.6**	29.5	70.1	0.6	58.1	**158.3**	1.2	2.7	0.1	7.7	**11.7**
2022	87,341	208,307	14,683	36,374	**346,705**	428	1108	12.9	16	**1564.9**	0.4	1	0.1	0.2	**1.7**	95.8	228	3.2	89.3	**416.3**	29.4	70.1	0.5	58.1	**158.1**	1.2	2.7	0.1	7.7	**11.7**
2023	87,249	208,307	10,145	36,374	**342,075**	427	1108	8.9	16	**1559.9**	0.4	1	0.0	0.2	**1.6**	95.7	228	2.2	89.3	**415.2**	29.3	70.1	0.3	58.1	**157.8**	1.2	2.7	0	7.7	**11.6**
2024	86,978	208,307	7,953	41,812	**345,050**	424	1108	7	18.4	**1557.4**	0.4	1	0.0	0.2	**1.6**	95.4	228	1.7	103	**428.1**	29.3	70.1	0.3	66.8	**166.5**	1.1	2.7	0	8	**11.8**
2025	86,608	208,307	12,111	36,374	**343,400**	419	1108	10.6	16	**1553.6**	0.4	1	0.1	0.2	**1.7**	95	228	2.7	89.3	**415.0**	29.1	70.1	0.4	58.1	**157.7**	1.1	2.7	0	7.7	**11.5**
2026	86,133	208,307	18,613	36,374	**349,427**	414	1108	16.3	16	**1554.3**	0.4	1	0.1	0.2	**1.7**	94.5	228	4.1	89.3	**415.9**	29	70.1	0.6	58.1	**157.8**	1.1	2.7	0.1	7.7	**11.6**
2027	85,617	208,307	25,116	36,374	**355,414**	409	1108	22	16	**1555.0**	0.4	1	0.1	0.2	**1.7**	93.9	228	5.5	89.3	**416.7**	28.8	70.1	0.8	58.1	**157.8**	1.1	2.7	0.1	7.7	**11.6**
2028	85,025	208,307	19,623	36,374	**349,329**	402	1108	17.2	16	**1543.2**	0.4	1	0.1	0.2	**1.7**	93.3	228	4.3	89.3	**414.9**	28.6	70.1	0.6	58.1	**157.4**	1.1	2.7	0.1	7.7	**11.6**
2029	84,214	208,307	14,133	41,812	**348,466**	394	1108	12.4	18.4	**1532.8**	0.4	1	0.1	0.2	**1.7**	92.4	228	3.1	103	**426.5**	28.3	70.1	0.5	66.8	**165.7**	1.1	2.7	0.1	8.9	**12.8**
2030	83,158	208,307	8,642	36,374	**336,481**	383	1108	7.6	16	**1514.6**	0.4	1	0.0	0.2	**1.6**	91.2	228	1.9	89.3	**410.4**	28	70.1	0.3	58.1	**156.5**	1.1	2.7	0	7.7	**11.5**
2031	82,839	208,307	7,953	36,374	**335,473**	380	1108	7	16	**1511.0**	0.4	1	0.0	0.2	**1.6**	90.9	228	1.7	89.3	**409.9**	27.9	70.1	0.3	58.1	**156.4**	1.1	2.7	0	7.7	**11.5**
2032	81,656	206,653	7,953	36,374	**332,636**	368	1086	7	16	**1477.0**	0.4	1	0.0	0.2	**1.6**	89.6	227	1.7	89.3	**407.6**	27.5	69.5	0.3	58.1	**155.4**	1.1	2.7	0	7.7	**11.5**
2033	78,504	192,495	7,953	36,374	**315,326**	337	916	7	16	**1276.0**	0.4	0.9	0.0	0.2	**1.5**	86.1	211	1.7	89.3	**388.1**	26.4	64.7	0.3	58.1	**149.5**	1	2.5	0	7.7	**11.2**
2034	78,225	153,949	7,953	41,812	**281,939**	334	539	7	18.4	**898.4**	0.4	0.7	0.0	0.2	**1.3**	85.8	169	1.7	103	**359.5**	26.3	51.8	0.3	66.8	**145.2**	1	2	0	8.9	**11.9**
2035	78,069	122,367	7,953	36,374	**244,763**	333	547	7	16	**903.0**	0.4	0.6	0.0	0.2	**1.2**	85.6	134	1.7	89.3	**310.6**	26.3	41.2	0.3	58.1	**125.9**	1	1.6	0	7.7	**10.3**
2036	78,032	120,598	7,953	36,374	**242,957**	332	525	7	16	**880.0**	0.4	0.6	0.0	0.2	**1.2**	85.6	132	1.7	89.3	**308.6**	26.2	40.6	0.3	58.1	**125.2**	1	1.6	0	7.7	**10.3**
PSA Total	1,587,313	3,514,173	249,445	711,546	**6,062,477**	7,370	17,729	219	313	**25,631**	7.6	16.9	0.9	3.8	**29.2**	1,741	3,848	54	1,748	**7391.6**	534	1,182	8	1,137	**2,862**	21	46	1	150	**217**

Emissions during onshore operations will also arise from:

- Fugitive emissions e.g. from fittings (refer to Annex 1 of this Appendix); and
- Fugitive emissions from the new SD2 condensate tank. These were calculated based on estimated mode of operation of the tank including anticipated turnovers and filling levels and using the tank characteristics as provided by the SD2 project engineers. The emissions of total VOCs were calculated using the US EPA TANKS model and volumes of NMVOC and CH4 calculated using Appendix II of EEMS - Guidelines for the Compilation of an Atmospheric Emissions Inventory, UKOOA, 2002.

Table 16 presented the total estimated emissions during onshore operations.

Table 16 Total Estimated Onshore Operations Emissions

	CO_2	CO	NO_x	SO_2	CH_4	VOC	GHG
	ktonnes	tonnes	tonnes	tonnes	tonnes	tonnes	ktonnes
Combustion Sources (including Flaring)	6,062.5	7,391.6	25,631.0	29.2	2,861.5	217.3	6,122.6
Fugitive Sources (fittings)	0	0	0	0	1,318	80	32.9
Fugitive Sources (tanks)	0	0	0	0	11.0	0.7	231.0
TOTAL	**6,062.5**	**7,391.6**	**25,631.0**	**29.2**	**4,190.1**	**297.9**	**6150.5**

Annex 1 Fugitive Emissions from Fittings

Offshore:

Table A1 Fugitive Emissions Estimate - Offshore

Component	Emission Rate(kg/ component/year)[1]	Number of Components[2]	Fugitive Emissions (te/year)
Connections	0.946	12,760	12
Valves	4.52	7,280	33
Other[3]	60.9	2,100	128
		Total Fugitive Emissions (tonnes/year)	**173**

Notes:
1. EEMS-Atmospheric Emissions Calculations, UK Department of Energy & Climate Change, 2008, Issue 1.810a
2. EEMS - Guidelines for the Compilation of an Atmospheric Emissions Inventory, UKOOA, 2002 - number of components for gas platform facility Type B - production rate 330 mmscfd - multiplied by 5.4 based on SD2 production rate of 1777 mmscfd
3. Includes pumps and open-ended fittings.

Table A2 Offshore Fugitive GHG Emissions

Emission Gas	Total Volume (tonnes/year)[1]	GHG (tonnes/year)	Total Volume (over PSA)[1]	GHG (over PSA)
CH_4	102	2,150	1,945	48,623
VOC	24	-	454	
Total Fugitive Emissions (GHG) tonnes		2,559		48,623

Notes:

1. Volumes of CH_4 and VOC emissions calculated from total fugitive emissions multiplied by CH4 and VOC factors respectively (derived from Appendix II of EEMS - Guidelines for the Compilation of an Atmospheric Emissions Inventory, UKOOA, 2002)

Onshore:

Table A3 Fugitive Emissions Estimate - Onshore

Component	Emission Rate(kg/ component/year)[1]	Number of Components[2]	Fugitive Emissions (te/year)
Connections	2.4	5,546	13
Valves	33.9	1,521	52
Pumps	101	41	4
Other	42.7	268	11
		Total Fugitive Emissions (tonnes/year)	**80.46**

Notes:
1. EEMS-Atmospheric Emissions Calculations, UK Department of Energy & Climate Change, 2008, Issue 1.810a
2. EEMS - Guidelines for the Compilation of an Atmospheric Emissions Inventory, UKOOA, 2002

Emission Gas	Total Volume (te/year)[1]	GHG (tonnes/year)	Total Volume (over PSA)[1]	GHG (over PSA)
CH_4	69	1,734	1,318	32,939
VOC	4	-	80	-
Total Fugitive Emissions (GHG) tonnes		1,734		32,939

Notes:

1. Volumes of CH4 and VOC emissions calculated from total fugitive emissions multiplied by CH4 and VOC factors respectively (derived from Appendix II of EEMS - Guidelines for the Compilation of an Atmospheric Emissions Inventory, UKOOA, 2002)

Annex 2 PI Forecasting Software

Performance Improvements (PI) Ltd are international market leaders in CO_2 reduction and energy assessments, having developed energy reduction protocols, carried out site assessments and implemented remedial work plans for oil, gas and power production sites all over the world. Over 150 assessments have been completed for companies including BP, Shell, BG, Shell, Talisman, Total, ConocoPhillips, Chevron, ExxonMobil and globally in countries including the UK, Ireland, Holland, Norway, Azerbaijan, UAE, Kazakhstan, USA, Pakistan, Trinidad, Gabon and Australia.

PI has developed a software application specifically intended to allow energy and emissions forecasts to be carried out over the Life of Field (LoF). The forecast software does not rely on the use of energy factors (i.e. power per unit production). It uses bespoke machinery curves to take into account the changes in machine efficiency relating to the load point actually occurring at a particular throughput.

The performance characteristics of most modern gas turbines are modelled in the PI Forecaster software using Original Equipment Manufacturers' (OEM) performance curves for these engines.

The 'Forecaster' software allows for both operating assets and project teams to forecast the atmospheric emissions, fuel gas consumption and associated fuel and CO_2 costs which can be expected for different machinery configurations.

The concept of the 'Forecaster' software is based on the fact that the fundamental thermodynamics, aerodynamics and hydrodynamics of gas turbines, centrifugal gas compressors and centrifugal liquid pumps that form the major power users on most oil and gas facilities do not change. What does change from installation to installation is the production throughput and hence the scale of the equipment required to process it. Because the fundamental physics involved does not change, it is possible to scale the equipment performance characteristics to suit a particular installation and its production throughput. Knowing the production throughput in terms of volumes of oil and gas produced, volumes of water pumped for re-injection and cooling, quantities of heat required in the process and the balance of utility electrical power, it is possible to build a software model of the plant that will predict its overall power consumption. It then follows that, given the type and numbers of prime movers on the installation the fuel requirement can be determined. Again, given definition of the fuel types to be used, the emissions arising from the prime-movers can be determined. Emissions from process heaters and flares can be similarly obtained.

The production rate of oil and gas inevitably varies over the life of a field, building up from low levels in the early years as wells are drilled and output capacity increases up to the nameplate rating of the associated process plant. There are then a number of years of steady, or plateau, production until the reservoir depletes to a point where the wells can no longer provide sufficient flow to satisfy process plant nameplate rating and the plant throughput follows an ever reducing decline curve until the reservoir is exhausted and the field is abandoned. The "Forecaster" software can be programmed to calculate the power consumption and emissions production throughout the build-up / plateau / decline sequence of a field's exploitation and can hence predict the total emissions to be expected over the whole life of field.

The Forecaster software has been "blind" tested against several existing oil and gas installations and has been shown to predict the combustion emissions to an uncertainty of better than +/- 5%. Additional detail on how the model has been developed and the validation work completed can be found within SPE 111527. Developing Rigorous GHG Forecasts for E&P Operations.GHG Forecasting Tool. J.Edwards, A. Watson and M.Guinee.