

ENVIRONMENTAL IMPACT OF STANDARD OIL DRILLING INSTALLATIONS VERSUS THE LOC250

-Confidential-

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SUMMARY

Ecofys BV has been contracted by Huisman-Itrec to evaluate the environmental impact of Drillmar and Huisman-Itrec's new Land Offshore Containerised (LOC250) oil drilling installation, the next generation in the Genesis series of casing drilling technology.

This report is to serve as an independent review of the LOC250's activities compared with the environmental impact of "standard" drilling installations. By standard drilling installation we refer to non-casing. Comparisons are based on constant factors such as similar hook load, drill string, geology, and well depth. Our investigations have been based on industry literature, discussions with industry experts, drilling reports from the Wardner wells in the Stratton oil field of Texas, USA, and company performance specifications and reports.

Our environmental impact investigations focus on polluting gases, such as CO₂, NO_x, CO, SO₂ and PM (particulate matter) to the three primary activities in the operation of a drilling installation:

1. Emissions related to the transport over a relatively short distances (transport over land) and relatively long distances (transport over sea);
2. Emissions related to energy needs: direct emissions related to the use of energy during the construction of a well bore;
3. Emissions related to construction of the drilling installation itself.

It should be noted that comparable fuel data figures were not readily available. Industry figures were used to create as conservative an estimate as possible.

Other environmental circumstances that could be useful in comparing the full environmental load of the standard oil drilling installation versus the LOC250 were not reviewed. These additional circumstances could be included in a future study of the environmental impacts of the LOC250, but in general and perhaps more importantly, a more comprehensive conclusion could be drawn with an improvement in data quality. This is particularly true with respect to daily fuel usage as well as engine performance.

Nevertheless, drilling contributes about 80 to 90% to the total emissions, except for SO₂, where only negligible emissions of SO₂ originate from the engines. The contribution of transport and construction to the total emissions is low and the relative

contributions from transport, construction and drilling are comparable to the LOC250 and standard rigs.

Overall, the LOC250 can be shown to conservatively emit 35 to 60% less than a standard drilling operation concerning carbon dioxide, nitrogen oxide, carbon monoxide, particulate matter and sulphur oxide.

An overview of emissions from constructing, transporting and operating drilling equipment is shown in the following table.

		LOC250		Standard (low)		Standard (high)	
Weight	t/well	475		600		1000	
Drilling time	days/well	5.5		5.8		9.2	
			share (%)		share (%)		share (%)

Transport							
CO2 emissions	t/well	4	8%	5	7%	8	7%
NOx emissions	kg/well	41	7%	52	6%	87	6%
CO emissions	kg/well	8	5%	10	4%	17	4%
PM emissions	kg/well	1	11%	2	9%	3	9%
SO2 emissions	kg/well	5	65%	7	65%	11	65%

Drilling							
CO2 emissions	t/well	42	88%	67	90%	106	90%
NOx emissions	kg/well	551	93%	868	94%	1374	94%
CO emissions	kg/well	140	79%	220	83%	349	82%
PM emissions	kg/well	12	89%	19	91%	29	91%
SO2 emissions	kg/well	0	0%	0	0%	0	0%

Construction							
CO2 emissions	t/well	2	4%	2	3%	4	3%
NOx emissions	kg/well	2	0%	2	0%	4	0%
CO emissions	kg/well	29	16%	36	14%	60	14%
PM emissions	kg/well	0	0%	0	0%	0	0%
SO2 emissions	kg/well	3	35%	4	35%	6	35%

Total			relative to 'Standard high'		relative to 'Standard high'		Standard high
CO2 emissions	t/well	48	41%	74	63%	118	100%
NOx emissions	kg/well	594	41%	922	63%	1465	100%
CO emissions	kg/well	176	41%	266	63%	426	100%
PM emissions	kg/well	13	41%	20	63%	32	100%
SO2 emissions	kg/well	8	48%	10	60%	17	100%

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1 Introduction

The scope of this study encompasses an evaluation of the environmental impact of the Land Offshore Containerised (LOC250) oil drilling installation. Drillmar and Huisman-Itrec are currently manufacturing the LOC250 for the market, with support from Tesco Corporation. The installation's activities will be compared with the environmental impact of "standard" drilling installations. By standard drilling installation we use data for rigs that are comparable to the LOC250 in terms of drill string and hook load.

The LOC250 differs from standard drilling installations in that it utilises casing drilling technology. Casing while drilling was first developed in the 1950s but has recently seen renewed interest. Initially casing drilling technology had issues with drilling bits and did not have top drives (the component that rotates the whole drill-string from the top down), but today developments have allowed the replacement of drill bits and bottom hole assemblies without the extraction of the casing. This allows the casing to act as a drill pipe and offers further improved efficiency over non-casing drilling installations.

The LOC250 can be seen as the "next generation" of casing while drilling oil rigs. An artist's conception of the installation's land configuration is shown below.



Land configuration for the LOC250

As the graphic illustrates, there are some major differences in the design of the LOC250. In addition to the benefits associated with the Genesis casing drilling rigs, the LOC250 is designed to fit and collapse in sections according to ISO standards (i.e. standard container size) and while drilling, an automated pipe handler requires no drillers crew on the drill floor. The rig also differs in that it can test blow out preventers (BOP – a high pressure closing unit on the well head that opens or closes a well) and can handle bottom hole assemblies (BHA) while drilling.

Based on these benefits, our environmental impact investigations In Chapter 2 refer to applicable polluting gases, such as CO₂ NO_x, CO, SO₂ and PM (particulate matter). We limit our review of these gases to the three primary activities in the operation of a drilling installation:

4. Emissions related to the transport over a relatively short distances (transport over land) and relatively long distances (transport over sea);
5. Emissions related to energy needs: direct emissions related to the use of energy during the construction of a well bore;
6. Emissions related to construction of the drilling installation itself.

While a direct comparison of fuel consumption was not possible due to data availability, an accurate investigation of the LOC250 was possible by reviewing actual drilling reports. Reports for fuel consumption figures confirmed and focused the estimates that were provided by industry experts (see Reference section). The results should therefore serve as a conservative estimate of the LOC250's environmental impact. Actual testing of the LOC250 is expected to begin in 2005.

Other areas that Huisman-Itrec could review in further exploring the environmental impacts of the LOC250 are presented in Chapter 3.

The report ends with concluding remarks, and consolidates the LOC250's environmental advantages over standard drilling installations.

2 Emissions

This chapter reviews emissions to air from three activities: emissions from transport, emissions from operation and emissions from due to construction. A consolidated analysis of emissions is then performed.

2.1 Emissions due to transport

Oil drilling equipment needs to be transported from drilling location to drilling location. Depending on the location, transport over secondary roads, primary roads and water may be required. The share these types of transport may vary considerably and depends on equipment availability.

Transport trucks and ship used in these transport modes carry the primary environmental impact on the environment due to their emissions to air. In this study we do not consider other environmental impacts, which we consider of lesser importance.

The emissions from transport are typically determined by:

- Transport distance (subdivided to type of roads, waterways)
- Weight of equipment to transport
- Mode of transport and specific emissions from trucks and ships

These issues are further explained in the following sections.

2.1.1 Transport distances

Transport differs on a case-by-case basis. In some situations various wells are drilled in the same area and limited transport is required. In these cases transport is restricted over short distances (in the tens of kilometres as reported by operations based in Houston) where there is much in the way of hydrocarbon exploration activities. In some cases, it might be required to transport the rig over larger distances and even between continents.

The average transportation distance of a rig between two drilling activities depends on many factors, among which is the availability of the rig. If only a few rigs are available worldwide, the average transportation distance will be higher than for rigs widely available. In this study we use the experts estimate for average distance per type of drilling installation between two drillings activities. Standard rigs are more widely available than the new LOC250. The average transportation distance between two drilling activities will therefore be less.

2.1.2 Weight of equipment to transport

The weight of equipment is an important factor in deterring emissions to air. The following information on weight was supplied to Ecofys.

Standard rig: 600 to 1000 tonnes (requiring 20 or more loads)
 LOC250: 475 tonnes (requiring 17 containers)

The data on weight is supplied by Huisman-Itrec and external experts and includes all associated equipment for the drilling installation such as engines, generators, and pipes/casing.

2.1.3 Mode of transport and specific emissions from trucks and ships

Heavy equipment involved with drilling installations is transported over land by trucks. Each type of vehicle needs to comply with the European emission standards, depending on the year of construction. Road vehicles are subdivided into cars, light-duty vehicles and heavy-duty vehicles. The standards are gradually becoming more severe (indicated by the heading of “Euro” followed by an additional character). Emissions related to truck transport therefore depend on the age of the truck. In this study we assume that trucks are used with an average weight of 36 tonnes that have to comply the Euro-III standards.

For ships we used the emission factors for sea transport, including sailing, landing and idle time. Table 1 gives an overview of the used emission factors [CBS, 2004].

Table 1. Average emission factors for conventional sea ships with average fuel use of 6.4 grams per tonne per kilometre

Substance	Emission Factor (g/kg fuel)
Carbon dioxide - CO ₂	3100
Nitrogen oxides– NO _x	61.6
Carbon monoxide – CO	7.8
Particulate matter – PM	4.6
Sulphur dioxide - SO ₂	37

2.1.4 Results transport emissions

In Table 2 the specific emissions are shown for transporting one tonne one kilometre over road. We assumed an average transport of 20% over primary roads (freeways) and 80% over secondary roads. In Table 3, specific emissions are shown for transporting a standard rig and the LOC250 rig one kilometre at sea. In Table 4, a comparison is shown for road transport. According to experts, the LOC250 weighs 475 tonne and the weight of standard rigs varies from about 600 to 1000 tonnes. In the tables both emissions associ-

ated with both weights are presented. In Table 5 the same comparison is made for sea transport.

Table 2. Specific road transport emissions

		high	medium	best
Type of truck/construction year		tractor/1996	tractor/1999	tractor/2003
Weight empty truck	t	14	14	14
Weight loaded truck	t	36	36	36
Net load truck	t	22	22	22
Share secondary roads	%	80%	80%	80%
Specific NOx emission	g/km	16	13	11
Specific CO emission	g/km	3.1	2.4	2.4
Specific PM emission	g/km	0.66	0.27	0.26
Share primary roads	%	20%	20%	20%
Specific NOx emission	g/km	13	10	8.1
Specific CO emission	g/km	2.2	1.6	1.6
Specific PM emission	g/km	0.48	0.22	0.16
Average emissions				
Specific CO2 emission	g/km/t	50	50	50
Specific NOx emission	g/km/t	0.70	0.56	0.47
Specific CO emission	g/km/t	0.13	0.10	0.10
Specific PM emission	g/km/t	0.03	0.01	0.01

Table 3. Specific sea transport emissions

		LOC250	Conventional	Conventional
		typical	low	high
Specific CO2 emission	g/km/t	19.8	19.8	19.8
Specific NOx emission	g/km/t	0.4	0.4	0.4
Specific CO emission	g/km/t	0.0	0.0	0.0
Specific PM emission	g/km/t	0.0	0.0	0.0
Specific SO2 emission	g/km/t	0.2	0.2	0.2

Table 4. Comparison of specific road transport emissions for the standard rig and LOC250

		LOC250	Conventional	Conventional
		typical	low	high
Weight	t	475	600	1000
Specific CO2 emission	kg/km	9.4	11.9	19.8
Specific NOx emission	g/km	187	237	394
Specific CO emission	g/km	24	30	50
Specific PM emission	g/km	14	18	29
Specific SO2 emission	g/km	112	142	237

Table 5. Comparison of specific sea transport emissions for the standard rig and LOC250

		LOC250	Conventional	Conventional
		typical	low	high
Weight	t	475	600	1000
Specific CO ₂ emission	kg/km	9.4	11.9	19.8
Specific NO _x emission	g/km	187	237	394
Specific CO emission	g/km	24	30	50
Specific PM emission	g/km	14	18	29
Specific SO ₂ emission	g/km	112	142	237

2.2 Emissions due to drilling

Emissions associated with drilling are derived from the engines to produce electric and mechanical power. Power is used for the various tasks in the drilling cycle, such as drilling, tripping, and cementing.

The LOC250 casing drilling uses three Volvo Penta TAD1642GE/VE engines. As this is not a typical feature of drilling rigs, for sake of comparison, we assume that the same engines are used in standard drilling installations. In practise, of course, this might be different engines. Table 6 shows the emission factors (expressed in mg/Nm³ and grams per litre of diesel) for various load factors [Volvo, 2005a; Volvo, 2005b; Volvo, 2005c]

Table 6. Emission factors for the Volvo Penta TAD1642 GE engines for various load factors

Load (%)		100%	75%	50%	25%	10%
NO _x	mg/Nm ³	1748	1752	1758	1698	1787
CO	mg/Nm ³	713	575	156	165	542
PM	mg/Nm ³	27	20	10	9	6
SO ₂	mg/Nm ³	0	0	0	0	0
HC	mg/Nm ³	15	21	35	51	145

NO _x	g/l	30	30	30	29	30
CO	g/l	12	10	3	3	9
PM	g/l	0.3	0.4	0.6	0.9	2.5
SO ₂	g/l	0.0	0.0	0.0	0.0	0.0
HC	g/l	0.46	0.34	0.17	0.15	0.10

The engines are typically not running at full load. Based on expert information we assume 60% at a load factor of 75%, 30% at a load factor of 50% and 10% at a load factor of 10%. Furthermore, based on expert information, casing drilling can be done 5 to 40% faster than drilling with standard rigs.

Typical fuel consumption is about 3400 litres per day for the LOC250 while estimates for a standard rig are as high as 10,000 litres per day. Given there were no actual fuel usage reports for standard rigs to compare with casing while drilling installations at the time of this study, we assume that the typical standard rig is comparable to the 250 tonne hook-load M.I.L. Series 500 (vertical erection) rig. This rig uses CAT 3508 engines and it is upon these that we base our consumption figures. As detailed in industry reports, [CAODC, 2001], average fuel usage per hour ranges between 16 and 17 gallons per hour. We assume a value of 16.5 gallons per hour that results in a daily fuel usage of 5029 litres.

Table 7. Emissions from the Volvo Penta TAD1642 GE engines during drilling of a typical well by a standard rig and a LOC250 rig. For the LOC250 rig, drilling times are assumed to be 5% and 40% less

		LOC250	Standard	Standard
		typical	low	high
Drilling time	days	5.5	5.8	9.2
Fuel consumption	l/day	3360	5029	5029
CO ₂	t/well	42	67	106
NO _x	kg/well	551	868	1374
CO	kg/well	140	220	349
PM	kg/well	12	19	29
SO ₂	kg/well	0	0	0
HC	kg/well	5	8	12

2.3 Emissions due to construction

To be able to compare the total emissions from drilling activities, all main emission sources should be taken into account. Our final source of emissions comes from the rig's construction process. The primary construction material is steel; we only took emissions derived from steel production into account. Emissions arising from the production of other construction materials are negligible.

Table 8 presents energy use and emission factors for the main steel making process – integrated steel plant, scrap-based minimill and direct reduction process. Processes based on scrap produce somewhat less qualitative steel but have generally better environmental performances. We assume here a mixture of required steel from the various steel making processes. Table 9 provides an overview of the results from constructing the rigs for the main polluting gases.

Table 8. Energy use and emission factors for the production of steel for the main steel production processes

		min	max	typical
Integrated steel plant				
Energy use	MJ/kg	18.2	25.1	22
CO2	kg/kg	1.62	2.2	2
Scrap-based minimill				
Energy use	MJ/kg	7.7	12.5	10
CO2	kg/kg	0.56	0.91	1
DR EAF				
Energy use	MJ/kg	21.9	31	26
CO2	kg/kg	1.38	1.97	2
Average emissions				
Energy use	MJ/kg	18	30	24
CO2	g/kg	1500	2100	1800
NOx	g/kg	1.5	3	2
CO	g/kg	25	35	30
PM	g/kg	0	0	0
SO2	g/kg	2	4	3

Table 9. Emissions due to the construction of the LOC250 and standard drilling rigs

		LOC250 typical	Standard low	Standard high
Weight	tonne	475	600	1,000
Energy use	PJ/rig	11	14	24
CO2	t/rig	855	1,080	1,800
NOx	kg/rig	950	1,200	2,000
CO	kg/rig	14,250	18,000	30,000
PM	kg/rig	-	-	-
SO2	kg/rig	1,425	1,800	3,000

2.4 Consolidated emission analysis

In this chapter we assess the emissions resulting by drilling one well from standard drilling rig equipment and from the LOC250. There are many varieties possible in drilling. Including, for instance, depth of the well, hook load, drill string, geology, type of engine and fuel used, and transport distance. We assume all conditions are the same as long as they are not specifically for the LOC250 or standard drilling rigs. Based on these conditions, the total emissions from construction of the rig, transport of the rig and drilling of the well for both type of rigs are summed up and compared.

2.4.1 Assumptions for typical values

Table 10 presents the main assumptions in constructing, transporting and operating the LOC250 and standard drilling rig.

Table 10. Main assumptions for the comparison of emissions from LOC250 and Standard rigs

		LOC250	Standard	Standard
		typical	low	high
Lifetime of rig	years	20	20	20
Weight of rig	tonne	475	600	1000
Steel making process		weighted average of integrated steel making and scrap-based processes		
Type of truck		tractor - Euro-III standards		
Type of ship		conventional container ships		
Transport distance				
<i>over sea</i>	km/year	72000	12000	12000
<i>over land</i>	km/year	24000	12000	12000
Drilling time	days	5.5	5.8	9.2
Engines		Volvo Penta TAD1642		
fuel use engines	l/day	3360	5029	5029
share load of engines				
75% load		60%	60%	60%
50% load		30%	30%	30%
10% load		10%	10%	10%

2.4.2 Results of the comparison

Table 11 presents the emissions that can be attributed by drilling one well for both the LOC250 and the standard drilling rig. The main conclusion is that the LOC250 has emissions 35 to 60% less than a standard drilling operation concerning main air pollutants that consist of carbon dioxide, nitrogen oxide, carbon monoxide, particulate matter and sulphur oxide.

Drilling contributes about 80 to 90% to the total emissions, except for SO₂, where only negligible emissions of SO₂ originate from the engines. The contribution of transport and construction to the total emissions is low and the relative contributions from transport, construction and drilling are comparable to the LOC250 and standard rigs.

Table 11. Emissions from constructing, transporting and operating drilling equipment

		LOC250		Standard (low)		Standard (high)	
Weight	t/well	475		600		1000	
Drilling time	days/well	5.5		5.8		9.2	
			share (%)		share (%)		share (%)

Transport							
CO2 emissions	t/well	4	8%	5	7%	8	7%
NOx emissions	kg/well	41	7%	52	6%	87	6%
CO emissions	kg/well	8	5%	10	4%	17	4%
PM emissions	kg/well	1	11%	2	9%	3	9%
SO2 emissions	kg/well	5	65%	7	65%	11	65%

Drilling							
CO2 emissions	t/well	42	88%	67	90%	106	90%
NOx emissions	kg/well	551	93%	868	94%	1374	94%
CO emissions	kg/well	140	79%	220	83%	349	82%
PM emissions	kg/well	12	89%	19	91%	29	91%
SO2 emissions	kg/well	0	0%	0	0%	0	0%

Construction							
CO2 emissions	t/well	2	4%	2	3%	4	3%
NOx emissions	kg/well	2	0%	2	0%	4	0%
CO emissions	kg/well	29	16%	36	14%	60	14%
PM emissions	kg/well	0	0%	0	0%	0	0%
SO2 emissions	kg/well	3	35%	4	35%	6	35%

			relative to 'Standard high'		relative to 'Standard high'		Standard high
Total							
CO2 emissions	t/well	48	41%	74	63%	118	100%
NOx emissions	kg/well	594	41%	922	63%	1465	100%
CO emissions	kg/well	176	41%	266	63%	426	100%
PM emissions	kg/well	13	41%	20	63%	32	100%
SO2 emissions	kg/well	8	48%	10	60%	17	100%

3 Other environmental circumstances for possible review

This chapter briefly presents other environmental circumstances that could be reviewed in addition to the factors presented in this report. The factors reviewed lie outside of emissions to air.

Notwithstanding the environmental impacts discussed in Chapter 2, a number of other environmental circumstances could be of interest to Huisman-Itrec. An initial remark should be made on the non-operational environmental circumstances of the LOC250. Advantages can be seen in reducing the aural and visual environment the LOC250's mast is also about 38 metres, slightly lower than comparable rig masts of standard oil rigs, and therefore has the potential to reduce horizon pollution.

These aspects are relatively of lesser importance and less qualifiable than other environmental circumstances though. Solid wastes from drilling operations such as cuttings and drilling muds could use a more in-depth review. It has been estimated that the Genesis series has mud losses of about 218 barrels per well while a conventional rig can have a figure many times as high with literature sources quoting typical reductions in mud losses in the 20 to 30% range. Cutting waste contaminated with oil and heavy metals is also expected to be reduced in the LOC250 due to its cascading shaker system and cement use is expected to be reduced by 10 to 20%.

Other operational fluids and contaminants produced in water, such as acids, corrosion inhibitors, radionuclides, and other additives, could prove of interest in comparing the operation the two technologies. Information concerning the tracking of these additives appears relatively easy to secure. This is also of particular interest as the LOC250 is being designed to be "zero discharge capable".

Emissions to air from leaks and from venting of overpressure or from emissions such as methane and nitrogen oxides due to flaring can also play a role. The impact of the LOC250's ability to test blow out preventers could prove for an interesting comparison. Given the high carbon dioxide equivalence for methane, the global warming potential over 100 years for 1 kilogram of methane is equivalent to 23 kilograms of carbon dioxide, losses here could play a significant role in the overall emissions between the two drilling systems.

Finally, the LOC250 is designed to operate with fewer accidents, whether they be on a personnel or material level. Contaminating fluids resulting from accidents such as spills, leaks, and blowouts are expected to be reduced in the LOC250. Pipe and material han-

drilling has been shown to cause 50% of recorded accidents and the LOC250 by design intends to take out the human requirement on the drilling floor.

Although providing a cursory overview, the LOC250 can be shown to offer advantages over standard drilling installations, over and above what can be seen in direct emission calculations. These issues deserve further attention by Huisman-Itrec in comparing the LOC250 to other drilling installation types.

4 Conclusions

Based on various industry sources and feedback from industry experts, the LOC250 carries a number of environmental benefits over a standard drilling installation.

Reviewing emissions from three sources:

1. Emissions related to the transport over a relatively short distances (transport over land) and relatively long distances (transport over sea);
2. Emissions related to energy needs: direct or indirect emissions related to the use of energy during the construction of a well bore;
3. Emissions related to the construction

It should be noted that comparable fuel data figures were not readily available. Industry figures were used to create as conservative an estimate as possible.

Other environmental circumstances that could be useful in comparing the full environmental load of the standard oil drilling installation versus the LOC250 were not reviewed. These additional circumstances could be included in a future study of the environmental impacts of the LOC250, but in general and perhaps more importantly, a more comprehensive conclusion could be drawn with an improvement in data quality. This is particularly true with respect to daily fuel usage as well as engine performance.

Nevertheless, drilling contributes about 80 to 90% to the total emissions, except for SO₂, where only negligible emissions of SO₂ originate from the engines. The contribution of transport and construction to the total emissions is low and the relative contributions from transport, construction and drilling are comparable to the LOC250 and standard rigs.

Overall, the LOC250 can be shown to conservatively emit 35 to 60% less than a standard drilling operation concerning carbon dioxide, nitrogen oxide, carbon monoxide, particulate matter and sulphur oxide.

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