

The Impact of Rig Design and Drilling Methods on the Environmental Impact of Drilling Operations Eric Quinlan, Robert van Kuilenburg (Huisman), Tom Williams (EFD Project), Gerhard Thonhauser (Montan University, Leoben)

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Abstract

Drilling efficiency has been investigated in numerous publications discussing potential improvements in productive, non-productive and invisible lost time. New challenges driven by the development of unconventional gas reservoirs require a continued effort looking deeper into improvement potentials of drilling operations in terms of efficiency, but even more so in environmental compliance and friendliness.

This paper identifies the improvement potential from increasing the energy efficiency of a land rig through design and alternative drilling techniques. Current drilling rigs require the generation of several thousand kilowatts (horsepower) for the rig where only a limited amount of this energy is translated in to rock destruction. Fuel costs are a significant portion of overall daily rig cost. Rigs with less fuel consumption for the same well construction process will not only save cost of fuel but also significantly reduce the environmental impact of drilling operations.

The results presented show differences between a conventional and an energy efficient rig concept and give directions to future improvements in rig design and utilization of rig automation towards improved rig efficiency.

Introduction

The drilling landscape is changing rapidly. Unconventional energy sources, such as shale oil and gas are completely changing the energy landscape. However these opportunities require an enormous amount of wells and are often located in populated or environmentally sensitive locations. Public perception and (un)willingness to accept the consequences of drilling are becoming an important factor. The perception of drilling is fairly negative by the general public as numerous studies have shown, most notably the work of Gene Theodori, Sam Houston State University. The public perception of drilling has also not been helped by the Macondo disaster nor by the film "Gasland". However, public acceptance and support is a key element in order to gain permission to drill in certain areas; this is particularly true in Europe.

It can be expected that the importance of the environmental performance of drilling rigs will grow to be an important decision factor for choosing rigs or even allowing a well program to be executed. Environmentally Friendly Drilling Systems (EFD) has been promoting environmentally friendly drilling for years and has developed the EFD Low Impact Drilling Scorecard which can be used to measure the trade-offs associated with implementing low impact drilling

technology in environmentally sensitive areas. A step further is to analyse the impact that an individual drilling rig can make through its design and operations.

This article will describe how, with careful design, the impact of a drilling rig can be minimized. It will also show that a rig, designed to minimize the environmental impact, can be very efficient even outpacing conventional rigs.

Environmental Impact

Environmental impact can be measured in different ways including air, water, soil, social, and sight pollutions. Various studies have been performed on the LOC 250 & 400 to assess noise, emissions to air, and the effects of the rig design on these forms of pollution.

Emissions

For these series of rigs, air pollution through emissions was investigated by assessing three different activities:

- Construction of the drilling rig;
- Transportation of the drilling rig, and;
- Operation of the drilling rig in different cases
 - Drilling normally
 - Drilling with casing
 - Using the power grid as opposed to diesel driven gen-sets.

The environmental performance of the drilling rigs is assessed in terms of emissions to air (CO₂, NO_x, CO, PM and SO₂).

Emissions of operations while drilling traditionally with drill pipe (DP mode) and operations while drilling with casing (CWD mode) mode are assessed. For other drilling rigs on the market, for basis of comparison, we only included DP mode as the LOC was designed specifically for Casing While Drilling and does not require hiring in extra tools for this form of drilling. Note: The LOC drilling rig is designed to drill efficiently with drill pipe as well.

The standard drilling installation is represented by a 'standard low' and 'standard high' case. Emissions were defined related to construction, transportation and drilling for a typical one year drilling programme consisting of drilling fifteen wells at various locations and the transport of the rig between these locations.

Rig Design

Huisman started the design of the LOC drilling rigs in 2003. After two years of drilling in South Texas the lessons

learned were incorporated in the next generation. The LOC series of rigs are characterized by being fully containerized, and by being highly automated and built to include modern drilling techniques. These modular rigs are also completely electrically driven, electronically controlled, fully integrated and can be scaled in size by adding more containers. It is designed for fast rig moves, and is able to compete globally with local rigs.

The basic specifications of the rig are:

Class	Supersingle	[-]
Modes	Drill Pipe	[-]
	Casing Drilling	[-]
Hookload	400	[sht]
Topdrive	350	[sht]
	600	[hp]
Rotary Table	37.5	[inch]
Pipe Handling	Automatic	[-]
Tank Capacity (expandable)	870	[bbls]
Mud Pumps	3x800	[HP]
Drillfloor	Unmanned	[-]
Number of loads	26 ISO containers	
	7 x 20'	
	19 x 40'	

Construction Emissions

The type of steel used in a drilling rig is low-alloyed steel. Based on the expert information on standard drilling rigs it is estimated that these rigs to be 1.5 – 1.75 times heavier than the modular rig design. Table 1 presents the resulting emission values.

It is evident that due to the smaller weight of the modular design the construction emissions are considerably lower.

Transport Emissions

During its lifetime, a drilling rig is transported frequently. Drilling rigs can be used anywhere around the world, but in practice they are mostly used regionally. Besides the regional transportation between the drilling locations, the drilling rig is first transported from the factory where it is manufactured to the continent or region where it is going to be used. This can include intercontinental transport. For a standard basis of comparison, the manufacturing of the LOC 400 and the other drilling rigs in this study are located in Europe.

Modular design has several advantages:

- small individual units, enabling transport in limited areas (cities, back roads)
- lower weight per unit, less damage to environment, less cost for transport
- containerized design, enabling efficient transport modes (container ship and train), less cost for transport

Once the initial transportation is complete, the rigs will likely stay in one region for most of their lives.

The distances for transportation over land are based on the typical transportation cycles that have been constructed for two different continents based on practical experience. When

needed, the cycles are extended to represent the drilling of fifteen wells at fifteen different locations. For calculation of the emissions the average (un-weighted) distance (1,554 km) is used.

The results for transportation over land show that emissions from truck transport of containerized rigs over an average distance of 1,554 km are significantly less compared to emissions of standard drilling rigs (Figures 2 and 3). For basis of comparison, the LOC 400 was compared with other 350t – 400t drilling rigs operating in the USA and Europe and based on expert advice of people who have worked with these rigs. The results do not reflect a comparison with each individual rig on the market.

Transporting the standard rig 'high' case causes the emissions of more than two times as much CO₂ as containerized rigs. Compared to a diesel passenger car travelling 25,000 km per year, the CO₂ emissions from transporting the containerized rig design by truck is the same as about 8.9 diesel passenger cars. Train transport might be considered for environmentally friendly drilling rigs as an interesting option. In principle one train would be sufficient to transport an entire rig. Transporting the rig with a train would have a significant beneficial effect on the CO₂ emissions (Figure 4).

Rig Operations Emissions

The third source of emissions results from drilling operations. Power is used for the various activities that make up the drilling cycle. A standard drilling cycle consists of many activities, including:

- Standby
- Drilling
- Tripping
- (Back)reaming
- Casing running
- Cementing (although this uses often 3rd party equipment)

Drilling and (back) reaming are the most power intensive activities of the drilling phase, followed by tripping and casing running. In this analysis the drilling time for standard drilling mode (DP) is set to three weeks (500 hours) for both the containerized rig and standard rigs.

The containerized rig is built with an Autodriller function that leads to improved drilling performance. However, due to lack of offset data for the wells drilled and due to lack of data from other similar rigs, it was decided to treat drilling performance as the same between all rigs for this study. It is obvious though, that a reduction on the time spent on the well will also reduce the emissions released while drilling.

Operating in CWD drilling mode involves a number of changes compared to DP drilling mode:

1. total drilling time is reduced by an assumed 30%;
2. the relative importance of activities in total drilling time changes (tripping time reduces from 26% to 10%), and;
3. the mud pumps can run at 50% of their capacity

instead of 80%.

The time required on the well is 350 hours in CWD mode compared to 500 hours for drilling in DP. For this study, we have assumed the mud pumps are operated at 50% of their load instead of 80% in DP mode. The power demand and time for each drilling activity is presented in Table 2. It must be noted that CWD is not suited for drilling all types of wells.

If we look at a period of a year a significant beneficial effect can be seen (Figure 5) if CWD technology is used.

Figure 6 shows that rigs operating in CWD represent the lowest CO₂ emissions of 3.4 kt CO₂ per year, followed by the containerized rig in DP drilling mode (5.8 kt CO₂). The CO₂ emissions for standard drilling rigs 'high' are almost twice the emissions of the LOC 400 in CWD mode. The figure shows that drilling operations have the highest contribution to CO₂ emissions, typically about 96 to 98 percent. CO₂ emissions resulting from the construction process contribute typically between 1 and 2 per cent. The contribution of transport to total CO₂ emissions is between 1 and 2 per cent as well.

Energy from the existing power grid

As an alternative for diesel generators the electricity grid can be used to power the drilling rigs. This will not always be possible as grid connections are not available on all locations. It should also be noted that drilling rigs require high power capacities, which should be arranged beforehand with power suppliers and local utilities. To connect the drilling rig to the grid, a transformer is needed. The advantage of connecting the drilling rig to the grid is that the emission factor of the electricity mix is mostly lower than of dedicated diesel generators. In addition logistical support and impact is decreased since diesel fuel does not have to be delivered to the rig for the generation. This is especially the case for countries that have a significant part of renewable energy in their energy mix.

Based on the information on drilling activities, the electricity demand for drilling one well is about 500 MWh in the DP mode and about 285 MWh in the CWD mode. Note that this varies for each individual well and drilling rig type. The containerized rig is designed for easy conversion to work from the grid, and it can be powered by both 480V 60Hz and 400V 50Hz sources. In order to further benefit working from the power grid, it is important to keep the Total Harmonic Distortion to a minimum in order to minimize potential problems to the grid.

Using electricity from the grid results in around 39% less CO₂ emissions compared to using diesel generators in the Netherlands. CO₂ emissions decrease from 5,751 tons to 3,521 tons of CO₂ for DP drilling and from 3,275 tons to 2,018 tons of CO₂ for CWD drilling in the Netherlands. Should the grid be powered by renewable energy sources (wind, geothermal, solar), the emissions would be reduced to next to zero. This reduction of emissions does not include the emissions that would have been eliminated by not having to supply fuel to the rig site.

Connecting the rig to the power grid also has a significant cost benefit for a typical well. Cost savings for a typical well

can go up to 50% or more on fuel cost with the current energy price mix (Table 3).

The question remains, does it pay to be more energy efficient considering all options the same? An average rig uses 21,000 gal of fuel for a 10 day program. Assuming 30 wells a year and a 10% efficiency gain equates to a savings of 4,700 USD/well or 142,000 USD/year. Theoretically, using casing while drilling and running from the power grid, a savings of 26,000 USD should be feasible. This is more than a day's rig hire in fuel savings per well.

Noise Pollution

The new shift to unconventional energy sources (shale oil, shale gas, geothermal sources) has resulted in more wells being drilled in populated areas. A result of drilling close to houses is that the local population does not allow noisy drilling operations. This has resulted in some areas where rigs are required to be completely housed in (Los Angeles), or requiring temporary sound proofing.

An added benefit to running the rigs off the grid is the reduction of noise as compared to the diesel generators.

For two geothermal wells, drilled in the center of The Hague (the Netherlands), intensive noise studies have been done to evaluate the potential impact of the drilling rig (Figure 8). Due to the nature of the rigs design, most major noise producers are at ground level, including the draw works, with a notable exception being the top drive. To further reduce noise levels, the rig drilled from the local power grid instead of diesel engine/generator sets.

Noise studies were completed according to Dutch Norms, base line measurements were taken and extrapolated to the distance of housing from the worksite. Noise levels had to be kept under 50 dBA within the houses 35m away. These noise studies were completed while working from the generator sets on wells in the center and in the north of the Netherlands (Table 4). 50dBA is the noise equivalent to a quiet street, in comparison 60dB is a normal conversation.

The results have led to the rig requiring minimal sound proofing to deflect the noise caused by the top drive cooling fan (Figure 9). The slim design of the mast has enabled minimal sound proofing to be built and easily installed on the rig.

Site impact

The containerized rig was designed for a minimal location size (Figure 10). Minimizing the location size also minimizes the impact to local ecologies around the drill site. The containerized design also allows for adapting the layout of the rig to its location, and for standard truck transportation. This leads to smaller access roads on top of minimizing the location size.

The footprint of the rig is approximately 49ft by 197ft, but can be adapted to specific constraints caused by geography, housing, etc.

Conclusions

It can be expected that the importance of the environmental performance of drilling rigs will grow to be an important decision factor for choosing rigs or even allowing a well program to be executed. Through careful design, the environmental impact of a drilling rig can be minimized while still maintaining high drilling performance.

Through the design of a drilling rig, the following environmental improvements can be achieved compared to the use of more traditional equipment:

1. Lower carbon foot print through
 - Containerization
 - Quick rig moves
 - Less time on well (improved drilling performance)
 - Casing drilling
 - Ability to work from the grid, which can be run from renewable resources
2. Noise mitigated through:
 - Main noise producers at ground level
 - Ability to work from main power grid
 - Sound wall around site and on mast and top drive
 - Horizontal setback of drill pipe

It has also been shown that a more efficient and environmentally friendly rig design can be significantly cheaper to operate in terms of fuel costs than standard rigs.

The data presented as a theoretical study will be followed up and compared to practical analysis to further target improvements for improving both drilling and practical performance. Examples of programs already in place are the evaluation of natural gas powered generators, and on mud system design.

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they make it all happen.

References

1. Theodori, Gene L., Jackson-Smith, Douglas “Public Perception of the Oil and Gas Industry: The Good, the Bad and The Ugly”, SPE 134253.
2. Visser, Erika de, Noothout, Paul, Hendricks, Chris “Environmental Performance of the LOC 400 Drilling Rig”
3. Hendricks, Chris, Janzic, Robert, “Environmental Impact of Standard Oil Drilling Installations vs. the LOC 250”
4. EFD Program (<http://www.efdsystems.org/>)
5. Diesel Service and Supply – Fuel Consumption Chart

6. <http://www.energy.eu/#Industrial> – Electric Energy Prices Europe
7. <http://www.eia.doe.gov/> - Electric Energy Prices US
8. <http://www.eia.doe.gov/emeu/> - Diesel Prices EU/US

Tables

Table 1:
Emissions (in t/rig) for the LOC400 and standard drilling rigs²

Emissions	Unit	LOC 400	Standard (low)	Standard (high)
CO ₂	t/riq	1027	1540	1797
NO _x	t/riq	3	4.5	5.2
CO	t/riq	17.3	25.9	30.2
PM	t/riq	2	3	3.5
SO ₂	t/riq	2.7	4	4.6

Table 2:
Power demand (in % of maximum power demand) and time per activity²

Activity	Power demand DP drilling (in kW)	Time needed on DP drilling (%)	Power demand CWD (in kW)	Time needed on CWD (%)
Drilling	1839	0.32	1359	0.35
Tripping	948	0.26	948	0.1
(Back)reaming	2187	0.01	1707	0.04
Cementing	173	0.05	173	0.08
Casing running	904	0.08	904	0.11
Stand-by	173	0.28	173	0.32
Total		100% (500 hrs)		100% (350 hrs)

Table 3:
Cost savings for a typical well (USD)

Power	DP			CWD			Fuel	DP	CWD	
	[-]	[hrs]	[kWh]	[-]	[hrs]	[kWh]	[gal/kWh]	[gal]	[gal]	
75%	33%	165	82500				0.069	5731	0	
50%				39%	137	55185	0.073	0	4017	
25%	34%	170	85000	21%	0.74	29715	0.086	7344	2567	
10%	33%	165	82500	40%	1.4	56600	0.095	7838	5377	
		kWh	250000			kWh	141500		20913	11962
							[usd/gal]	[usd]	[usd]	
DIESEL		US				2.26	47,000	27,000		
		EU				7	146,000	84,000		
							[cent/kWh]	[usd]	[usd]	
ELECTRICITY		US				15	38,000	21,000		
		EU				24	60,000	34,000		
Delta - Diesel/Elec		US					81%	78%		
		EU					41%	40%		
Max Difference (CWD/ELECTRIC)							US	45%		
							EU	23%		

1	RIG UP AND TEAR DOWN	43.1	(L _{Aeq} , dB(A))
2	DRILL ACTUAL	46.2	(L _{Aeq} , dB(A))
3	REAMING	45.3	(L _{Aeq} , dB(A))
4	CORING	-	(L _{Aeq} , dB(A))
5	CONDITIONING MUD & CIRCULATE	44.7	(L _{Aeq} , dB(A))
6	TRIPS	44.9	(L _{Aeq} , dB(A))
7	LUBRICATE RIG	-	(L _{Aeq} , dB(A))
8	REPAIR RIG	43.8	(L _{Aeq} , dB(A))
9	CUT OFF DRILLING LINE	-	(L _{Aeq} , dB(A))
10	DEVIATION SURVEY	-	(L _{Aeq} , dB(A))
11	WIRE LINE LOSS	43.2	(L _{Aeq} , dB(A))
12	RUN CASING & CEMENT	45.5	(L _{Aeq} , dB(A))
13	WAIT ON CEMENT	44.3	(L _{Aeq} , dB(A))
14	NIFFLE UP & O.P.	44.7	(L _{Aeq} , dB(A))
15	TEST B.O.P.	43.8	(L _{Aeq} , dB(A))
16	DRILL STEM TEST	-	(L _{Aeq} , dB(A))
17	PLUG BACK	-	(L _{Aeq} , dB(A))
18	GRABBER TEST	-	(L _{Aeq} , dB(A))
19	FISHING	-	(L _{Aeq} , dB(A))
20	CIP WORK	-	(L _{Aeq} , dB(A))
21		43.1	(L _{Aeq} , dB(A))
22		44.5	(L _{Aeq} , dB(A))
23		43.8	(L _{Aeq} , dB(A))

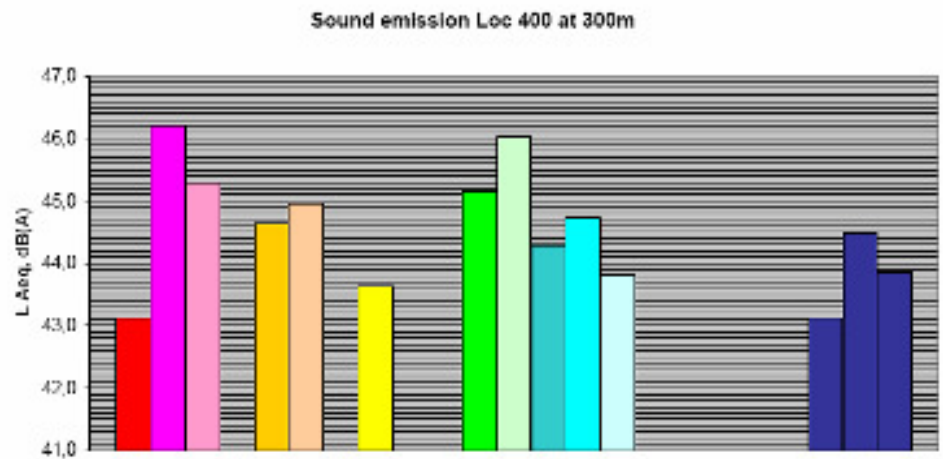


Table 4: Noise profile of the LOC 400 drilling rig at 300m

Figures



Figure 1: LOC 400 drilling rig on location in the Netherlands

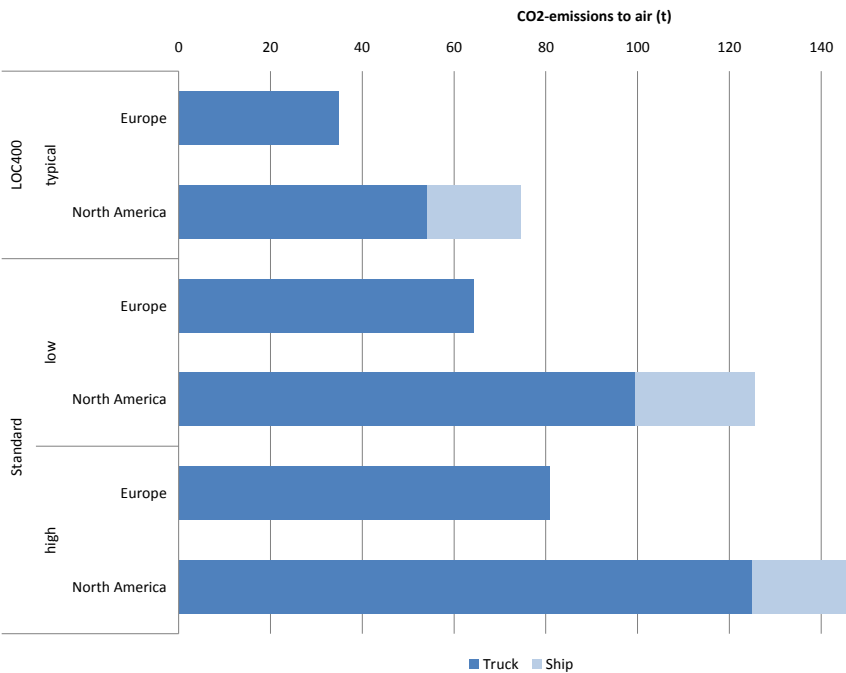
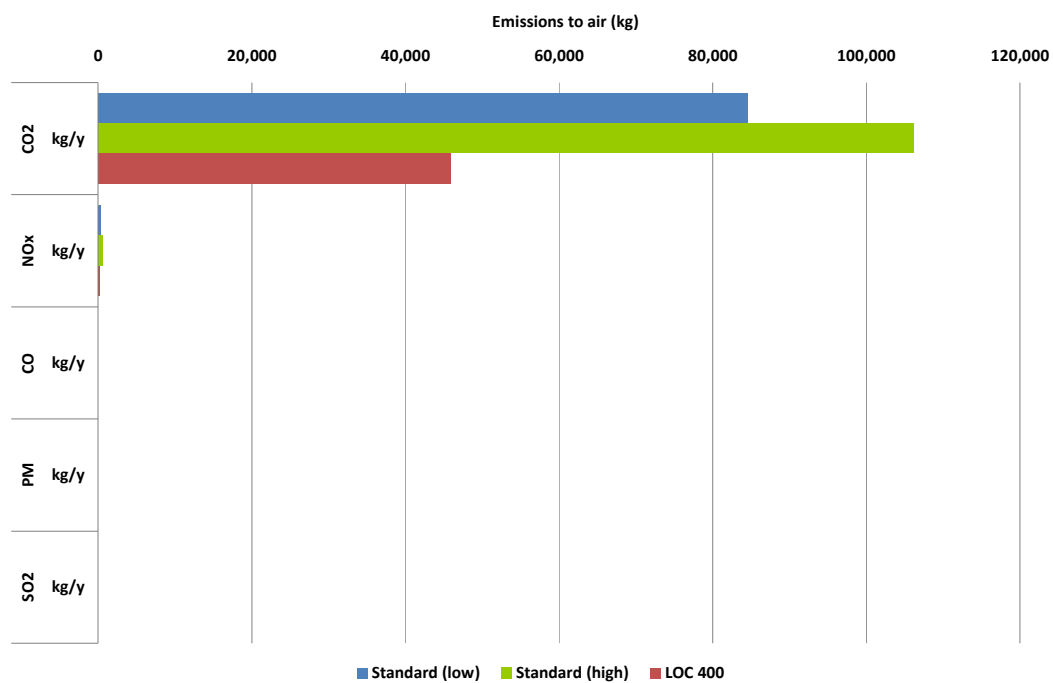
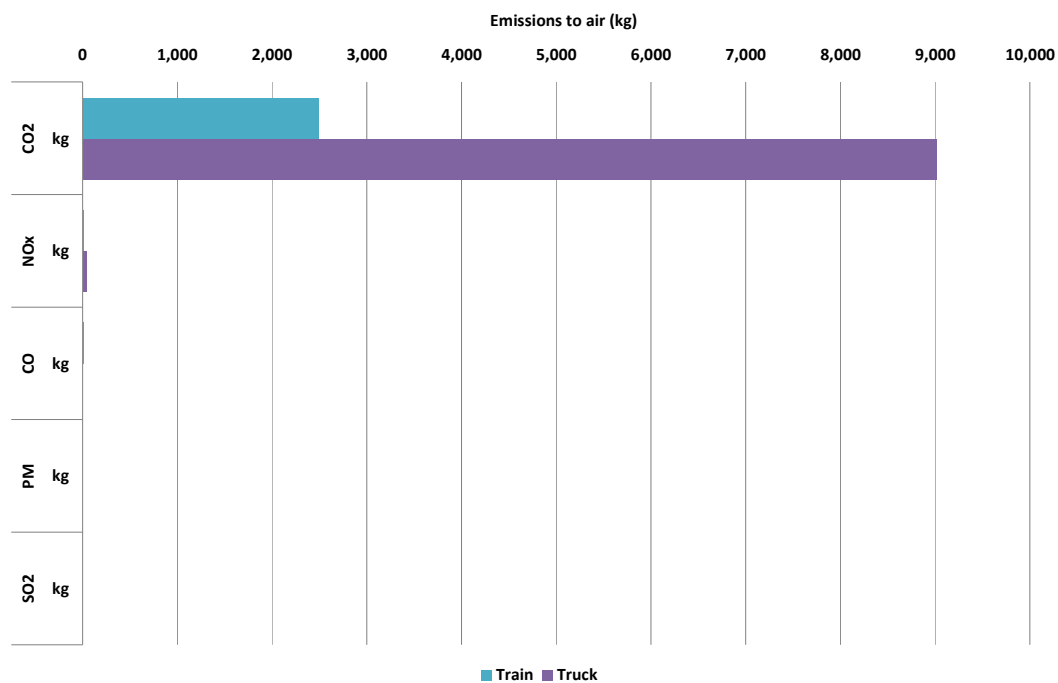


Figure 2: CO2 emissions (in kg) from initial transport from Europe & North America²

Figure 3: Emissions to air from truck transport (in kg/year)²Figure 4: Emissions of transporting the LOC400 by truck and train (in kg)²

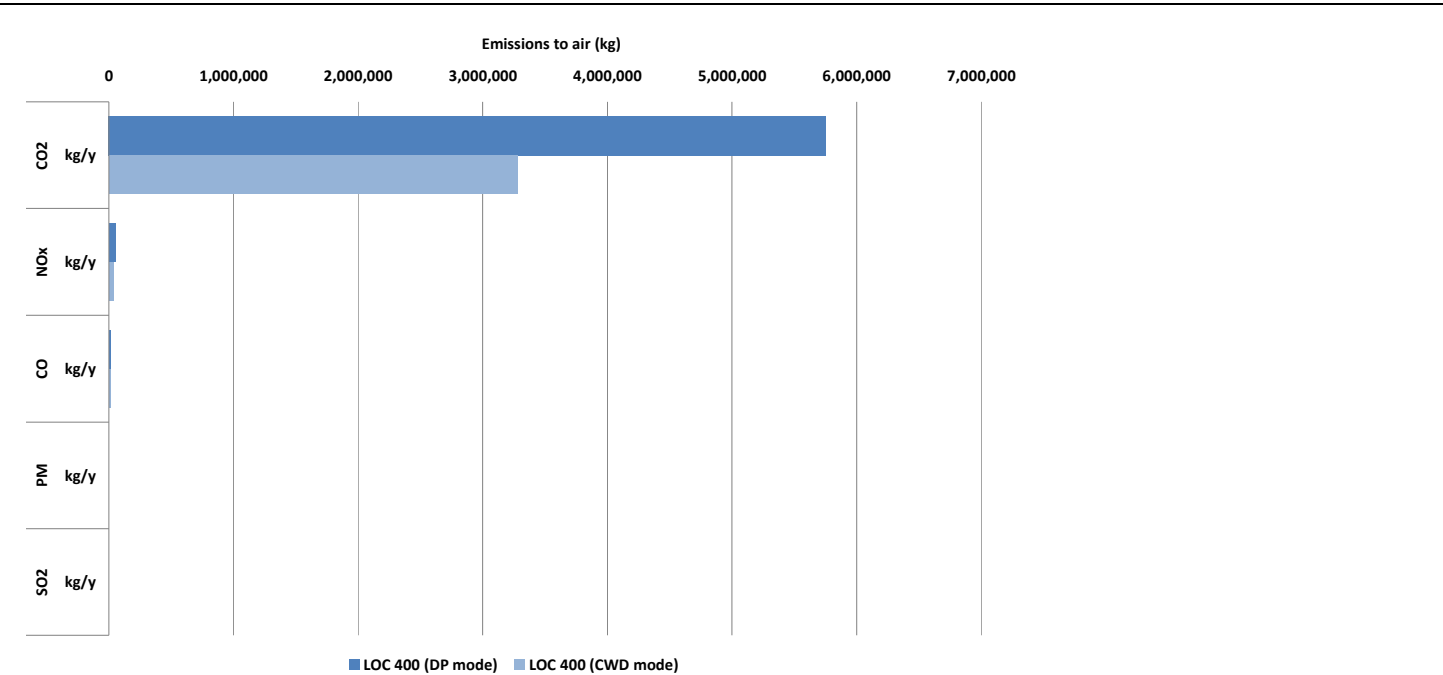


Figure 5: Emissions from drilling operations (in kg/y)²

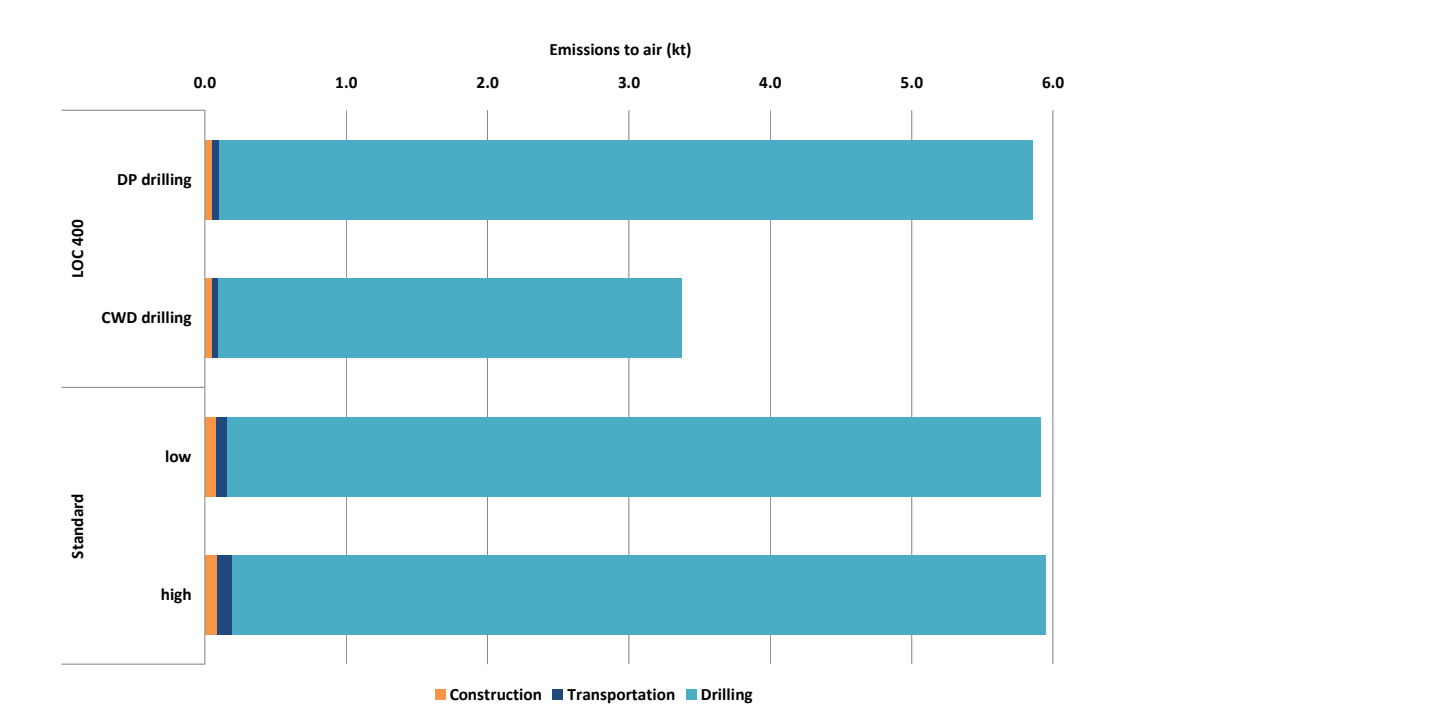


Figure 6: CO₂ emissions of a one year drilling program, generator powered (in kt/year)²

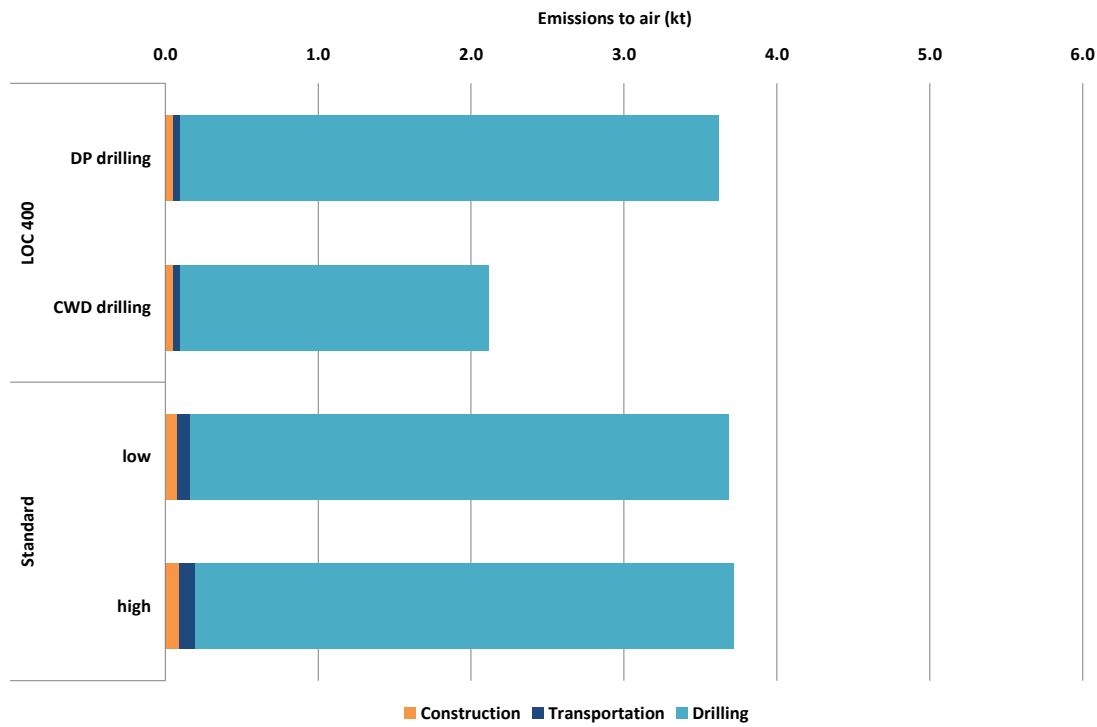


Figure 7: CO₂ emissions of a one year drilling program, grid powered (in kt/y)²



Figure 8, Well location in the Hague – Large building on the left is a hospital



Figure 9: Sound protection on the rig.



Figure 10: Drilling in a densely populated location with minimal impact.