TEST REPORT

Liebherr LB 16 unplugged vs. Liebherr LB 16

The progressive effects of climate change require a fundamental and timely re-orientation. Politics and industry in particular are expected to develop solutions that can contribute to significant reductions in CO_2 emissions. Regarding the traffic amount the automobile industry took a pioneering role some years ago and started to change their fleets by an increasing number of vehicles with alternative powertrains. Manufacturers of construction machinery are aware no longer to miss out of taking part in this process. For example, research found out that a single 14-ton Diesel excavator emits 32 tons of CO_2 per year. An air passenger can travel a distance like from Munich to Berlin by aircraft 150 times to cause a similar emission (www.traktuell.at).

Particularly the foundation business can contribute quite a lot to carbon emissions reduction as it is a mainly machinery-dependent work by its very nature. That reason for manufacturers of, for instance, drilling rigs can play an important role in the development of battery-powered machinery and stepping into the market in addition to conventional powertrain technologies. Simultaneously, future-oriented foundation companies will be interested in the performance of an electric drilling rig in direct comparison to its conventional diesel counterpart.

Therefore, a performance test on a foundation construction site in Weiden, Germany provided crucial information. In August 2022, the battery-powered drilling rig Liebherr LB 16 Unplugged has been sent into a competition with an identical, but diesel-powered Liebherr LB 16. To ensure comparability of the obtained data, both rigs had to perform half of the specified tasks under identical conditions, i. e. the same soil, the same drilling depth, the same drilling tools and the same equipment operator.

Liebherr LB 16 unplugged

Liebherr LB 16

The test focused on identifying the performance as well as the economic efficiency of both rigs under the conditions of a real-life construction site.

For this purpose, the following aspects of the two machines have been taken into account:

- Battery management
- Drilling performance
- Economy
- Energy consumption
- CO_2 balance
- Heat emission
- Noise pollution

Construction Site Data

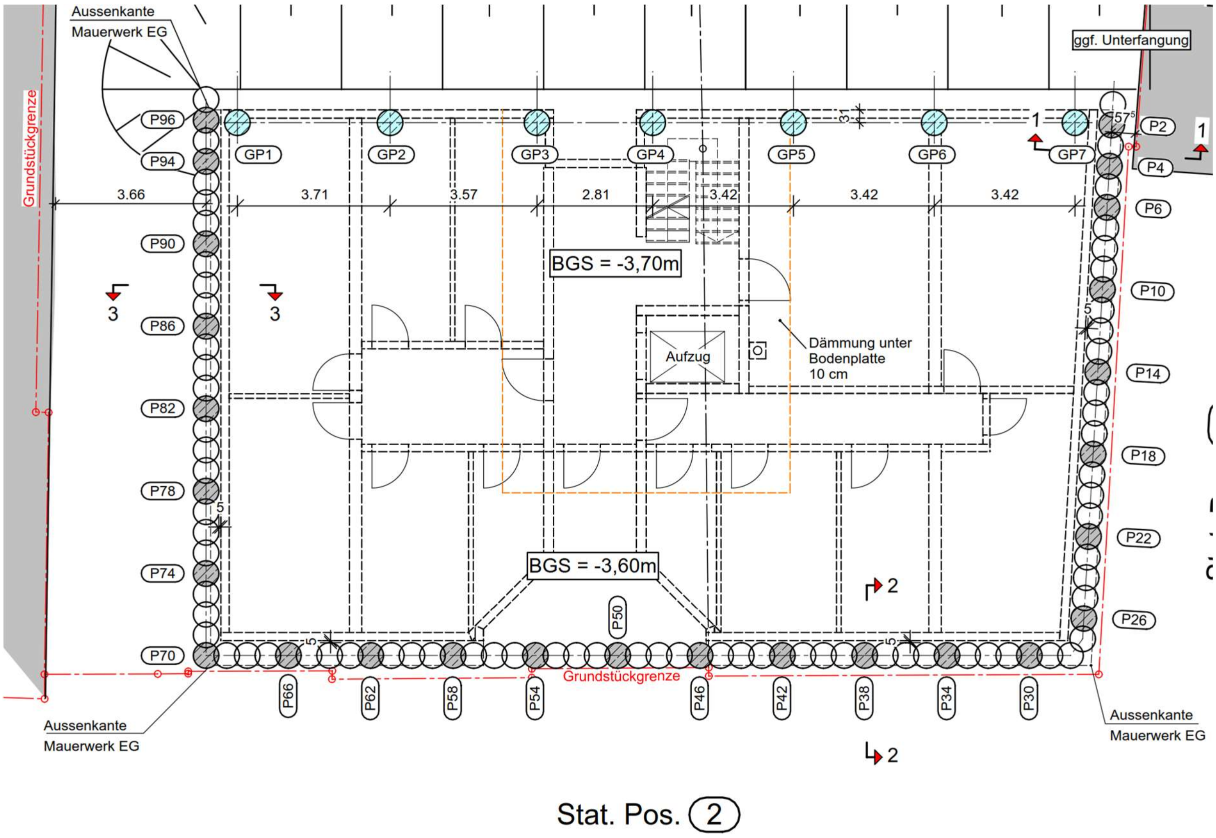
Construction Site: Weiden, Germany

Project: Office & Residential Building

Investor: ADAC Nordbayern e.V.

Assignment: Secant Pile Wall; Pile Diameter 620mm (2ft), Depth 6.80m (22.3ft)

Ground-plan:



Ø620/500, 1-3-1 System

Diameter 2ft / Distance 1.64ft; 1-3-1 System

Fig. Ground plan

Source: MKIngenieure im Bauwesen GmbH, Regensburg

Ground Profile (Depth in meters):

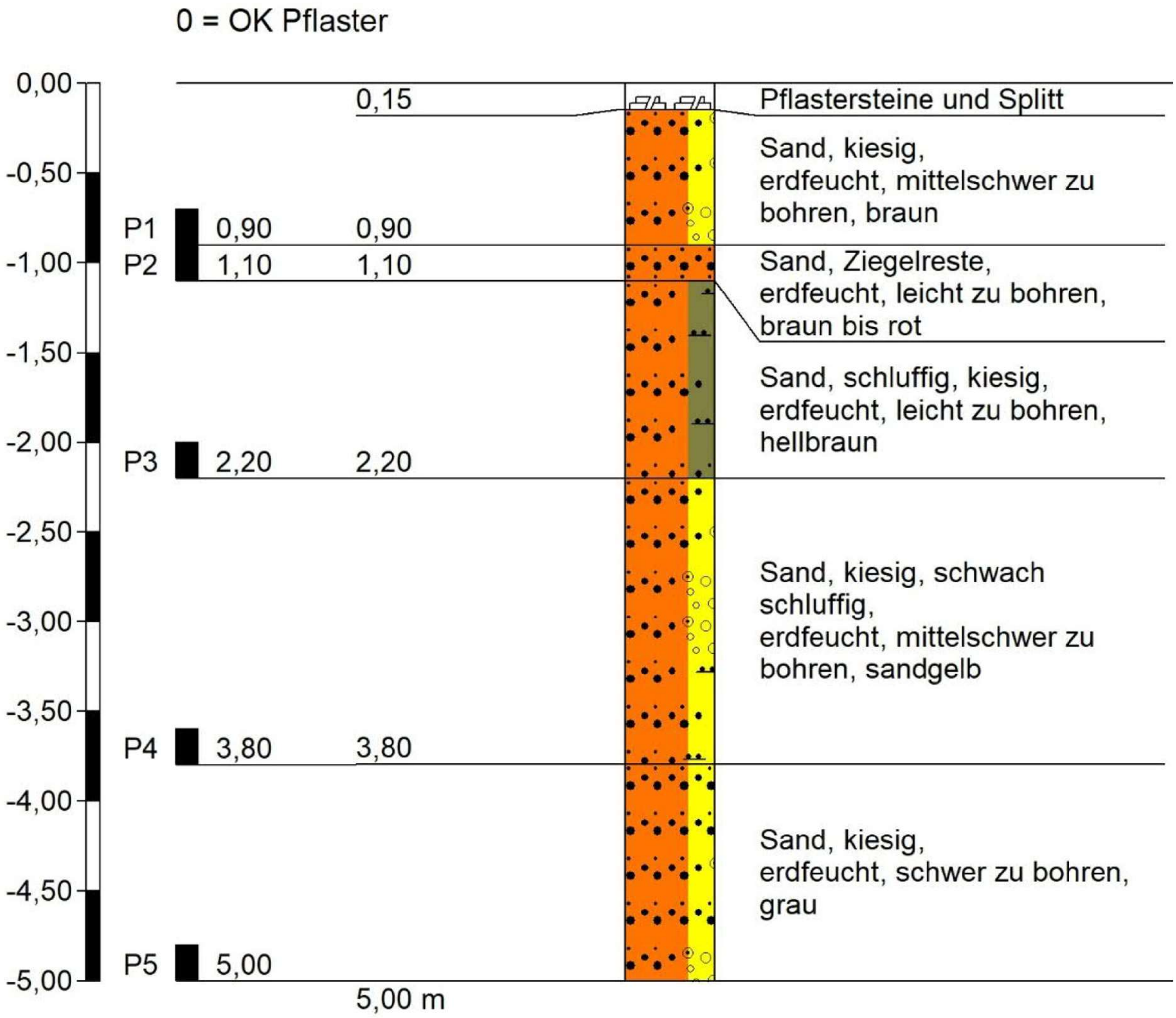


Fig. Ground Profile

Source: Institut Dr.-Ing. Gauer Ingenieurgesellschaft mbH, Regenstauf

Maschinery Data

	Liebherr LB 16 Unplugged	Liebherr LB 16
Performance	265 kW (Top Performance)	ISO 9249, 230 kW (313 PS) bei 1700 U/min
Drive Train	High Performance Battery System	Diesel Engine Liebherr D 944 A7-04
Emission Certification		EPA/CARB Tier 4f
Charging Power	20 kW CEE- Socket 32 A/400V AC 40 kW CEE- Socket 63 A/400V AC 80 kW CEE- Socket 125 A/400V AC	
Voltageng	400 V AC (3-phasig + N + PE)	

Fig. Maschinery Data

Testing Procedure

To ensure comparability both devices were to drill piles with a depth of 6.8m (22.3ft) using the Kelly drilling method.

One single working cycle included:

1. Drilling 2 pile holes of 6.8m (22.3ft) each
2. Pouring concrete up to ground level
3. Dragging of casings

Since a power supply 125 A/400 V AC unfortunately was not available on site the LB 16 Unplugged had to be charged with 63 A/400V AC instead. The rig was connected to the mains every day after the end of a shift and charged until the shift's start at the next morning. This was to ensure that the Liebherr LB 16 Unplugged was ready to be used for a full work day without additional loading operations.

Correspondingly the Liebherr LB 16 diesel rig was re-fueled daily after a shift's end up to the maximum tank level.

The following data was recorded to allow conclusions about drilling performance, profitability, CO_2 balance, battery management, heat emission and noise pollution:

Date, outside temperature & weather, pile number, battery charge (at the start of drilling), battery charge (at the end of drilling), battery consumption in percent and KWh, consumption per drilling meter, temperature of battery-pack, air conditioning, start time of drilling, end time concreting, production time, total working time.

Battery Management

Battery life Liebherr LB 16 unplugged:

According to the manufacturer's specifications, the rig with a fully charged battery is supposed to provide an operating time of up to 10 hours. Unfortunately, this goal has not been achieved. The test operators rather determined an average battery durability of 7 working hours per shift (see table).

Date	18.07.2022	18.07.2022	18.07.2022	18.07.2022	18.07.2022
Outside Temperature	17 °C	24 °C	27 °C	28 °C	29 °C
Weather	Sunny	Sunny	Sunny	Sunny	Sunny
Pile number	87/71	92/75	79/96	83/69	73/90
Battery Charge (Start)	98 %	80 %	64 %	45 %	29 %
Battery Charge (End of concreting)	80 %	64 %	45 %	29 %	7 %
Battery Consumption	18 %	16 %	19 %	16 %	22 %
Consumption at 100 %=560 kWh	108 kWh	96 kWh	114 kWh	96 kWh	132 kWh
Consumption per Drilled Meter	7,94 kWh	7,06 kWh	8,38 kWh	7,06 kWh	9,71 kWh
Battery-Pack Temperature	20 °C	27 °C	29 °C	29 °C	29 °C
AC ON/OFF	OFF	OFF	ON	ON	ON
Start time Drilling	7:00	10:22	11:40	13:35	14:48
End time Concreting	8:26	11:40	13:00	14:48	16:32
Production duration	1 h 26 min	1 h 18 min	1 h 20 min	1 h 13 min	1 h 44 min
Total time of Shift	7 Hours				

Abb. Tabelle Dokumentation

Ladedauer Liebherr LB 16 unplugged:

The average charging time for the Liebherr LB 16 Unplugged in this practical test was 14.5 hours. The reason for this non-specific long charging time was the insufficient power output of the existing 63A/400V AC electricity supply, while a 125A supply actually was required. Consequently, even the long charging time of some days hasn’t been sufficient to fill up the battery pack to a level of more than 95%. Accordingly, a charging time of 15.5 hours must be anticipated for a power supply of only 63A/400V AC.

	11.07.2022	14.07.2022	18.07.20222	18.07.2022	19.07.2022
Battery display Start of Charging	91 %	35 %	7 %	18 %	5 %
Battery display End of Charging	100 %	98 %	94 %	21 %	35 %
Start Time of Charging	14:30	16:15	16:32	12:45	14:30
End Time of Charging	16:30	7:00 - 15.07.22	7:00 - 19.07.22	13:15	7:00 - 20.07.22
Duration	2 h	14 h 45 min	14 h 28 min	30 min	16 h 30 min
Meter Reading Start of Charging	570 kWh	654 kWh	1150 kWh	1749 kWh	1771 kWh
Meter Reading End of Charging	651 kWh	1150 kWh	1749 kWh	1771 kWh	2329 kWh
Charged kWh	81 kWh	496 kWh	599 kWh	22 kWh	558 kWh

Fig. Charging duration LB 16 Unplugged

In the night of July 19 to July 20 a malfunction of the battery management occured. As a result, only one battery pack was charged. After a reset by the remote access on the charging control, the device could have been charged regularly again.

Drilling Performance

Liebherr LB 16 Unplugged:

Based on the reported data an average output of 68 drilling meters (223ft) per shift was recorded for the Liebherr LB 16 Unplugged thus a worse performance as its counterpart. This is very likely due to the limited capacity of the battery during the test period (see tables illustration daily output Liebherr LB 16 unplugged / illustration daily output Liebherr LB 16).

Date	Pile Number	Start Drilling	End Concreting	Duration	Drilled Meters	Performance
18.07.2022	87/71	7:00	8:26	1 h 26 min	13,6 m	9,51 m/h
18.07.2022	92/75	10:22	11:40	1 h 18 min	13,6 m	10,46 m/h
18.07.2022	79/96	11:40	13:00	1 h 20 min	13,6 m	10,23 m/h
18.07.2022	83/69	13:35	14:48	1 h 13 min	13,6 m	11,15 m/h
18.07.2022	90/73	14:48	16:32	1 h 44 min	13,6 m	7,86 m/h
The Meter reading stated a 7% battery load at shift's end. Proceeding with cable-connection was impossible.						
Total Working Time				7 h 1 min		
Performance per Day					68,0 m	
Average Performance						9,84 m/h
Average Time of Production				1 h 24 min		

Fig. Performance Liebherr LB 16 Unplugged

Between the production process of pile 82/71 and 92/75 a leakage on the hydraulic quick-coupler had to be repaired..

Liebherr LB 16:

On the contrary, the conventional Liebherr LB 16 performed 81.6 drilling meters (268ft) in average (figure drilling performance Liebherr LB 16). In comparison, the diesel device is therefore quite clearly ahead of its electrically powered competitor Liebherr LB 16 unplugged with a drilling capacity of about 17%.

Date	Pile Number	Start Drilling	End Concreting	Duration	Drilled Meters	Performance
26.07.2022	27/49	7:00	8:27	1 h 27 min	13,6 m	9,37 m/h
26.07.2022	41/45	8:50	9:53	1 h 3 min	13,6 m	12,95 m/h
26.07.2022	33/37	10:04	11:02	58 min	13,6 m	14,16 m/h
26.07.2022	58/62	11:22	12:48	1 h 26 min	13,6 m	9,51 m/h
26.07.2022	29/54	13:52	15:12	1 h 20 min	13,6 m	10,23 m/h
26.07.2022	56/60	15:28	16:32	1 h 4 min	13,6 m	12,83 m/h
Total Working Time				7 h 18 min		
Performance per Day					81,6 m	
Average Performance						11,50 m/h
Average Time of Production				1 h 13 min		

Fig. Performance Liebherr LB 16

Profilability

One of the most important aspects for the decision between the emission-free machine and its conventional counterpart is cost-effectiveness. A first indication of this is provided by the operating costs based on the determined daily outputs (Figure Liebherr LB 16 unplugged economy / Figure Liebherr LB 16 profitability). The factors 'purchase' and 'maintenance' have not been taken into account.

Liebherr LB 16 Unplugged:

Date	Drilled Meters per Day	Loaded Energy per Day	Energy Consump. per Drilled Meter	Cost per Day at 0,35 €/kWh	Cost per Drilled Meter at 0,35 €/kWh
14.07.2022	54,4 m	496 kWh	9,12 kWh	173,60 €	3,19 €
18.07.2022	68,0 m	621 kWh	9,13 kWh	217,35 €	3,20 €
19.07.2022	54,4 m	558 kWh	10,26 kWh	195,30 €	3,59 €

Fig. Liebherr LB 16 Unplugged Profitability

As a Battery Management fault occured on 19.07.2022 the day has not been counted.

Liebherr LB 16:

Date	Drilled Meters per Day	Diesel Consump. per Day	Diesel Consump. per Drilled Meter	Cost per Day at 1,75 €/Liter	Cost per Drilled Meter at 1,75 €/Liter
25.07.2022	81,6 m	201 l	2,46 l	351,75 €	4,31 €
26.07.2022	81,6 m	210 l	2,57 l	367,50 €	4,50 €
27.07.2022	68,0 m	194 l	2,85 l	339,50 €	4,99 €

Fig. Liebherr LB 16 Profitability

The figures based on drilled meters indicate that the Liebherr LB 16 Unplugged is by 27% more economical than the diesel-powered drilling rig. Though the daily output is lower compared to its diesel counterpart the electricity-diesel ratio relativizes this fact.

At this point, it should be kept in mind that the basis of this comparative figure are solely regional prices for electricity and diesel at the time of testing. The purchase prices for diesel in Germany are subject to considerable fluctuations almost daily, which makes it difficult to determine this comparative value even in the medium term. However, this comparison is sufficient as a tendentious proof of an economic advantage of the battery-powered Liebherr LB 16 unplugged.

CO_2 Balance

The balance of CO_2 emissions is evaluated according to § 42 EnWG (Energy Industry Act).

With reference to the electricity mix factor, which is regarded as standard in Germany, an average CO_2 emission of approx. 4.61 kg per drilling meter has been calculated for the Liebherr LB 16 Unplugged (Fig. Liebherr LB 16 Unplugged CO_2).
The average CO_2 emissions of the Liebherr LB 16 with diesel drive were approx. 8.27 kg per meter drilled (Fig. Liebherr LB 16 CO_2). Thus, a reduction of approx. 44 % CO_2 is possible.

Liebherr LB 16 Unplugged

Date	Drill Meters per Day	Energy Consump. per Day	Energy consump. per drilled meter	CO_2 in kg Green Energy*	CO_2 in kg Electricity-Mix**	CO_2 in kg per Drill Meter***
14.07.2022	54,4 m	496 kWh	9,12 kWh	16,86 kg	240,56 kg	4,42 kg
18.07.2022	68,0 m	621 kWh	9,13 kWh	21,11 kg	301,19 kg	4,43 kg
19.07.2022	54,4 m	558 kWh	10,26 kWh	18,97 kg	270,63 kg	4,98 kg

Fig. Liebherr LB 16 Unplugged CO_2

Liebherr LB 16

Date	Drill Meters per Day	Diesel Consumption per Day	Diesel consump. per drilled meter	CO_2 in kg Per Day	CO_2 in kg per Drill Meter
25.07.2022	81,6 m	201 l	2,46 l	633,15 kg	7,75 kg
26.07.2022	81,6 m	210 l	2,57 l	661,50 kg	8,10 kg
27.07.2022	68,0 m	194 l	2,58 l	611,10 kg	8,98 kg

Fig. Liebherr LB 16 CO_2

Comparison of average figures

	Liebherr LB 16	Liebherr LB 16 Unplugged	Savings
CO_2 Total	1905,75 kg CO_2	812,38 kg CO_2	1093,38 kg CO_2
CO_2 per Drilled Meter	8,27 kg CO_2	4,61 kg CO_2	3,66 kg CO_2

Fig. Direct Comparison

* Green Energy (German: Grünstrom) is no own power generation, thus approx. 34 g/kWh incur for the upstream chain
** Electricity-Mix (German: Strom-Mix) in Germany consists of generation including preliminary work (§42 EnWG)
*** Assumption Electricity-Mix, as this is most likely for construction sites: 3.15 kg CO_2 per Liter Diesel:

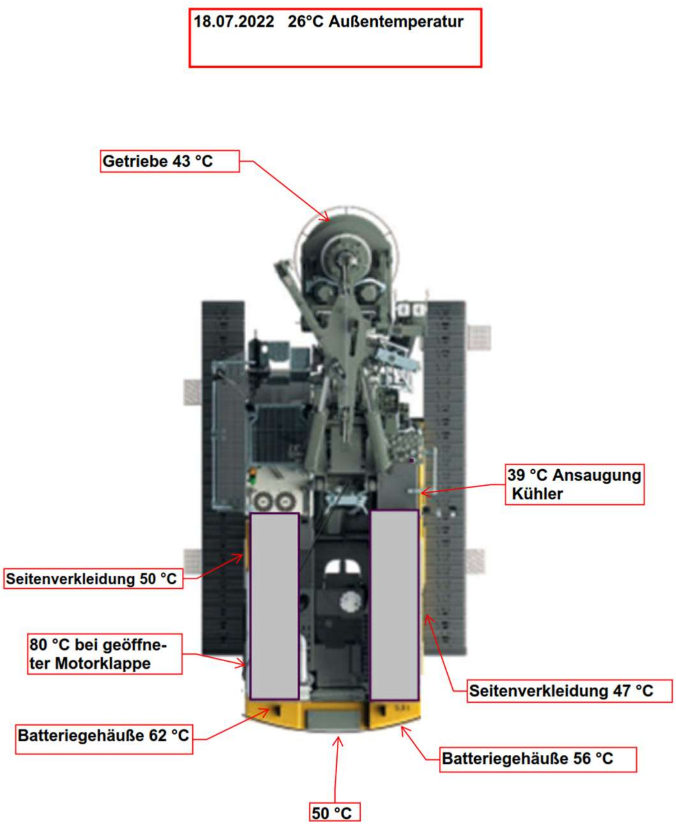
Heat Emission

Both drilling rigs generate more or less thermal energy. To enable a correct determination of the disparities, two independent measurements were conducted for each machine involving a handheld and a drone both with thermal imaging cameras.
As expected, measurements showed significant deviations between the two machines. As a result, a significantly higher emission of heat energy from the Liebherr LB 16 was determined (fig. heat emission).

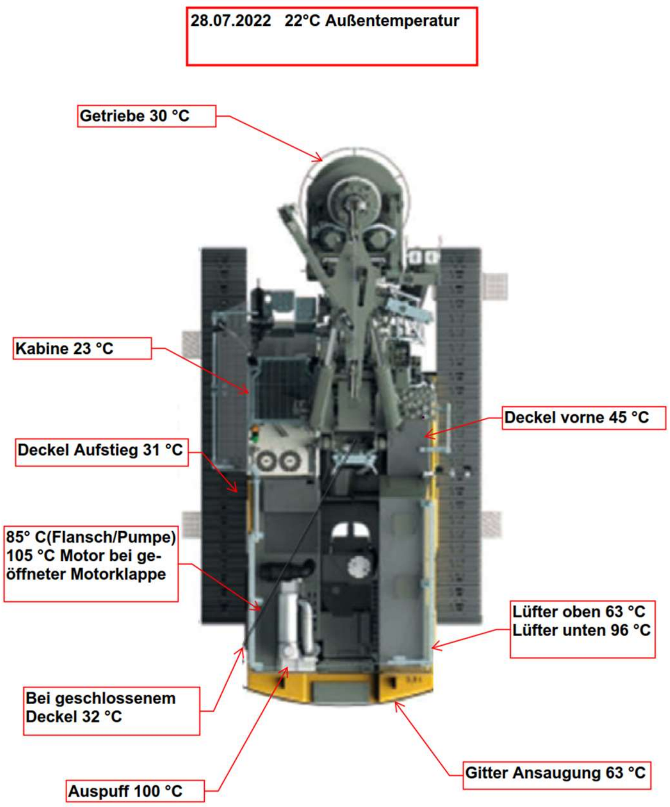
Liebherr LB 16 unplugged	Difference	Liebherr LB 16
Fan 66 °C	30,5 %	Fan 95 °C
Engine 80 °C	23,8 %	Engine 105 °C
Upper Carriage 53 °C	18,9 %	Upper Carriage 43 °C
		Exaust 100 °C

Fig. Heat Emission

Liebherr LB 16 unplugged:



Liebherr LB 16:



Noise Pollution

Due to the basically different drive trains the Liebherr LB 16 Unplugged most likely is less noisy than the diesel rig. Any other result would surprise. Indeed, this expectation was confirmed by measurements. It was found out that the Liebherr LB 16 Unplugged works with an average of 3 db(A) lower noise emission than the Liebherr LB 16 (illustration Liebherr LB 16 Unplugged/LB 16 noise level) during machine operation. This means that the diesel-powered rig generates twice the noise level compared to the battery-powered LB 16 Unplugged.
Operation noise such as cleaning the auger can be ignored, as these occur with both machines.

If official regulations for inner-city construction sites require adherence to certain noise levels a battery-powered drilling rig will meet such requirements much easier than its conventional counterpart. This goes as well for restrictions on working times with regard to noise pollution and might result in a higher drilling performance for the battery machine.

Activity		**Liebherr LB 16 Unplugged**	**Liebherr LB 16**
Machine Operation		104 dB(A)	107 dB(A)
Auger Cleaning		109 dB(A)	110 dB(A)
Casing pull-out		101 dB(A)	104 dB(A)

Fig. Liebherr LB16 Unplugged/LB16 Noise Level

Conclusion

The Liebherr LB 16 Unplugged drilling rig is a very powerful machine for inner-city construction sites. Due to the low noise emission, it shows its advantage over a diesel-powered machine.
The downside of the Unplugged drilling rig is its limited working time of about 7 hours if no intermediate charge is applied. Energy consumption, however, is at least 27% less and heat emission about 25% less than with the diesel rig.
Further research needs to determine additional facts such as the service life of the batteries as no data on long-term use is yet assessable.