Guidelines for Onshore Repowering in Germany

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Abstract

Wind energy plays a major role among renewable energies. Its expansion is therefore important in order to achieve the climate targets. Repowering is an important element in the expansion of wind energy. On the one hand, it offers a solution for many wind turbines in Germany that are no longer subsidised due to their age. On the other hand, modern turbines are significantly more powerful and enable more efficient land utilisation. This article provides an overview of the most important aspects of onshore repowering.

There is a lot to consider when repowering wind turbines. The legal situation for repowering aims to be improved through simplified authorisation procedures. Even though efforts are being made by the government, there is still room for improvement. The repowering potential is also dependent on the various distance regulations to residential buildings in the federal states. These regulations might also be improved in the future. Another aspect is the remuneration, which is now closer to market developments due to the market premium model. It is also subject to greater competition as a result of the tendering process. At the same time, interest rates and turbine prices have risen, which creates economic challenges for the operators of future wind farms. Last but not least, repowering also depends on public acceptance. This is also to be regulated by law in the future.

Keywords: Onshore repowering, simplified authorisation procedure, distance regulations, market premium model, tendering, inflation, public participation,

1 Introduction

To achieve the set climate protection targets, it is important to accelerate the expansion of renewable energies [1]. Wind energy plays a key role in this with a share of 25 % of the renewable energy supply in 2022 [2].

Wind turbines in Germany receive remuneration for 20 years [§25 EEG 2023]. As can be seen in Figure 1, many wind turbines are in the final years of subsidisation or have already been phased out. Operators of such plants must weigh up whether they want to continue operating the plants without remuneration (if technically possible). Old turbines also often cause the highest maintenance costs in the final years of operation, which is why repowering can be a better alternative.

Repowering means replacing outdated, low-performance and low-yield wind turbines with modern ones. The construction of new turbines has many advantages. Modern turbines are now being erected with outputs of 4-7 MW and achieve higher yields. Good wind farm sites can therefore be utilised more efficiently. In addition, the appropriate infrastructure is already in place from the old plants. [4–6]

This paper aims to provide an overview of the relevant aspects that currently need to be considered regarding the repowering of onshore wind turbines in Germany.

2 Legal regulations

Wind turbines with a total height of over 50 metres are approved under the Federal Immission Control Act (BImSchG) [§2 4. Federal Immission Control Ordinance (BImSchV)]. The requirements for the authorisation of repowering projects are described in the BImSchG and the Federal Nature Conservation Act (BNatSchG).

2.1 Federal Immission Control Act / BImSchG

The BImSchG regulates the requirements for repowering in §16b. This is a modification of the authorisation of installations with significant changes (§16 BImSchG). It was introduced in 2021 to transpose the requirements of the Renewable Energy Directive of the European Union (EU) into German law [7]. Repowering should therefore be carried out in a simplified procedure [Art. 16 Section 6 Directive (EU) 2018/2001].

The paragraph 16b BImSchG contains the following aspects:

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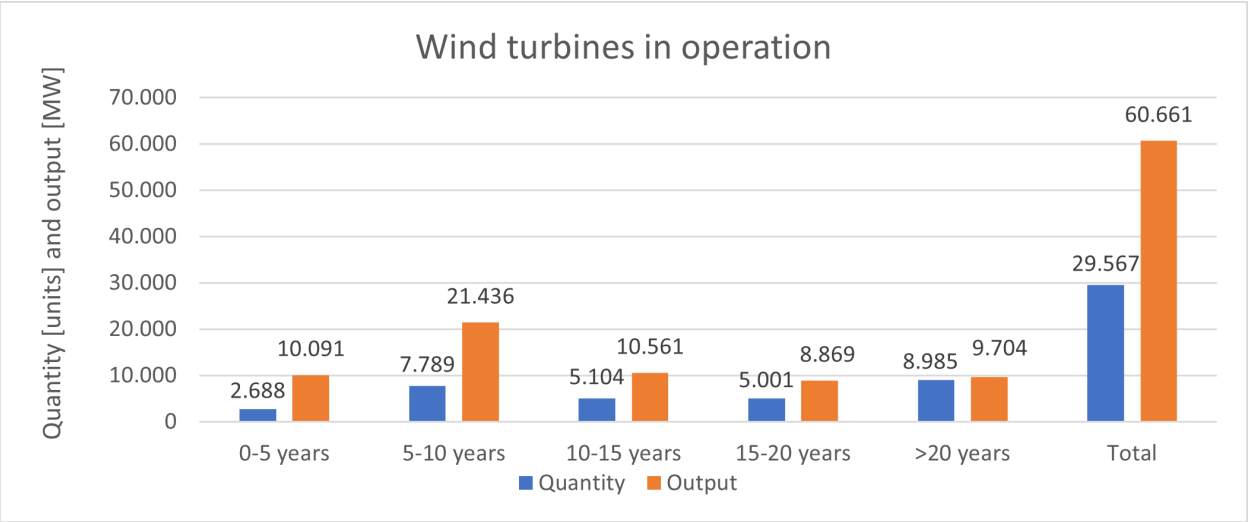

Fig. 1: Age structure of wind turbines in Germany (status 08.12.2023). Own illustration based on [3].

- Only check requirements according to BImSchG if negative effects are expected (due to repowering or change of turbine type)
- Examination of other public law concerns in all aspects (e.g. construction planning, labour protection, nature conservation, etc.)
- No limitation of the repowering measure in terms of size, increase in output, number of turbines
- Construction within 24 months of dismantling the old turbine
- Maximum distance between old and new turbine two times the total height
- Authorisation despite non-compliance with some immission limits if the total immission contribution is lower
- No need for a public hearing
- Simplified procedure for up to 19 wind turbines
- Simple assessment of stability and effects of noise and turbulence in the event of a change in power output

According to §16b, repowering includes the complete or partial replacement of wind turbines, operating systems or operating equipment. Only requirements that change the current conditions, taking into account the old systems, need to be checked. There will be a so-called delta test for this purpose. If the repowering leads to an improvement or unchanged impact on the wind farm sites, no assessment is required. [8]

A draft bill is currently being discussed in the Bundestag that contains the following improvements to §16b [1, 9]:

- Construction within **48 months** of dismantling the old turbine
- Maximum distance between old and new turbine **five times (5H)** the total height
- Use of §16b also for turbines that have been authorised under other specific laws
- Authorisation despite non-compliance with some immission limit values if the total immission contribution is lower **in absolute terms** (e.g. 0.1 dB is sufficient[10, 11])

Although the wind industry welcomes the planned changes in general, there are still suggestions for improvement. According to the BImSchG, a modification authorisation can only be obtained by an identical operator. There is no corresponding special regulation for repowering, although in reality the operator often changes in this case. [10–12]

Another suggestion for improvement is the seamless transition between old and new wind turbines. In fact, it makes sense to continue operating the old turbine until the new one has been completed to ensure a high level of efficiency. A corresponding clarification is missing so far. [10, 11]

The regulations on changing the type of wind turbine were also criticised. It is no longer possible to change the type of turbine via a simple modification authorisation [10]. This type of authorisation is regulated in §15 BImSchG and only requires notification to the responsible authority [§15 BImSchG]. It also remains unclear whether the change in turbine type also takes relocations into account. This often occurs in the practice and is not mentioned in the law. [8]

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2.2 Federal Nature Conservation Act / BNatSchG

In addition to §16b, there are also regulations on repowering in the Federal Nature Conservation Act (BNatSchG). Similar to the delta test, the effects of old turbines are also taken into account in protecting wildlife. For example, protective measures already taken, breeding sites and characteristics of the old turbines are analysed. Compensatory measures already taken are also assessed and deducted from the new measures to be taken. In the BNatSchG, the 5H regulation and the time limit of 48 months in deviation from §16b already apply. [§45c BNatSchG]

3 Political aspects

As a result of repowering, wind turbines are not only significantly more powerful but also significantly taller. According to a study by Lacal-Arántegui et al. [13], repowered wind turbines have on average twice the hub height and three times the rotor diameter . This results in a significantly greater total height compared to the old turbines. For a high energy yield, wind turbines must keep a certain distance from each other [14]. A general rule of thumb is based on the rotor diameter and specifies a distance of 10 rotor diameters in the wind direction and 5 rotor diameters in the crosswind direction to keep field losses below 10% [14]. New wind turbines therefore require significantly more space than the old ones. This can lead to conflicts with politically determined distance regulations regarding residential buildings [4].

There are currently different distance regulations in Germany depending on the federal state. In Bavaria, for example, wind turbines may not be built closer to residential buildings than ten times their total height (10H). In other federal states, on the other hand, a distance rule of up to 1000 metres applies. Saxony-Anhalt, Saarland and, more recently, North Rhine-Westphalia have not set any blanket distance regulations. [15, 16]

Grau et al. [17] demonstrate the relevance of distance regulations in a study on the repowering potential in Germany. In the study, the potential of various scenarios was determined, which differ according to the size of the new wind turbines and the strictness of the distance regulations. The potential in the various scenarios was identified with distances of 500 metres (scenario 1-5), 1000 metres (scenario 5-10) and 10H (scenario 10-15). Figure 2 shows an example of three scenarios with different potentials for repowering turbines with a capacity of 4 MW (230 m total height) and various distance regulations. Table 1 expresses the potential of the scenarios for the year 2040 in numbers. It is clear to see that the repowering potential is affected, particularly with the 10H regulation as in Bavaria.

The possibilities for repowering therefore depend on the political regulations of the respective federal state. This situation may improve in the future. To accelerate the expansion of wind power in general, the Wind Energy Area Requirement Act (WindBG) came into force on 1 Feb. 2023. Therefore, all federal states must designate an area of around 2 % for wind turbines by the end of 2032 [§3 WindBG]. Previously, only 0.8 % of the area was designated across the country and only 0.5 % was available. The individual distance rules of the federal states will then only apply if the requirement of the new law is met. [18]

Tab. 1: Repowering scenarios and potential wind energy generation (WEG) in 2040. Modified by the author. Based on [17].

Scenario	Distance (m)	WEG (TWh/yr)
S5	500	85,37
S10	1000	70,91
S15	10H / 2300	26,54

4 Economical aspects

The economic situation today is not the same as when the old wind turbines were built. This is not only due to a different remuneration model for the electricity generated but also to the changes in recent years regarding the financing of wind power projects and the costs of wind turbines.

4.1 Remuneration for electricity generated from wind turbines

The remuneration for electricity generated from wind turbines has been in existence since the Renewable Energy Sources Act (EEG) came into force in the year 2000 [§9 EEG 2000, §25 EEG 2023]. Under the old system (until EEG 2012), the electricity was sold to the grid operators and remunerated independently of the market. This reduced the investment risk and increased planning security for project planners, which led to an ever-increasing expansion of wind energy. [6]

The EEG 2017 fundamentally changed the remuneration model. Accordingly, the remuneration is now determined via a tendering procedure. The tender is limited in volume and also specifies the highest possible remuneration [§28, §36b EEG 2023]. Future wind farm operators can take part in the tendering process after receiving the authorisation under BImSchG and submit a bid for the desired remuneration [§36 EEG 2023]. The limited volume ensures competition as the highest bids are excluded due to the limited volume [Section 32 EEG 2023]. If, for example, the volume

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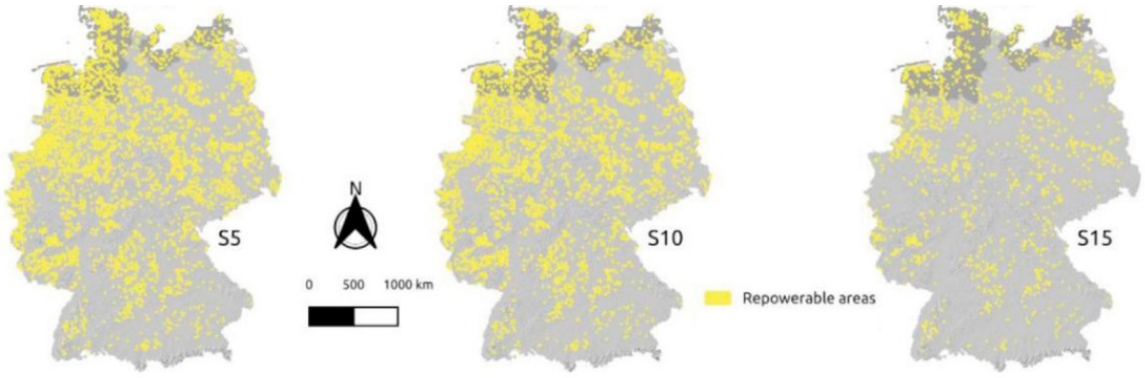

Fig. 2: Repowerable areas with various distance regulations and a wind turbine capacity of 4 MW. Modified by the author. Based on [17].

is not utilised, the Bundesnetzagentur (Federal Network Agency) can subsequently adjust the volume to maintain competition [§28 EEG 2023]. If the highest possible remuneration is no longer appropriate, this value can also be adjusted by up to 25% [§85a EEG 2023].

The remuneration value determined in the tender is adjusted using a location factor. If the wind forecast is better than a defined reference location, the remuneration value is adjusted downwards. If the wind farm site is estimated to be worse, the remuneration is set higher. The actual performance is analysed every 5 years and subsequently adjusted. This may result in subsequent refunds or payments. [§36h EEG 2023]

The EEG 2012 also introduced the market premium model. It became mandatory for systems with an output of more than 100 kW with the EEG 2017 [§19 EEG 2017]. Under this model, the electricity must be sold directly to third parties or via the stock markets. The remuneration (set in the tender since EEG 2017) is offset against the earnings from direct marketing. [§33 EEG 2012, §23a EEG 2017] The actual remuneration therefore only covers the difference between the sales earnings and the remuneration value [6]. If the proceeds from sales are equal to or higher than the remuneration value, the remuneration is reduced to zero.

From EEG 2014, there is also a rule that no more remuneration is paid if the spot market price on the stock market is negative for a certain period in succession [§24 EEG 2014]. According to the latest regulations, the number of hours is reduced annually to 1 hour in 2027. Currently, no remuneration is paid for negative price periods of four hours or more. [§51 EEG 2023]

The tenders and the market premium model ensure more competition and market orientation for renewable energies. Due to the fixed remuneration value, this system nevertheless offers guarantees to ensure a certain degree of planning security for investors [6].

4.2 Financing and costs

The planned expansion of wind power was not achieved in 2022 and will not be achieved in 2023 either. Table 2 shows an overview of the tenders. It shows the initially planned tender volume, the offered volume and the volume that was finally awarded.

Tab. 2: Results of the tender process. Own illustration based on [19–26].

Date	Quantity (MW)			Price
	planned	offered	awarded	(ct/kWh)
01.02.22	1333	1328	1332	5,88
01.05.22	1333	1320	931	5,88
01.09.22	1333	1320	773	5,88
01.12.22	1190	603	189	5,88
01.02.23	3210	3210	1441	7,35
01.05.23	3210	2866	1535	7,35
01.08.23	3210	1667	1433	7,35
01.11.23	3210	2088	unknown	7,35

It can be seen that the volume offered was not achieved in all tenders after February 2022 despite frequent reductions. The last tender date in 2022 in particular was significantly below the volume offered. This problematic development can be explained by various mechanisms. In addition to the effects of the COVID-19 pandemic, the war in Ukraine in particular has recently led to major price increases and inflation of up to 8.8 % (November 2022) [27, 28]. To reduce the high inflation, the ECB has started to raise the interest rate on the main refinancing operations since July 2022 [28, 29]. If this interest rate is raised, credit interest rates will also rise [28, 30]. The financing conditions for investments in renewable energies have therefore deteriorated. For example, loans from the KfW-bank for renewable energies were available for an interest rate of 1.8 % in 2021 [31]. The interest rate is now 5.04 % [32] (assumptions: as in [31]: 20-year term, 3 redemption-free start-up years, 20-year fixed interest rate, risk class B).

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Due to the price increases and higher financing costs, the electricity production costs in the wind industry have risen. An expert report by Deutsche Windguard [31] analysed the cost trend in great detail (status: 29.11.2022). Table 3 shows the result of a comparison of two similar wind turbines from the report. Due to the changed financing conditions, a higher equity ratio and a higher return on equity were assumed. It can be seen that all cost units show an increase. However, the financing costs in particular stand out clearly. Despite the improved technology of the newer turbine, the LCOE increased by 43 %.

The operators of future wind farms are therefore faced with the challenge of achieving good profitability under the maximum prices prescribed in the tender and at the same time significantly higher electricity production costs. Based on the report by Deutsche Windguard, the Federal Network Agency raised the maximum tender price for 2023 to 7.35 ct/kWh to improve the situation for wind power expansion [31, 33]. As can be seen in table 2, there was a higher expansion this year compared to 2022. However, the planned tender volume was undercut again despite being reduced. The increase in the maximum price seems to be not sufficient yet. The results of the last tender on 11/01/2023 are not yet known.

5 Social aspects

If a wind power project is to be realised, it is also important to consider the social aspects. The acceptance of the public plays a central role in the selection of wind turbine sites and is therefore a key criterion for enabling the expansion of renewable energies [34, 35]. According to a survey conducted by Fachagentur Windenergie an Land e.V. [36] in 2022, over 80% of the German population consider the use of wind energy to be rather important or very important (figure 3). Figure 4 also shows the survey results regarding wind turbines in the immediate residential area. A distinction is made here as to whether wind turbines have already been erected in the residential area or not. Acceptance is high in both parties. It can also be seen that citizens with wind turbines in their surroundings show an even higher level of acceptance, which is beneficial for repowering projects.

Even if acceptance is generally very high, there is always a part of the local population that is against wind turbines. Windemer [34] conducted a survey in which citizens living near wind farms were interviewed. The survey showed that even years after the wind turbines were erected, there were no major changes in attitudes towards wind power. In repowering projects, negative attitudes in particular can therefore lead to new protests . To maintain a high level of acceptance and increase it further for future expansion, it is important to consider what the affected citizens wish for. According to Windemer [34], a study by Huebner

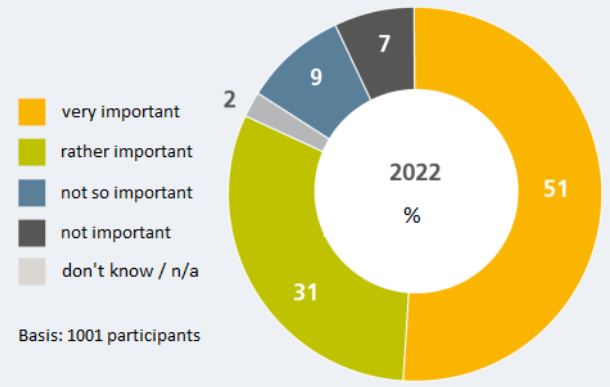

Fig. 3: Acceptance of wind energy onshore. Modified by the author. Based on [36].

and Pohl [37], as well as the survey by Fachangentur Windenergie an Land e.V. [36], the following factors can increase acceptance:

- Transparency and information over the entire operating period (not just the planning phase)
- Participation of citizens and local authorities in the planning process
- Taking issues and complaints seriously
- Financial participation opportunities for citizens and municipalities
- Enable discounted electricity contracts

In the version of the EEG valid from 1 January 2023, local authorities are to be paid 0.2 ct/kWh to increase the acceptance of wind energy expansion. However, this is only a voluntary measure. [§6 EEG 2023] To give citizens an appropriate financial share in the future, a draft bill is currently under discussion in the state parliament of North Rhine-Westphalia [35]. The proposed Citizens' Energy Act (BueEnG) provides for the mandatory participation of citizens living in municipalities where wind turbines are built [§7, §8, §9 BueEnG]. Nevertheless, as the studies show, citizens should not only be financially involved in wind farm projects.

The study by Huebner and Pohl [37] also shows that citizens are more likely to be disturbed by changes to the visual landscape, whereby a greater distance does not lead to greater acceptance. Repowering projects could therefore be advantageous, as the greater output of the turbines means that not as many are needed as in the old wind farms. The new wind turbines technically require more space to achieve a high level of efficiency [13]. However, the noise pollution from new turbines is lower [38]. As the influence of distance on citizens appears to be minimal, it is possible that the space criterion does not affect acceptance significantly.

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Tab. 3: Comparison of the cost components of wind turbines. Modified by the author. Based on [31].

Start of operation	**2021**	**2025**	**Change**
Site quality	100 %	100 %	
Turbine output	4317 kW	4573 kW	+6 %
Hub height	140 m	146 m	+4 %
Rotor diameter	138 m	140 m	+1 %
Annual energy yield	14666 MWh/a	15287 MWh/a	+4 %
Equity share	14 %	18 %	+25 %
Debt capital share	86 %	82 %	-5 %
Return on equity	8 %	10 %	+25 %
Debt capital interest rate	1,8 %	4,81 %	+167 %
Main investment costs	958 €/kW	1159 €/kW	+21 %
Ancillary investment costs	488 €/kW	637 €/kW	+31 %
Operating costs - first decade - fixed, annual	28 €/kW	33 €/kW	+19 %
Operating costs - first decade -variable	0,6 ct/kWh	0,7 ct/kWh	+18 %
Operating costs - second decade - fixed, annual	35 €/kW	43 €/kW	+22 %
Operating costs - second decade - variable	0,8 ct/kWh	0,9 ct/kWh	+22 %
Power generation costs	**4,8 ct/kWh**	**6,8 ct/kWh**	**+43 %**

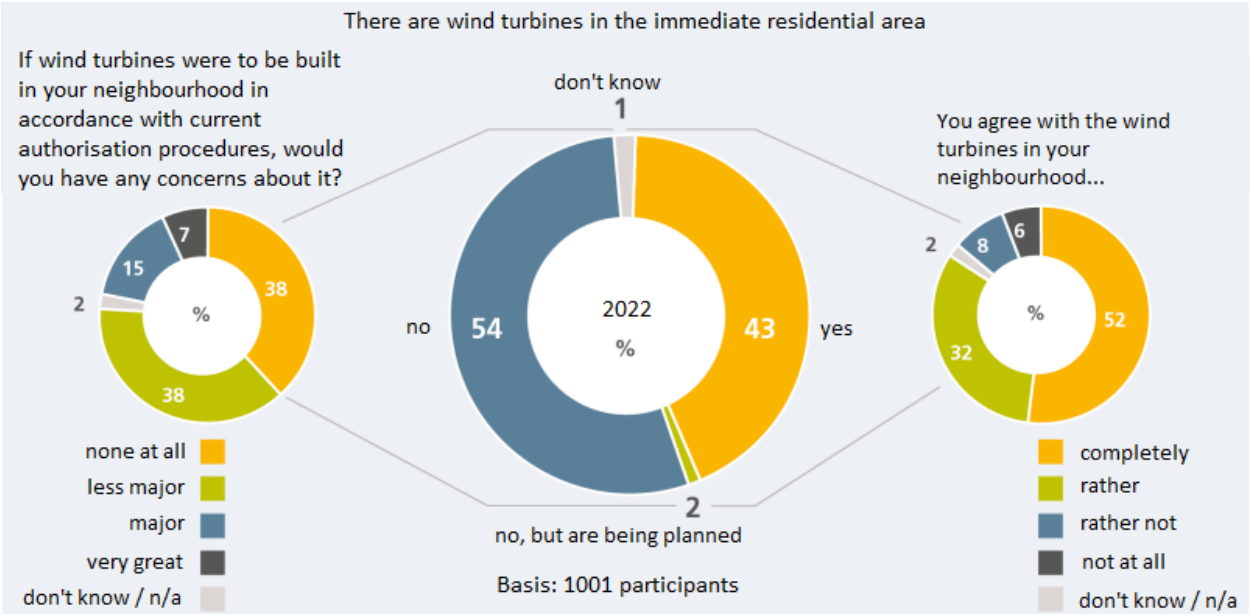

Fig. 4: Opinions on wind turbines near residential buildings. Modified by the author. Based on [36].

6 Conclusion

To summarise, many important aspects should be considered in a repowering project. The wind industry is highly dynamic and conditions can change quickly. There are various reasons for this. One of the main reasons centres on the actions taken to achieve the climate targets. The expansion of wind energy needs to be accelerated, which affects all of the mentioned aspects in different ways. At the same time, new wind energy projects shall be orientated closer to the market to increase competitiveness. Last but not least, the crises of recent years are also causing turbulence and major changes.

Due to the changing conditions, it is difficult to give generalised and quantitative statements. In a repowering project, the aspects explained should be taken into account to draw individual conclusions.

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