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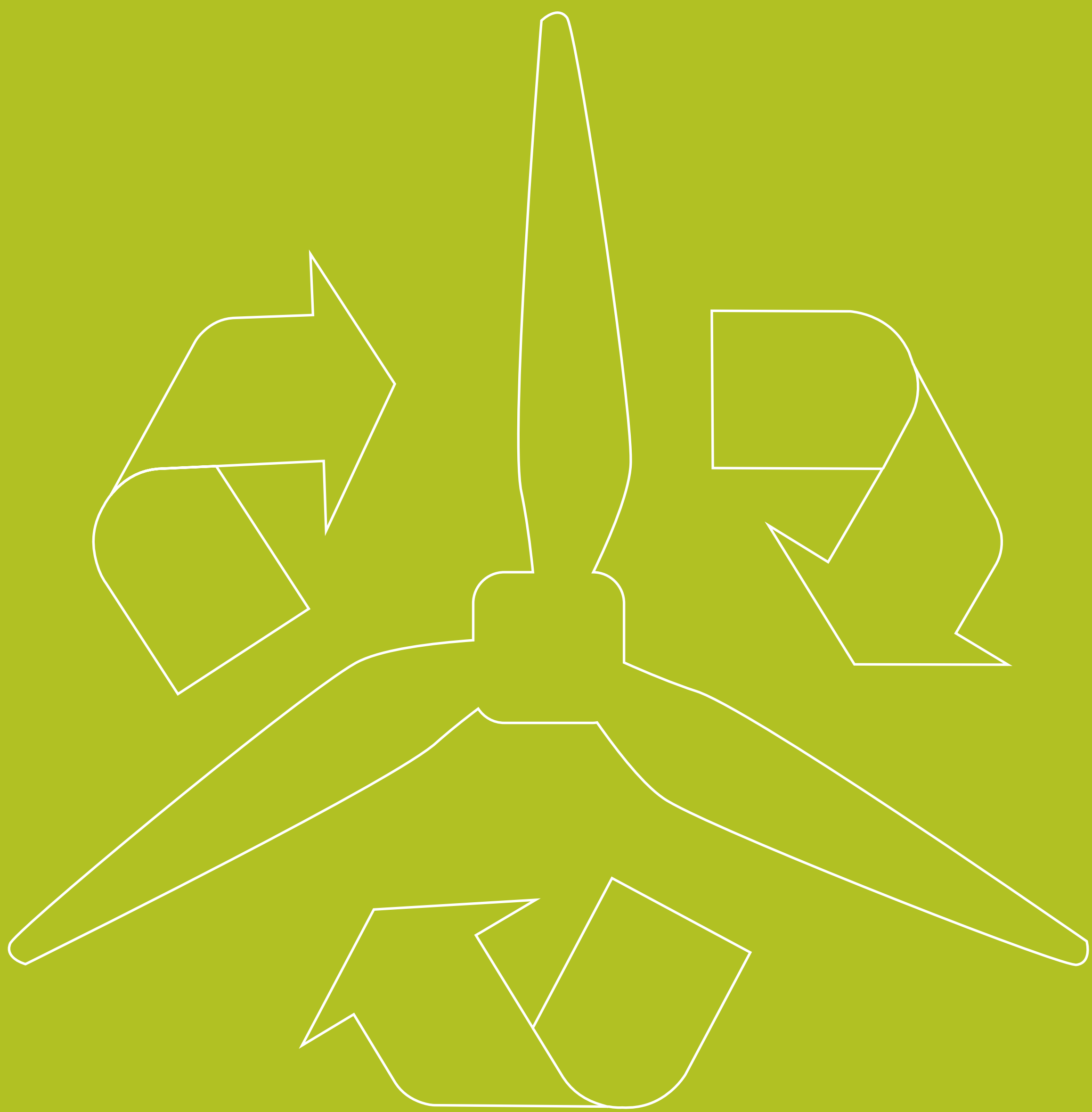
DOCUMENTATION

Breaking & Sifting

Expert exchange on the end-of-life of wind turbines



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Note

For better legibility, the following report refrains from using the female gender which is instead subsumed under the respective male form.

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Foreword

Dr. Antje Wagenknecht, Managing Director of Onshore Wind Energy Agency.

Careful planning is key to ensuring continued public acceptance of wind energy expansion. This applies to all project stages, from the decision on the location of a wind farm, commissioning and the entire operating period to decommissioning, repowering or dismantling. At the end of their service life, wind turbines have to be dismantled without leaving any remnants behind, and the sites then have to be recultivated. While so far only smaller wind turbines have been repowered or permanently shut down, it is foreseeable that the size and number of wind turbines to be dismantled will increase in the near future – at the latest when the subsidy paid to operators under the Renewable Energies Act (EEG) expires.

The aim of the Onshore Wind Energy Agency's (FA Wind) expert exchange is to present the topic of dismantling and recycling to members and other interested parties in a generally understandable way. To this end, the agency gathered specialists from science, the wind energy and waste management industries, politics and administration for an expert exchange on **Breaking & Sifting** in Bremen on 4 September 2018. Together, we examined various aspects and questions. This multidisciplinary event is intended to ensure awareness among federal states and authorities, stimulate and intensify the exchange of experience between the relevant players, and highlight emerging challenges.

The papers presented at the event were subsequently published and have been included in this brochure. Special attention has been given both to the regulatory framework governing wind turbine dismantling and recycling, the principles of which were explained by attorney Hartmut Gaßner, and to the plenum discussions, which have been summarised by the journalist Bernward Janzing.

My special thanks go to our cooperation partner, EnergyAgency.NRW, the speakers, and everyone who took part in the discussions. All of them have made a huge contribution to the success of this expert exchange.

In 2016, a multi-disciplinary working group was established on the initiative of operators, project developers, plant manufacturers, consultancies, dismantling contractors, waste disposal companies and scientific, public and political institutions, and this now meets every six months for a so-called "Dismantling Network Gathering". Everyone with a keen interest in the highly diverse issues and challenges relating to the dismantling, disposal and recycling of wind turbines is cordially invited to attend the next meeting to drive progress on this important topic.

With this in mind, I hope you enjoy reading this issue.

Yours

Dr. Antje Wagenknecht
Managing Director
Onshore Wind Energy Agency

Status quo and current challenges in recycling and dismantling wind turbines

PROF. DR.-ING. HENNING ALBERS, DR. RER. NAT. FRAUKE GERMER, KALLE WULF B. SC.

THE SITUATION

For more than two decades, wind turbines have been used in Germany on a significant scale as one of the newer distributed and renewable technologies for electricity generation. The oldest smaller wind turbines with an installed capacity of less than 1 megawatt (MW) have now been in service for around 30 years [FhG-IEE 2018]. Over the next few years, more and more of these older plants will be decommissioned because operating permits expire or continued operation at electricity market prices of less than 4 cents per kilowatt hour (ct/kWh) without the EEG subsidy is no longer economically viable [Wallasch et al. 2016]. Whilst there is, in principle, the option of continued operation in other countries ("second life"), more wind turbines than ever now have to be disposed of. Employing a resource-saving and environmentally friendly way to dispose of the resulting materials is critical.

"So far, there is no technology for fibre-to-fibre recycling of GFRP."

For a number of materials used in wind turbines, such as reinforced concrete, steel, cast iron, metals and operating fluids, established recycling methods with appropriate processing technologies are available. As these materials account for the largest share (some 97 % by mass), high recovery rates of over 80 % are frequently reported for entire plants [Kaiser, Seitz 2014]. Unlike these materials, the fibre composites used in rotor blades and nacelle housings, which account for around 2 to 3 % (by mass) of the total wind turbines, have so far hardly ever lent themselves to high-grade recycling.

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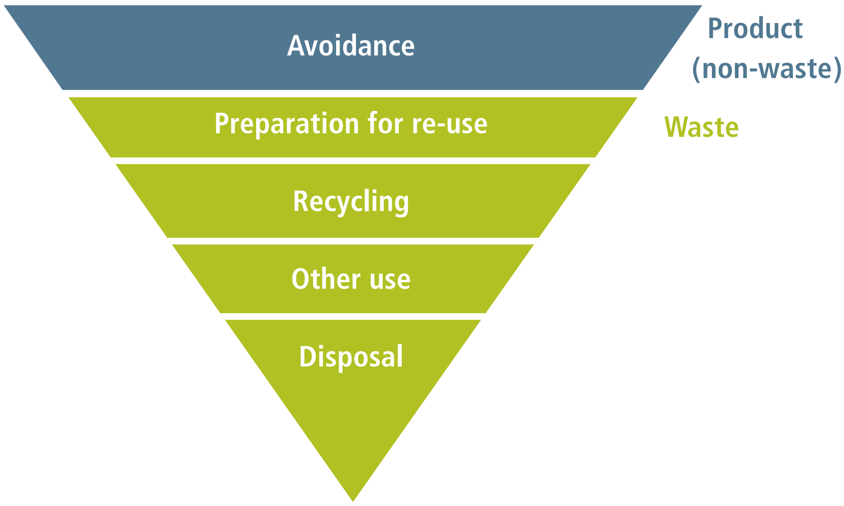
Fig. 1:
Ranking under the 2012 Waste Management Act, as amended [European Commission 2015]



REQUIREMENTS OF THE CIRCULAR ECONOMY

If retired wind turbines cannot be used for second-life applications, they have to be disposed of as waste in accordance with the requirements of the 2012 Circular Economy Act [Federal Government 2017] (Fig. 1).

According to current legislation, waste should first and foremost be avoided. The "avoidance" requirement is primarily aimed at wind turbine manufacturers and wind farm operators, as it can most probably be met by using a material-efficient rotor blade and extending the life cycle of the turbines. The second priority in the legal order of precedence, which is "preparation for re-use", can best be achieved by contractors specialising in wind turbine refurbishment for the second-life market. This priority is actually being put into practice, particularly for smaller wind turbines with a rated capacity of less than 1 MW.

The third priority, i.e. "recycling" of the materials to allow re-use for their original purpose (e. g. fibre-to-fibre) or for another purpose (e. g. broken concrete as load-bearing road construction material) is only possible for rotor blades after the blades have been sectioned and the different materials have been separated. One example is the separate re-use of balsa wood or of lightning protection system components made from copper.

neocomp and the Lägerdorf cement plant have together developed a combination of priorities three and four, "recycling" and "other use", specifically for rotor blades [neocomp 2018]. Glass fibre components replace mineral raw materials required in cement, while the energy content of the resins is used as a substitute fuel. Carbon fibre composites contained in rotor blades have to be located and mechanically separated. At CarboNXT, for example, these fibres can be separated by thermal treatment and then further processed [CarboNXT GmbH 2018].

The "other use" category is the use of small quantities for co-firing in waste incineration plants. Given the fibre content of these materials, plant operators have to pay particular attention to operational and occupational safety. With these plants, the fifth priority in the form of "thermal disposal" is also an option. Disposal in landfills, however, is not permitted, because, due to the resins, the organic content of these materials is too high.

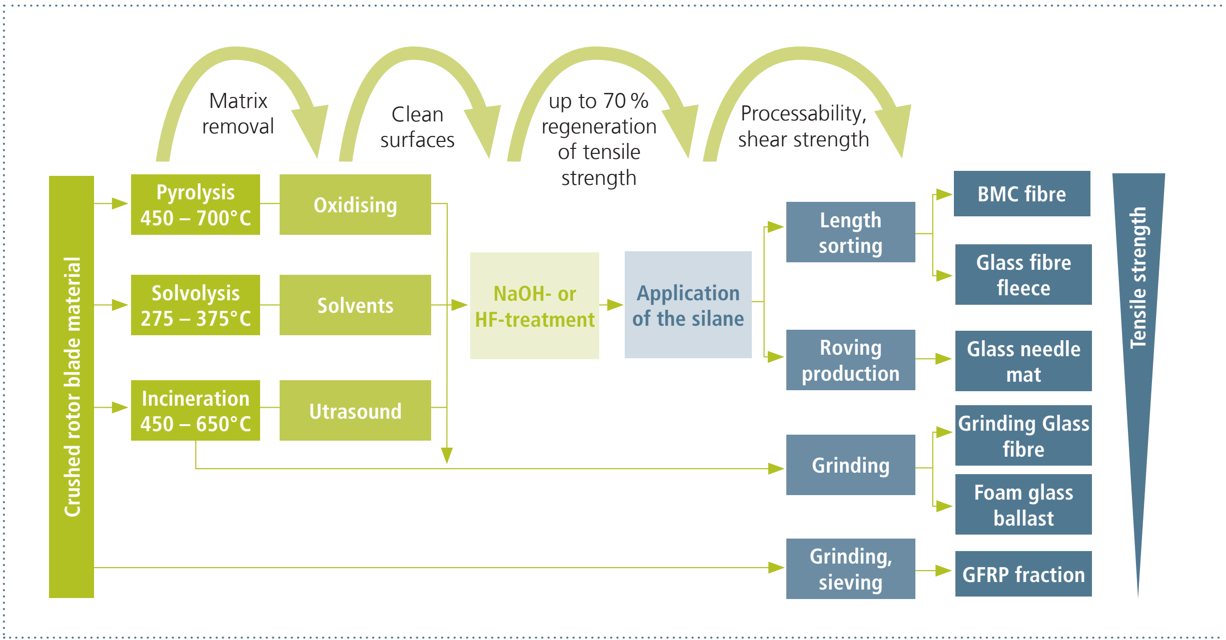
APPROACHES TO GLASS FIBRE RECYCLING

Fibre-to-fibre (F2F) recycling of glass fibre has so far not been implemented on a large scale, but would be regarded as high-quality recycling if primary fibres were replaced by secondary fibres.

Fig. 2 shows various process options and possible products made of secondary fibres. In any case, the first step would be mechanical treatment to prepare the material for subsequent process steps. This would generally involve at least one coarse grinding stage, a sorting process to remove unsuitable materials and a fine preparation stage.

If fibre and resin can be retained as a composite, grinding and sieving technologies are an option. If the matrix has to be separated from the composite to expose the fibre, two thermal processes – pyrolysis and combustion – or solvolysis, a chemical process, would be conceivable. Additional effort in the form of thermal energy or chemicals will be necessary to produce clean fibre surfaces, while subsequent grinding steps could make it possible to use the material as foam glass ballast.

Fig. 2:
Concepts for fibre-to-fibre recycling according to scientific research [modified according to Spörlein 2017]



High-quality products such as glass needle mats, glass fibre non-wovens or BMC fibres place higher demands on the tensile and shear strengths of the fibres and the functionality of the surface structure. Chemical treatments with hydrofluoric acid or sodium hydroxide solutions and post-treatment to reactivate the silane layer with APS solutions represent possible options [Yang et al. 2015/Bahir et al. 2018].

"AIt is unlikely that wind turbines with a capacity of around 1 MW or more will be exported to emerging or developing countries for further operation. They are much too sophisticated for this. In many cases, the electricity grids will probably not be able to cope either."

CHALLENGES

The dismantling of wind turbines and the recycling of the materials places many demands on everyone involved, particularly where composite components such as rotor blades and nacelle housings have to be dealt with. This poses a number of challenges.

Quite often, the parties involved in the dismantling and recovery process do not know the exact material composition of the blades. These details and the design and construction documents either no longer exist after more than 20 years of operation or they are not made available.

For the recycling companies having to mobilise the necessary technical and human resources, it is critical to be able to estimate the waste masses that will be generated and require treatment in the near future. The end-of-life of wind turbines and the other options available for these plants and materials depend on a large number of factors that are difficult to predict. These include, above all, the technical condition of the assets, the dynamics of the second-life market, repowering options, the political framework both in waste and energy law, and the development of electricity prices.

The different requirements for decommissioning in terms of standards and processes as well as the technical procedures and the demands of the parties involved determine the quality of the materials to be treated.

Mechanical treatment of the blades in several steps – i. e. crushing, screening and grinding – is technologically demanding and complex.

Fibre exposure can pose a risk to people's health, to the technical equipment used and to the environment, which still needs to be comprehensively assessed.

Large-scale fibre-to-fibre (F2F) recycling is still a long way off, and at present it cannot be done in line with market requirements.

Standard approaches to dismantling and recycling, supported by the entire chain of market players, have yet to be established.

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Legal framework for the recycling and dismantling of wind turbines

PROF. HARTMUT GAßNER, LINUS VIEZENS

Over the coming years, more and more wind turbines will have to be dismantled as funding periods under the Renewable Energy Sources Act (EEG) expire and units reach the end of their lifecycle, etc. The following is a summary of the legal framework governing the dismantling obligations (see chapter 1) and waste disposal requirements (see chapter 2).

1 DISMANTLING OBLIGATION

The dismantling obligation a wind turbine may arise from various legal provisions (chapter 1.1). These determine the extent to which wind turbines have to be dismantled (chapter 1.2) and the types of security to be provided (chapter 1.3). In addition, municipalities can use their urban land-use planning process to establish an obligation to either dismantle a wind turbine or tolerate the dismantling of a wind turbine (chapter 1.4). Landowners found to be "disturbers through situation, ownership or possession" ("Zustandsstörer") can be obligated to remove a wind turbine. It is recommended that they lease their land only where they have a right of self-performance and a suitable security (chapter 1.5).

1.1 Relevant regulations

Dismantling obligations result from declarations of voluntary commitment pursuant to section 35 (5), sentence 2, half-sentence 1 of the Federal Building Code (BauGB)[1] and state law (chapter 1.1.1). In addition, authorities in some federal states may order that wind turbines be removed under the state's building codes (chapter 1.1.2).

The Clean Air Act (also known as the Federal Immission Control Act or BImSchG), on the other hand, neither imposes a dismantling obligation to dismantle wind turbines nor does it provide any such powers (chapter 2.2.3). A removal order based on the general authorisations pursuant to safety law will in most cases be disproportionate (chapter 1.1.4).

1.1.1 Voluntary commitments

1.1.1.1 Section 35 (5), sentence 2, half-sentence 1 of the Federal Building Code (BauGB)

Since 20 July 2004, wind turbines to be built in so-called "outskirt", i.e. areas for which there is no qualified development plan and which are not part of a built-up district, may only be approved if the applicant commits themselves to dismantling the installation and removing all sealed surfaces once the turbine has permanently ceased to be used in accordance with the permit (section 35 (5), sentence 2 BauGB[2]). Any modification of a wind turbine after the deadline (e.g. repowering) also requires a voluntary commitment.

The dismantling obligation does not exist by law, but is established only by a declaration of voluntary commitment. This is confirmed in particular by the wording of the legislation[3].

*"For **projects** pursuant to paragraph 1, nos. 2 to 6, **a further condition of admissibility** shall be the submission of a **declaration of voluntary commitment** to dismantle the project after permanently discontinuing its permissible use and to remove sealed surfaces; in the case of a change of use permissible under paragraph 1 nos. 2 to 6, the **dismantling obligation** shall be accepted and continued; in the case of a change of permissible use under paragraph 1, no. 1 or paragraph 2, the obligation **shall cease to apply**."* (emphasis added)

1 Building Code in the version published on 3 November 2017 (Federal Law Gazette I p. 3634).

2 For period of validity, refer to section 233 (1) of the Federal Building Code (BauGB) in conjunction with Article 7 of the European Law Adaptation Act for the Construction Sector of 24 June 2004, Federal Law Gazette 2004, p. 1359 et seq.

3 The Federal Administrative Court (BVerwG) has indicated that the dismantling obligations are only established by the voluntary declaration of commitment, ruling of 17 October 2012, 4 C 5/11, marginal no. 10.

If a legally justified obligation to dismantle the installation had been intended, the legislator could have selected a clearer, simpler wording, e. g.:

*"Projects […] **shall** be dismantled after the permanent discontinuation of their use and all sealed surfaces **shall** be removed:"*

Moreover, the second half-sentence explaining the continued validity of the voluntary declaration of commitment following a change of use would be irrelevant if the first half-sentence already established a statutory dismantling obligation. The "project" carried out under construction planning law also includes changes of use (section 29 (1) BauGB). For these changes, a statutory dismantling obligation would also already be established by the first half-sentence. The declaration of commitment would not have to be accepted for changes of use pursuant to paragraph 1, nos. 2–6 and would not be waived for changes of use pursuant to paragraph 1 no. 1 and paragraph 2.[4]

"So far there is no general dismantling obligation for wind turbines, only a self-commitment according to section 35 (5) BauGB."

The dismantling obligation is not independently enforceable[5] and may have to be enforced in court.[6]

A dismantling obligation cannot be linked to the building permit by an ancillary provision.[7] This would have to be permitted by law or be necessary to ensure compliance with the legal requirements of the building permit (cf. section 36 of the Administrative Procedure Act (VwVfG)[8]).

Where the building regulations of the federal states permit ancillary provisions to building permits, they do not constitute a general authorisation which would warrant the adoption of a dismantling obligation as a requirement. The building regulations also only allow auxiliary provisions where this is necessary to fulfil statutory licensing requirements or where a corresponding margin of discretion is granted.[9] However, the dismantling obligation is not a statutory obligation, which means there are no prerequisites for issuing a corresponding requirement.

The dismantling obligation must be declared in the event that the permissible use of wind turbines for research, development or the use of wind energy (cf. section 35 (1) no. 5 BauGB) is permanently discontinued. The circumstances characterising a permanent discontinuation of use can be specified in the voluntary commitment itself.[10] If there is no specification, it is primarily the will of the operator that is decisive.[11] If the will of the operator is not evident, it depends on whether according to general consensus a resumption of the permissible use can be permanently ruled out.[12]

The Federal Administrative Court (BVerwG) has developed the "time model[13]" to operationalise the prevailing view. According to this model, a resumption of the permissible use within one year is

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4 Cf. Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 80 et seq.

5 Federal Administrative Court (BVerwG), ruling of 17 October 2012, 4 C 5/11, marginal no. 11. Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 133 et seq.

6 Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 133 et seq.

7 A different view is held by Becht/Lukas, Rückbauverpflichtung von Windenergieanlagen: Grenzen der Verhältnismäßigkeit, Verwaltungsrundschau 2018, p. 11 et seq. (13).

8 Administrative Procedure Act (Verwaltungsverfahrensgesetz) as published on 23 January 2003 (Federal Law Gazette I. p. 102), last amended by section 11 (2) of the Act of 18 July 2017 implementing the eIDAS Regulation (Federal Law Gazette I., S 2745). To simplify the use of references, we also refer to national administrative procedure laws even where the administrative procedure laws of the federal states apply.

9 Cf. Kop/Rammsauer in: Administrative Procedure Act (VwVfG), 17th edition 2015, section 36, marginal no. 40.

10 Cf. Mitschang/Reidt in: Battis/Kratzberger/Löhr, Federal Building Code (BauGB), section 35, marginal no. 181.

11 Mitschang/Reidt in: Battis/Kratzberger/Löhr, Federal Building Code (BauGB), section 35, marginal no. 181.

12 Söfker in: Ernst/Zinkahn/Bielenberg/Krautzberger, Federal Building Code (BauGB), 129th supplement, Mai 2018, section 35, marginal no. 165b.

13 Federal Administrative Court (BVerwG), ruling of 18 May 1995, 4 C 20/94 with further references. On the transferability of the model to assess the permanent abandonment of wind turbines: Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, pp. 23 et seq. and Mitschang/Reidt in: Battis/Kratzberger/Löhr, Federal Building Code (BauGB), section 35, marginal no. 181 in conjunction with marginal no. 151

unproblematic. In the second year, a resumption of use is also presumed if the circumstances of the individual case (condition of the structure, etc.) do not present problems (legal presumption against permanent abandonment). After the second year, special circumstances are required that favour the intention to resume the permissible use (legal presumption in favour of permanent abandonment).

1.1.1.2 Section 72 (2) sentence 3 of the Brandenburg Building Code

Only the Brandenburg Building Code (BbgBO)[14] states again that a building permit may not be granted without a voluntary commitment (section 72 (2), sentence 3 BbgBO) and refers to the requirements under federal law.

1.1.2 Removal orders according to the state building regulations

With the exception of North Rhine-Westphalia (NRW), the building codes of all federal states include authorisations to issue orders to remove a wind turbine structure, which correspond to or are modelled on section 80, sentence 1 of the Model Building Code (MBO)[15] (see 1.1.2.1). The building codes of some federal states contain further, more extensive authorisations (see 1.1.2.2).

1.1.2.1 Powers to issue orders according to section 80, sentence 1 of the Model Building Code (MBO)

With the exception of NRW, the authorities in all federal states[16] may order the removal of a plant (cf. section 80, sentence 1 MBO), if

- its installation or modification,
- violates public law regulations,
- a legal state cannot otherwise be achieved and
- the removal order is free from error of assessment.

The NRW Building Code (BO NW) does not provide for any special authorisation to issue a removal order. Therefore, such a special authorisation can at most be based on the general legal norm pursuant to section 61 (1), sentence 2 BO NW. In our opinion, the intervention rights granted by the said legal norm cannot go further than provided under section 80, sentence 1 MBO.[17]

1.1.2.1.1 Violation of construction planning law/ no protection of existing rights

According to construction planning law, the admissibility of a structure is assessed not only on the basis of its structural parts, but also its use. Construction planning law – in particular sections 30 to 37 of the Federal Building Code (BauGB) – applies to "projects", which covers not only the construction or modification of structural parts, but also the changed use of a structure (section 29 (1) BauGB). According to the Federal Land Utilisation Ordinance (BauNVO)[18] the admissibility of a plant is always also determined by its intended use (sections 2 to 11, 13 BauNVO). Likewise, the intended use of a building will determine whether it qualifies as a "privileged" building in outskirt areas (section 35 (1) BauGB).

The aforementioned regulations reflect a standard approach to the building structure and its function in planning law.[19] It follows from this that abandoning the use of a plant must be seen as a change of use within the meaning of section 29 (1) BauGB if it can lead to a different assessment under building law.[20] This can in principle be assumed for permanently abandoned wind turbines: A wind turbine that is not used to generate wind energy would neither be permissible in the "outskirt"[21], nor in a special area pursuant to section 11 BauNVO. Different provisions may apply to wind turbines in so-called unplanned interior areas for which there is no development plan ("unbeplanter Innenbereich"). If the nature of the surrounding area does not correspond to any construction area as set out in the Federal Land Utilisation Ordinance (BauNVO), admissibility will depend on whether the decommissioned wind turbine fits into the surrounding area (section 34 (1), sentence 1 BauGB).

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14 In the following, the building codes of the federal states are referred to by the abbreviation of the federal state together with the German building code acronym BO as a prefix or suffix. Without any further information, reference is made to the respective valid version as amended up until 27 August 2018.

15 Model Building Code, version of 1 November 2002, last amended by resolution of the Conference of Ministers of Construction of 13 May 2016, last downloaded on 28 August 2018 at https://www.bauministerkonferenz.de/dokumente/42318979.pdf.

16 See section 76 sentence 1 BY BO; section 80, sentence 1 BO BE; section 72 (1), sentence 1 HE BO; section 80 (1) sentence 1 BO MV; section 82 (1) SL BO; section 80 sentence 1 SN BO; section 79, sentence 1 BO ST. The following building codes also contain a disposal order in accordance with the MBO, but also special authorization bases (see below, bb)): section 81, sentence 1 BO RP; section 79 (1), sentence 1 BO HB; section 80 (1) sentence 1 BB BO; section 79 (1) sentence 1 TH BO; section 79 (1) sentence 1 and 2, no. 4 NI BO; section 59 (2) sentence 1, no. 3 half sentence 1 SH BO; section 76 (1) sentence 1 BO HH.

17 Another view: Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 55 et seq.

18 Federal Land Utilisation Ordinance as published in 21 November 2017 (Federal Law Gazette I p. 3786).

19 Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 16 et seq.

20 Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 16 et seq.

21 With the abandonment of the use, the justifiable reason for the privilege according to section 35 (1), no. 5 BauGB no longer applies: Jäde, Bauordnungsrechtliche Schnittstellenprobleme des EAG Bau, ZfBR 2005, p. 153 et seq. (144); cf. Document 15/2250, p. 56.

This may be the case if the wind turbine is surrounded by already decommissioned[22] wind turbines.

The point in time of the permanent abandonment of use is to be determined according to the Federal Administrative Court's "time model" (see above). Upon the final abandonment of use, the protection ("right of continuance") enjoyed by the plant as a result of the building permit also ceases to apply.[23]

1.1.2.1.2 By construction or modification

In almost all countries, the starting point determining any violation of public law regulations must be the construction or modification of the plant. This does not include a mere change of use. The building regulations distinguish between a "modification" of the main structural parts and a "change of use"[24], but the latter only enables the authorities to prohibit its use if such use is unlawful (cf. section 80, sentence 2 MBO). Baden-Württemberg's building planning law, however, provides for something different: Here, a change of use (in the form of the abandonment of use) fulfils that criterion because a change of use is treated in the same way as the construction of a plant (section 65, sentence 1 in conjunction with section 2 (13) (1) BO BW).

Conclusion:
In Baden-Württemberg only, a removal order for permanently abandoned wind turbines is possible if the following conditions are satisfied.

1.1.2.1.3 No establishment of lawful conditions by other means

One prerequisite for a removal order pursuant to section 65, sentence 1 BO BW, is that a lawful condition cannot be established in any other way. A lawful condition could, however, only be brought about by the resumption of the use of the relevant wind turbine. For this purpose, the operation of the wind turbine would have to be resumed on a voluntary basis because the resumption cannot be enforced by way of an order.[25]

1.1.2.1.4 Exercise of discretion

The removal order is suitable for eliminating the situation that contravenes building planning law. Unless the owner resumes the use of the wind turbine by themselves, there is also no other approach that is equally suitable but interferes less with the rights of the affected parties. Such an order is also likely to be appropriate, as a general rule. The operator will no longer be able to derive any profits from a decommissioned plant, but will only delay the removal costs while having to pay for maintenance. On the other hand, the disposal of the plant is generally justified by the requirement to use land sparingly (section 1a (2) BauGB) and to enable subsequent use.

1.1.2.2 Powers to issue orders on account of a lack of use and imminent deterioration / neglect

Some federal states provide for authorisation to request the demolition of a structure,

- its is not used threatens to fall into disrepair[26] / is in disrepair[27] / is falling into disrepair[28] and
- there is no legitimate public or private interest in the preservation of the plant.

The first two prerequisites correspond to the relevant criteria of the "time model" of the Federal Administrative Court. However, external (at least threatening) signs of deterioration are a necessary precondition – even in the third year after abandonment of use.[29] Under certain circumstances, a very long period of time may elapse before such phenomena occur on wind turbines.

A special public interest (e. g. protection of a listed structure) or legitimate private interest does not stand in the way of an order, at least in typical cases.

According to section 59 (2), sentence 1, no. 3 BO SH, the removal of a plant may be ordered if, owing to its condition, it is no longer likely to be used permanently.

The Hamburg Building Regulations provides for the authorisation to order a plant to be removed if it is dilapidated and repair is no longer an option (section 76 (2), no. 1, half-sentence 2 HBO).

22 At the time of the final abandonment of use see section 1.1.1. above

23 Federal Administrative Court (BVerwG), ruling of 21 November 2000, 4 B 36 / 00; see also BVerwG resolution of 21 June 1994, 4 B 108 /94.

24 Cf. Pfeil, Beseitigungspflichten für stillgelegte Anlagen, p. 51 for the state building codes of Bavaria and Hesse.

25 Cf. Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 62.

26 Section 79 (2) TH BO; section 80 (2) BB BO.

27 Section 82 sentence 1 BO RP; section 79 (2) BO HB.

28 Section 79 (3) sentence 1 NI BO.

29 Cf. Reimus / Semtner / Langer, Die neue Brandenburgische Bauordnung, 3rd issue 2009, section 74, marginal no. 19.

1.1.2.3 Interim conclusion

The legal basis provided by the state building regulations, which correspond to and are modelled on section 80, sentence 1 MBO, allow the authorities to order the removal of permanently abandoned wind turbines in Baden-Württemberg alone.

The authorisations, which are based on a certain external deterioration, can, however, be used to order the removal of dilapidated wind turbines. However, a few years may pass before a wind turbine shows such external conditions. In addition, the operator can escape an order by keeping the wind turbine in a proper condition.

1.1.2.4 Selection of disturbers

As a rule, the recipients of a removal order can be all those responsible under applicable regulatory law (the builder-owner and contractor as the originator; the landowner as the status disturber ("Zustandsstörer").[30] The party most likely able to remove the wind turbine most safely and quickly will be the disturber selected. After that, it is primarily the municipalities who can also be obligated as landowners.

1.1.3 Dismantling obligations under the Federal Immission Control Act (BImSchG)

An obligation to dismantle wind turbines – insofar as they are subject to the Federal Immission Control Act (BImSchG) (cf. section 4 (1) BImSchG in conjunction with section 1 and Annex 1 section 1.6 et seq. of 4th Ordinance for the Implementation of the Federal Immission Control Act (BImSchV)[31]) – could result from section 5 (3), no. 3 BImSchG. The standard stipulates that the site must be put into a proper condition after the decommissioning of a plant. A condition is deemed to be proper if it complies with all applicable rules and regulations.[32] However, there is no legal obligation to dismantle permanently decommissioned wind turbines. Therefore, the after-care obligations under immission control law do not include the dismantling of wind turbines.

In principle, a dismantling order under the BImSchG is also conceivable. However, authorisation is subject to the condition that the plant has been erected, operated or substantially modified without the required permit (section 20 (2), sentence 1 BImSchG). According to section 16 (2), sentence 1 and section 3 (1) and (3) of the Federal Immission Control Act, however, the decommissioning of a plant in itself is not a material change.[33] Therefore, the removal of a permanently decommissioned wind turbine cannot be ordered under section 20 (2) BImSchG.

1.1.4 Safety and regulatory law

A demolition order under blanket clauses in police law seems at least possible if the condition of a wind turbine acutely endangers high-level legally protected interests or objects (e. g. human life and health). However, safety measures (e. g. prohibition of use, cordoning-off, removal of individual plant components, etc.) will have priority for reasons of proportionality.

1.2 Scope of the dismantling obligation

The scope of the dismantling obligation will in each case depend on the reason for the obligation.

1.2.1 Dismantling obligation according to section 35 (5), sentence 2 BauGB

The voluntary commitment according to section 35 (5), sentences 2 and 3 BauGB covers the dismantling of all plant components (tower, turbine, foundation, ancillary building, etc.) and the unsealing of sealed surfaces (access roads, etc.).[34] The removal of mere soil compaction, on the other hand, is not part of the duties.[35]

The dismantling obligation also covers buried cabling, insofar as it is part of the structure, i. e. all cabling covered by the application submitted as part of the licensing procedure. However, cabling that is not part of the structure, for example because it was installed by the grid operator in accordance with the relevant regulations (in particular sections 8 et seq. EEG), is not covered by the dismantling obligation.

It has not yet been decided whether the foundation of a wind turbine must be removed completely or only to a certain depth. However, according to jurisdiction, safety

30 Higher Regional Court of Berlin-Brandenburg, ruling of 20 June 2012, 10 p. 3/12; cf. Wilke in: Wilke et. al., Bauordnung für Berlin, 6th edition 2008, section 79, marginal no.

31 Ordinance on Installations Requiring a Permit as published on 31 May 2017 (Federal Law Gazette I p. 1440).

32 BT Document 15/4599 (bill submitted by the parliamentary groups of the SPD and Bündnis 90/Die Grünen), p. 127; Dietlein in: Landmann/Rohmer, Umweltrecht, 84th supplement, July 2017, section 5 BImSchG, marginal no. 230; Becht/Kehl, Rückbauverpflichtung von Windenergieanlagen: Grenzen der Verhältnismäßigkeit, Verwaltungsrundschau 2018, 11 et seq. (13).

33 Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 14 et seq.; Schiller in: Landmann/Rohmer, Umweltrecht, 85th supplement, December 2017, section 15 BImSchG, marginal no. 28.

34 Cf. Stock in: Ernst et.al., Federal Building Code, 128th supplement, February 2018, section 179, marginal no. 42 et seq.

35 Stock loc. cit. with reference to contrary opinion, Ginzky in: Giesberts/Reinhardt, BeckOK UmweltR, as amended on 1 January 2014, section 5 BBodSchG, marginal no. 4.

measures (see section 1.3 below) must also cover the costs for the "removal of the concrete foundation"[36], which seems to suggest an obligation to completely remove the foundation.

The administrative regulations of the federal states pursuant to section 35 (5) BauGB require complete dismantling "including the unsealing of sealed surfaces" (Brandenburg[37]), "including the foundation sealing the soil surface" (NRW[38]) and "basically all above-ground and buried facilities and parts of facilities (including the complete foundations)" (Hesse[39]). Current practice only calls for the first 1 to 2.5 metres to be removed in some cases.[40]

In our opinion, the foundation should, as a rule, be completely removed. The dismantling obligation refers to the structural "project", which includes buried parts (cf. section 29 BauGB). The obligation to unseal sealed surfaces once again emphasises this point, but it does not limit the dismantling obligation. This interpretation is also supported by the purpose of the dismantling obligation, which is to protect the "outer area" (area for which there is no development plan) as much as possible.[41] Section 35 (5), sentence 2 BauGB leaves no room for discretion with regard to the scope of the dismantling obligation.

1.2.2 Removal orders in accordance with state building regulations

If the dismantling obligation is based on an authorisation granted under the building regulations of the federal states, the government authority must decide whether it requires partial or complete removal. Contrary to section 35 (5, sentence 2 BauGB), the scope of the dismantling obligation is not prescribed by state law, but is left to the discretion of the authority. For example, the order to dismantle the complete foundation may be disproportionate. According to the state building regulations, the removal order may also apply to underground cables that are not part of the structure in the planning law sense, if the underground cables are themselves a structure as provided in the applicable state building regulations. Otherwise, a dismantling order cannot be issued.

"Operating provisions for the dismantling work may not be worth much when needed; bank guarantees are much safer."

1.3 Securities

As a rule[42], the dismantling of wind turbines for which there is a cut-off date must be secured by an "insolvency-proof"[43] security (section 35 (5), sentence 3 BauGB). In Brandenburg and Saxony-Anhalt, this security must be set up before the permit is granted (section 72 (1), sentence 3 BB BO, section 71 BO ST).

The building permit for a wind turbine must be made subject to a condition to that effect (section 36 (1), alternative 2 VwVfG or corresponding provisions of state building law). Insofar as the wind turbine is subject to the BImSchG, the condition is imposed in accordance with section 12 (1), sentence 1 and section 6 (1), no. 2 BImSchG in conjunction with section 35 (5), sentence 3 BauGB.[44]

The law mentions only the landowner's duty to comply with specified conditions ("Baulast") by way of an example of a means of security, but it does also permit "other suitable means of security". This gives the competent authority a wider choice.[45] They are authorised to take whatever measures are appropriate to ensure compliance with the voluntary commitment[46] and, most significantly, are not limited to the securities under section 232 of the German Civil Code (BGB).[47]

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36 Cf. Hessian Higher Administrative Court (OVG), ruling of 12 January 2005, 3 CU 2619/03.

37 Section 67.4.4.7 of Administrative Regulation of the Brandenburg Building Code, Official Journal 2009, p. 459 et seq. (hereinafter referred to as "WBbgBO").

38 Section 5.2.2.4 of the Decree for the Planning and Approval of Wind Turbines and Information on their Objectives and Application of 8 May 2018, (hereinafter referred to as the "NRW Wind Energy Decree", last viewed on 27 August 2018 at https://recht.nrw.de/lmi/owa/br_vbl_detail_text?anw_nr=7&vd_id=16977&sg=0.

39 Hessian Ministry of Economics, Transport and Regional Development (MWVL) and Ministry of the Environment, Climate Protection, Agriculture and Consumer Protection (MUELV), Implementation of the Building Planning Law Requirement for the Dismantling Obligation and Security Pursuant to section 35 (5) Sentence 2 and 3 BauGB when Approving Energy Plants in Areas for which there is no Development Plan, last revised: 7 November 2013, section III.2, StAnz. 2013, p. 1454 et seq. (hereinafter referred to as "Hessian Wind Energy Decree"), last viewed at https://service.hessen.de/html/files/erlass-aenderung_2013_endg_0.pdf.

40 Cf. NDR, "Dismantling of wind turbines often inadequate", documentary about administrative practice in Schleswig-Holstein broadcast on 23 January 2018, last viewed on 7 July 2018 at www.ndr.de/nachrichten/schleswig-holstein/Rueckbau-bei-Windraedern-oft-mangelhaft,windkraft920.html.

41 Federal Administrative Court (BVerwG), ruling dated 17 October 2012, 4 C 5/11, marginal no. 19, with a reference to BT Document 15/2250, p. 56 (bill by German government).

42 Security e.g. generally not necessary for public-sector projects (atypical case), cf. Mitschang/Reidt in: Battis/Kratzberger/Löhr, BauGB, section 35, marginal no. 183.

43 Cf. Lüneburg Higher Administrative Court (OVG), ruling dated 10 January 2017, 4 LC 198/15.

44 Lüneburg Higher Administrative Court (OVG), ruling dated 10 January 2017, 4 LC 198/15; Hessian Higher Administrative Court, ruling dated 12 January 2005, 3 ZU 2619/03; Becht/Lukas, Rückbauverpflichtung von Windenergieanlagen: Grenzen der Verhältnismäßigkeit, Verwaltungsrundschau 2018, p. 11 et seq. (13).

45 Federal Administrative Court (BVerwG), ruling dated 17 October 2012, 4 C 5/11, marginal no. 15. with a reference to the background.

46 Loc. cit.

47 Opposing view: Becht/Lukas, Rückbauverpflichtung von Windenergieanlagen: Grenzen der Verhältnismäßigkeit, Verwaltungsrundschau 2018, p. 11 et seq. (14).

The type and scope of the security must be selected such that it covers all dismantling and unsealing costs in the event of substitute performance. The dismantling obligation can be secured against any legal successors of the landowner by way of a Baulast and a limited personal servitude.

By accepting a **"Baulast"**, the landowner can commit himself to complying with specific requirements (e. g. the dismantling of a wind turbine) (cf. section 83 (1), sentence 1 MBO). This obligation becomes effective upon entry in the "register of public easements and encumbrances" ("Baulastenverzeichnis") and also applies to legal successors (cf. section 83 (1), sentence 2 MBO).

Advantage: The dismantling obligation is linked to the plot of land.
Drawback: A landowner who is not the operator is under no such obligation; only the dismantling obligation is secured, funds cannot be acquired from a Baulast.

A **limited personal servitude** can be used to encumber the property in favour of the legal entity representing the competent authority. This can entail an obligation on the landowner not to perform certain acts on the property (section 1090 (1) in conjunction with section 1018, alternative 2 BGB), which may mean an obligation not to leave an installation on the land once the installation is no longer used.[48]

The main advantages and drawbacks are comparable with a Baulast.

One of the options that may be considered by way of a safeguard against the liquidity risk is to deposit money and/or provide a guarantee (cf. section 323 BGB[49]). In practice, the parties often agree to operating provisions made under a savings plan.

When a **deposit** is made, the beneficiary acquires a lien on the deposited money (section 323 (1) in conjunction with section 233 BGB). Deposits are governed by the deposit laws of the federal states.[50] The depositories are the local courts (e. g. section 1 (2) HHintG)[51].

Advantage: Security even in the event of a change of operator.
Drawback: Usually bears no interest (cf. section 12 HHintG), substantial bureaucratic effort, amount not available until payment is made.

Another option is to entrust a bank with the **fiduciary administration** of an amount of money. The trustee is instructed to pay out the amount to the creditor or the debtor under certain conditions.

Advantage: High level of security, even in the event of a change of operator (depending on the details agreed), may be interest-bearing.
Drawback: The amount is not available until payment is made.

Where a security is provided under a **savings model**, the profits generated by the operation of a wind turbine are either held in trust or deferred. The sum required for dismantling is thus saved over the forecast period of use. Advantages / drawbacks compared to the fiduciary administration of an amount of money:

Advantage: The debtor does not have to provide the security at the start of operations.
Drawback: Dismantling costs not fully covered in the event of an early termination of wind turbine operation, provisions not insolvency-proof.

A guarantor may undertake to pay the dismantling costs (sections 765 et seq. BGB) vis-à-vis the legal entity / competent authority. In practice, such an undertaking is usually given as a **bank guarantee or group guarantee**. It can be arranged in such a way that the creditor can address the guarantor without taking prior legal action against its debtor (section 773 (1), no. 1 BGB).

Advantage: Depending on the structure, pay-out may be fast, the debtor does not have to "freeze" their money, and handling guarantees forms part of standard business transactions.
Drawback: Guarantee does not automatically follow a change of operator.

The dismantling costs cannot be secured by imposing a duty on the landowner to comply with specified

48 Becht / Lukas, Rückbauverpflichtung von Windenergieanlagen: Grenzen der Verhältnismäßigkeit, Verwaltungsrundschau 2018, p. 11 et seq. (14).
49 The provisions of the Civil Code are applicable mutatis mutandis via section 62, sentence 2 VwVfG. The application is not highlighted below.
50 Grothe in: MüKoBGB, 7th edition 2015, section 232, marginal no. 5.
51 Hamburg deposit act, published on 25 November 2010 (HmbGVBl. 2010, p. 614).

conditions (Baulast) or a limited personal servitude. In addition, they often place the dismantling obligation on the landowner, who may not be the owner/operator. In practice, bank or group guarantees are usually used. Here, it is important to ensure sufficient security in the event of a change of operator. Holding the money in a trust account is another appropriate option.

According to established jurisdiction, a savings-model-based security is not an equally appropriate means.[52] If the security is saved over the predicted operating period, the public purse bears the risk of an early termination of wind turbine operation.

The amount of the security depends on when the turbine will most probably be dismantled, because the security has to cover the actual costs. Inflation and cost increases must therefore be taken into account.

Administrative practice tends to rely on a flat-rate dismantling cost forecast (€ 30,000.00 per MW of installed capacity[53], € 1,000.00 per meter of hub height[54], 6.5 % of the investment costs[55], 10% of the costs of the construction shell[56]). This is permissible as long as it is objectively comprehensible.[57] The different flat-rate approaches can lead to very different results depending on the turbine plant.[58] Possible sales proceeds from recycling cannot be taken into account in the cost forecast, because the public sector has no direct access to the proceeds and should not bear any further uncertainties.[59]

If the predicted dismantling needs change, the question is whether a security in accordance with section 232 of the German Civil Code (BGB) was provided. If so, the authorities are entitled to a supplement or other security (section 240 BGB).[60] The adjustment can only be enforced in court as a general claim under public law (not by administrative act).[61] If section 240 BGB does not apply (e. g. in the case of a deposit held in trust), the corresponding adjustment clauses in the security agreement will apply.

The approval authority is not entitled to adjust the level of security. Also, there can be no subsequent order under the Federal Immission Control Act because the provision of sufficient security is not a specific obligation under clean air law[62], which could be implemented by means of section 17 of the Federal Immission Control Act. If the basis for the forecast dismantling costs changes drastically, a reason for revocation may exist[63] and the obligated party may be made to increase the security deposit by means of a threat to revoke the building permit or immission control approval.

In the event of insolvency of the wind turbine operator and the landowner, a municipality may not take possession of the wind turbine to operate it itself, because the wind turbine, like the plot of land, will generally become part of the insolvency estate.

1.4 Dismantling obligation under an urban development plan ("Bauleitplan") or town planning contract; dismantling by the municipalities

Planning law can stipulate[64] that the construction of wind turbines is only permissible if other facilities are dismantled within a reasonable period of time (section 249 (2) BauGB). The old facilities to be dismantled must be precisely identified, but may also be located outside the planning area and even the municipal area. This makes it possible to combine the designation of new sites with the decommissioning of wind turbines installed prior to the stipulated deadline. The dismantling of old plants thus becomes the task of new investors. Section 249 (2) BauGB therefore does not provide any way of ensuring that dismantling is already carried out at the time of construction.

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52 Magdeburg Higher Administrative Court (OVG), ruling dated 12 May 2011,2 L 239/09; Hanover Administrative Court (VG), ruling dated 22 November 2012, 12 A 2305/11.

53 Document 15/1417 German government reply to inquiry by several liberal democrat MPs, p. 2; Cf. Federal Administrative Court (BVerwG), ruling dated 17 October 2012, 4 C 5/11, marginal no. 34 with cross-reference to information from the Ministry of Construction and Transport of the State of Saxony-Anhalt of 21 June 2005.

54 Section III.2. Hessian Wind Energy Decree.

55 Section 5.2.2.4. Wind Energy Decree NRW.

56 Section 67.3.3.7 VVBbgBO; whereby the shell construction costs for wind turbines are estimated at 40 % of the manufacturing costs. The manufacturing costs are calculated according to section 4 (2) of the Ordinance on Fees in Building Regulations in the State of Brandenburg in the version of 20 August 2009 (GVBl. II p. 562), last amended by Art. 1 Third Amendment Ordinance of 5 October 2016 (GVBl. II, no. 53).

57 Federal Administrative Court (BVerwG), ruling dated 17 October 2012, 4 C 5/11, marginal no. 34.

58 Cf. matters in: Lüneburg Administrative Court (VG), ruling dated 7 May 2015, 2 A 210/12; VG Hannover ruling dated 22 November 2012, 12 A 2305/11; VG Halle ruling dated 12 July 2011,4 A 29/10; VG Halle ruling dated 23 November 2010, 4 A 43/10.

59 Lüneburg Higher Administrative Court (OVG), ruling dated 10 January 2017, 4 LC 198/15.

60 Pfeil, Beseitigungspflichten für stillgelegte Anlagen, 2012, p. 167 et seq.

61 Loc. cit. p. 168 et seq.

62 Hansmann/Ohms in: Landmann/Rohmer, Umweltrecht, 84th supplement, July 2017, section 17 BImSchG, marginal no. 87.

63 Section 21 (1), no. 3 BImSchG, section 49 (2) sentence 1, no. 3 VwVfG.

64 Determination of special areas in the B Plan or designation areas in the F Plan.

Town planning contracts can also be used to create dismantling obligations – possibly as part of a multi-pole legal relationship.[65] A town planning contract may also include dismantling obligations and associated security instruments. The limits are defined by Section 11 (2), sentence 1 BauGB, according to which the agreed services must be appropriate to all circumstances.

Municipalities can pass administrative acts to oblige landowners to tolerate the dismantling of wind turbines that can no longer be used and the unsealing of sealed surfaces (section 179 (1), sentence 1 no. 2 in conjunction with section 177 (3) BauGB). As a result, they can dismantle wind turbines on their own and, in principle, at their own expense.[66] They are entitled to absorb the owner's pecuniary gains resulting from such dismantling activities.

1.5 Security from the landowners' point of view

Even if the landowner is not the operator, he can still be obligated to dismantle the wind turbine if he is a status "disturber". The landowner should therefore ensure there is a contract clause committing the operator to dismantle the wind turbine, to bear the dismantling costs, and to provide a security to ensure they can pay for the dismantling work:

As a rule, the operator is granted rights of use to the land under the law of obligations (lease agreement, sections 581 et seq. BGB) and in rem (e. g. limited personal servitude, sections 1090 et seq. BGB[67]). The tenancy creates an obligation for the lessee to dismantle the wind turbine upon termination of the lease (section 518 (1) BGB in conjunction with section 546 (1) BGB).[68] An obligation to remove the wind turbine at the end of the servitude is partly derived from sections 1020, 242 BGB[69]; there are also other claims for wind turbine removal according to section 1004 BGB.[70] The landowner's security may be more extensive than the dismantling obligation under building law: it may also cover buried cables which are not part of the building structure.

It may happen that the operator already discontinues their permanent use of the wind turbine before the rights of use to the land expire. In this case, the landowner – as a disturber – can be obligated to take action before he can ask the operator to dismantle the wind turbine. The landowner should therefore also agree a dismantling obligation in the event of an early termination of wind turbine operation. Here it is important to reach as precise an agreement as possible on the conditions under which the dismantling obligation arises.[71]

In practice, a bank or parent company guarantee is usually considered one way of securing the dismantling obligation[72]. If a new operator wishes to take over from the old operator and enter into the contract with the landowner, the landowner can refuse his approval until the new operator also provides a corresponding security.

The landowner is not allowed to dismantle the wind turbine himself – even if its use is permanently terminated. However, the owner may have a clause put into the contract granting him the right to dismantle the wind tubine using the security.

2 DISPOSAL OF PLANT COMPONENTS

Wind turbines governed by the BImSchG shall be decomissioned in such a way that, even after the operation has been discontinued,

"existing […] waste is correctly and harmlessly recovered or disposed of without causing any damage or any adverse effet on the general public […]", section 5 (3), no. 3 BImSchG.[73]

65 Söfker in: Ernst et al., BauGB, section 35. marginal no. 165 a.

66 NRW Higher Administrative Court (OVG), ruling dated 27 May 2004, 7a D 55/03.NE states that section 179 (1) BauGB provides no authorisation to require the owner to dismantle the installations.

67 See also 3 above.

68 Bieber in: MüKoBGB, section 546, marginal no. 7 with additional supporting references to decisions of the ordinary courts.

69 Morh in: MüKoBGB, section 1020, marginal no. 11.

70 Loc. cit.

71 While the time model of the Federal Administrative Court (BVerwG) [see above, 1.1] leaves considerable room for manoeuvre, the owner can secure a certain "advantage" over a possible claim with as clear a rule as possible.

72 See above, 1.3 for an overview of the common means of security with a brief list of advantages and disadvantages.

73 See above, 1.1.3 on the requirement to restore the relevant piece of land to a proper condition (section 5 (3), no. 3 BImSchG).

This obligation to properly dispose of dismantled or excavated plant components is defined by waste law. Waste-related obligations under the provisions of pollution control law only apply during the construction and operation phase (section 13 of the Circular Economy Act (KrWG).[74]

The wind turbine to be dismantled falls under the Circular Economy Act if it generates "waste" as defined in section 3 (1) – (3) KrWG. As a rule, this is the case if the owner wishes to dispose of the plant or plant components (subjective concept of waste). Only in exceptional cases, e.g. when the entire plant can be sold directly, is it conceivable that no waste is produced at all. Individual parts of the plant can lose their waste character at a later stage if they have been processed in such a way that they can be re-used.

Section 6 (1) KrWG establishes a waste hierarchy which applies to the disposal of the components: Depending on the technical practicability and the economic reasonableness, preparation for re-use[75] takes precedence over recycling; both take precedence over "other use" through incineration or use as filling material. All three types of recovery take precedence over disposal.

Accordingly, the individual parts of the wind turbines have to be maintained as far as possible, repaired if necessary, etc. and re-used (e.g. plant export).

Non-reusable components must be recycled. For this purpose, the components of a wind turbine must be collected separately according to waste fractions (concrete 60–65 %, steel 30–35 %, rotors 2–3 %) (section 8 (2) of the Commercial Waste Ordinance (GewAbfV)). Metal can be almost completely recycled, but so far, there is no economical process for concrete. It is usually broken down to the desired size and used as backfilling material.

When disposing of plant components, the rules of the selected process must be observed. If, for example, the concrete parts are recycled in a construction waste crusher, the requirements stipulated by the BImSchG and the plant permit must be observed. DIN standards only have to be observed where this is stipulated by applicable specific legislation (e.g. in some of the ordinances issued under the BImSchG).

Current legislation does not provide for specific product responsibility on the part of the manufacturers of wind turbines for disposal if they contain "problematic" constituents. Whilst section 23 KrWG includes a general clause on product responsibility, it lacks the required statutory instrument (section 23 (4) KrWG). It is therefore left to the regulator to define rules on product responsibility.[76]

The re-use of the rotor blades is problematic. They consist largely of glass-reinforced plastics (GFRP) and increasingly also of carbon-fibre-reinforced plastics (CFRP). So far there are no economically viable recycling methods for these materials. Rotor blades are mainly thermally used. A large proportion of the ash can be used as a raw material substitute for the production of cement. The rotors must not be disposed of at a landfill because they contain organic substances in large proportions.

The safe combustion of CFRP (section 7 (3) KrWG) requires high temperatures.[77] At low temperatures, the fibres merely shorten, become respirable and can endanger health.[78] CFRP components must therefore be collected and re-used separately.[79]

The separate collection and re-use of the waste must be fully documented (photographs, delivery documents, disposal and weighing certificates, etc.). The waste disposal contractor (e.g. incineration plant operator) must provide proof of what ultimately happens to the waste (section 8 (3) GewAbfV).

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74 Delfis in: Schmehl, Commentary on Circular Economy Act (GK-KrWG) 2013, section 12, marginal nos. 8 and 4: Due to the remittal in section 5 (1), no. 3 Federal Immission Control Act (BImSchG), the requirements of the Circular Economy Act (KrWG) with regard to the obligations to recover and dispose of waste also apply to the construction and operation phase.

23 Circular Economy Act (KrWG) legally defined as any process the principal result of which is that the waste is used for a useful purpose within the installation or in the wider economy, either by replacing other materials which would otherwise have been used to fulfil a particular function, or by preparing the waste such that it fulfils that function.

75 The concept of re-use ("Wiederverwertung") is alien to the Circular Economy Act. Nevertheless, the term is partly used, s. no. 77. The term "recovery" ("Verwertung") is defined in section 3 (23).

76 Beckmann in: Landmann/Rohmer, Umweltrecht, 86th supplement, April 2018, section 23 KrWG, marginal no. 55–58.

77 BWE, Möglichkeiten zur Wiederverwertung von Rotorblättern von Onshore-Windenergieanlagen, December 2017, p. 4, last viewed on 2 July 2018 at https://www.wind-energie.de/fileadmin/redaktion/dokumente/hintergrundpapiere-oeffentlich/themen/Technik/20171221_hintergrundpapier_moeglichkeiten_des_recyclings_von_rotorblaetter.pdf

78 LfU ST, Entsorgungsmöglichkeiten von glas- und kohlefaserhaltigen Abfällen, slides 14 et seq., last downloaded on 2 July 2018 at https://lau.sachsen-anhalt.de/fileadmin/Bibliothek/Politik_und_Verwaltung/MLU/LAU/Abfallwirtschaft/Abfallstatistik/Dateien/Faserverstaerkte_Kunststoffe.pdf.

79 LfU ST, loc. cit.

Dismantling of wind turbines

RALF VOßHENRICH

Ralf Voßhenrich works for the Hagedorn Group where he is in charge of the dismantling and demolition of wind turbines.

"For foundations of 250 cubic metres and above, it's worth performing a controlled explosion. With old plants getting bigger and bigger, we will have to do more controlled explosions in future."

The dismantling of a wind turbine is an important phase in its lifecycle that should by no means be disregarded. The many facets of a dismantling project are as diverse as they are complex. It is certainly not enough to simply knock over an old wind turbine. Instead, it needs to be dismantled systematically and in an environmentally friendly way. An important point here is the protection of the immediate surroundings.

The Hagedorn Group plays a pioneering role in this difficult field. It offers a convincing and sustainable solution for the diverse field of wind turbine removal.

REUSE OF ROTOR BLADES

The decision on what to do with, or how to re-use, old rotor blades often presents wind turbine operators with a big challenge. One option is to recover the materials from the blades on site. Following disassembly, the blades are segmented using a saw mounted on an excavator. This saw has a permanent water supply to allow all GFRP dust to be collected as plastic sludge directly on site. The sludge is collected in a filter fleece so that the ground is protected as much as possible. CFRP elements installed in the blades can also be professionally separated.

In order to allow independent and efficient work, the equipment used by the excavator is mounted on a trailer as a so-called sawing platform. Despite its compactness, this trailer offers sufficient space for the necessary tools.

"As a rule, we will only perform a controlled explosion on a wind turbine in an emergency, for example after a fire, when there are concerns about its structural integrity."


HAGEDORN

DISMANTLING OF THE TOWER

The demolition of the turbine tower is one of the most demanding tasks when it comes to dismantling a wind turbine. There are a wide range of methods available. The method used will depend on local conditions at the site and the materials involved.

One option is to cut a tower into ring segments, starting at the top of the tower. The ring segments are lifted by a crane and lowered to the ground for further processing.

Another option is to use demolition shears, provided the tower is made of concrete. This method is much faster than cutting a tower into segments. Concrete parts produced this way will ideally come down inside the tower. To protect against concrete parts falling down on the outside, an earth wall and wooden planks are erected.

The most cost-effective method is the use of a demolition ball which allows the tower be brought down in an efficient and precise way. Slots are cut into the side of the tower at several points, so it can be folded into predefined segments. The advantage here, apart from the cost aspect, is the speed at which this can be done.

Finally, there is the option of performing a controlled explosion. This involves preparing a fall zone around the structure. Although blasting is by far the fastest way to bring down a structure, this method requires a number of additional prerequisites to be met, including the need for sufficient free space to "lay down" the tower and rule out collateral damage.

DISMANTLING OF THE FOUNDATION

Wind turbine foundations are usually dismantled by a 40-ton excavator, which is also the main tool for most of the other work. Using a hydraulic hammer, the foundation can be effectively cut into pieces and removed. The reinforcing steel is professionally separated and recycled. For larger foundations, controlled blasts can be an option to loosen foundation segments. For foundations of around 250 cubic metres and above, blasting also helps to speed up the overall process. It involves drilling a number of holes into the concrete foundation which are then filled with an emulsion and covered with mats. This keeps the blast pressure in the foundation, and there is no danger from flying debris. The blast will loosen the concrete structure and help detach the reinforcing steel from the concrete.

RECOVERY OF THE MATERIALS

Concrete pieces produced by dismantling wind turbines can be processed and recycled on site if required. The resulting material can be used, among other things, for the construction of roads and foundations. Alternatively, the material can be put on the market or disposed of.

Recovered steel will not usually pose a recycling problem. It can be sold for the benefit of the client and processed into new components or semi-finished products.

The glass-fibre-reinforced plastic also has its place in the material cycle. The associated process is handled by neowa GmbH.

Recycling rotor blades

MIKA LANGE

Mika Lange is an authorised signatory of neowa GmbH. neocomp is an affiliate of neowa GmbH.

Rotor blades essentially consist of glass-fibre-reinforced plastics (GFRP). If you take a closer look you will find epoxy or polyester resins, glass fibres, adhesives, balsa wood, ferrous metals and various non-ferrous metals. GFRP products are designed for a long service life. Apart from their mechanical strength, positive properties include a low weight (lightweight design), UV stability, corrosion resistance and electrical shielding. At the end of the lifecycle, however, it is these properties that can become a "disposal problem":

- GFRPs have been banned from disposal in landfills since 2005
- Waste incineration plants (WIPs) are not designed for GFRPs:
- Glass fibres cannot be collected in electrostatic precipitators
- GFRPs can cause vitrification inside the WIP combustion chamber
- GFRPs are not completely burned (unburned GFRP collecting in the ash pit)
- GFRPs have a highly abrasive effect on shredder components
- Classic plastic recycling is not possible. GFRPs (thermosetting plastics) cannot be melted down and re-used.

HOLISTIC RECYCLING SOLUTION – NEOWA

Rotor blades are cut into manageable pieces on site in a clean and environmentally friendly process and separated into GFRP and CFRP (carbon-fibre-reinforced plastic) fractions.

CFRP waste is recycled by pyrolysis. In this process the carbon fibres are recovered and returned to the material cycle, i. e. re-used.

Treatment facilities located across Germany prepare the GFRP blade segments for shipment to neocomp's recycling plant in Bremen. This also involves removing solid ferrous metals, which would cause problems during subsequent processing.

PROCESSING FOR THE CEMENT INDUSTRY

The GFRP waste is mechanically processed in two main stages at neocomp's recycling plant using a specially developed dry process together with dust control additives. Separators remove ferrous and non-ferrous materials.

The process turns a 60 m rotor blade into a mass of two-dimensional, roughly 40 mm long fibre bundles referred to as substitute fuel GFRP.

"The low calorific value, the high ash content and the fact that the fibres cannot be removed by electrostatic precipitators suggest that GFRP waste should not be incinerated."

100 % RECYCLING

The substitute fuel GFRP is transferred to a clinker brick production line. Here, the GFRP is first used as a fuel, replacing fossil fuels such as coal or gas.

The silicates from the ashes are then used to replace sand as a raw material.

This dual use saves finite resources and allows GFRP materials to be fully recycled. In a best-case scenario, the old rotor blades will thus be used for the foundations of new, modern and highly efficient wind turbines.

neocomp GmbH is registered and certified as follows:

Approved according to BImSchG (Federal Immission Control

- Certified (as a specialist waste management company) according to EFB
- Certified according to DIN ISO 14001: 2004/OHSAS 18001: 2007/ISO 9001: 2008

1st place in the Recycling and Resources category at the GreenTec Awards 2017

neowa GmbH provides guidance and support through every stage of the blade recycling process, from the initial consultation, the approval procedure, the coordination of preparations on site, the removal and recycling of the materials through to the complete documentation for all wind turbine components in accordance with health and safety standards and environmental protection regulations.

Challenges in CFRP recycling

TIM RADEMACKER

Tim Rademacker has been Managing Director of carboNXT and CFK Valley Stade Recycling since 2010.

The carbon fibre market is growing worldwide. Due to their thermal and electrical conductivity, lower density, high strength and stiffness, carbon fibres (CF) are a popular candidate for use in lightweight and high-performance applications such as aerospace and wind energy. They are also increasingly used in the automotive and construction industries.

GAt the same time, CFRP production waste is on the rise. According to experts, global CFRP production waste will increase to 20,000 tonnes a year by 2025. CFK Valley Stade Recycling specialises not only in the disposal of CFRP waste, but also in the recycling of high-quality carbon fibres. Under the product name carboNXT, recycled CF materials are being returned to the market in a cost-efficient way.

It is not only the complex and energy-intensive manufacturing process of virgin fibres but also the lack of solutions for the disposal of CFRP materials that make the recycling of fibres unavoidable both from an economic and ecological point of view. CFRP Valley Stade Recycling takes care of CFRP components that have reached the end of their service life. In 2011, the company commissioned its pyrolysis plant, which has an annual capacity of around 1,000 tonnes. That same year the company also received the German Raw Material Efficiency Award.

"The incineration of CFRP components is problematic and expensive."

The CFRP material shipped to the plant passes through several processing stages before the actual pyrolysis process takes place. After preparation the material is transferred through the pyrolysis furnace by means of a special transfer system. Pyrolytic decomposition of the plastic structure takes place in the absence of oxygen at temperatures of over 350° C. Pure carbon fibres that show no negative material changes or damage are freed from their matrix. Fibres with a clean surface are then turned into marketable products. carboNXT GmbH, the sister company of CFK Valley Stade Recycling, sells a range of products made of pyrolyzed and non-pyrolyzed material. Depending on customer requirements, the recycled fibres are cut to a certain length, re-coated or turned into textile semi-finished products by non-woven processes. These non-woven products, such as e. g. carboNXT non-woven and veil, form an excellent basis for the production of a sheet moulding compounds.

Milling block made of carboNXT non-woven material

carboNXT carbon fibres reinforce the front bumper and rear apron of the new Mercedes AMG GT R

"We have solved the recycling of CFRP fibres by removing them from the composite material using pyrolysis. These fibres could be used in new products – but so far there has not really been a market for that."

Although the recycling and recovery of high-quality carbon fibres on an industrial scale has been solved for all CFRP waste, there are still reservations on the part of potential users and OEMs with regard to re-using secondary CFs. CFK Valley Stade Recycling focuses on the development of applications for high-quality secondary raw materials, which – in the right regulatory environment – can combine economic interests with sustainable solutions.

Technical challenges of dismantling

Summary of the plenary discussion

BERNWARD JANZING

What is current practice in wind turbine dismantling and disposal? Ralf Voßhenrich from Hagedorn UG reported that rotors are normally dismantled and the blades segmented on site. This is usually done using a large mobile, diamond-studded circular saw to cut the blades into pieces seven to eight metres long, which are easy to transport.

He explained that controlled explosions are only used in exceptional cases – for example if, after a fire in the nacelle, there are doubts about the structural integrity of the individual components – because controlled explosions produce a lot of debris, which means that the topsoil around the structure has to be removed afterwards.

One challenge for the dismantling contractor is that very little is known about the design of the blades and the materials used by the various manufacturers. Over the course of time, his company has gained some knowledge about which materials are used in which types of plant. Nevertheless, there are always a few surprises because it is difficult to obtain first-hand information from manufacturers, as some of the installations are more than 20 years old. He explained that it is now known that CFRP is hardly ever used in blades less than 40 metres long. CFRP layers are only used on some longer blades in the area of the spar caps in the half-shells. Where CFRP appears, it is always separated from the other materials when the blades are dismantled.

After other materials such as metals, pure plastics and balsa wood have been sorted, the GFRP components are crushed in a cross-flow shredder equipped with rotating anchor chains that smash the material into fibre bundles about 40 millimetres long. One practical problem is that the Waste Catalogue Ordinance (AVV), which classifies waste according to its need for monitoring, does not yet have a waste code for wind turbine blades. This frequently leads to legal uncertainty.

What is detrimental for the wind industry from an economic point of view is the fact that the cement industry, which uses GFRP waste as a substitute for raw materials, is the only commercial user of the shredded material. The cement industry therefore knows it has a strong negotiating position and can dictate prices at the expense of the disposal contractors. There is no market for recycled glass fibres, which could be re-used as they are for new products, because the production of new fibres is much cheaper.

For the tower, too, contactors use various methods depending on material (concrete, steel or hybrids). These range from excavators to demolition balls to blasting in some cases. Today, a mobile crusher is usually used for the foundations, but for foundations of 250 cubic metres and above, it is worth considering a controlled explosion to speed up the process, Voßhenrich said. As more and more larger plants are dismantled in future, more and more foundations will have to be demolished by blasting.

The legal side of wind turbine dismantling is anything but clear. Henning Albers from the University of Applied Sciences in Bremen explained that these days wind turbines are hardly ever removed under a dismantling permit; sometimes all that is issued is a dismantling notice. Often there is nothing at all because there is no sound technical basis for the dismantling and recycling of wind turbines. There are hardly any rules or regulations defining who has to do what and in what way.

For German operators, another way of re-using old wind turbines is to export them to countries where they can still be used. Henning Albers explained, however, that this "second life" option is increasingly difficult for turbines rated more than one megawatt because these units are so technologically advanced that they are hardly suitable for the target countries, which are often emerging markets. The plenary discussion also touched on another fundamental problem: What can be done to ensure that plants that are treated as an asset up to the German border do not suddenly become waste on the other side of that border?

Albers also called for a correct use of terminology by distinguishing between re-use and recycling quotas, which is also the official terminology used in the Circular Economy Act. According to the Act, the thermal use of waste is regarded as re-use, but not as recycling. According to the official definition of the Circular Economy Act, recycling only denotes the utilisation of the material. His conclusion that wind turbines have so far not been entirely green underlined how important it is for the recycling of wind turbines to be given more attention by political, administrative and business leaders.

Afterwards, lawyer Hartmut Gaßner explained that there is no general product responsibility for wind turbine manufacturers under the Circular Economy Act. Accordingly, the requirements are not yet sufficiently taken into account for wind turbine design. The cost benefits that come with easier recycling were not enough to create economic incentives for designing products that are easy to dismantle.

However, enshrining higher product requirements such as recycling quotas in law would have to be done EU-wide.

He explained that the voluntary commitment to dismantling, which has been in place since 20 July 2004, is a weak instrument because it is not independently enforceable. It is therefore important to regulate the financing of the dismantling work as part of the construction project. This is possible on the one hand by imposing an obligation to comply with specified conditions ("Baulast") which, however, does not necessarily mean that the money required for dismantling would actually be available in the end.

A guarantee or a deposit of the money is always the better option. The sum required varies from federal state to federal state – sometimes it is 30,000 euro per megawatt (Saxony-Anhalt), sometimes 1,000 euro per meter of hub height (Hesse), 6.5 per cent of the investment costs (NRW) or 10 per cent of the building shell sum (Brandenburg).

Tim Rademacker from CFK Valley Stade Recycling GmbH & Co. KG showed that there is now also a recycling process for CFRP components. The company recovers the carbon fibres from the composite material by pyrolysis. The problem is the market because manufacturers of CFRP products often find it difficult to re-use recycled fibres as an equivalent raw material, particularly in safety-relevant applications in aviation, for example. This was an issue the audience could relate to.

Rademacker is now advocating the introduction of a recycling code (also known as resin identification code) for CFRP products. These triangles consisting of three arrows, which exist today for plastics ranging from PET to PVC, could also be used to indicate for CFRP that the material can be used as required for a circular economy. Rademacker emphasised that CFK Valley Stade Recycling does not see itself as a disposal company, but as a producer of carbon fibres.


MEGALIFT

Field report from the Lippe district

Summary of the plenary discussion

CHRISTIAN KERKMANN

In the district of Lippe, the debate about the dismantling of wind turbines began with a repowering project in 2016. From the outset, the competent approval authorities (i. e. in NRW the emission prevention authorities of the districts and cities with district status), the soil protection authority and the competent building authority for the municipalities in the districts agreed that the dismantling of the wind turbine should also include the complete removal of the foundations provided they were shallow foundations.

The application documents for the first repowering projects didn't specify whether the foundations of the wind turbines to be dismantled would be completely removed, but the approvals issued for these repowering projects required the applicants to fully remove each installation complete with its foundation (flat foundation in each case). While some applicants complained about certain aspects of approval, no one objected to completely removing the old foundations.

"In future the dismantling obligation will also include the cable duct to the next public cable route."

All wind turbines in the district of Lippe have flat foundations, which is why complete dismantling doesn't pose any legal or technical problems. For wind turbines supported by pile foundations, however, things can be much more complicated, both legally and in terms of technical complexity. The Wind Energy Decree in NRW called for the dismantling of wind turbines, including the foundation sealing the soil surface. This can be understood to mean that the foundation piles do not have to be completely removed. Depending on the subsoil conditions, a single pile can be reach 15 metres or more into the subsoil. In addition to the technical challenges, dismantling must also take account of soil and groundwater protection requirements. The principle of proportionality as specified by the authorities must also be taken into consideration when deciding on the required extent of a dismantling project. It is therefore not possible to clearly define a standard scope for dismantling here. Rather, whether or not pile foundations have to be removed should be decided on a case-by-case basis.

Christian Kerkmann works for the Emission Prevention and Climate Protection, Energy and Soil Protection department FG 702 of the Lippe District Administration in North Rhine-Westphalia.

"We demand the complete removal of the foundation, and we include a clause to this effect in the dismantling permit. In the case of repowering, we also demand the removal of the old foundation."

In order to ensure wind turbines are dismantled, the district of Lippe routinely demands a security in the form of a bank guarantee. Another option is to have an obligation to comply with specific conditions registered for the owner of the land in question, but this will not ensure that sufficient financial resources will be available at the time the wind turbine needs to be removed. It is for this reason, first and foremost, that the district of Lippe requires the applicant to provide a security, which will only be returned after the old wind turbine has been completely dismantled. This security is usually in the order of 6.5 % of the total investment costs, which is the level set out in the NRW Wind Energy Decree. The information provided by the manufacturer or applicant is checked in this regard. The district of Lippe also requires an additional premium for inflation, and this has so far never been legally contested by wind turbine operators.

There are currently 124 wind turbines in operation in the district of Lippe. Most of them were approved on the basis of building law in accordance with the requirements applicable at the time. The building permits did not contain any provisions for the dismantling of the structures. When applications for dismantling are made, the permits issued now include provisions calling for the complete removal of the entire wind turbine.

Dismantling becomes an issue for wind turbines when they reach the end of their service life or are operated beyond their design life. There are currently five such wind turbines in the district. By 2025, a further 50 of the wind turbines in service will have reached the end of their design life, and initial inspections have shown that the inspected turbines located in the district will be able to safely generate electricity for another five to six years. In addition to structural stability, economic efficiency is another important aspect for the plant operator. Funding for these plants under the Renewable Energies Act (EEG) will be phased out soon after their inspection. The operator will have to decide whether it is economically viable to continue operating these units, provided they are structurally safe, or whether they should be shut down and dismantled or repowered. Operators looking to replace a wind turbine need to check whether this is still possible under planning law. Some areas previously classified as priority zones for wind energy generation have since been reclassified in updated land use plans, so repowering may not be possible for this reason alone. More and more operators have to address these questions and explore the options described above.

Research project exploring resource-saving dismantling options for wind turbines

FLORIAN LANGNER

A significant proportion of the onshore wind turbines erected in Germany as part of the energy transition are approaching the end of their service life and will have to be dismantled over the coming years. The reasons are both economic and technical: The EEG subsidy will expire on 31 December 2020, and some of these units will soon reach the end of their design life. As this is a relatively young industry (the first wind turbines were commissioned in the 1990s), there is still little dismantling experience. Most of the decommissioning and dismantling work to date has been done as part of repowering projects. As a result, the dismantling of wind turbines is increasingly becoming the focus of public attention.

"There are a wide variety of wind turbines in Germany, which is why we first had to get an overview and have grouped the existing turbines into clusters."

Politicians and administration officials also regard the topic as relevant, because not only do wind turbines have to be dismantled in an environmentally friendly and resource-saving way, but high-quality components also have to be recycled. The materials to be recycled separately are basically concrete, ferrous and non-ferrous metals (steel, copper, aluminium, rare earth elements), glass-fibre-reinforced plastics (GFRP) and carbon fibre reinforced plastics (CFRP). The Federal Environment Agency has initiated a research project entitled "Development of a concept and measures providing a resource-saving approach to the dismantling of wind turbines" to ensure good practice in the dismantling and recycling of onshore wind turbines. It is divided into five work packages, which are carried out by several departments of the Danish consulting company Ramboll BBB and the Institute for Processing and Recycling of RWTH Aachen University, with support from an external project advisory board.

The first work package defined the overall framework governing the dismantling and recycling of wind turbines, which comprises legal requirements, engineering practice and environmental evaluations. One central aspect here is the operator's dismantling obligation. To determine current practices, the project team reviewed literature as well as their own experience and conducted telephone interviews with a number of stakeholders, including wind turbine manufacturers and operators, dismantling and disposal companies, authorities, associations, Internet portals, landowners and banks. These interviews showed that, due to a lack of specifications, there are currently very different approaches to dismantling and recycling wind turbines and that, in addition to widespread good practice, a number of unconventional and unsuitable dismantling methods are also being used.

Florian Langner is Senior Consultant at the planning and management consultancy firm Ramboll BBB.

The second work package was about predicting the number of upcoming dismantling projects and the amounts of waste up until 2040. The problem here was "stocktaking", as there is no complete, public database of the wind turbines installed in Germany. The team therefore used the in-house database, which contains a host of information (wind turbine type, hub height, date of commissioning, etc.) and correlates sufficiently with other publications in terms of total capacity and wind turbine numbers. After the available data had been reviewed, the different wind turbine variants (combinations of turbine types, hub heights, towers, etc.) were grouped into meaningful clusters. Here, a distinction was made between turbine clusters, which are defined by their rated output and rotor diameter, and tower clusters, which are primarily characterised by hub heights. The wind turbine clusters also covered different drive train designs (with/without gearbox) while the tower clusters reflected the different tower types (tubular steel towers, lattice towers, concrete hybrid towers). This way, all German wind turbines were classified in a meaningful way. The team then developed a meaningful approach to determining the relevant material quantities for each cluster from the available documentation. This meant taking account of the quantity-weight ed properties (rated power, rotor diameter, hub height) for each cluster while also giving due consideration to the most frequent wind turbine types and towers in each cluster. In a next step, the quantities of waste were calculated on the basis of the year of commissioning, the expected service life, the cluster allocation and the amount of material per cluster. These calculations were also based on forecasts for GFRP and CFRP composites, concrete, steel, copper and aluminium. In addition, a forecast was also made for the waste streams generated for rare earth elements/magnets. These streams, however, were not determined using the cluster methodology described above, but were based on other publications and the internal database. Apart from the forecast for waste streams over time, the team also estimated the dismantling costs for each wind turbine cluster and each tower cluster, also drawing on information obtained in the telephone survey. The results provide a clear picture as to which types of turbine will increasingly start to be decommissioned and when.

"So far, there are no specific, binding waste regulations or disposal recommendations."

The next work packages will draw up technical recommendations for decommissioning and recycling on the basis of the results of the earlier work and develop recommendations for the organisational and financial implementation of dismantling projects. The project has a duration of 19 months and is expected to be completed by mid-2019.

A glance at implementation practices

Summary of the plenary discussion

BERNWARD JANZING

Christian Kerkmann from Lippe district council used two case studies to illustrate how local authorities deal with old wind turbines for which no dismantling requirements were specified at the time of construction. Since both sites were set to undergo repowering, the new permits also included a clause calling for the removal of the old foundations. In both cases the applicant did not raise any complaints about this clause.

Kerkmann reported that there are quite a number of old plants where the building permits did not include a dismantling clause and where such a clause could not be introduced later because the operator was not planning to repower the site. He explained that in these situations, the authorities will demand the complete removal of the installation including the foundation whenever an application for dismantling is filed.

Pile foundations are problematic, as he explained, but there are no such installations in the Lippe district. It is important, however, that dismantling is always carried out using state-of-the-art technology, processes and equipment. Nevertheless, Kerkmann did point out that there is no standard answer to the question of how far these foundations should be removed, because the greatest potential threat from an ecological perspective are the construction activities. For this reason, it could even be advisable under certain circumstances to leave pile foundations in the ground.

Responding to a question about the connection cables, which are often installed in the ground over many kilometres during construction, Kerkmann explained that the Lippe district council also requires these to be completely removed up to the next grid connection node.

Kerkmann also reported that there has been one operator insolvency in the Lippe district, which affected two installations approved before 20 July 2004. This is relevant because on that date a new Federal Building Code (BauGB) came into force which changed the way environmental issues are dealt with as part of urban land-use planning, and this also affects dismantling regulations.

For the two relevant wind turbines in the Lippe district, the permit therefore did not include a dismantling obligation. What's more, the operator could no longer be tracked down. The authorities are therefore exploring ways of transferring ownership of these two wind turbines to the district. This way, the district could generate income from both units before having to dismantle them at the end of their life.

Responding to a question about the how to define who should cover the dismantling costs for new wind turbines, Kerkmann said that the authorities generally rely on securities in the form of bank guarantees because – unlike a duty imposed on the landowner to comply with specific conditions – these securities guarantee that the capital needed for dismantling will be available when required. The security will not be returned until the plant has been completely removed and the site restored to its original condition. Registering a duty for the landowner and requiring a security means that one has to deal with two different parties, which is why this is no longer done.

Next, Florian Langner from the Danish engineering and consultancy firm Ramboll BBB addressed the question of how many wind turbines would have to be dismantled in Germany over the coming years. Ramboll BBB has been commissioned by the German Environmental Protection

Agency to conduct a study entitled "Development of a concept and measures for resource-saving dismantling of wind turbines". The results are expected to be available by mid-2019.

The study aims to come up with proposals for fibre-reinforced materials, gearboxes and fluids as well as permanent magnets. It will also discuss whether legal standardisation can help to increase the recycling rate, for example by introducing material-specific requirements or an extended product responsibility. Langner explained that it is important to define responsibilities more clearly. Cost forecasts will also be made even though they are fraught with uncertainties because it is difficult to predict demand and hence the workload for and capacity utilisation of the specialist contractors. Advances in recycling technology and fluctuations in raw material markets (e. g. steel) are another reason why the study will provide only rough estimates.

The study will present a forecast of dismantling costs for each of the different types of plant. Responding to the question of whether all the results of the study will be made available to interested parties next year, a representative of the Environmental Protection Agency confirmed that this was planned.

Langner noted that more than 5,000 wind turbines will no longer receive funding under the Renewable Energies Act (EEG) from 2021 onwards. In subsequent years, this number will be between 1,000 and 2,000. Based on clusters of similar designs – size, tower type, output, drive train – Langner provided an estimate of the quantities of steel and GFRP produced.

Such an analysis is necessary because the existing portfolio of wind turbines in Germany is very heterogeneous, he explained. The data has not only been collected through literature research, but also through the questioning of numerous market players. After the rather large quantities of waste material expected for 2021, Langner predicted a decline in annual quantities of GFRP and steel by 2030, after which the quantities will reach a new peak in 2038.

Langner has also investigated the extent to which CFRP might be found in the wind turbines to be dismantled. He explained that the manufacturer Vestas was one of the first to use this composite material, and others now claim to use CFRP too, while Enercon has since stated that their units built in Germany do not contain CFRP.

The discussion also shows how much the forecasts of the number of wind turbines due for dismantling depend on the energy policy framework, because the end of EEG funding does not necessarily mean that the units will immediately be taken off the grid. Just recently, the price on the electricity exchange for the coming year once again exceeded the five-cent mark after a long period at below three cents. The higher the market price, the more units will be able to hold their own even after EEG subsidies expire at the end of the 20-year period, at least until more extensive repairs become necessary.

Langner pointed out that the sensitivity of the forecasts is in fact very high. And if emissions trading pushes up CO_2 prices, which seemed to be the case in the summer of 2018, operators will be encouraged to continue running their older units. Indeed, the electricity price could even be the key factor determining the extent to which wind turbines are decommissioned.

He noted, however, that there was no reliable data that would allow estimates of how many wind turbines will be taken off the market at what electricity price. There are just too many varying factors determining the operators' calculations, including the technical condition of the units in question, the wind conditions at the site, and the costs such as lease and maintenance expenses.

Recycling of rotor blades containing carbon-fibre-reinforced plastics

ELISA SEILER

The aerodynamically designed rotor blades are the key component of a wind turbine and determine its performance significantly. Due to their low specific density and high strength, fibre-reinforced composites (FRP) are frequently used for lightweight designs and have become the standard material for wind turbines.[1] Glass fibre composites (GFRP) in particular and, increasingly, a mixed construction method consisting of GFRP and carbon-fibre-reinforced plastics (CFRP) are being used in particular stressed areas such as the spar caps. Since the CFRP from rotor blades cannot be recycled as a material or source of energy like the GFRP material (see neocomp process), it must be separated before disposal. Another reason for recycling carbon fibres is their higher value compared to glass fibres.

The recycling of rotor blades can be broken down into three steps: the disassembly of the rotor blades on site, the actual recycling process to produce secondary raw materials and the subsequent use of these secondary raw materials for manufacturing new products.

"It is often not even known which products contain CFRP at all, which makes recycling difficult."

DISMANTLING ROTOR BLADES BY CONTROLLED BLASTING

In order to avoid having to obtain permits for transporting entire rotor blades, operators can cut the blades into container-sized pieces on site. During this step, the formation of dusts containing fibres and resins cannot be completely ruled out, which is why it is important to ensure that emissions are contained (e. g. by water mist) in order to guarantee health- and safety-compliant conditions. Cutting methods include the use of water jets, diamond wires, saws and hydraulic shears. As the materials are very abrasive, mechanical processes such as sawing or cutting generate a lot of wear on the tools.[2]

Elisa Seiler is a research assistant at the Fraunhofer Institute for Chemical Technology in Karlsruhe.

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2 Albers, H., Recycling of Wind Turbine Rotor Blades – Fact or Fiction? 2009. 34: pp. 32 – 41.

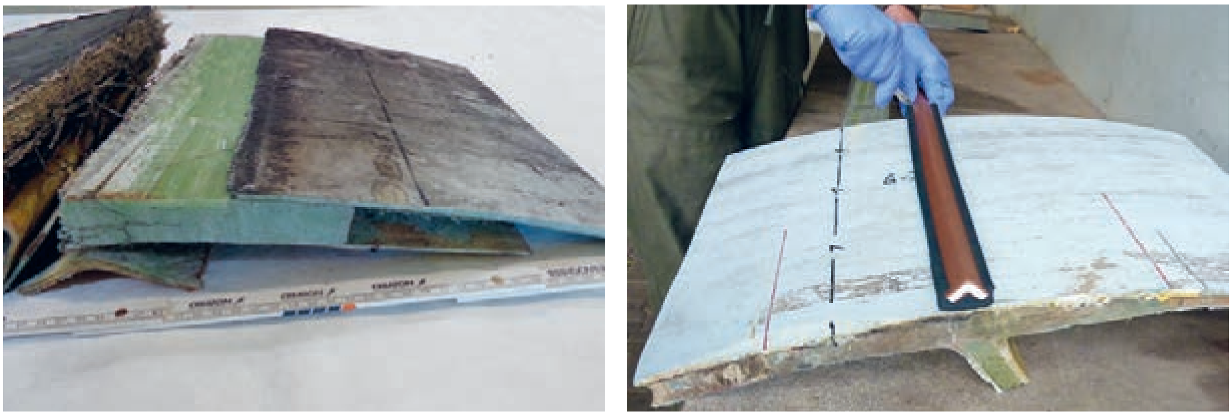

Fig. 1: Dismantling of rotor blade material (left) by applying cutting charges (right) and subsequent ignition in the bunker

The process of using controlled blasting on rotor blades, as developed at the Fraunhofer Institute for Chemical Technology (ICT), has been adapted from the classic demolition process. The demolition of tall buildings by controlled blasting is a suitable method from an economic and ecological point of view, since the demolition process is extremely brief, and this greatly reduces the impact on the environment. The technical feasibility of using controlled blasting (e. g. cutting charges) to cut rotor blade material was successfully demonstrated in a research project entitled "Recycling of composite components made of plastics as matrix material – ReKomp". Sample material segments from disused rotor blade parts were dismantled using explosive charges available on the market.

"Filament for 3 D printing with recycled CFRP is just as efficient as comparable virgin material."

Apart from the general feasibility of the controlled blasting method for rotor blade materials, the required charge strength for different material ranges and thicknesses was also determined. The blasting material used (e. g. a cutting charge) was applied to the specimen with double-sided adhesive tape at the desired separation line (Fig. 1, right) and then ignited in the bunker. The sufficiently strong charge cut the specimen in two at the cutting line, and there was some disbonding of the layers of the sandwich material (Fig. 1 left).

Using this technology, it is possible to separate different material areas like the CFRP spar caps from the rotor blade directly on site. The charge materials used are still too expensive for an immediate wider use of this method, which is why the aim of further investigations is to develop a low-cost material for use on fibre plastic composites and to examine dust containment more closely for use at the wind turbine site.

CHALLENGES IN CFRP RECYCLING

In order to assess the recyclability of carbon fibre waste, it is necessary to take a closer look at the different waste streams that may be generated by the use of CFRP. The cost of recovering carbon fibres is essentially determined by whether the waste is a dry fibre residue without matrix material or a combination of fibre and matrix material.

TDry fibre residues have not been infiltrated with a matrix and are therefore only produced when the material is cut to size. These may be, for example, fibre or fabric rolls or waste from the preforming process. Recycling textile production waste is simpler in the sense that there is no need to separate the matrix from the fibre. Production waste has long been recycled on a large scale in the car industry. The carbon fibre cuttings are turned into nonwovens and further processed as part of the RTM process. The wet residues are fibre materials which have already been combined with the matrix material. These may be production waste or end-of-life components and/or products. When recycling composite components, it is important to distinguish between the different types of plastic matrix. Thermoplastic materials such as polypropylene have less closely cross-linked chain molecules and can therefore be re-melted for re-use. Duroplastic materials such as epoxy resins, on the other hand, which are also used in rotor blades, have closely cross-linked chain molecules, which prevents them from melting again. For high-quality recycling of carbon fibre reinforced plastics (CFRP), the carbon fibres have to be separated from the matrix. Different approaches to fibre matrix separation are currently being explored in various research projects:

- Thermal processes: pyrolysis, partial oxidation, fluidised bed process
- Chemical processes: hydrogenation, solvolysis, supercritical fluids
- Other processes: electrodynamic fragmentation, enzymatic decomposition, etc.

Pyrolysis as a thermal process is already being used on an industrial scale and is offered by companies such as CarboNXT or ELG. After successful fibre/matrix separation, the carbon fibres can be processed like textiles and used in new products. The length of the fibres essentially determines the recycling path. Possible recycling methods would be textile processing into non-wovens or yarns, but also use as short fibres in injection moulding.[4/5]

The recycling of carbon-fibre-reinforced plastics has been extensively researched and successfully industrialised in recent years. Recycled carbon fibres and semi-finished products made from recycled carbon fibres (e.g. granules, non-wovens or yarns) are available on the market, but the consistent use of secondary carbon fibres has not yet established itself. One reason for this is the varying flows of waste streams. The availability of production waste is much easier to predict over the course of time than end-of-life waste. What's more, often too little is known about the available secondary materials and their capabilities.

These very barriers to secondary materials are what the research project entitled "Processing of recycled materials into a filament that can be processed in 3D printing – Recycl3D" set out to remove. The project showed that filaments used for printing components exposed to high structural stresses can be produced economically from recycled materials and are competitive with new materials in terms of their processing and product properties. The pyrolyzed short fibre material was compounded into an ABS polymer matrix and then granulated.

3 Hang, W.: Ressourceneffizienz und Recycling am Beispiel BMWi; Vortrag auf Zuliefertag Automobil 12.11.2013, München, http://www.rkw-bw.de/rde/pdf/RKW-Organisation-2013/Hang.pdf, zuletzt aufgerufen am: 21.09.2018

4 Sigmund, I.; Verarbeitung von rCF zu strangförmigen Produkten; Workshop "Carbon Composite Recycling" des CCeV-Strategiekreises "Nachhaltigkeit" am 31.07.2017.

5 Prof. Dr. Schlichter; Schlussbericht der RWTH Aachen: MAI RecyTape / Entwicklung einer neuartigen Recycling-Prozesslinie für Carbonfasern; August 2017.

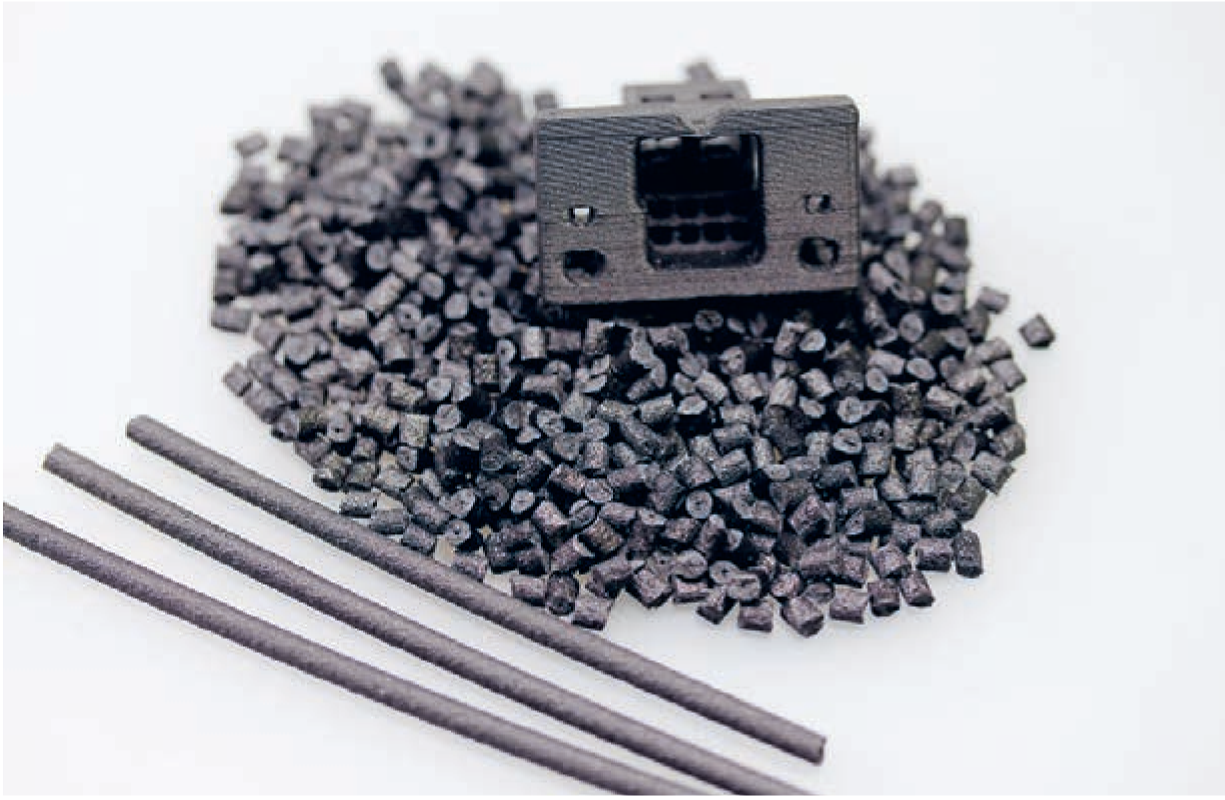

Fig. 2: Granules, filaments and printed demonstrator (connector housing) made of recycled ABS and recycled carbon fibres

For the ABS material too, production waste entirely replaced primary material, with the aim being to produce filaments consisting of 100 % secondary material. The granules produced were extruded into filaments by a single-screw extruder, coiled up and then made available for printing (cf. Fig. 2). Subsequent mechanical characterisation of the recycled filament with commercial filament confirmed the product's capabilities. In terms of their mechanical properties, recycled materials are therefore well able to compete with commercially available filaments produced from new fibres and new ABS as starting materials for filament production for 3 D printing.

It therefore seems there are technological developments that allow, for example, CFRP recovered from rotor blades to be recycled into carbon-fibre-reinforced filaments for 3 D printing. However, establishing a recycling system for CFRP will mean more general conditions – including acceptance, availability, logistics and cost-effectiveness – will have to be met.

Continued operation, repowering or decommissioning?

Assessments and recommendations for selecting optimum post-use strategies for wind turbines after 20 years of operation

JAN-HENDRIK PIEL AND MARTIN WESTBOMKE

At the end of 2020, the first 5,200 or so wind turbines will reach the end of the funding period under the Renewable Energy Sources Act (EEG). Another 8,000 units will follow by the end of 2025. More and more players in the German wind energy industry are therefore becoming involved in exploring optimal post-utilisation strategies for the ageing German wind fleet. After the funding period has expired, operators of affected wind farms will then have a choice between (I) the continued operation of their installations to directly market the electricity on the European Energy Exchange or through alternative marketing models such as power purchase agreements with industrial customers, (II) the repowering of their wind turbines by replacing them with more efficient units at feed-in tariffs equal to the surcharge values of future tenders or (III) the final decommissioning of their wind turbines.

However, the question of the optimal post-utilisation strategy is not only of great interest to the operators of the old wind turbines but also to various other stakeholders in the German wind energy industry:

Project developers, plant manufacturers and investors are interested in evaluating plant-specific repowering potentials in the existing wind fleet in order to provide operators of old installations with early and targeted support for new projects.

Dismantling and disposal companies, on the other hand, are particularly interested in estimates of plant-specific dismantling potentials and times as well as associated disposal and recycling flows, in order to be able to engage in meaningful planning for the comprehensive dismantling and optimum handling processes of the old plants.

Public and political institutions are interested in estimates of the installed wind energy capacity after the dismantling wave in order to be able to properly control future capacity expansion.

Jan-Hendrik Piel is CIO of Nefino GmbH and a researcher at the Institute for Information Systems at the Leibniz University in Hanover. His co-author is a project engineer at the Institute for Integrated Production in Hanover and a partner of Nefino GmbH.

As part of the "Demo-NetXXL" project funded by the German Research Association, scientists from the Institute for Integrated Production in Hanover have teamed up with the Institute for Business Informatics at Leibniz University in Hanover to select and design optimal post-utilisation strategies for wind turbines that are more than 20 years old. To help transfer the knowledge gained from science into practice following the research project, the scientists have now founded the start-up Nefino, which has been funded by the Federal Ministry of Economics and Energy and the European Social Fund since the beginning of September 2018.

One of the start-up's objectives is to develop an innovative geo-information system that allows the different options for all wind turbines in Germany (i.e. continued operation, repowering or decommissioning) to be systematically evaluated. This system can ultimately be used to define the optimum post-utilisation strategy for each individual wind turbine. To this end, the scientists have collected extensive geographic, wind, plant and financial data, which are processed in an integrated system of time series models to predict site-specific wind conditions as well as extensive spatial planning tools and innovative financial mathematical models. For example, users of the software can determine spatial planning potentials for repowering projects (see Fig. 1), define the economically optimum repowering time, analyse the economic efficiency of various strategies for continued operation, and ultimately determine the optimum decommissioning time for an old wind turbine on the basis of the knowledge gained (see Fig. 2).

By applying the software to the entire German wind fleet, aggregated further operation, repowering and dismantling potentials can be derived on any spatial scale, for example at country, regional or district level. In order to support dismantling and disposal companies as well as operators of wind turbines in dealing with the upcoming dismantling wave, the scientists are currently also working on a forecast model which will allow estimates of the costs as well as masses and volumes of raw materials, such as GFRP, steel and copper, from old installations.

"The big unknown in the forecast of the number of turbines that will be dismantled is the market price on the electricity exchange; the higher this is, the more wind turbines will remain in operation after the end of the EEG subsidies.". "

Analyses conducted by the scientists for the entire German wind fleet have shown that it is by no means possible to apply a uniform, optimum post-utilisation strategy to all currently operated wind turbines that will no longer receive EEG funding after the end of 2025. The choice and design of the optimal strategy rather depends on different plant-specific aspects, such as their distance to neighbouring residential and nature conservation areas, site-specific wind speeds, hub heights and the efficiency of the old wind turbine. It has been shown that very early generations of wind turbines in particular have very low efficiencies, which significantly reduce their chance of continued cost-efficient operation and makes repowering the more attractive option. However, in addition to the plant-specific aspects, two exogenous factors in particular play an overriding role when it comes to the optimum post-utilisation strategy: (I) the development of the spot market prices on the European Electricity Exchange and (II) the level of the surcharges in future tenders.

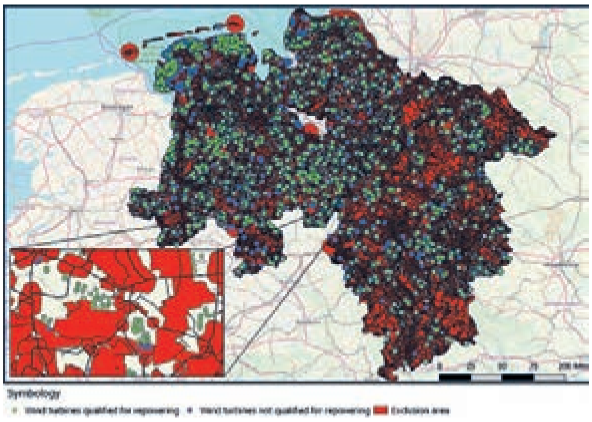

Fig. 1. Geo-information system: Example of the spatial planning analyses in Lower Saxony, showing the locations of all wind turbines that are suitable or unsuitable for repowering projects.

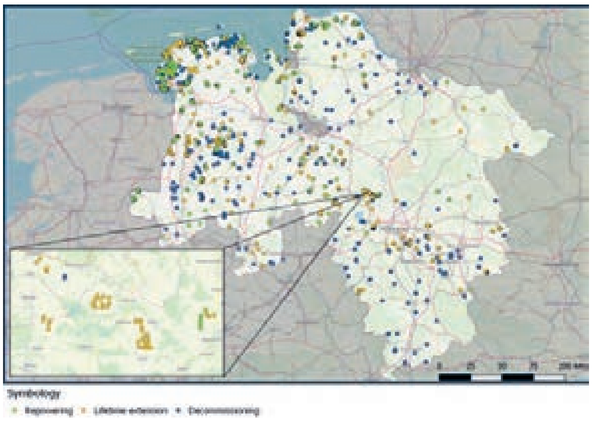

Fig. 2. Geo-information system: Optimal post-utilisation strategies for around 1,650 wind turbines that will no longer receive EEG funding after the end of 2020.

While rising spot market prices would increase the probability of continued economic operation, higher surcharge values would result in an increase in the financial incentives for early repowering.

Determining the dismantling potential across the entire German wind fleet will therefore depend particularly on the assessment of market players with regard to the future development of these two exogenous factors.

With all spatial planning requirements of the federal states taken into consideration, the scientists' geoanalyses show that, theoretically, only about 10 to 11 % of the total surface area in Germany is currently available for new wind energy plants. This means that for about 36 to 40 % of the old wind turbines, repowering is not an option because of the increased hub heights of new wind turbines and more stringent distance requirements. This finding coincides with an operator survey conducted by FA Wind, which does not see any repowering potential in the vicinity of the old installations for around 40 % of a total of 1,621 wind turbines surveyed. As an alternative to decommissioning, the only option for the operators of these wind turbines is to continue operating them. According to several studies by various research institutes, which take account of the current regulatory framework and market forecasts, it is highly questionable whether most of the wind turbines that are more than 20 years old can be operated economically in future.

However, this conclusion is not fully confirmed in the latest analyses by the scientists from August 2018 for the entire wind fleet of Lower Saxony. Given the most recent development of exogenous factors, such as higher spot market prices in 2018, the emergence of the first power purchase agreements in the German wind market and increasing surcharge values in the last tender rounds, continued operation or repowering is becoming much more attractive in comparison to final decommissioning. In their analyses, the scientists took account of three different operation and maintenance strategies of Deutsche WindGuard GmbH, which are explicitly geared to the requirements of continued operation:

Firstly, the existing operation and maintenance strategy, which is to enable continued long-term operation. Secondly, the medium-term continuation of operations with due consideration for condition-based repair and maintenance measures, and thirdly, a cost-efficient operation and maintenance strategy that allows the continuation of operations only until the first critical defects occur.

In contrast to analyses by scientists from earlier years, such as the findings published in the magazine Energie & Management for the entire German wind fleet, the results of the latest simulations paint a different picture with regard to the feasibility of continued operation for wind turbines that are more than 20 years old. While earlier analyses indicated that it would be difficult for many operators to achieve economically viable continued operation, the results for Lower Saxony now show that the current market situation could very well enable economical continued operation for a large number of wind turbines that are more than 20 years old (see Fig. 2). This is particularly true in the event that the operators of the affected plants opt for one of the two more cost-effective operation and maintenance strategies.

"In repowering projects, synergies should be exploited; the concrete of the old foundation, for example, could be used as gravel for road construction."

From the scientists' point of view, the change in the findings compared to earlier analyses is due, on the one hand, to the fact that the available wind resources in Lower Saxony are far above the national average. Since the effect of the EEG reference yield model, which supports less windy locations with regard to the level of feed-in tariffs, will no longer apply after the EEG subsidy has expired, plants with higher wind resources will be in a better situation when it comes to direct marketing. It can therefore be assumed that the feasibility of continued economic operation in less windy regions of Germany is significantly lower than in Lower Saxony. On the other hand, in earlier analyses the scientists assumed significantly lower spot market prices, but there has now been a clear and sustained upward trend since March 2018. If, for example, the average spot market price from August 2018 of 5.24 cents per kilowatt hour is taken as a basis, long-term operation would still be economically viable for the vast majority of all wind turbines that are more than 20 years old. Nevertheless, scientists do not assume as yet that spot market prices will remain at this level in the long term.

Despite the varied findings regarding the choice of the optimal post-utilisation strategy, the analyses of the scientists indicate that the German wind energy industry will see a wave of decommissioned and dismantled wind turbines in the coming years. According to a study by FA Wind, only 400 wind turbines were decommissioned in 2016, with a further 387 following in 2017. To put this in perspective: by 2025 up to 13,200 wind turbines may have to be shut down, dismantled and disposed of.

Such a decommissioning and dismantling wave will be a major challenge, which can only be overcome if the different players in the German wind energy industry act in unison. This is why, back in 2016, the scientists established an interdisciplinary working group consisting of operators, project developers, plant manufacturers, consulting companies, dismantlers and disposal companies, as well as scientific, public and political institutions, which gathers every six months for a "Dismantling Network Meeting". These events offer interested stakeholders the opportunity to regularly exchange views on current challenges and to actively participate in developing joint solutions for the dismantling, disposal and recycling of wind turbines. The aim is to find the right process for tackling the upcoming decommissioning and dismantling, taking account of ecological and economic aspects.

State of research and new knowledge needs

Summary of the plenary discussion

BERNWARD JANZING

Intensive research is being carried out into the recycling of CFRP because from an environmental perspective the recycling of carbon fibres is a more urgent issue than glass fibre recycling. CFRPs are much more difficult to handle from an ecological point of view because, unlike glass fibre composites, carbon composite materials conduct electricity and can therefore cause the electrostatic precipitators in waste incineration plants to fail. Finding ways of thermally disposing of CFRP fibres is currently the subject of research in a UFOPlan project being conducted at RWTH Aachen University.

For the moment, however, CFRP must still be separated before the waste is incinerated. According to Elisa Seiler from the Fraunhofer Institute for Chemical Technology, one problem is that people often do not even know which products contain CFRP. As the use of CFRP is set to increase globally not only in the wind industry over the coming years, the development of new processes that allow cost- and energy-efficient processing and recycling of carbon fibres for re-use in the production cycle is an important topic.

The easiest way is to recycle production waste because it often occurs as pure material. After all, this waste accounts for 30 % of all CFRP waste. Regardless, with large CFRP structures at least, such as the spars in rotor blades, the composite material can be separated.

There are various technical processes for the subsequent separation of fibre and matrix material, including pyrolysis, solvolysis, supercritical water oxidation, multi-stage comminution and microwave digestion for the classical thermosetting CFRPs. Chemical methods only work with specific substances. In the case of a thermoplastic matrix, this can also be re-melted for the fibre-matrix composite to be re-used.

The discussions showed that the lack of a market for recycled fibres in particular is hampering the development of recycling processes. There is no demand for these raw materials, which is why there are no products, especially since recycling is currently more of a down-cycling because – as is usual with fibre products – the individual fibres become shorter with each further processing cycle.

Research is now underway to find new applications for recycled CFRP and further improve its properties by optimising the processes. One option is to fractionate the fibres after recovery in order to be able to guarantee optimum material properties depending for the relevant application.

The shorter fibres do not have to be a disadvantage for every application. For example, according to Elisa Seiler, CFRP can be used in filaments for 3D printing, an area where carbon fibre powder is sometimes used. This can be produced with recycled fibres in a quality comparable to that of virgin material. One problem, however, is further exacerbated by the use of filament-containing CFRP: the more this filament is used, the more difficult it becomes to get an overview of which products contain the fibres.

Jan-Hendrik Piel of Nefino, a spin-off of Leibniz University in Hanover, analysed the logistical side of dismantling projects, which involves weighing up time-consuming and expensive dismantling at the site with the costly transfer of individual parts to a dismantling centre. Somewhere in between is an optimum solution that leads to minimal overall costs and which can be determined for each site on a case-by-case basis.

Piel therefore suggested setting up temporary regional dismantling factories to avoid long haulage distances for large components. The working hypothesis is that a spatial division of the dismantling process is the most economical approach. The research question addresses the conditions under which distributed dismantling can be used in a meaningful way for dismantling large structures.

Depending on the wind turbine components to be handled, it might therefore also make sense to use a mix of different concepts, as is already done today. The rotor would only be dismantled into its main components at the site for easier and hence more cost-efficient transportation, and for the nacelle a preferably non-destructive pre-dismantling method would be recommended. The tower, whether steel or concrete, is best dismantled on site, and the same goes for the foundation. For repowering projects, there could be synergies, provided that the dismantling and the construction of the new turbine are coordinated in terms of time. One example would be to use concrete gravel from the old foundation for the construction of the new plant.

Piel explained that early planning of dismantling projects is the most important recommendation he can give. It might even make sense to bring a project forward to avoid being caught in a dismantling wave. The next such wave is expected to start in 2021, even if it is not yet clear to what extent old plants will remain in service beyond the end of the EEG funding period. Repowering, meanwhile, may accelerate the dismantling process, because it also involves plants that have not exhausted their 20 years of operation.

He went on to explain that the optimal organisation of a "reverse supply chain" is a dynamic project that depends on numerous time-variable parameters, such as shipping and dismantling costs, disposal costs and revenues from recyclable raw materials.

In such a complex causal model (operations research model), in which the shipping distances, the number and location of the wind turbines to be dismantled, and the dismantling depth are also included as parameters, there will be constant readjustments. This is due to the fact that every decision also affects all subsequent processes. At the moment, therefore, the main question is not to decide in detail to what extent dismantling should ideally take place and at which locations, but only to establish the basis for this process.

More precisely, the aim is to set up an appropriate geo-information system for the purpose of optimally supporting the dismantling process with interactive maps. This will allow wind turbine operators to determine the best possible dismantling period or repowering date in commercial terms, with due consideration for all relevant influencing factors. On this basis, project developers and plant manufacturers, as well as dismantling and disposal companies, will also be able to plan their business with maximum efficiency.

Amal Shankar Ramachandran Nair from the University of Flensburg presented the concept of a mobile recycling plant for fibre composites, consisting of mechanical shredding, an electrostatic separation process and a downstream thermal treatment unit. As this concept is so far only a theoretical one, doubts were expressed in the subsequent discussion as to whether this concept would offer a viable practical solution, both technically and economically, due to its complexity.

Conclusion and outlook

Wind turbines have been shaping the energy market and the German landscape for more than 20 years. As a comparatively "young" technology, they have undergone dynamic development and are constantly reaching new highs in terms of efficiency and size. However, with the imminent end of fixed remuneration rates under the Renewable Energies Act (EEG), many plant operators will be faced with new issues. In addition to questions such as repowering or continuing operation, the dismantling and recycling of wind turbines is a growing priority for authorities and wind turbine operators.

This issue of Breaking & Sifting has looked into these topics, presenting current developments and new potential, applicable rules and regulations, and experiences and methods relating to the professional dismantling of wind turbines. It has also discussed the future of dismantling and the central question of how to fully (re-)use the potentially large quantities of materials collected during the dismantling process.

A look at the current regulatory framework revealed the great potential for more mature solutions and specifications. Although the legislator has meanwhile recognised the need for the introduction of a dismantling obligation for wind turbines, the law only provides for a voluntary commitment on the part of the plant operators. This voluntary commitment, however, does not cover the older wind turbines, nor is it very specific, and, incidentally, it is subject to the legislation of the individual federal states. The requirements of the Circular Economy Act (KrWG), the Commercial Waste Ordinance (GewAbfV) and Waste Catalogue Ordinance (AVV) are just as unspecific when it comes to the actual dismantling of the turbines, governmental obligations, the need for monitoring, and the product responsibility of wind turbine manufacturers.

The participants attending this expert exchange had the opportunity to watch the sawing of a rotor blade at a recycling company in Bremen and see first-hand the dismantling and recycling of a wind turbine as part of a site tour, which also revealed the impressive dimensions of the wind turbines in terms of their size and the quantities of material generated. Apart from the handling of the material quantities, special attention was given to the material composition of wind turbines. While the tower of a wind turbine consists mainly of concrete or steel, the composition of the rotor blades is much more varied: in addition to balsa wood, metal and pure plastic, they also contain newer materials such as glass- or carbon-fibre-reinforced composites.

The metallic components of a wind turbine present no problems for recycling. Concrete recovered from towers and foundations is recycled into reusable material, for which customers have to be found when there are larger projects. The greatest challenge, however, is the composite materials used in the rotor blades. One interesting option for glass fibre materials is their use in cement production, where the mineral fibres collected as residues are also recycled into a usable material. Carbon fibres pose even greater practical challenges. So far, only a very energy-intensive process makes it possible for them to be utilized without leaving any residues. Also, there are hardly any markets here, even though recycled carbon fibres could already replace new fibres in certain applications and the demand is rising, but science and practice are working on initial solutions here.

The expert exchange also made it clear that there is a desire for wind turbine manufacturers to provide more specific information about their products. From the point of view of legislators, stakeholders and the industry itself, clearer legal, technical and informal specifications and standards are needed for dismantling projects. This will be the only way that such large quantities of materials can be managed in a legally reliable, socially acceptable and sustainable manner for future generations. The current and future wind energy industry should be aware of this responsibility. It will have to engage all players in the wind energy sector and commit everyone to actively working together to find viable solutions.

https://www.fachagentur-windenergie.de/services/veranstaltungen/archiv-fachaustausch-rueckbau.html

Picture gallery


neocomp

Picture gallery

Programme

4 September 2018

10:00 a.m. Dismantling and recovery in practice — neocomp facilities

Tour of the recycling plant
Mika Lange, neowa GmbH
Ralf Voßhenrich, Hagedorn Group

1:00 p.m. Expert exchange — Forum K Tagungszentrum

Welcome
Dr. Antje Wagenknecht, Onshore Wind Energy Agency

Greeting
Lars Schnatbaum-Laumann, EnergyAgency.NRW

Introductory paper: Status quo and challenges
Prof. Henning Albers, Bremen University

1:35 p.m. Block I: Legal and technical

Regulatory framework for decommissioning and recycling wind turbines
Prof. Hartmut Gaßner, Kanzlei Gaßner, Groth, Siederer & Coll.

CFRP recycling challenges from the waste management industry's point of view
Mika Lange, neocomp GmbH
Ralf Voßhenrich, Hagedorn UG

CFRP recycling challenges from the waste management industry's point of view
Tim Rademacker, CFK Valley Stade Recyclung GmbH & Co. KG

1:35 Uhr Q & A I: Legal and technical

Hartmut Gaßner, Mika Lange, Ralf Voßhenrich, Tim Rademacker
Moderation: Dr. Dirk Sudhaus, Onshore Wind Energy Agency

Lunch

1:35 p.m. Block II: Projects currently underway

Experience report from the point of view of an authority responsible for the dismantling of wind turbines
Christian Kerkmann, District of Lippe, North Rhine-Westphalia

Development of a concept and measures to ensure resource-saving dismantling of wind turbines
Florian Langner, Ramboll BBB GmbH

4:10 p.m. Q & A II: A look at practical implemenation

Christian Kerkmann, Florian Langner
Moderation: Dr. Antje Wagenknecht, Onshore Wind Energy Agency

Small break

4:35 p.m. Block III: Research into dismantling and recycling

Current research into CFRP recycling
Elisa Seiler, Fraunhofer Institute for Chemical Technology

Wind energy dismantling potential and dismantling networks in Germany
Jan-Hendrik Piel, Nefino (currently being established)

Research project on rotor blade recycling
Amal Shankar Ramachandran Nair, Hochschule Flensburg

5:20 p.m. Q & A III: New demand for knowledge

Elisa Seiler, Jan-Hendrik Piel, Amal Shankar Ramachandran Nair
Moderation: Dr. Petra Weißhaupt, Federal Environment Agency

5:35 p.m. Outlook

Dr. Antje Wagenknecht, Onshore Wind Energy Agency

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