The toxic wings – Damage and casualty of wind turbine blades

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The toxic wings -

Damage and casualty of wind turbine blades

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First English edition (May 2023): Jan Erik Weinbach, Asbjørn Solberg og Bård-Einar Rimereit.

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Summary

This document started with an intention to bring together research and established knowledge about the total extent of major damage to wind turbine blades and the causes. The aim was to obtain figures for how often a modern wind turbine experiences major damage and/or failure of blades. Such numbers could be used to estimate the extent of emissions and the resulting pollution of the natural environment.

The blades of a 15 MW sea turbine are 120 meters long and weigh around 65,200 kilograms.[1] Around 55% is fiberglass and 45% various forms of plastic.

Obtaining sources and knowledge about the topic was done by asking our large network of specialist resources throughout Europe and independent literature searches. As feedback came in, a clear and divided pattern emerged. Firstly, there was great enthusiasm for the project and secondly, that they had little structured and scientific knowledge to share. Our own literature searches on Google and ResearchGate yielded only a few results.

Although we thought that a little is better than nothing - optimism quickly hit the wall. It seems that the few researchers who have tried to research this have found that there is little/no data on this problem and that the figures that do exist are unreliable. Furthermore, we find that the numerical material almost exclusively applies to wind turbines which are very small (with blades from 20 meters to a little over 60 metres). It is like studying accident statistics for the T-Ford car from 1913 to 1923. It has little value for the accident statistics of future Fords. In the field of methodology, this means that the findings are not valid for the problem.

The document has therefore become the opposite of our intention. We had hoped to be able to contribute with research-based knowledge and figures, but it resulted in an acknowledgment that there is no reliable and valid knowledge that can be of help when Health Safety and Environment impact analyses for wind turbines' impact on life and health are to be prepared. In other words, it is not possible to say anything reliable about how great a problem emissions from wind turbines will be in the future, or about the extent of the contamination of nature and the food chain.

That recognition is so disturbing that we have felt obliged to share research that shows that operating and maintenance costs increased in line with the size of the wind turbines, and that they increased in particular for marine turbines. This at least gives an argument to decision-makers who are worried about the consequences of the release of plastic – a lot more plastic - and contamination of the food chain.

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[1] https://www.nrel.gov/docs/fy20osti/75698.pdf

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The entire western world has enumerated and adopted gigantic development targets with this unproven technology, and that without having a scientific basis for the overall scope of consequences for HSE (health, safety and environment). It is almost unbelievable, and we know of no other industry that have been allowed such "Wild West" conditions ever.

The closest we come to historical comparisons is to the tobacco industry, which for many decades was allowed to advertise that cigarettes were good for life and health, even long after it was widely known that cigarettes have a very negative effect on life and health.

Smoking cigarettes was an individual choice, and the damage caused by these was largely self-inflicted. **The toxic emissions from wind turbines are imposed on each and every one of us, including the voiceless creatures of nature.**

The responsibility for this must and will be assigned to those who imposed this on us without a scientific basis about the consequences for life and health.

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Introduction

It is difficult to give a true picture of the extent of damage to the blades of wind turbines and the causes.

This is due, among other things, to the fact that the wind turbine industry guarantees confidentiality to its buyers and users.

"*In the UK, the HSE do not currently have a database of wind turbine failures on which they can base judgments on the reliability and risk assessments for wind turbines.*

Please refer to https://www.hse.gov.uk/research/rrpdf/rr968.pdf.

This is because the wind industry "guarantees confidentiality" of incidents reported.

No other energy industry works with such secrecy regarding incidents. The wind industry should be no different, and the sooner RenewableUK makes its database available to the HSE and public, the better.

The truth is out there, however RenewableUK don't like to admit it."[2]

Scotland against Spin, which probably has the most up-to-date publicly available statistics on accidents and injuries globally, write that their data is probably only the tip of the iceberg.

"*Data in the detailed table attached is by no means fully comprehensive - we believe that what is attached may only be the "tip of the iceberg" in terms of numbers of accidents and their frequency.*"[3]

The latest and most recent research reports on wind turbine failures are from April 2022[4] and December 2022[5]. The April report used GCube figures from 2015[6] but it is not stated as a source. GCube is the largest supplier of insurance to the "renewable energy" industry.

We can only speculate as to why the famous wind turbine researcher Mishnaevsky[7] did not provide this reference. This is not in accordance with academic standards and therefore does not inspire confidence.

Furthermore, we can only speculate as to why there is no updated data since 2015, either from the wind turbine industry itself, from the insurance industry or from neutral sources, when it

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[2] https://scotlandagainstspin.org/turbine-accident-statistics/
[3] https://scotlandagainstspin.org/turbine-accident-statistics/
[4] Mishnaevsky, L., Jr. Root Causes and Mechanisms of Failure of Wind Turbine Blades: Overview. Materials 2022, 15, 2959. https://doi.org/10.3390/ma15092959
[5] *Li, H.; Peng, W.; Huang, C.-G.; Guedes Soares, C. Failure Rate Assessment for Onshore and Floating Offshore Wind Turbines.* J. Mar. Sci. Eng. ***2022***, 10*, 1965.* *https://doi.org/10.3390/jmse10121965*
[6] *https://www.windpowermonthly.com/article/1347145/annual-blade-failures-estimated-around-3800*
[7] *https://sciprofiles.com/profile/leonmjr*

comes to such a large and global industry as the wind turbine industry. However, the fact that the wind turbine industry guarantees secrecy and that government administration and municipalities globally accept being ignorant is of course decisive.

Katsaprakakis, Papadakis and Ntintakis (2021) concluded that despite extensive research on how to avoid damage and wear on wind turbine blades, there was no research-based knowledge and overview of the total scope.

"*From the literature research performed during the development of this article, it was noticed that, although extensive work has been implemented on specific types of wind turbine blade damage and remedies, presented in corresponding separate and focused articles, there was no article that gathered this information and presented it in a comprehensive mode.*"[8]

The December 2022 report, Li et. al, tells us the same story, in but more important they tell us that there is an urgent need to new and more recent data:

"The above indicates that the old datasets represent the properties of the previous wind turbines but may not apply to the recent ones. Hence, reporting new and more recent operation data with a comprehensive analysis can provide stakeholders and practitioners in the wind energy sector with urgently needed information on wind turbines failure and maintenance features.

Floating offshore wind turbines, representing the next step in the wind energy market, are new concepts with limited installations. Failure, risk, reliability, availability, and maintainability investigations of such equipment are restricted by unavailable failure and operation data.

Reported onshore-data-based analyses such as reliability analysis, failure rate assessment, mean time to failure prediction, and maintenance strategy planning cannot be applied to floating offshore wind facilities without pre-treatments. To this end, the construction and application of the failure rate correction approach to transfer the fruitful accumulated operation data of onshore wind turbines to the corresponding components of floating offshore structures would enrich the database of floating offshore wind turbines at an early stage of operation under the situation of unavailable operation data."[9]

Li et. Al (2022) anyway went on trying to predict the failure rate of floating offshore wind turbines. They found it is 28.6% higher and suffers 8.37 failures per year with a mean time to failure of 1046 hours, than that of onshore wind turbines. But this is an uncertain and weakly

[8] Katsaprakakis, D.A.; Papadakis, N.; Ntintakis, I. A Comprehensive Analysis of Wind Turbine Blade Damage. Energies 2021, 14, 5974; https://www.mdpi.com/1996-1073/14/18/5974

[9] Li, H.; Peng, W.; Huang, C.-G.; Guedes Soares, C. Failure Rate Assessment for Onshore and Floating Offshore Wind Turbines. *J. Mar. Sci. Eng.* **2022**, *10*, 1965. https://doi.org/10.3390/jmse10121965

founded prediction. The only thing we can be sure of is that offshore will fail more than onshore wind turbine.

The entire western world has enumerated and adopted gigantic development targets with this technology, without having a scientific basis on the consequences for HSE.

It is almost unbelievable, and we know of no other industry that have been allowed such "Wild West" conditions ever.

This "Wild West" state is well described by Bjarne Jensen in his reader's post "*The offshore wind announcement is illegal and there are no HSE requirements*". Jensen writes that the following laws and regulations do not apply to offshore wind turbines.

- The Natural Diversity Act
- The Pollution Act
- The Working Environment Act
- The Electricity Supervision Act
- The Fire and Explosion Protection Act
- The Machinery Regulations
- Regulations on systematic health, environmental and safety work

And Jensen quotes a lawyer who stated at the High Wind 2023 conference "*We lack a legal framework, especially for creating security over the wind turbines and licenses*".[10]

We have to go to Scotland against spin's website to find Mishnaevsky's (2022) sources for the extent of damage in the report "*Root Causes and Mechanisms of Failure of Wind Turbine Blades: Overview*"[11], there we can read:

"*In June 2015, the wind industry's own publication "WindPower Monthly" published an article confirming that "Annual blade failures estimated at around 3,800", based on Gcube information.*

"Wind turbine rotor blades are failing at a rate of around 3,800 a year, 0.54% of the 700,000 or so blades that are in operation worldwide."[12]

[10] https://www.h-avis.no/havvindutlysningen-er-lovlos-og-det-er-ingen-hms-krav/o/5-62-1507217?fbclid=IwAR0yMisCa0IkZLsa3aN-GSZNlQd0ta3Xzh081mtPjf24ZQ3hp4rXDTZPJGk

[11] *Mishnaevsky, L., Jr. Root Causes and Mechanisms of Failure of Wind Turbine Blades: Overview. Materials 2022, 15, 2959.* https://doi.org/10.3390/ma15092959

[12] https://www.windpowermonthly.com/article/1347145/annual-blade-failures-estimated-around-3800

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This is almost verbatim what Mishnaevsky (2022) writes in his report, but without disclosing the source or informing that these are figures published by the wind turbine industry and not figures from neutral sources.

With our knowledge and familiarity with developments in the wind turbine industry, it is reasonable to believe that the extent of damage and accidents has not decreased since 2015. We base this on the fact that wind turbine wings have doubled in size since 2015 and we are approaching what is physically possible with today's plastic materials (glass fiber reinforced epoxy plastic/carbon fiber reinforced epoxy plastic).

Furthermore, we see that wind turbines are increasingly being deployed in tougher climatic conditions.

If we combine this knowledge with the extensive scope of research into how to prevent injuries and accidents, it gives a clear impression that the problem is increasing.

"*All potential causes of damage to wind turbine blades strongly depend on the surrounding environment and climate conditions.*

Consequently, the selection of an installation site with favourable conditions is the most effective measure to minimize the possibility of blade damage."[13]

The insurance industry (Gcube) published the following notes on wind turbine failures in 2018[14]:

1. *Failure of operators to carry out sufficient due diligence through maintenance checks is of increasing concern, and;*
2. *Operating wind farms outside of design parameters has been cited as a significant contributor to fires.*

Given what we know from research and our material knowledge of today's wind turbine blades, it is more likely to expect an increase in damage and breakdowns. How much is difficult to say, but if the extent is 1%, or more, it will not surprise us. We must bear in mind that what we know of damages and breakdowns probably constitutes the "***tip of the iceberg***".

Research findings and discussion

Despite undocumented claims from the power industry and wind turbine manufacturers about better quality and ever-better solutions to well-known problems, research shows that expenses

[13] Katsaprakakis, D.A.; Papadakis, N.; Ntintakis, I. A Comprehensive Analysis of Wind Turbine Blade Damage. Energies 2021, 14, 5974. https://doi.org/10.3390/en14185974
[14] https://scotlandagainstspin.org/turbine-accident-statistics/

for maintenance, operation and unplanned repairs for these well-known problems are **increasing both on land turbines and especially sea turbines.**

"*The total repair budgets in Europe increased from 2019 to 2020 from USD 4.7 to 8.6 mil, and unplanned repairs also increased slightly in Europe (2%) and even by 10% in America.*"[15]

"*If actual capex costs per MW in the UK have been rising for 15 years, there is no reason to believe that the trend will abruptly change.*

It is plausible to assume that capex and opex costs will rise by a minimum of 20% and probably closer to 50% above the already high costs that we observe in the audited accounts".[16]

"***Bottom fixed turbines at sea, larger than 2MW, statistically have 40% of faults before two years of operation, and after 10 years 80 %*".**[17]

Increase in downtime and maintenance

Professor Hughes is perhaps the person who has studied the costs and downtime of wind turbines the most in the world. In a study from Denmark, he researched 6,400 wind turbines in Denmark, and found that 80% of large offshore turbines will be out of service within 7 years.

For onshore turbines, this applies to 75% within 15 years for the largest and 80% within 18 years for small ones and 70% within 25 years for the smallest.

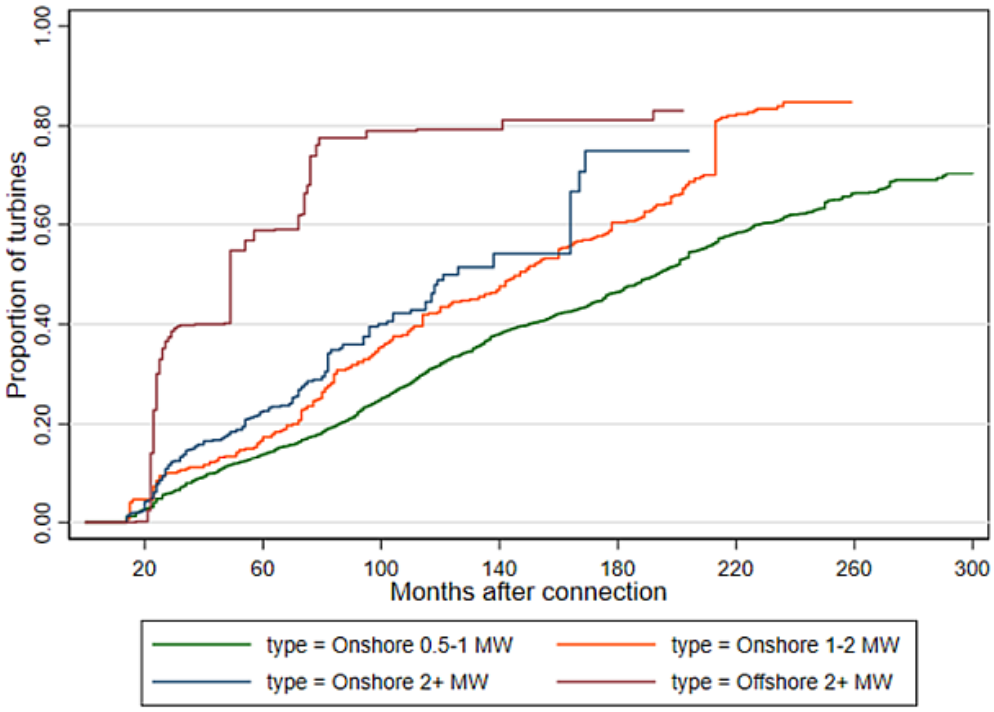
Hughes writes that these unexpected operational stops increase operating costs (OPEX = operating costs). He further writes that the wind turbines also have an annual effect loss (reduced production capacity). The findings from Denmark show that production capacity is decreasing by around 3% per year for land turbines and 4.5% per year for marine turbines. This gives 10 percentage points of lost production capacity for onshore turbines and 20 percentage points for offshore turbines over the course of 12 years.

"*If the market price of electricity does not become monetarily higher than today, it will be unprofitable to maintain turbines after 12 to 15 years.*

These findings break dramatically from the investment calculations with a lifetime of 25-30 years."[18]

[15] Mishnaevsky, L., Jr. Root Causes and Mechanisms of Failure of Wind Turbine Blades: Overview. Materials 2022, 15, 2959. https://doi.org/10.3390/ma15092959
[16] https://www.ref.org.uk/ref-blog/365-wind-power-economics-rhetoric-and-reality?fbclid=IwAR29p0MT5HHzcJdtHVF90v_yE16z0HxWUmf7SqwwUIta8Ppxsyl_hfMPNVE
[17] https://www.aftenbladet.no/meninger/debatt/i/0KBzGJ/utviklingen-innen-havvind-gaar-i-feil-retning?fbclid=IwAR0LWEVEayopcAb1I8h5TycYPdpSfLJCvJ8w1vPIOh8PDLmXrOM3tN_owYI
[18] https://klimatsans.com/2020/11/19/danska-mollors-livslangd/?fbclid=IwAR2g51Z8JJADiD1j5A2cngmqMBoXX3iDxM-lfuiL3bEZQkb-KZb8S0fRnKA

It is important to stress that Hughes studied relatively small wind turbines (from 0.5 MW to 2+ MW) in Denmark. The findings are therefore not directly transferable to today's and tomorrow's wind turbines, which in are 4 MW to 15 MW machines. But the trend in Hughes's findings is indisputable and shows a dramatic increase in the number of unexpected outages until the turbines become larger.



The table below applies to offshore turbines. The right column shows real expenditure in the UK, which is based on figures from Hughes and Constable (2020)[19]. The column in the middle shows what Swedish wind turbine investors report on expected expenses. Professor Jan Blomgren[20] has produced the table.

	Energy companies	**Reality**
Investment costs (SEK/kWh)	28,00	52,00
Maintenance (SEK/kWh)	0,20	0,72
Capacity factor %	54,00	40,00
Lifetime (year)	30,00	20,00

We see that actual maintenance costs are 260% greater than the wind turbine industry states. It is a strong indication that injuries, accidents and breakdowns with subsequent releases/pollution and wear and tear are far greater than the industry would have us believe. Correspondingly, the operational and technical lifespan of wind turbines **is far shorter than the industry would have us believe**. Something we also find in the technical research on wind turbines.

[19] https://www.briefingsforbritain.co.uk/the-costs-offshore-wind-power-blindness-and-insight/
[20] https://youtu.be/Z4u5j_xv-v8?t=1089

If the findings of Hughes are transferable to large and gigantic wind turbines from 10 to 15 MW, which are intended to be deployed in the North Sea and the Norwegian Sea in a few years, it means an imminent financial disaster for all investors and those who have to cover losses. All experience so far is that the bill is sent to the consumers.

The wind turbine industry's own statements also agree well with the conclusion above and clearly prove that Hughes's findings are moderate estimates of slightly older wind turbines. The trend is increasing:

«*In 2023, even as global demand revived strongly on the back of a fresh push for energy security based on renewables, the firms have been unable to take full advantage due to a whole new issue. Turbine failures and other component failures. These O&M failure risks continue to be a subject of agony for wind turbine manufacturers. Repairs and replacements have emerged as major liabilities, impacting the revenue numbers.*

Speaking at its quarterly results, Vestas CEO Henrik Andersen made it clear that the provisions for warranty claims were too high to be sustainable. Vestas had earmarked just 2 to 3% for repairs and maintenance, but last year, this figure exceeded 4% that were devoted for warranty provisions. Even as insurance companies seek higher premiums to backstop warranty claims, these firms risk a damaging a cash cow that had served them very well until now.»[21]

Motvind Sweden has also mapped accidents, and can state that the lobby organization Svensk Vindenergi writes the following on its website:

«*In terms of operating time, wind power has suffered few accidents. The power plants are safe and CE marked according to the requirements of the machinery directive. Only 11 breakdowns have occurred in over 32,000 operating years during the period 2001-2021*».

Motvind Sverige's surveys show that the Swedish press has reported on more than 50 accidents in the same period.[22]

Once again, we see that there is a large discrepancy between the wind turbine industry's figures and the true figures. Most frightening is the explanation for this discrepancy. The trick is to build the operating and control room on the outside of the industrial area. Then the power plant avoids the obligation to report work accidents.

"*According to information, more and more wind power companies are building their on-site depots right next to the wind power area, but technically "offsite". This means that even if*

[21] https://www.saurenergy.com/solar-energy-news/as-global-wind-turbine-manufacturers-face-headwinds-over-failures-should-india-firms-worry 31. januar 2023
[22] https://motvindsverige.org/sammanstallning-over-vindkraftsolyckor/

people are in the control room and there is an accident, they can say that "no one was there". Accidents where there are no people on site do not need to be reported to the Work Environment Authority. As a result, there is no investigation by any authority, but the wind power company has been given its own control and cover-up of the number of accidents is possible."[23]

What Hughes finds in the accounting of operating expenses, and when in the lifetime of the wind turbines these expenses occur, we also recognize from technical research on wind turbines about damages and breakdowns.

Increased wear and tear and damage due to harsh climate

Above all, all research on wind turbine blades is consistent in terms of what is problematic[24] [25] [26]. Different publications give somewhat different definitions, but in general we can say that the cause of damage and breakdowns is

1. Lightning
2. Material fatigue
3. Erosion and wear of the leading edge
4. Frost and icing

The four points are all linked to climatic conditions that expose the turbine wings for load and wear.
They are woven together in such a way that one cause can contribute to the development of one or more of the other causes of injury and accidents. They can also alone result in breakdowns and damage.

Despite the recognition that it is the climatic conditions, in which a wind turbine stands, which is the most important factor in damages, breakdowns and service life, there are few sources and few studies done on how the climatic conditions affect damage, breakdowns and service life. Most of the research is on erosion and wear from the edge of the wings (known as Leading Edge Erosion), and some research has been done in connection with material fatigue.

"*One should note that the damage mechanisms of wind turbine blades are strongly influenced by environmental effects such as humidity, temperature variations and ultraviolet (UV) radiation.*

[23] https://www.saurenergy.com/solar-energy-news/as-global-wind-turbine-manufacturers-face-headwinds-over-failures-should-india-firms-worry 31. januar 2023
[24] Katsaprakakis, D.A.; Papadakis, N.; Ntintakis, I. A Comprehensive Analysis of Wind Turbine Blade Damage. Energies 2021, 14, 5974. https://doi.org/10.3390/en14185974
[25] Mishnaevsky, L., Jr. Root Causes and Mechanisms of Failure of Wind Turbine Blades: Overview. Materials 2022, 15, 2959. https://doi.org/10.3390/ma15092959
[26] Luis Bartolomé, Julie Teuwen (2019) Wind energy **Volume22, Issue1** **https://doi.org/10.1002/we.2272**

In this review, these effects were not discussed, due to very few sources in the literature and very few investigations devoted to the environmental degradation of wind turbine blades."[27]

We have previously published work which thoroughly explains the challenges and consequences of erosion of the leading edge.[28] In this memo, the aim is to say something about damage and breakdowns due to material fatigue of turbine blades, resulting in the entire blade or large parts of it breaking off and contaminating either pasture or the blue field. Regrettably, there is little research to look at when it comes to this topic, but we have found something:

"*However, the most important cause of fatigue damage is the load development from intensively fluctuating forces. Wind constitutes the main source of such forces, especially in cases of wind park installations in intensively turbulent wind conditions.*"[29]

In order to avoid unnecessary stress and unfavourable material load on the blades, it is an important measure to have enough distance between the wind turbines.

"*The aerodynamic shading also constitutes another source of fatigue due to unsteady mechanical loads imposed by turbulent wind flow and shear effect. To avoid this probability, wind turbines should be sited properly, with adequate distances between them, accounting also for the prevailing wind direction, so as to ensure maximum efficiency and minimum impact on the normal atmospheric boundary layer*."[30]

If the distance is too small, it increases the chance of the entire blade breaking off inside the rotor, and ends up with total failure of one blade, several blades or even the entire wind turbine.

"*Wind turbine blades, subject to repeated bending, are the most vulnerable components of the overall structure with regard to fatigue damage due to fluctuating forces. The fatigue damage initially appears as tiny cracks, usually located in the joining zone of the blade with the hub. It is then concluded that the blade joints with the turbine's hub constitute the most likely places for the appearance of fatigue damage, regardless of the source of the fatigue conditions.*"[31]

The research is not reliable or valid

An attempt to map damage to wind turbine blades, published in 2021, shows that there are a relatively small number of turbines with blades up to 67 meters (equivalent to a Vestas V136

[27] Mishnaevsky, L., Jr. Root Causes and Mechanisms of Failure of Wind Turbine Blades: Overview. Materials 2022, 15, 2959. https://doi.org/10.3390/ma15092959
[28] Solberg. A, Rimereit. B, og Weinbach. J.E (2021) «Leading Edge erosion and pollution from wind turbine blades» https://docs.wind-watch.org/Leading-Edge-erosion-and-pollution-from-wind-turbine-blades_5_july_English.pdf
[29] Katsaprakakis, D.A.; Papadakis, N.; Ntintakis, I. A Comprehensive Analysis of Wind Turbine Blade Damage. Energies 2021, 14, 5974. https://doi.org/10.3390/en14185974
[30] Katsaprakakis, D.A.; Papadakis, N.; Ntintakis, I. A Comprehensive Analysis of Wind Turbine Blade Damage. Energies 2021, 14, 5974. https://doi.org/10.3390/en14185974
[31] Katsaprakakis, D.A.; Papadakis, N.; Ntintakis, I. A Comprehensive Analysis of Wind Turbine Blade Damage. Energies 2021, 14, 5974. https://doi.org/10.3390/en14185974

turbine with around 4 MW capacity). This means that the knowledge is of little relevance to the current situation, where the smallest turbines that are installed have blades of at least 67 metres, and even less relevant for the monster turbines that are planned and determined to be put into operation in the next few years with blades of 100 meters and more.

"*Responses show us the minimum rated capacity of the turbine was 250 kW while the maximum rated capacity went unto 4 MW*."[32]

Not only is the knowledge base based on small and outdated turbines, but also the industry's self-reported figures are used as the basis for the researchers' reports. Something the researchers themselves make us aware of has less scientific quality than desired. They write:

"*In some sense, the results to be collected are similar to "family doctors reports" and "ambulance call statistics" in medical research (which are surely less scientific than for instance medical research in special institutes)."*[33]

Such quotes are not unusual in research on plastic wind turbine blades. They seem to persist over time. Here is a quote from 2018:

"*Although the study of the rain erosion on the leading edge has become an essential issue for the wind turbine industry to reduce maintenance costs and to increase the annual energy production, the available literature about the cause and the mechanisms of rain erosion is very limited. Mainly, the reasons for this scarce literature are that the sources, as manufacturers, operators, and maintenance and repair companies, rarely provide details about the issue of rain erosion on the leading edge and, when they provide them, the information is referred to the first-hand experiences with anecdotal reports.*"[34]

There are good methodological and academic reasons to question both the reliability and validity of the results and conclusions that are presented in this research.

"*The quality of quantitative data is expressed in terms of reliability and validity. Reliability is an expression of how reliable the data we have, and how accurate the data collection has been. Validity shows the extent to which we have data that is valid or relevant for the issues to be elucidated*."[35]

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[32] Boopathi, K, Mishnaevsky, L, Sumantraa, B, Premkumar, SA, Thamodharan, K, Balaraman, K. Failure mechanisms of wind turbine blades in India: Climatic, regional, and seasonal variability. Wind Energy. 2022; 25 (5): 968- 979. https://doi.org/10.1002/we.2706
[33] Boopathi, K, Mishnaevsky, L, Sumantraa, B, Premkumar, SA, Thamodharan, K, Balaraman, K. Failure mechanisms of wind turbine blades in India: Climatic, regional, and seasonal variability. Wind Energy. 2022; 25 (5): 968- 979. https://doi.org/10.1002/we.2706
[34] Luis Bartolomé, Julie Teuwen (2019) Wind energy **Volume22, Issue1** **https://doi.org/10.1002/we.2272**
[35] https://snl.no/kvantitativ_metode

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The researchers themselves go a long way in giving us the answer to the extent to which the information obtained is valid and reliable. They write:

"*The collected information does not provide a root case study for the damage mechanisms; however, the author considers the information collected worth sharing and useful both for scientists in this area and for practitioners.*" [36]

"*However, this analysis has an apparent time gap: the observations made on 10, 15 or even 20 years old wind turbines are not always applicable to wind turbines which are manufactured today. Both materials, quality control, technologies and sizes can be different.*"[37]

We agree that the information is useful, but primarily to show how little valid and reliable knowledge exists about the total extent of damage to and failure of wind turbine blades and the consequences of these.

It is more likely that the industry underreports, than discloses the truth, and that "old" wind turbines are completely different machines than today's and tomorrow's wind turbines.

It is our opinion that research into wind turbines cannot keep pace with the development of wind turbines. This means that the knowledge base of our decision-makers and our administration is not relevant in terms of assessments and decisions about the future wind turbine industry and the consequences it may have for life and health.

It is in the light of all this that we must read and understand the results and findings from the research by Boopathi, Mishnaevsky, Sumantraa, Premkumar, Thamodharan and Balaraman (2022) which is:

"*Results of a survey of failure mechanisms of wind turbine blades in India, observed by service companies, are presented.*

Surface erosion is the most often observed blade damage mechanism, followed by lightning strikes.

Leading edge erosion can be observed even 1–2 years after wind turbine installation, while structural cracks are observed most often only 5–8 years after installation of the wind turbines."[38]

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[36] Boopathi, K, Mishnaevsky, L, Sumantraa, B, Premkumar, SA, Thamodharan, K, Balaraman, K. Failure mechanisms of wind turbine blades in India: Climatic, regional, and seasonal variability. Wind Energy. 2022; 25 (5): 968- 979. https://doi.org/10.1002/we.2706
[37] Mishnaevsky, L., Jr. Root Causes and Mechanisms of Failure of Wind Turbine Blades: Overview. Materials 2022, 15, 2959. https://doi.org/10.3390/ma15092959
[38] Boopathi, K, Mishnaevsky, L, Sumantraa, B, Premkumar, SA, Thamodharan, K, Balaraman, K. Failure mechanisms of wind turbine blades in India: Climatic, regional, and seasonal variability. Wind Energy. 2022; 25 (5): 968- 979. https://doi.org/10.1002/we.2706

Correspondingly when Mishnaevsky (2022) refers to Carroll, J., McDonald, A., and McMillan, D. (2016).[39]

"*All offshore turbines in this analysis are between 3 and 10 years old and are from between 5 – 10 wind farms throughout Europe.*

The full data set consists of over 1768 turbine years of operational data.

For confidentiality reasons the exact number of wind farms/turbines cannot be provided.

For the same reasons the exact nominal power, blade size or drive train configuration of the turbine type used in this analysis is also not provided.

However, it can be stated that it is a modern multi MW scale turbine type with an identical blade size and nominal power in all turbines. It can also be stated that it is a geared turbine with an induction machine.

As a guide to the size of the turbine type, the rotor diameter is between 80m and 120m and the nominal power is between 2 and 4MW."

Once again, we see that the research front in 2022 uses publications and findings from studies that are approaching 10 years old and that it is completely different machines (2 and 4 MW wind turbines, with blades of 40 and 60 meters) that formed the knowledge base for today's research, where the goal is to be relevant in relation to today's and tomorrow's wind turbines and problems.

Almost the entire chapter 2 of the report by Carroll and colleagues (2016) discusses all the challenges linked to the lack of data and, not least, the absence of independent sources. The researchers themselves refer to it as such.

"*As the population contains these older smaller turbines, questions are raised as to whether the population is representative of modern multi MW turbines.*"[40]

We could not agree more with the researchers. Let's see what they found anyway.

"*The biggest contributor to the overall failure rate for offshore wind turbines is the pitch and hydraulic systems. The pitch and hydraulic systems make up ~13% of the overall failure rate. "Other Components" is the second largest contributor to the overall failure rate with ~12.2% of the overall failures.*

[39] Carroll, J., McDonald, A., and McMillan, D. (2016) Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines. *Wind Energ.*, 19: 1107– 1119. https://doi.org/10.1002/we.1887

[40] Carroll, J., McDonald, A., and McMillan, D. (2016) Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines. *Wind Energ.*, 19: 1107– 1119. https://doi.org/10.1002/we.1887

The "Other Components" group consists of failures to auxiliary components which enable the other systems to function such as lifts, ladders, hatches, door seals and nacelle seals.

The generator, gearbox and blades are the third, fourth and fifth biggest contributors to the overall offshore failure rates with 12.1%, 7.6% and 6.2%respectively."

We see that in the survey published in 2016, damage to and failure of wind turbine blades comes first in 5th place. Recent research clearly shows that the wings are the component most exposed to damage and breakdown. We recall an earlier quote confirming this change:

"*Wind turbine blades, subject to repeated bending, are the most vulnerable components of the overall structure with regard to fatigue damage due to fluctuating forces."*[41]

We look further at the findings of Carroll and colleagues (2016).

1. *The average failure rate for an offshore wind turbine level out at approximately 10 failures per turbine per year by a wind farm's third operational year. With ~80% of those repairs being minor repairs, ~17.5% major repairs and ~2.5% major replacements.*
2. *The subassemblies/components that fail the most are the pitch/hydraulic system, the other component group and the generator. The biggest failure modes in these groups are oil issues for pitch/hydraulic, door/hatch issues for other components and slip ring issues for generators.*
3. ***As with onshore there is a trend of rising average failure rates with rising average wind speeds. Offshore shows a stronger correlation meaning that there is a higher failure rate with higher wind speeds offshore than there is onshore.***
4. *Generators and converters have a higher failure rate onshore than they do offshore. The onshore to offshore failure rate difference is greater in generators than in converters. Although increased windspeeds, age of turbines and size of turbines go some way to explain the differences there are still some differences which perhaps are due to loading or scheduled O&M.*
5. *The hub, blades and gearbox have the highest repair times, repair costs and number of technicians required for repair out of all the components in an offshore wind turbine. However, as the major replacement failure rate is so low for the hub and blades, they are not likely to contribute as highly as the gearbox or generator to the overall O&M costs*

[41] Katsaprakakis, D.A.; Papadakis, N.; Ntintakis, I. A Comprehensive Analysis of Wind Turbine Blade Damage. Energies 2021, 14, 5974. https://doi.org/10.3390/en14185974

	Minor Repair		Major Repair		Major Replacement	
	This Paper	Ref. [21]	This Paper	Ref. [21]	This Paper	Ref. [21]
λ (/ Turbine / Year)	6.81	3.00	1.17	0.31	0.29	0.08
Repair Time (Days)	6.67	7.50	17.64	24.00	116.19	52.00
Req. Technicians	2.61	2.00	3.44	3.50	9.14	5.00
Repair Cost	£140	£1,000	£1726	£46,000	£40,906	£334,500

Table 2. O&M modelling inputs from this paper and reference [21] compared

The table above shows the difference between what wind turbine experts have estimated (ref. 21) and the findings from the study by Carroll and colleagues (2016). We recognize that the pattern in the table shows that the wind industry's experts use far lower numbers than the actual conditions mapped in the study. It is no less than a threefold increase when it comes to replacing large and important components. In addition to the fact that there are several extensive repairs, they are also more than twice as comprehensive in terms of how long it takes to fix such damage and breakdowns. Carol at al. (2016) solely included the cost of the materials used for repair. "*The higher cost of the failures (ref. 21) could be because of the experts included costs such as transport cost, labour cost, storage cost and/or using older cost data*" Carol at al. (2016).[42]

Beyond this, there is little we find useful from the research we have found when it concerns the total extent of damage to and breakdown of wind turbine blades.

We summarized by advising against using the wind turbine industry's figures as a basis for the extent of damage to and failure of wind turbine blades. We are left with the fact that the most objective figures are Gcube's figures from 2015. This is only the "Tip of the iceberg" as Scotland against spin has shown us.

"*Wind turbine rotor blades are failing at a rate of around 3,800 a year, 0.54% of the 700,000 or so blades that are in operation worldwide.*"[43]

Based on the information in the introduction and discussion, we can outline some percentage scenarios for the annual total volume of damage and breakdowns on wind turbine blades:

1. Gcube insurance level: 0.54% per year (minimum and unlikely scenario)
2. Tip of the iceberg level: 1.00% per year (cautious estimate that looks away from dark numbers)
3. Qualified estimate level: 2.00% per year (cautious estimate, golden mean)
4. Whole iceberg level: 3.00% per year (probably close to the truth)
5. Worst case level: 5.00% per year (probably close to the truth for large wings in harsh climates)

[42] Carroll, J., McDonald, A., and McMillan, D. (2016) Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines. *Wind Energ.*, 19: 1107– 1119. https://doi.org/10.1002/we.1887
[43] https://www.windpowermonthly.com/article/1347145/annual-blade-failures-estimated-around-3800

It is important to emphasize that these scenarios largely give estimated average figures, and that we must consider that the most important factor for damages and breakdowns are the climatic conditions the wind turbine is in. Furthermore, that marine climates with a lot of wind and rainfall have far more damage and breakdowns than inland climates.

We do not have any scientific basis to comment on how large a proportion of failures of whole or large parts of the wings make up these percentage scenarios. The closest we can find is the study by Carroll and colleagues (2016) who find 0.29% and that they found that the extent of damage increased with wind speed and that this finding is strongest for marine turbines. These findings also correspond to Hughes and Constable's (2020)[44] findings from the UK and Denmark.

Bearing in mind that the consequences of a wing accident is the release of toxic epoxy plastic with large amounts of Bisphenol A and PFAS, the precautionary principle should be used. We would rather benefit from high estimates than too low. For very harsh climatic conditions, such as the Norwegian coastal and ocean climate, and that marine biology is particularly sensitive to the chemicals Bisphenol A and PFAS, then in our view it should be calculated with a minimum of 3% and preferably 5% damage and release of epoxy plastic in relation to weight. For inland climates, a 2% release of toxic epoxy plastic can be calculated.

Our preferred alternative is that wind turbines are not installed at all, because nature and our food is so polluted by plastic and toxic chemicals such as PFAS and Bisphenol A that it is now contaminated above acceptable limit values for drinking water in most of the world.[45]

Conclusion

It is certainly possible to study the research reports, by Mishnaevsky and others, more thoroughly than we have done, in order to try to draw out certain findings and reflect (read speculate) on these and in relation to Norwegian conditions. However, in light of the quality of the research, it is our understanding that it is a waste of time and "grasping at straws", and not something we want to embark on.

We would also strongly advise others to use this research as a basis for decisions about national critical infrastructure.

[44] https://www.briefingsforbritain.co.uk/the-costs-offshore-wind-power-blindness-and-insight/
[45] https://www.dagensmedicin.se/alla-nyheter/forskning/gransvarden-for-pfas-overskrids-i-regnvatten/?fbclid=IwAR1dz8FE4PKZjEZEdc8JHJTCVSsiKcN6H7TpJrU71-ruOpJ8ppS4W0dn3cM

1. We must acknowledge that there is actually no relevant and reliable research into the total HSE consequences of using large, and largely untested machines, wind turbines as part of our electricity production.
2. On the other hand, solid research shows that wind turbines are expensive to operate, and that the costs increase in line with the size of the turbines and harsh climatic conditions (strong wind, a lot of precipitation, salt and cold).
3. **We can also state, based on solid research, that wind turbines that are located in harsh climatic areas will have far greater and more damage and breakdowns, with increased costs and HSE consequences.**
4. It is also our understanding that currently researched technical solutions for small wind turbines are not good enough solutions for today's and tomorrow's huge wind turbines, and that both the technical and economic problems associated with wind turbines will persist in the years to come.

The entire western world has enumerated and adopted gigantic development targets with this unproven technology, and that without having a scientific basis for the overall scope of consequences for HSE (health, environment and safety). It is almost unbelievable, and we know of no other industry allowed to operate this unregulated and what seems like "*Wild West*" conditions.

The closest historical comparison is with the tobacco industry, which for far too many decades was allowed to advertise that cigarettes were good for life and health, even long after it was widely known that cigarettes have a very negative effect on life and health.

Smoking cigarettes was an individual choice, and the harm from these was largely self-inflicted. The toxic emissions from wind turbines are imposed on each and every one of us, including the voiceless creatures of nature.

The responsibility for this must and will be assigned to those who imposed this on us without a scientific basis regarding the HSE consequences (life and health).

Norway and especially our coast and seas have a lot of weather. It is therefore tempting to believe that wind turbines can be a technology to harvest the energy from all this weather.

We have shown in this report that science tells us that wind turbines are no good technical solution to harvest the energy from all the weather we have in Norway.

Science tells us that it will be both a technical and financial disaster to build wind turbines in Norwegian waters.

The economic consequences we can survive. Regrettably, we cannot say the same about the technical challenges, which will result in large releases of toxic plastic and hydraulic oils in one of the world's largest food bowls.

We end our note by quoting Erik Solheim, associate professor with 50 years of experience in Norwegian energy development.

"*Basic, physical realities have no status in the desperate wind power investment in our country and in several others. The ecological consequences have no place in the whole. I have not seen worse, after following energy development for fifty years*."[46]

[46] https://www.facebook.com/janerik.weinbach/posts/10158786454751227

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