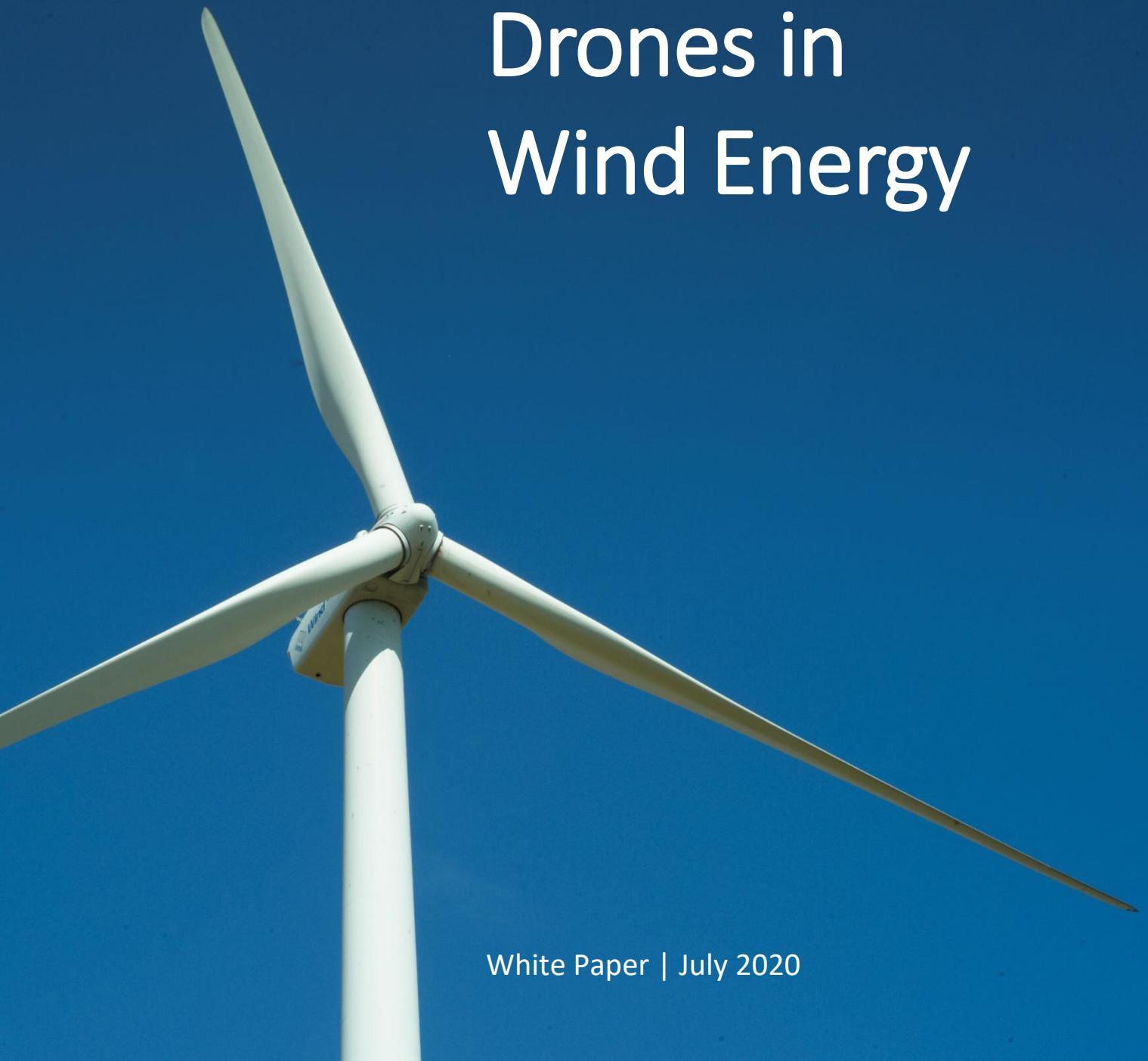




THE

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Drones in Wind Energy



White Paper | July 2020



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Drones in Wind Energy?

Originating from the military, drones or UAVs (Unmanned Aerial Vehicles) saw in the last years a massive commercial adoption and usage expansion across industries all over the world – and there is a high probability that your children already play with them.

Drone technologies developed in the past years and individuals, companies, and governments realized that drones have multiple uses, such as aerial photography, shipping and delivery, gathering information for disaster management as well as search & rescue operations, geographic mapping of inaccessible terrains and areas, building safety inspections, precision farming and crop monitoring, security and surveillance – to name a few. In general, drones have proven to be extremely beneficial in accessing places humans cannot reach or enter and on tasks they are unable to perform in a timely and efficient manner.

Today, the adoption of drone technology across industries is a mega trend and more and more

businesses understand their potential. Accordingly, we were wondering what role drones already have and will have in the future and what the future impact of drones in wind industry may be. As drones possess the capability of reaching the most remote areas with little to no manpower needed and require the least amount of effort, time, and energy, the adoption of using drones for wind turbine inspections is rapidly growing. Furthermore, they allow for capture of digital high-resolution images and as a result generate high-quality data in combination with less efforts and higher efficiency at lower costs.

Accordingly, we performed as part of our research work an online survey and invited more than 300 selected participants from the wind energy industry. Furthermore, interested individuals from the wind industry and academia were invited to participate by kind invitation through the European Energy Research Alliance (EERA) Joint Programme on Wind Energy.





Are drones known and already in use in the wind industry?

It was not a real surprise to us that all participants in this survey were aware and knew about the possibility of inspecting wind turbines with drones. As drone inspections are a topic that is discussed within the wind industry for several years and as some companies have started to operate in this business, the next logical question is: to which extend are drones already in use for wind turbine inspections today, and how many people and companies have already made experiences with this innovative technology – and what are their impressions and feedback?

There is already a high usage of drones for wind turbine inspections: nearly 70% of the respondents used drones already for inspection of wind turbines. The majority (58%) has used drones for inspections of onshore wind turbine, while 30% used drones already for offshore wind turbine inspections. This is a highly interesting finding, as offshore conditions are very challenging for drone

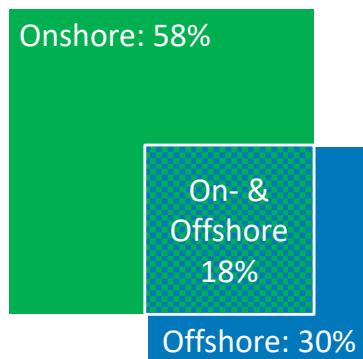
flight operations and only a few companies provide drones that are engineered to function properly under offshore conditions.

What is particularly noteworthy is that 60% of the respondents that used drones already for offshore inspections, have also used drones for onshore wind turbine inspections. Altogether, 18% of all respondents fall into this category of onshore and offshore users of drones. So, it appears that most drone users for offshore wind turbine inspections have already made compelling experiences with onshore drone inspections.

The 30% of the respondents that have not used drones so far for inspection purposes are typically working for companies that are investors, installers, O&M operators, etc. or are with associations or academic and research organisations and do not inspect wind turbines as part of their business activities.

Has your company already used drones to inspect wind turbines?

Yes: 70%



No: 30%

No
30%

What methods are used?

While nearly 70% of the respondents mentioned that their companies have already used drones for inspections of wind turbines onshore or offshore, it was interesting for us to understand what other methods are used by them and to which extent drones are already replacing other methods.

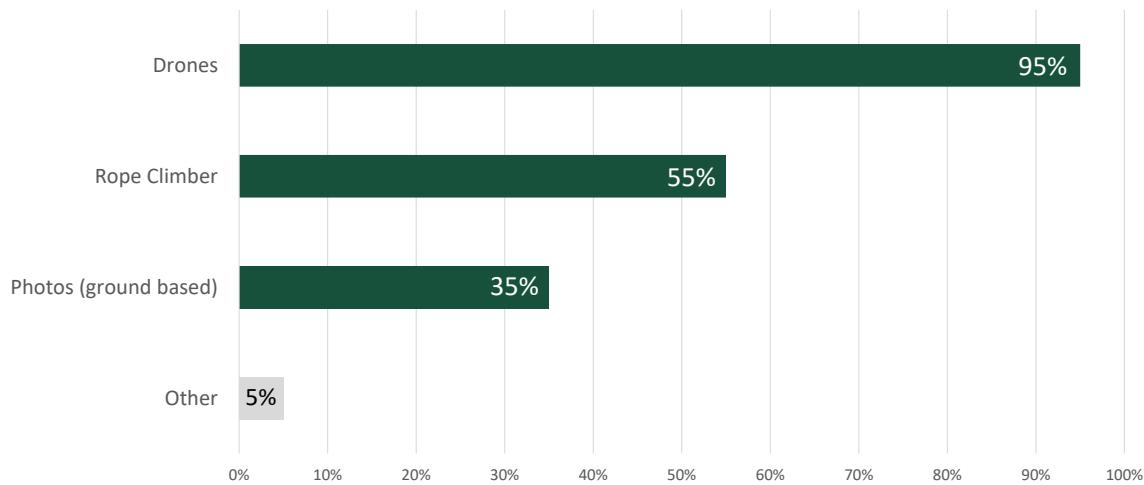
In order to get valid information on what methods are actually used by companies to inspect wind turbines, we decided to run a subgroup analysis of the survey data and evaluated only the data provided by respondents whose companies actually perform wind turbine inspections.

This corrected data showed that 95% of the companies already use drones for inspection purposes, while industrial or rope climbers are mentioned by only 55% of them. This comes as a real surprise to us as rope climbers are the established long-term industry standard method and we expected a much higher response rate.

However, there might be a bias in this response as we learned from the responses to other questions that most of the respondents are very much interested in drone inspections and many of them have already made first experiences. So, we can assume that the traditionalists that are sceptical about new technologies did not actively participate in our survey and did not respond to our questionnaire. Furthermore, it is unclear if drone inspections are performed on a regular basis or if they are more experimental to gain experiences and prepare for the future.

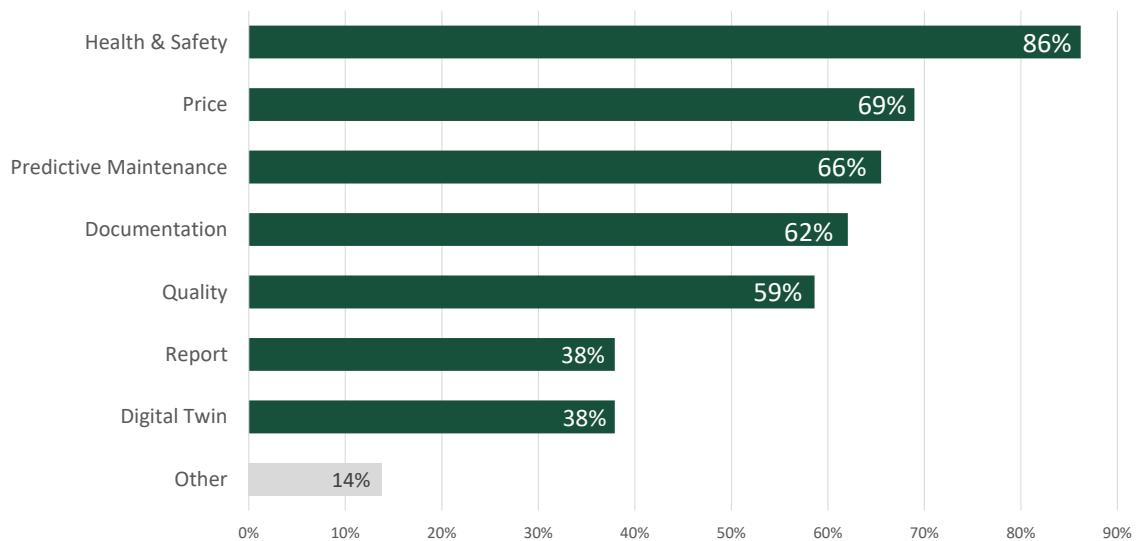
Worth to mention is that ground-based photography is used by 35% of the companies, which is still a reasonable percentage, and other methods such as visual inspections from below or from helicopters are used by 5% of the companies.

What methods does your company use to inspect wind turbines?





What advantages do you see in drone inspections of a wind turbine?



What are the advantages?

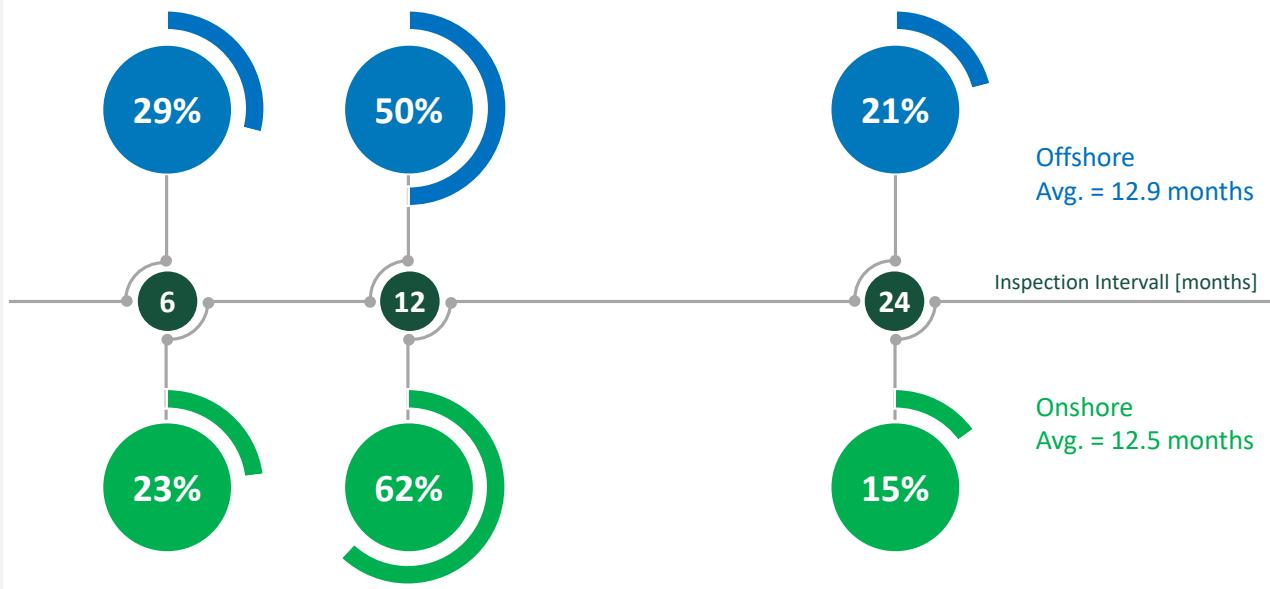
Putting people on top of a wind turbine and let them climb around is always associated with risks for their health and safety, especially offshore. Understandably, *Health & Safety* is mentioned as the most important advantage of using drones for wind turbine inspections: overall 86% of the respondents rated this point as a clear advantage. A deeper look into the data reveals that all respondents (100%) that have used drone inspections so far, rate *Health & Safety* as one main benefit. This is also in line with our experiences, which demonstrate that those companies that seriously care for their staff (and also include their subcontractors in their considerations) and act to protect their health, are actively seeking and exploring ways to minimize risks to humans involved in building and servicing their assets.

Health & Safety is followed by *Price*, *Predictive Maintenance*, *Documentation*, and *Quality*, all ranging between 69% and 59% of the replies. A closer look into the data reveals, that those respondents that already used drones for inspections rate *Price*, *Documentation*, *Quality* and *Predictive Maintenance* much higher than respondents that have no drone inspection experiences.

Price sensitivity is an important factor in the wind energy business and therefore it is no surprise that the price advantage of drone inspections is rated high: 80% of the respondents that used drones for inspection see the *Price* as a major advantage of drone inspections. This correlates with our experiences that the overall costs of a wind turbine inspection, including downtime, preparation, permits, etc., is lower when using drones instead of rope climbers.

Aside *Safety* and *Price* there is a clear advantage for using drones in wind turbine inspections: the *Quality of Data*, the *Documentation* and *Reports* generated thereof. Humans inspecting a wind turbine cannot always deliver the data and data quality expected. In comparison, data generated from a drone inspection is typically on a different level with respect to the quality of localisation/positioning data and detail of damage information. Furthermore, data generated by drones are in a digital format that can be assessed and reviewed by other experts and can be stored and easily retrieved in digital archives.

How often would you use drones to regularly inspect a wind turbine?



How often should drones perform inspections of wind turbines?

As the data shows quite obviously that drones are already considered as an advantageous method to inspect wind turbines compared to others, the next important question is how frequently they shall be utilized. Furthermore, as we have learned that many companies already use drones to perform inspections of wind turbines onshore and offshore, it was interesting to us to understand how many of them would use drones for regular inspection purposes and what would be the envisaged frequency of these inspections.

Again, to avoid any bias, we decided to run a subgroup analysis of the survey data and evaluated only the data provided by respondents whose companies perform wind turbine inspections on a regular basis.

Overall, most of the respondents would use drones to perform wind turbine inspections with a yearly interval. Approximately, one fourth preferred a shorter inspection interval of 6 months and a bit smaller percentage for longer interval of 2 years.

In order to identify possible differences between current onshore and offshore users of drone inspection services, we also decided to split the evaluation of the data into onshore and offshore users of drones to ensure that we get a reasonable outcome: even more interesting, 29% of users of drones for offshore wind turbine inspections would inspect with a shorter interval in the future. In the contrast, 21% of them stated that they would prefer an inspection interval of 21%. Overall, the arithmetic average of this subgroup is at 12.9 months – compared to 12.5 months of the onshore drone user subgroup.

Furthermore, it can be assumed that the cost/benefit ratio of drone inspections allows for shorter inspection intervals while reducing service costs due to a better and more efficient scheduling of repair and maintenance work. In the future, the advantages of combining digital data with predictive maintenance tools will allow for shorter inspection intervals and result in longer lifetime of the assets and even lower LCOE in wind energy.



What are the expectations with respect to a drone inspection?

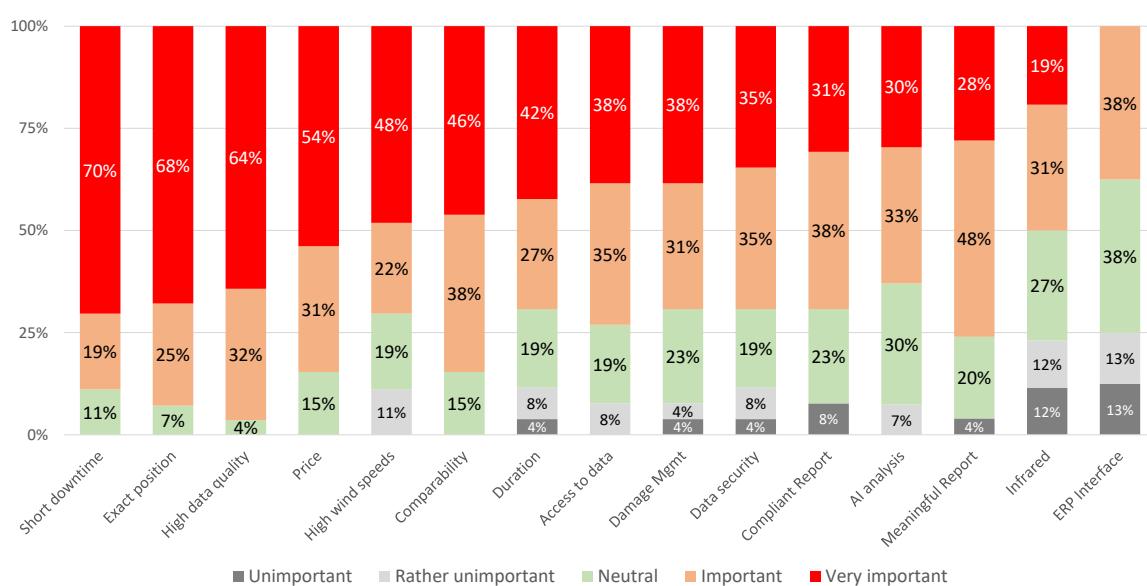
Keeping the advantages of drone inspections in mind, what are the expectations when using drones for the inspection of wind turbines? While the respondents stated that *Health & Safety*, followed by *Price*, *Predictive Maintenance*, *Documentation* and *Quality* are the main advantages, the main expectations are a high data quality (97%), exact position data (93%), short downtime (89%), and a lower price (85%) as well as comparable data (85%) and a meaningful report (76%).

The expectations in relation to data access, management, security, and analysis with artificial intelligence algorithms are more or less in the same range but still high (between 73% and 63%), while the option to make infrared images or an interface that connects with the corporate ERP system are not expected by the majority of the respondents (50% and 38% respectively).

This correlates with our experiences and shows that price is not the only driver when it comes to using drones for wind turbine inspections. More important are cost savings through shorter down-times of the inspected turbines and high-quality information on findings, especially with respect to position and type as well as extend of damage.

Not surprising is that users expect that data from wind turbine inspections can be compared to previous inspections, which is only possible to a certain degree with other methods. Especially for predictive maintenance and the decision making at the end of the life cycle of a wind turbine, the more accurate data you have allows for an improved prediction to base your outlook and forecast on and results in a much better and more efficient decision making.

What do you expect from a drone inspection of a wind turbine?



Where will drones play an important role in the future?

It is for sure that drones will play an important role in the future of wind energy. But what are exactly the areas where drones will play an important role – and where can we expect to see drones to complement other methods?

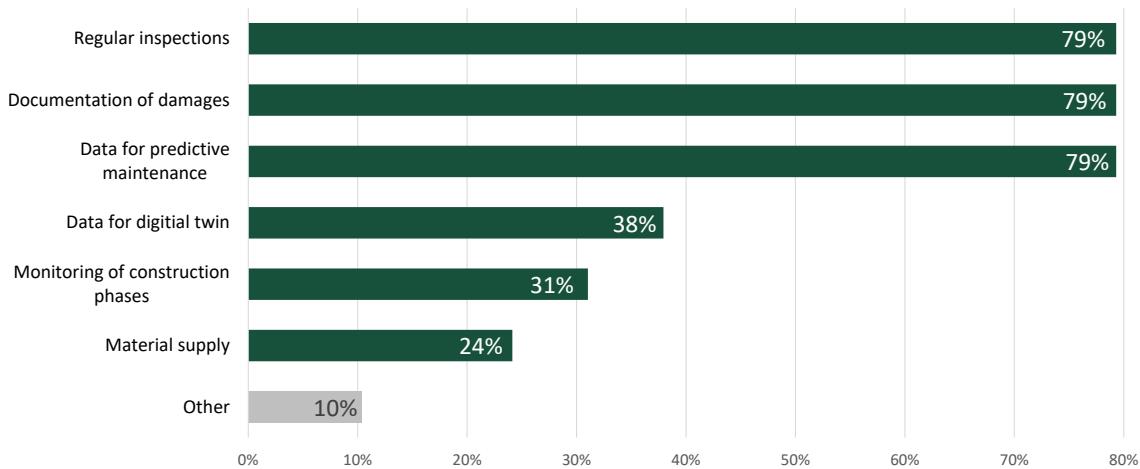
This survey made very clear that a huge percentage of the respondents see drones in an important role in the future when it comes to regular inspections, the precise documentation of damages, and in providing data for predictive maintenance – all at 79%, which is an impressive result.

Regarded as not that important is the future role of drones in generating data for digital twin models, monitoring construction phases and in material supply. However, as these areas are currently in a development phase, it is not surprising that these areas are not rated at the same high numbers. But a deep dive into the data is intere-

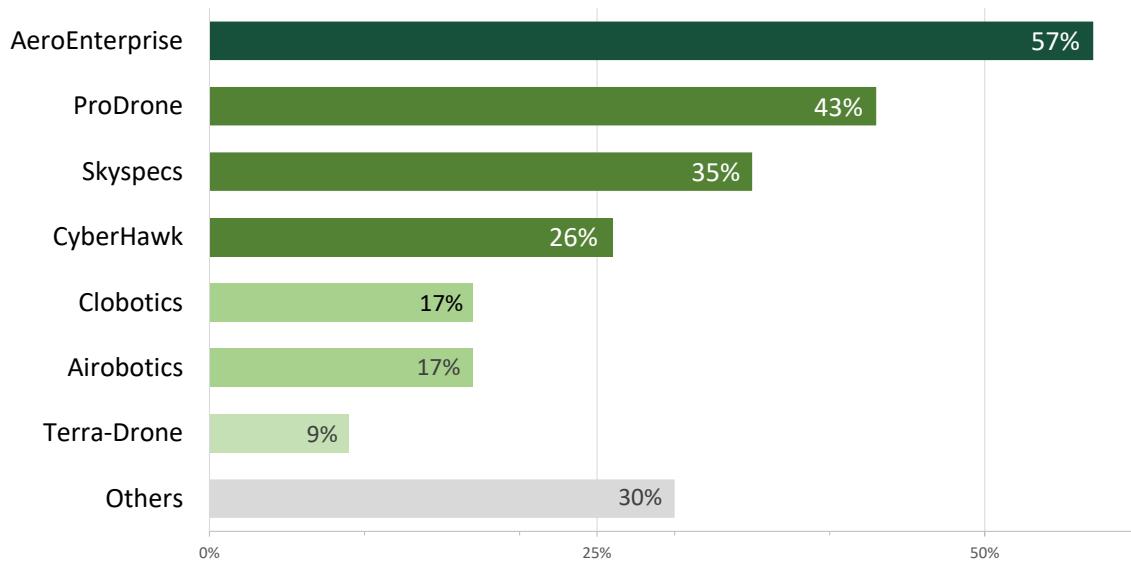
ting: when evaluating the responses from those participants that already use drones, their ratings on *Data for Digital Twin* is significantly higher. Also *Monitoring of Construction Phases* is rated much higher. A deeper look into the data also reveals a much higher scoring on *Data for Predictive Maintenance* and *Documentation of Damages* for those respondents that already used drones for wind turbine inspections.

Most interesting is that those respondents that already used drones for offshore wind turbine inspections had a much higher score on using drones for *Material Supply*. As the safe transfer of service staff to an offshore wind turbine can be already quite difficult, it is even more difficult when this staff has to carry many tools, spare parts and equipment, or if they have to bring some things up on a turbine during their work that are needed unexpectedly.

Where will drones play an important role in the inspection of wind turbines in the future?



Which providers of drone inspections for wind turbines do you know?



Who are the key players?

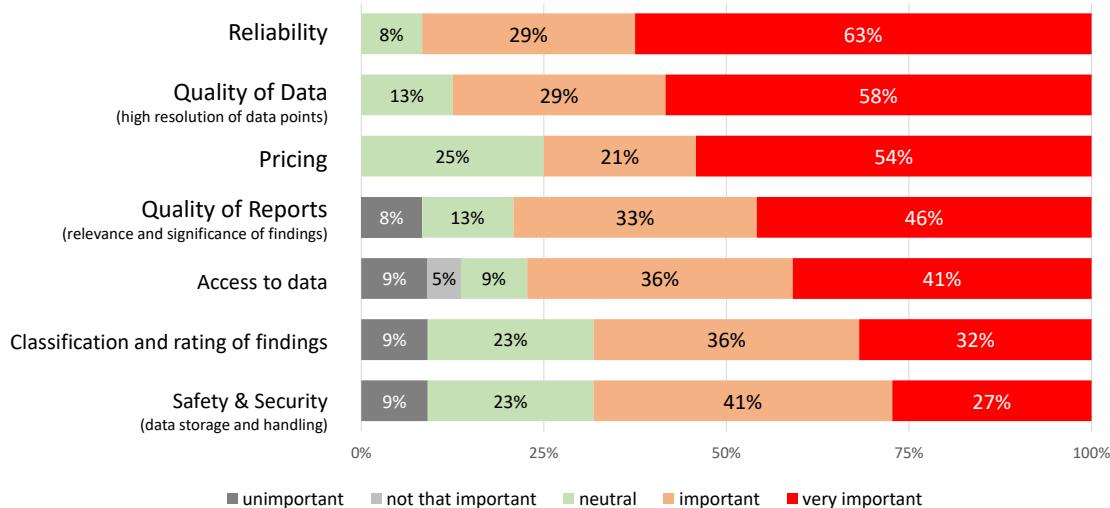
Top of mind, or the most recognised company in drone inspection services, is AeroEnterprise. It is not a real surprise that close to 60% of the respondents know the Austrian company: in the past years, AeroEnterprise has gained a reputation for the quality of data delivered and they are one of the frontrunners in integrating artificial intelligence in image analysis and evaluation. Furthermore, their drone technology is a proprietary development that has superior flight capabilities in strong winds when compared to the commercially available drone designs used or slightly upgraded by other drone inspection service providers.

Other drone inspection service providers known to the respondents were ProDrone, SkySpecs and CyberHawk, with 43%, 35%, and 26% respectively. Other drone inspection service companies such as Clobotics or Airobotics are recognised by slightly less than 17% of the respondents.

So it seems to us that despite the fact that drone inspections are a quite young business, there is already a separation starting to take place in the market of drone inspection service providers that develop into a market leading position and the others that are following with quite a distance.

In the light of this survey it seems also clear that drone inspection service providers that have not developed a proprietary technology that is superior to their competitors, focus primarily on low prices. It is obvious that low cost providers that cannot match the quality of data provided by the technology leaders will face hard times in this already highly competitive market that is driven by quality of data and superior flight and data analysis technologies. Especially in the offshore wind energy market only a few companies can offer drones that are able to operate under the harsh conditions at sea.

What are your key points when choosing a service provider?



How to choose the right service provider?

The most important factor when choosing a provider for drone inspection services is *Reliability*: 92% of the respondents name this a very important (63%) or important (29%) point – only 8% are neutral.

Interestingly, while pricing was seen as one of the key advantages of drone inspections, when choosing a service provider for drone inspections the *Quality of Data* (87%) and the *Quality of Reports* (79%), and even the *Access to Data* (77%), gets more important than *Pricing* (75%). This kind of pattern is frequently seen, when asking for the importance of innovative technologies or services, as pricing does not seem that relevant and is compensated by the advantages and expectations.

A deep dive into the data shows that respondents that have already used drones for inspection of offshore wind turbines rate the *Reliability* of the service provider (75% - very important), the *Quality of Data* (67% - very important), and *Reports* (65% - very important) even higher – and *Pricing* is even less important (33% - very important).

Remarkably, in this subgroup *Access to Data* is also significantly more important (78% – very important). Also, other factors gain higher importance in this subgroup of offshore drone inspection users such as *Classification of Findings* and *Safety*.

This is also reflected, but at a lower significance, in the subgroup of respondents that have already used drones for inspections of onshore wind turbines: *Access to Data* and *Safety* are regarded as more important and *Pricing* is less important.

As *Safety* and *Pricing* are the main advantages of drone inspections, these are not regarded as the most important criteria when choosing a service provider for drone inspections. When it comes to decision making this seems to be a prerequisite for all providers and the differentiation is focussed on trust and performance (*Reliability*, *Quality of Data*, *Quality of Reports*) as well as transparency (*Access to Data*).



Will companies use drones to inspect wind turbines in the future?

If one thing is clear from this survey than that companies that have already used drones to perform wind turbines inspections will do this in the future on a regular basis, and even more frequently.

The companies of 58% of the respondents plan to perform drone inspections of wind turbines: 46% plan to perform drone inspections regularly and 12% plan to perform not frequent (rarely) inspections of wind turbines with drones in the future.

While the response of 6% of the respondent that answered with a "No" is a bit misleading, the subgroup analysis of those respondents whose companies already used drones for inspection of onshore or offshore wind turbines is extremely clear: not a single one (0%) plans not to use drones in the future!

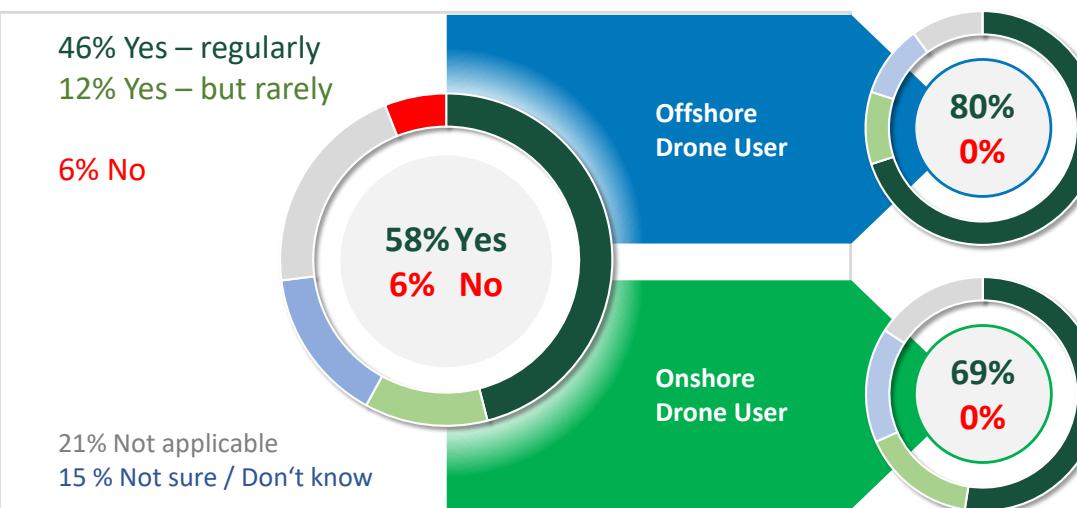
So, the "No"s came from respondents that made no experiences with drones so far. Furthermore, most of the respondents that were not sure or did

not know (15%) or for whom the question was not applicable (21%) were respondents from academia, agencies, investors, or audit companies.

Again, there is a significant difference when it comes to detail: those companies that already used drones for offshore wind turbine inspections plan to use drone in the future by 80% (70% regularly / 10% rarely), which is a remarkable statement. And 69% (53% regularly / 16% rarely) of the respondents that have used drones for inspections of onshore wind turbines state that their companies plan to use drones for wind turbine inspections in the future.

Altogether, it is very clear that companies that have made experiences with drone inspections of wind turbines are considering this technology as part of their future inspection plans. Especially, for offshore inspections the needs and advantages are clear and companies have an obvious preference to use drones for inspection purposes regularly.

Does your company plan to use drones to inspect wind turbines in the future?



What is our conclusion and advise?

Drones are there to stay

Drone inspections of wind turbines are even today superior to the traditional rope climber and there are clear indications that drones will become the predominantly used method for wind turbine inspections. Rope climbers and professional service staff will not disappear but will be seen mainly in performing maintenance and repair work that cannot be performed by drones. For reoccurring routine inspections drones offer many advantages and, as we have seen in other industries before, such work can be done by flying "robots" much safer, faster, and cheaper.

Performance & Efficiency trumps Price

But price is not everything: we saw in our survey that advantages of drones in inspections, such as safety, quality data and reports, and comparability, are more crucial to users than price. Even more important, we saw in subgroup analyses that companies that have already used drones for inspection purposes are convinced of the advantages and have much clearer expectations and a precise understanding of what matters when choosing a drone inspection service provider. And when comparing onshore and offshore wind turbine inspections, the responses for offshore application were even more significantly in favour of drones.

Challenges and Implications

What are the implications for a construction company that needs to confirm that its work was done properly? Or the wind turbine OEM that is changing its business model from being a product company to a solution provider? Or for the wind park operator to ensure optimum performance of his assets? Where shall the data for predictive maintenance and digital twin models come from? And how will the documentation of the status of its assets influence the asset valuation for the asset owner?

Integration in business model is key

As drones will play an integral role in future wind energy, the question is, how does this integrate with the current business models of windfarm owners, operators, constructors, and wind turbine OEMs. What is their long-term strategy and what are their goals? Cost cutting? Predictive maintenance? Digital twins?

Data is the new oil

As in other industries, those who own the data have the power and gain competitive advantage. It is not only the knowledge on the current status of wind energy assets, it's the ability to predict their performance and value that put those into power that own this data. So, it's not only predicting maintenance, it's about predicting the future.

The time to act is now

Once you have understood which role drones will play in your future business model, it is important to secure access to drone technology and know-how. Ensure to get in contact with the right partners early on to gain full advantage of a close and trusted, long-term collaboration.

And one thing is very clear: you must act fast. Now is the time to get into the game, to make your own experiences and walk through your learning curve - and to develop a sound strategy that includes drones as an integral part of your future business model.

We already see trends in the market that service and audit companies become shareholders of drone inspection companies to secure their access to this technology. On the other hand, there are OEMs and wind park operators that think on locating drones permanently to control, secure, and inspect their assets, especially in larger onshore and offshore wind parks, where drones may become something like the "watchdog" and the "custodian" of the future.



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