Periscope Network

Market Opportunity Report

Smart Inspection and Maintenance; Aerial Drones

Interreg North Sea Region PERISCOPE
European Regional Development Fund

EUROPEAN UNION

PERISCOPE
reaping the potential of the oceans

Dear Reader,

This report provides a summary on the prospects for aerial drone applications for the smart inspection and maintenance for maritime and offshore industries. The report's findings are based on respondents' answers to surveys and focuses on when aerial drones will come into smart maintenance operations and their business potential.

This report is produced by the PERISCOPE Group at Aarhus University for the PERISCOPE network.

Photographs
unsplash.com; pixabay.com; pexels.com

Copyright
PERISCOPE ©2020

Enquiries
Matthew J. Spaniol
Aarhus University
Tel: +45 50126444
Denmark

Website
www.periscope-network.eu

PERISCOPE is supported by the North Sea Region (NSR) EU grant J-No. 32-2-13-17 ©Interreg VB North Sea Region Programme

PERISCOPE is co-financed by the Interreg VB North Sea Region Programme.. The information contained in this report is for general information purposes only. You accept to use the data at your own risk. All the information provided on this Service is provided "AS-IS" and with NO WARRANTIES. No express or implied warranties of any type, including for example implied warranties of merchantability or fitness for a particular purpose, are made with respect to the information, or any use of the information, on this Service. The Periscope project ("the Service Provider"), assumes no responsibility nor liability for errors or omissions in the contents on the Service, including any false, inaccurate, inappropriate or incomplete information presented in this initial report. In no event shall the Service Provider be liable for any special, direct, indirect, consequential, or incidental damages or any damages whatsoever, whether in an action of contract, negligence or other tort, arising out of or in connection with the use of the report. No warranties - no liability - use at own risk. In no way do the companies whose logos appear in this report or any other publication by PERISCOPE constitute an endorsement of the reported findings on this or any publication by PERISCOPE.

PERISCOPE

PERISCOPE is an initiative of the Interreg VB North Sea Region Programme working to catalyse entrepreneurial discovery and promote trans-regional partnerships to unlock Blue Growth. We are supporting the combined maritime and marine innovation ecosystem in the North Sea region to accelerate innovation for sustainable business development in emerging blue markets.

The PERISCOPE network has identified more than 60 future business opportunities for the blue economy, developed these into venture concepts, and built an engagement tool for each of these. These studies include crowd-based forecasts about when these are expected to be realized. This information supports planning activities with the intention to orchestrate action towards the realization of said opportunities, and, indirectly, to a transition to a more innovative and sustainable character of the blue economy.

VISIT PERISCOPE

PERISCOPE PARTNERS

PERISCOPE is supported by the North Sea Region (NSR) EU grant J-No. 32-2-13-17

CONTENT

1 EXECUTIVE SUMMARY

The transition of the maritime and offshore industries toward a sustainable “Blue Growth” future is driven by incentives to unlock new growth areas, develop and apply new technologies, and increase productivity. The development and utilization of aerial drones for smart inspection and maintenance provides an opportunity to support the accomplishment of these goals. The rapid development in drone technology and the continuous growth in the amount and size of offshore installations provide the context for growth.

To support investment timing decisions for enterprises and research policy, an engagement tool was developed around future use cases for aerial drones. This report presents the outcome and analysis of 3 surveys taken by a total of 75 respondents. Respondents expect that:

- Drones for predator bird abatement at aquaculture farms are expected to become an accepted practice 5 years from now, and respondents rated the business potential at 3.6/5. In order to develop this opportunity, respondents mostly mention technical factors (40%), followed by economic (27%), political (6%), social factors (15%), and environmental factors (12%).

- Drones for offshore maintenance and repair are expected to become an accepted practice 8 years from now, and respondents rated the business potential at 4.1/5. In order to develop this opportunity, respondents mostly mention technical factors (54%), followed by economic (19%), social factors (15%), political (12%), and environmental factors (0%).

- Drones for de-icing offshore windmills are expected to become an accepted practice 7 years from now, and respondents rated the business potential at 3.3/5. In order to develop this opportunity, respondents mostly mention technical factors (52%), followed by economic factors (23%), social (16%), political (7%) and environmental factors (2%).

2 INTRODUCTION

The North Sea Region is a crucial area for Europe's Blue Economy with marine resources, technologically advanced industries, major port areas, and vibrant offshore activities. Due to global drivers, the wider maritime, marine and offshore economies are exposed to profound challenges with some industries undergoing a significant growth and change, and others facing stagnation and decline. To ensure the region's sustainable growth and long-term prosperity, innovation is called for to increase productivity. Smart maintenance and inspection using aerial drones have been proposed to this end. While initiatives and cases have begun to emerge, questions of what's next, how, and when further applications of aerial drones can be utilized for offshore industries remain.

To answer these questions, PERISCOPE identified potential next practices for smart inspection and maintenance for aerial drones and put them to the crowd for assessment and validation. Survey instruments were developed for a series of use cases that aim to cover different offshore maintenance and inspection tasks at different sites, and based on these, require different sensor technology, flight speeds, operation heights, and endurance. The use cases were described, posted online, and distributed to respondents identified as having a qualified opinion. The first question that was asked concerned the question of time to implementation: "On the sliding scale below, please estimate when it will become accepted practice that [technology X] will be used to complete [task Y], i.e. commercially available" with the scale spanning a maximum of 30 "years from now." In this question, respondents were also offered an option to answer "it will never happen" or if the use case in question is "already here." The second question: "What is needed to make this happen?" offered respondents an open text box in which they could write their answers. The third question asked respondents to rate the opportunity described on a Likert scale out of 5. Finally, respondents were offered another open text box to write any additional comments.

In what follows, each study will restate the prompt that was used in the survey, followed by an analysis of the responses. The crowd-based forecast provides the median estimate of the "time to accepted practice." A Political, Economic, Social, Technological, Environmental (PESTE) analysis organizes the responses into categories, the average rating on the business potential is presented, and an analysis is made based on these. After all of the studies are presented, general remarks are made, the business opportunity for smart inspection and maintenance by aerial drones is presented, and the report is concluded.

3 STUDY A: AQUACULTURE PREDATOR BIRD ABATEMENT DRONE

The European aquaculture industry produced 1.37 million tonnes of fish in 2017 with a total market value of €5.06bn.[1,2] The worldwide industry is growing by almost 7% annually, yet aquaculture firms can lose up to 15% of their fish to predator birds.[2,3,4]

Currently, physical barriers such as nets or wire cables are used to cover the surface water of the pens, but these are limited in their effectiveness and can be expensive to install and maintain.[5,6,7] In case of high losses, birds are shot - but this is environmentally unstabling, and many birds are also protected.[8,9]

Birds can also be scared away by light, pyrotechnics, and predator sounds.[5] But birds can also acclimate to these, and so they need to be moved aggressively around to remain effective.[8,9] Incorporating such techniques onto one or several autonomous drones could further protect fish farms. Demonstrations have shown that a 10-minute mission can scare birds away for over 2 hours.[10] Furthermore, autonomous abatement can be initiated when birds are detected nearby, and mimicking the bird's natural enemy - such as drones with flapping wings - could introduce an additional fear factor, thereby increasing the effect.[11]

3.1 RESULTS

3.1.1 FORECAST TO IMPLEMENTATION

The survey data are analyzed to find the median estimation for the opportunity. Median, rather than the mean (average), is used for this analysis to prevent skewness resulting from outliers. This analysis is represented in Figure 1 below, which shows that the median, i.e. the value separating the lower and upper half of the data samples, is 2025. According to the respondents, aquaculture predator bird abatement drones will become an accepted practice in 5 years.

When asked for the time to accepted practice, the respondents had the option to choose "will never happen", two (2) of the 20 respondents selected this option, indicating that it is, for most participants, more likely a question of *when* predator bird abatement drones will be installed/operated at aquacultures rather than a question of *if* it will happen.

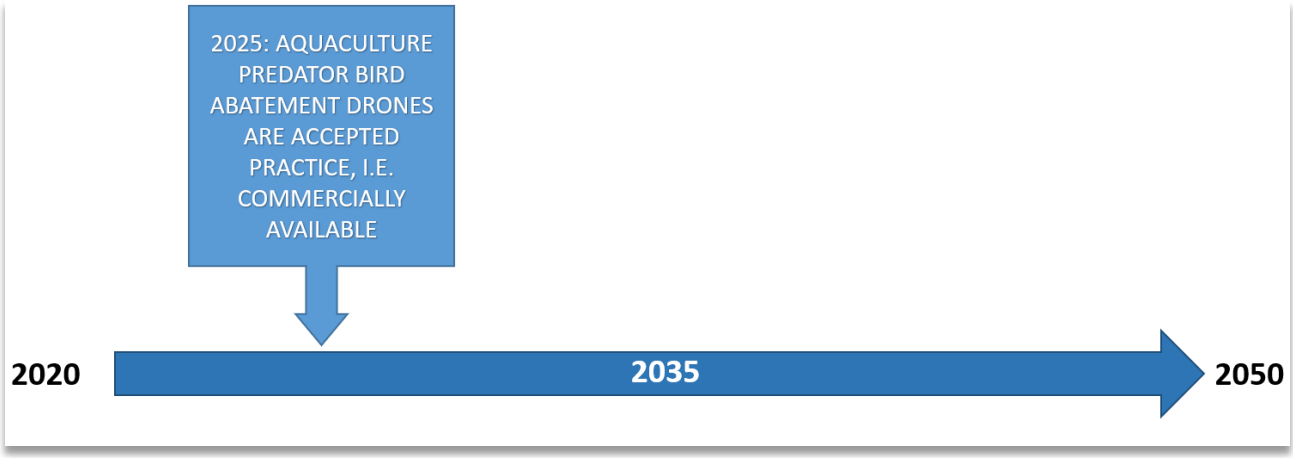

Figure 1: Median estimate for aquaculture predator bird abatement drones

3.1.2 WHAT IS NEEDED TO MAKE THIS OPPORTUNITY HAPPEN?

Respondents, in connection to their estimates, were asked to write what is needed to make this opportunity happen. This question was open-ended.

The comments from the respondents are presented below and have been divided into 5 categories, representing a Political, Economic, Social, Technological, and Environmental (PESTE) analysis. The text in the table are the responses. In some cases, spelling, grammatical corrections, and changes to improve comment clarity have been made. Furthermore, some comments were split to categorize them accordingly to their parts. These appear in no particular order.

POLITICAL
• For wildlife protection agencies to agree to this type of technology to be used - a consideration of the protected birds of species is needed. • If protected species are involved, there will be a legal fight involved before this becomes mainstream.
ECONOMIC
• Rise of competition and falling margins in the fishing industry which leads fishing companies to innovate to reduce theft by birds. • Financial investment is needed. • More funding. • The cost of drones might be prohibitive. • As a business opportunity, this is limited. • The trial runs have shown it works but also that the birds have eventually sussed out other attempts to get rid of them. • Drones might work out to be too expensive to buy and operate. • Companies to make the decision. • What size area are we needing to be manned by the drone, is this efficient for just one per area?
SOCIAL
• Drone operators will also be required to operate them. • General public's acceptance is needed. • There needs to be a commitment to making it work. • Drone technology is rapidly improving and the right team could bring this together quite easily. • People may be upset at the idea of scaring birds, birds might fly into drone path and get hit, flight routes may need to change to avoid coming into contact with drones.
TECHNOLOGICAL
• The right equipment is needed. • Prototypes of and production of predator mimicking drones, software to automate the drones as well as further research into the long-term viability. • More research. • We already pretty much have the technology, just need to modify a drone a bit. • The technology is already here but further tests would be needed to establish whether birds will become accustomed to drones as well the other methods already seen to be limited in effectiveness. • Further development possibly looks at startle response in birds. • Robustness of drones needs to be good.

• The technology exists, but I would anticipate it is the programming of the drones, and ultimately the powering of such drones over extended periods of time. • Drone technology must advance to the state where this units are housed from the launch site where they can return after a mission. • Why will birds not become acclimatised to the drone? • I think birds will adapt to this new technology as well. • Research into drone suitability, birds may equally become accustomed. • Drones may end up being less effective than first thought.
ENVIRONMENTAL
• The environmental implications for this make it a very unlikely scenario to be implemented. The simple fact is that fish farms are placed in areas that will always have a high number of birds. There are already big question marks on aquaculture and its damage to the environment as it stands so adding to this seems to be unfeasible. • The drones may provide some level of danger to protected species. • Maybe the drones can be solar powered or maybe through wave action. • It seems like a good opportunity to protect fish farms however I am sure there would be concerns regarding the natural food chain. Such as could this potentially harm the birds?

The distribution of comments among the 5 categories in the PESTE analysis is depicted in Figure 2 below. This shows that 6% of the comments can be considered political, 12% environmental, 15% social, 27% economic, and 40% technological. Thus, the majority of the comments point to technological factors as driving forces or concerns, many questioning the higher efficiency of drones and if birds would also get used to those technical applications.

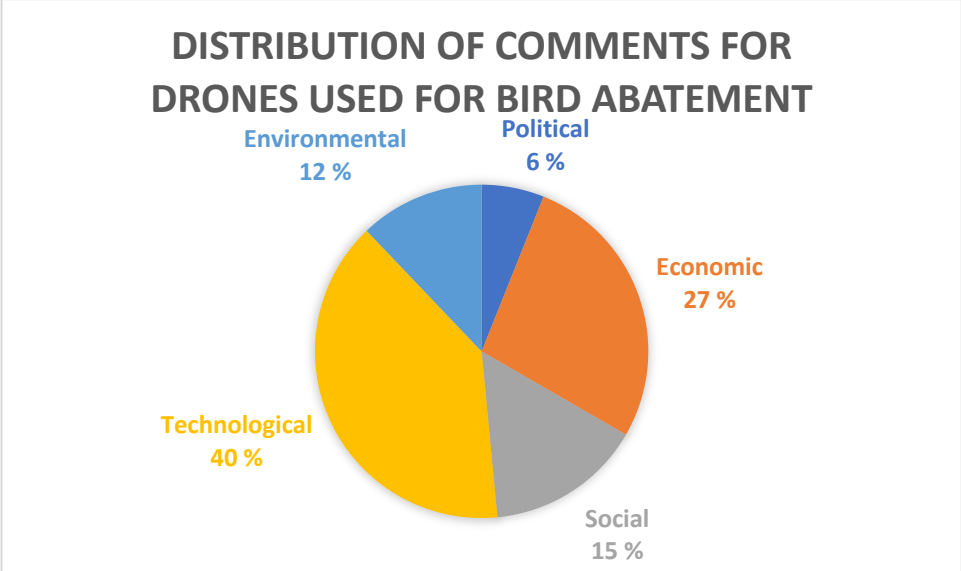

Figure 2: Respondents' comments to aquaculture predator bird abetment drones, categorized

3.1.3 BUSINESS POTENTIAL

On the question of the business potential of drones for bird abatement, respondents, on average, rated it 3.6/5.

3.1.4 ANALYSIS

This section reviews and provides commentary based on the responses. Respondents identified both technological and economic issues as the most important factors to realize this opportunity. On economic issues, comments were mixed, albeit with a focus on the need for "financial investment" and "more funding." However, concerns were also raised over the business potential of the opportunity, with respondents noting that the business case is "limited." They also point to concerns that the solution proposed may be too expensive: While the hardware is relatively cheap, programming software and/or training the drone to perform the task will require investment and commitment as multiple respondents suggest. On balance, it is mentioned that falling "margins" in fish farming due to increased "competition" can be an accelerator to be open and try new technologies as abatement drones to increase aquaculture productivity.

Mentioning that current abatement technologies are already being tested in the prompt text was not sufficient to convince the participants of long-term viability. Respondents inform that "trial runs" have taken place, and so the status of progress needs to be considered for an effective analysis to be made about this opportunity.

Multiple respondents mention how birds could eventually become desensitized to the drone, rendering it ineffective. Respondents mentioned that the drone technology will have to adapt to avoid "acclimation." This is the case of onshore bird abatement, as stated by bird abatement by predator bird (falconers). Drones have a temporary effect, and being that bird abatement is an ongoing service, improvements need to be made to maintain the effect. More than one respondent stated that more research is needed to unlock this problem, indicating that data and demonstration that drone-based abatement technology can deliver the desired effect.

Unlike the other surveys featured in this report, environmental concerns focused on environmental issues, mainly the concern of (protected) bird species and how they would be affected using drones. How to deal with these must be taken into consideration to convince authorities. Because the logistical placement of fish farms coincides with locations with "high numbers of birds," acclimation to drone abatement could accelerate. Regardless, "before this becomes mainstream" respondents express that "wildlife protection agencies" will need to be involved, in order to prevent lawsuits, and social acceptance must be won in order to level the concerns of the public.

Finally, one respondent suggests that recharging the drones could even be powered by renewable sources such as solar or wave energy, providing them with an enhanced sustainability profile in addition to the increased sensitivity to protected species. Moreover, this would also be another step to automate the drone and make it more independent of pilots or suitable electrical infrastructure which would make it locally more flexible and feasible.

3.2 REFERENCES TO STUDY A

[1]https://ec.europa.eu/fisheries/cfp/aquaculture/facts_en
[2]https://ec.europa.eu/fisheries/cfp/aquaculture_en#:~:text=In%20Europe%2C%20aquaculture%20accounts%20for,sustainability%20and%20consumer%20protection%20standards.
[3]http://www.fao.org/3/a-t0054e.pdf
[4]https://www.sciencedirect.com/science/article/pii/S2352513419300365
[5]http://fisheries.tamu.edu/files/2013/09/Overview-of-Techniques-for-Reducing-Bird-Predation-at-Aquaculture-Facilities.pdf
[6]https://ec.europa.eu/environment/nature/cormorants/management.htm
[7]https://www.aquaculturealliance.org/advocate/advice-managing-predatory-birds-part-1/
[8]https://ec.europa.eu/environment/enveco/water/pdf/SUSAQ%20Final%20Report%20Part%201.pdf
[9]http://animalbiosciences.uoguelph.ca/aquacentre/files/misc-factsheets/Predator%20Control%20in%20Commercial%20Aquaculture%20in%20Canada.pdf
[10]https://professionalpestmanager.com/are-drones-the-new-solution-for-bird-control/
[11]https://www.thedronebird.com/safe-humane-and-effective-bird-control/

4 STUDY B: OFFSHORE MAINTENANCE & REPAIR DRONE

Aerial drones are increasing in applicability, and are already used for structural inspections of offshore platforms and wind farms.[1,2,3] Their integration and modularization with more advanced tools will allow them to perform increasingly sophisticated maintenance and repair jobs in difficult-to-reach places. Robotic maintenance by drones will reduce costs, increase safety, and enhance servicing efforts.[4]

The drones and robotics market is undergoing tremendous growth, with an estimated market forecast to reach $81.4bn by 2022.[5] In the next 3 to 5 years, the oil and gas industry is planning to double its investment portfolio in drones and robotics, from 15% to 28%.[5] Drones are already incorporating light-weight components, such as radars, cameras, magnetometers, as well as instruments that measure light penetration, wind, and temperature.[1]

To perform routine maintenance and repair tasks, drones will need to be combined with heavier tools, such as cutting arms, precision grinders, manipulators, and/or welding equipment. Accommodating for the weight and providing the required power for tools onto aerial drones remains a challenge for their application.

4.1 RESULTS

4.1.1 FORECAST TO IMPLEMENTATION

According to the median answer by respondents, offshore maintenance and repair drones will become an accepted practice in 8 years (see Figure 3).

When asked for the time to accepted practice, the respondents had the option to choose "will never happen", none (0) of the 26 respondents selected this option, indicating that it is seemingly a question of *when* maintenance and repair drones will be installed and in operation at offshore installations rather than a question of *if* it will happen.

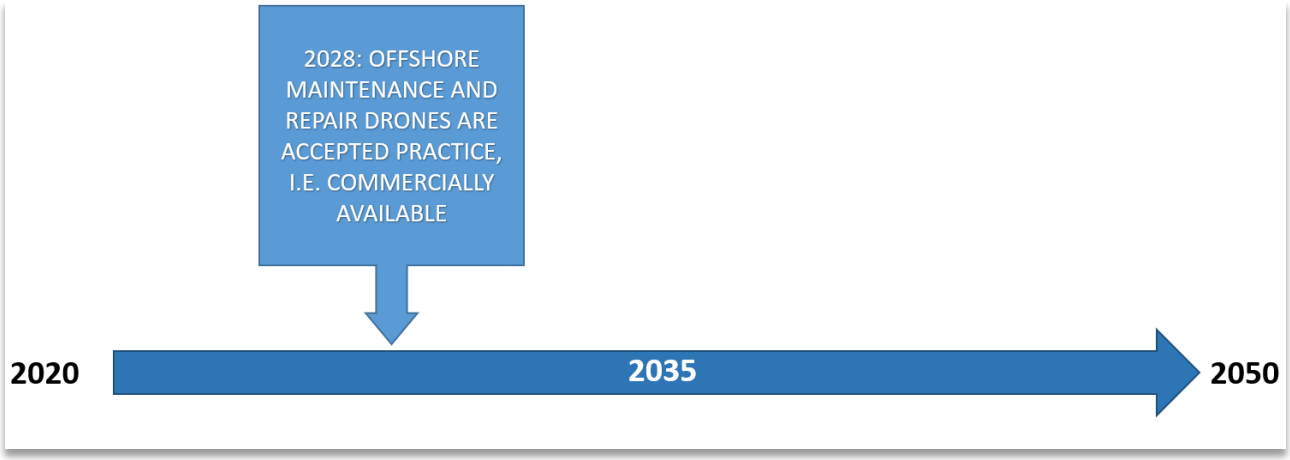

Figure 3: Median estimate for offshore maintenance and repair drones

4.1.2 WHAT IS NEEDED TO MAKE THIS OPPORTUNITY HAPPEN?

The comments from the respondents per this question are presented in the table below, organized across 5 categories, representing a Political, Economic, Social, Technological, and Environmental (PESTE) analysis. The text in the table are the responses. In some cases, spelling, grammatical corrections, and changes to improve comment clarity have been made. Furthermore, some comments were split to categorize them accordingly to their parts. These appear in no particular order.

POLITICAL
• Regulatory alignment on the risk related to accident with the drones. • More government funding for this tech. • Changes in laws are needed. • Radars and cameras need changes in privacy laws.

• The legal implication of the risks related to autonomous flying devices are massive and may prevent this from happening at all. • I am ex-army and I am re-joining as we speak there drones and other tech are become more crazier by the year I say we need more government funding for this tech as America seems to be the world leader at the minunte we can do so much better.
ECONOMIC
• Development at a cost-effective level is needed. • Investment is needed for this to design drones capable of carrying heavier loads and for longer distances. • It must also be financially viable, i.e it must be cheaper and safer than sending a human to perform maintenance. • A perfect example for what is already used, is delivery of mail. • If drones can do and think without help of people, this could make a lot of processes done quicker. • It can actually make some processes more efficient. • If we are talking only drones in the oil/gas sector, I think it will take some time to implement. In the wind industry, it will take less. • However, the business case is still very uncertain as the wind turbines are designed to degenerate over a period of time and the physical maintenance is limited to blades and some foundations and also, it is quite dependent on tethered and/or umbilical connections. • Here too, a joint approach with other (non-water) domains would be advisable, because on land, for onshore purposes, the same questions can be asked and for the most part the same solutions are available. • Maybe in the near future only with easy tasks, like delivery and moving materials around and later they can, like mentioned above here be used for more complex cases like maintaining and repairing complex installations.
SOCIAL
• If any human jobs are being replaced they should be retrained how to control or repair the drone to keep people employed. • Need to make sure their work is as good as that from a human worker. • For this to happen, it seems that the technology must advance so that it exceeds or matches the capabilities of a human worker. • Joint industry and demonstrators for specific applications. • This is something companies like Amazon are looking at for the delivery of parcels. So if they all worked together it wouldn't take long to come up with a workable system. • Be good to deliver tests for COVID. • I can't imagine drones being as accurate as humans.

TECNOLOGICAL
• You will have to show sound results and high precision. • More innovation to enable light weight tools to be equipped which will complete the task. • This will happen though as it already happens in some scenarios - just a case of when it is viable. • If weight and power supply for the required tools is the main challenge, then there would need to be an advancement in drone technology allowing them to carry it. • Prepare drone for heavy works. • A technological advancement so the drones can carry heavier tools needed for repairs. • Well, I think we are already far, but the technology has to develop more and more for it to become more efficient. Now drones can fulfil easy tasks, and in the future they could become more developed. However, this would require a lot of testing before this would become a full alternative of the manual work done now. • We can make the tech but it's going to be demanding on the tools attached I think that's the tricky part get that right. • Further development of drones. • The drones need to be adapted so that they can counter the additional weight, as they will be required to be combined with tools to complete the maintenance and repair work. • Experiments/research needs to be done to figure out an effective way to achieve this. • Drones need to be able to carry heavier equipment and still easy to manoeuvre. • The drone will first have to be manufactured. • Numerous tests will have to be carried out to check the reliability of the product. • Drones need to improve in their ability to perform maintenance and repair services not just monitoring. • Can stay in sky for longer and trust them. • Huge technology leaps. • Technology needs to be improved to ensure that the drones can carry and use the equipment required to make the repairs. • Attaching heavier tools to drones seems like a problem, and even if that is done, programming/controlling the drone to perform difficult tasks seems like a whole other problem. • Drones that can lift heavier equipment with more flight time. • It is a matter of combining co-bot technologies used today in manufacturing. • Modular drones that can retrofit different equipment depending on the job. • Possibly two drones working together. One as a power supply the other as the operating drone. • Technology - and more efficient batteries - low weight to power ratio - the scope will require "heavy" lifting - this requires energy for longer periods. • Reliability, efficiency better than alternatives.

• Integration of several technologies. • Drones / planes are already able to carry people, but then they're also getting quite big. So it's going to be interesting to see if the industry is able to get drones to be relatively small in size, and able to lift heavy equipment that can reach in hard to reach places. This probably means the 'arms' of the drone need to reach beyond the centre of drone, making it hard to maintain its balance. • Until drones can become able to operate heavy machinery tools this opportunity will not be a good investment.
ENVIRONMENTAL
• N/A

The distribution of comments among the 5 categories in the PESTE analysis is depicted in Figure 4 below. This shows that 56% of the comments can be considered technical by nature, and of these, 57% see the problem in the lifting capability of heavy tool equipment. 19% of the comments point to economic factors, while, political and social factors amount to 12% and 15% respectively. None of the comments could be assigned to environmental factors.

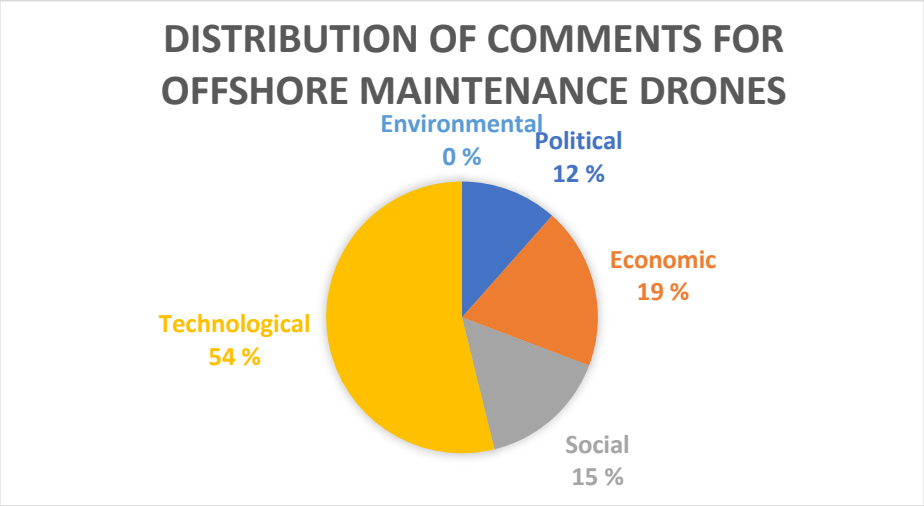

Figure 4: Respondents' comments to offshore maintenance and repair drones, categorized

4.1.3 BUSINESS POTENTIAL

On the question of the business potential of drones for offshore maintenance and repair, respondents, on average, rated it 4.1/5.

4.1.4 ANALYSIS

The respondents to this survey opine that given the difficulty of this task, it is important to approach this opportunity incrementally. Strategies suggested by the respondents include 1) inter-industrial cooperation in order to learn from existing practices elsewhere; 2) include more actors

in order to distribute the investment costs; 3) go after the lower hanging fruit by starting with tasks that are technically easier; 4) start on-shore before moving off-shore; 5) learn before pursuing more complex tasks.

The technical feasibility, reliability, and precision of such a solution was called into question by many participants, often using human capabilities as a benchmark against which success will be measured, e.g. “I can't imagine drones being as accurate as humans.” Thus demonstrations are required to overcome these arguments and convince problem owners of the benefits. In all likelihood, drones will begin as a tool that supports and helps human operators accomplish their work, and gradually take on more tasks over time. In the long term, one respondent observes the conflict between drones and workers: “If any human jobs are being replaced they should be retrained how to control or repair the drone to keep people employed”, indicating that the replacement of displaced personnel may not come without friction.

Many participants raised concerns over drones’ abilities to lift heavy equipment required to do repairs and still be “easy to manoeuvre” and to be able to withstand the operational endurance. While these issues are primarily related to the hardware of the drone itself, software might be an even larger challenge in that “controlling the drone to perform difficult tasks seems like a whole other problem.” Design concepts is another factor, since some participants think of a drone with “arms” or work sharing with “possibly two drones” together “one as a power supply the other as the operating drone.”

4.2 REFERENCES TO STUDY B

[1] Joshi, D., (2019), Drone technology uses and applications for commercial, industrial and military drones in 2020 and the future
[2] Brogaard, R., (2020), Inspektion med droneteknologi
[3] Daponte, P., De Vito, L., Glielmo, L., Iannelli, L., Liuzza, D., Picariello, F. and Silano, G., (2019), A review on the use of drones for precision agriculture.
[4] UAS Vision, (2018), 10 Benefits of Drone-Based Asset Inspections
[5] Frost & Sullivan, (2017), Application of Drones and Robots in Oil and Gas Industry – A Cost Effective and Safe Method of Inspection and Surveillance.

More information:

The Construction Index, (2019), Funding boost for pipe repair robots.
Boesch, D., (2018), Trump’s offshore oil drilling plans ignore the lessons of BP Deepwater Horizon.
Kimberley, G., (2018), Robotic and drone technology could transform the offshore oil market.
Nichols, M., (2017), Advantages Of Drone-Based Preventive Maintenance In Offshore Oil Inspections.
Shukla, A., Karki, H.,(2016), Application of robotics in offshore oil and gas industry— A review Part II.
Miller, P., (2019), High-Tech Inspections.

5 STUDY C: DE-ICING WINDMILL DRONE

The accumulation of ice on offshore wind turbine blades negatively influences aerodynamics and can result in a loss of up to 50% of energy production.[1,2] Ice also causes an imbalance among the blades, putting stress on the structure and components of the windmill, thus reducing its lifespan.[3] De-icing the blades removes the imbalance and restores power output. [4,5]

Current practice sees turbine blades being de-iced by helicopters or maintenance workers repelling down with a water jet. These options are costly, time consuming, and dangerous.[1] Pre-installed in-blade heating systems are also currently available, but retrofitting or replacing existing blades with new ones is expensive.

Outstanding challenges include the cost of heavy lifting drones that are capable of carrying the weight of the water jet and the hose. Additionally, the calibration of the pilot algorithm for the rough weather conditions at offshore wind farms needs to be stable enough to get close to the blades while shooting a high-pressure stream without damaging them or the drone.

5.1 RESULTS

5.1.1 FORECAST TO IMPLEMENTATION

The survey data are analyzed to find the median estimation for the opportunity (see Figure 5). According to the respondents, offshore maintenance and repair drones will become an accepted practice in 7 years.

When asked for the time to accepted practice, the respondents had the option to choose “will never happen”, six (6) of the 29 respondents, or 21%, selected this option.

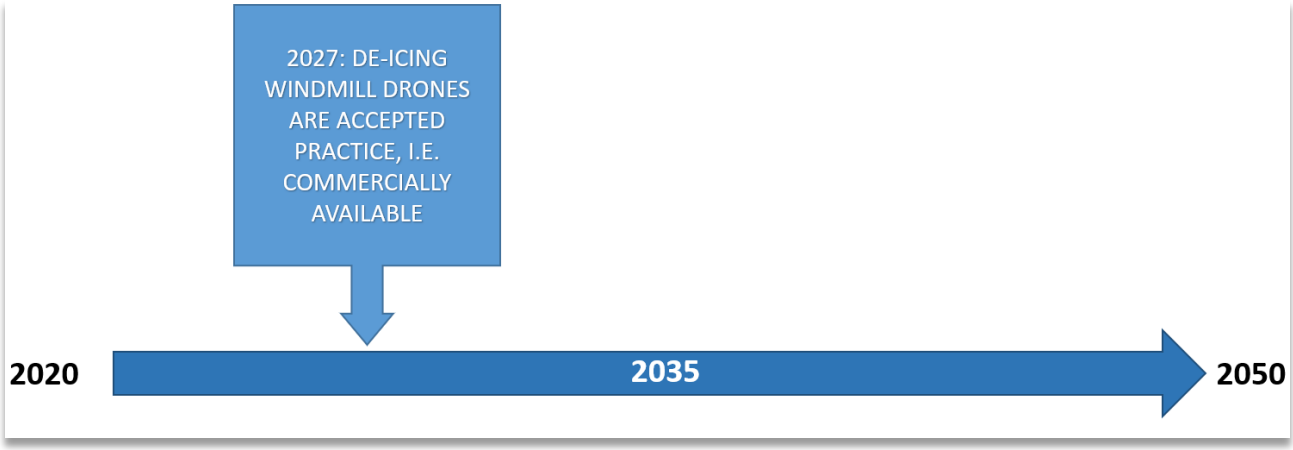

Figure 5: Median estimate for de-icing windmill drones

5.1.2 WHAT IS NEEDED TO MAKE THIS OPPORTUNITY HAPPEN?

The comments from the respondents per this question are presented in the table below, organized across 5 categories, representing a Political, Economic, Social, Technological, and Environmental (PESTE) analysis. The text in the table are the responses. In some cases, spelling, grammatical corrections, and changes to improve comment clarity have been made. Furthermore, some comments were split to categorize them accordingly to their parts. These appear in no particular order.

POLITICAL
• Legal reasons makes remotely or autonomous checks less likely in the near future. • More government support is needed. • Guidelines on how to fly/where to fly to make the airspace not dangerous for planes, etc.

ECONOMIC
• I don’t think this will happen in the sense that, I don’t think it will be commercially viable. There is simple not a very good business case and the issue with icing is being solved in other ways - e.g. Vestas' de-icing technology. • Funding is needed. • Drone costs going down. • This sounds like it would be a cheaper and safer option than humans doing it. • Decrease the cost of production of these drones. • The technology to add heating to the blades is there, but they need to be fitted. There is also a cost of fitting these which is expensive. But looking at the current challenges and costs I think the benefits of the heated blades outweigh the cost, as currently it is expensive hiring helicopters or heavy carrying drones to jet the blades. • Lots of funds. • I think drones would be more obviously used during inspection. • Saving money. • The idea is interesting but it is only meant for a niche problem. I think that it is better to improve wind turbines with build-in heating system in the blades.
SOCIAL
• To ensure the public will be updated on the regular basis with the pros & cons of wind turbines and using the drones for cleaning turbines. • It has started to happen already, trials are taking place as we speak because it is much cheaper and safer to de-ice the blades by using a drone. • Training for the drone operator. • Good pilot training systems in place who can fly them properly. • Less danger. • Drones are so useful and this will make the process easier and safer. • There should probably be some safety manuals.
TECHNOLOGICAL
• Evolution of technology is needed. • I believe in in-blade heating systems or coating of the blades - not drones. • Chemical de-icing instead of waterjets. • It seems like a situation of 'stirring with the oars that are there', sitting out and waiting for new types of windmills that do have heated rotors. • Technically possible and spraying already used in agriculture. • Manufacture bigger drones that could carry all the equipment necessary and could withstand that kind of weathers. • I don't think it's the most reliable way to clean the blades, but it should work most of the time in good weather.

• I'm not sure how this idea is better than current options. • At this stage it feels that using drones for de-icing is unfeasible in a near future. • To carry the load for de-icing blades, it is necessary a helicopter size-drone... but we already have helicopters of different types, it is only necessary a smart auto-pilot system; So, I do not see that this topic is relevant. Drone will be really relevant for asset integrity with smart measuring systems. • Availability of the equipment and I assume coordination with the turbines to ensure they are switched off as the drones are doing their work. • I feel like technology needs to rapidly advance to make a drone with such power and multitasking capabilities. • Improvements in drone stability. • Design of a drone capable of withstanding the weight of the water and capable of delivering the water jet. • Just the ability for the drone to be able to lift the hose. • We need much better drones that we currently have commercially. • Development of drones that are capable of the described. • Drones that are capable of carrying weight of the water jet. • Increase their ability to function in harsh weather conditions and increase the load the drone can carry. • Better batteries. • Lots of and technological solutions to create this type of drone. • Bigger, heavier drones capable of lifting. • Easier to control drones in rough conditions.
ENVIRONMENTAL
• Not replacing blades means less environmental impact.

The distribution of comments among the 5 categories in the PESTE analysis is depicted in Figure 6 below. This shows that 52% of the comments can be considered technical by nature. 23% of the comments point to economic factors as driving forces. Social, political, and environmental factors amount to 16%, 7%, and 2% of the comments, respectively.

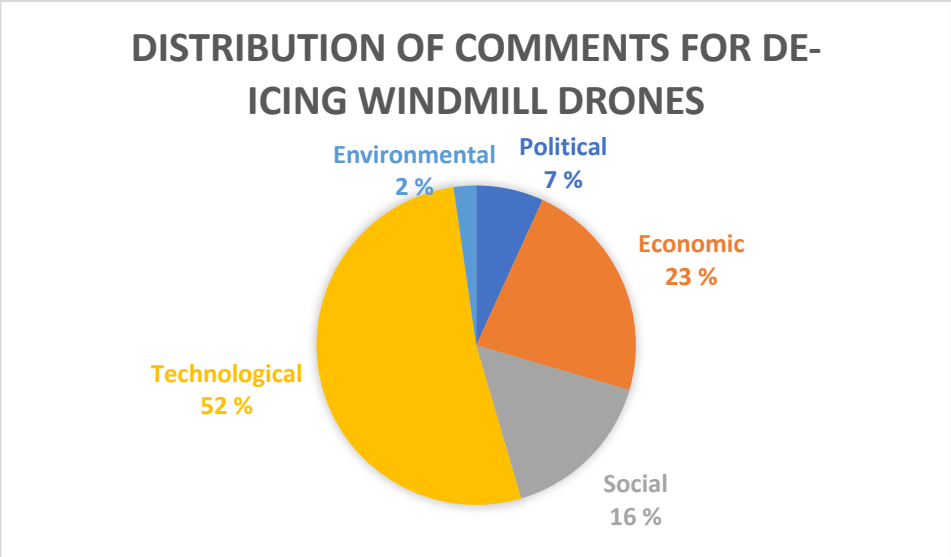

Figure 6: Respondents' comments to de-icing windmill drones, categorized

5.1.3 BUSINESS POTENTIAL

On the question of the business potential of de-icing wind turbine blades, respondents, on average, rated it 3.3/5.

5.1.4 ANALYSIS

Many respondents challenge the business case outright, since for them heating coils in windmill blades e.g. "Vestas' de-icing technology" are seemingly more persuasive, resulting in comments such as: "I don't think this will happen in the sense that, I don't think it will be commercially viable." As new windmills are currently being equipped with integrated heating technology, the drone solution would solve according to some participants only a "niche problem"; 21% of respondents think that this will never happen.

Technical concerns over implementation account for the biggest part of the feedback. Most comments to this end regard the opportunity technical feasible and seemingly easy to implement. Comments such as similar solutions are "technically possible and spraying already used in agriculture," show progress from other industries. Nevertheless, concerns over the drones' ability to lift payload and long endurance frequent the comments. In addition, it seems necessary to "increase their ability to function in harsh weather conditions and increase the load the drone can carry." This pinpoints that the heavy lifting capability is alone not sufficient since the North Sea is a rough environment, wherefore the technology has to be implemented.

However, there may be some benefits for human safety which could go beyond the economic rationale. "It has started to happen already, trials are taking place as we speak because it is much cheaper and safer to de-ice the blades by using a drone." This indicates that more research on state-of-the art is required for an effective analysis, and to what extent blades are being replaced in order to clarify the market potential.

5.2 REFERENCES TO STUDY C

References:
[1]https://orbit.dtu.dk/files/104279722/Icing_Impacts_on_Wind_Energy_Production_final.pdf
[2]http://cdn.intechweb.org/pdfs/14802.pdf
[3]https://www.sciencedirect.com/science/article/pii/S0960148115004048
[4]http://www.bladecleaning.com/problematica_EN.htm
[5]https://projekter.aau.dk/projekter/files/294661634/Master_Thesis_Cristian_Gidinceanu.pdf
[6]http://www.iaarc.org/publications/fulltext/Maintenance_robot_for_wind_power_blade_cleaning.pdf

More information:
https://northsearegion.eu/northsee/e-energy/offshore-renewable-energy-developments-offshore-wind/
https://pdfs.semanticscholar.org/8bb1/10a8c86abf785b1b019dcc37150f09de90ae.pdf
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.452.7240&rep=rep1&type=pdf
https://www.windpowerengineering.com/cracking-icing-problem-turbine-blades/
https://www.researchgate.net/publication/228552784_Sea_ice_and_icing_risk_for_offshore_wind_turbines
https://pdfs.semanticscholar.org/8bb1/10a8c86abf785b1b019dcc37150f09de90ae.pdf?_ga=2.29359028.901660152.1573028142-1878112648.1568293971

6 BUSINESS OPPORTUNITIES

The increase of installed infrastructure on the North Sea requires a bigger effort to ensure maintenance. Maintenance drones will support this development by saving time, manpower and therefore reducing the operating cost and manual danger. Drones thereby can utilize the wide space offshore, which has a lower operational risk to harm humans than on land or crowded cities.

Drones have been around for quite some time, but only now are beginning to take on increasingly complex tasks. While off-the-shelf drone hardware has come a long way, it is the software that give them advanced capabilities. Many projects are underway that make them able to autonomously react to their environment, enabled by advanced sensors, pattern recognition, and machine learning and AI. The growing capability of piloted and autonomous drones offer the opportunity to take over (initially repetitive) maintenance tasks currently carried out by humans.

Current limitations include access to power sources, performance and stability in rough weather conditions, and long distances from human oversight. Yet these are challenges for the ingenuity of engineers, and solutions are expected to follow. The more data they are able to process, the more complex tasks they will be able to fulfill, moving from using it as a mobile camera to a flying computer with situational awareness, and able to select the tool for the job and execute work on the task. With cloud-based data processing power, increasing Internet coverage and speeds promise the enhancement of capabilities and quality.

Drones, although limited by their power supply, do not suffer the same fatigue as humans. This way the danger for humans is first reduced because they only remotely analyze the collected sensor data. In a second step the analysis can be taken over by a smart algorithm implemented in the drone software, detecting and analyzing the gathered data on its own, which would further remove the human factor in the maintenance process.

According to estimates from PWC, the estimated global market potential will exceed USD 125 Billion [1] with the main application being in infrastructure, transport sector, insurance, media, telecommunication and agriculture. This indicates that the technology will be driven by the general use of drones and that the applications in this report will benefit from the general development and advances of drone technology. PWC mentions safety as one of the main blockers for the technology, which is not a significant issue for the applications discussed here as they are off-shore and thereby only cause an economic loss in case of a malfunction. The significance of the development can furthermore be seen from major consulting firms are opening center focusing on the drones and data analysis [2]. Furthermore, the investment in the drone industry has increased from USD 30 million in 2008 to 1.205 billion in 2019 [3], indicating that there is a general belief that this is a market with a large potential.

AQUACULTURE DRONE POTENTIAL

Aquaculture is a growing market that could incorporate aerial drones for smart inspection and maintenance. Due to the growing world population the food industry is challenged to feed more and more people. Extrapolating the current meat consumption per capita of Western European countries to the rest of the world would result in shortages, and so new methods for improving productivity are necessary. Moreover, the fishing quotas get gradually stricter as overfishing becomes a serious concern for the marine ecosystems, shifting production to the growing aquaculture industry. Furthermore, due to the population increase space gets more valuable which limits the development of onshore indoor aquacultures till a certain extent, whereas ¾ of the earth's surface is covered by water.

The increase in aquaculture production from 1990 to 2018 is 527% showing a rapid growth of the sector [4]. It is a major employer as well with an estimated 129.000 people employed in Europe alone within the sector [4]. Within the EU 23% is freshwater fish, 27% is marine fish while the remaining 50% is mollusks and crustaceans [5]. There is an expectation that the farmed fish within a short period of time will surpass the wild fisheries. Within the North Sea region is Norway the country with the most aquatic farming, a total output of 1.3 million tons annually [6], followed by the UK with 194.000 tons annually [7].

With an increasing amount of aquaculture facilities, the loss created by predator birds start playing a substantial roll for the enterprises. Currently the most severe loss reason, fish disease [8] is the focus of a large number of research projects and experiments. While there has been progress within this area, there is still relatively little change to the protection against predator birds. The question is if mechanical fencing or separation will be most effective against predators while still allowing the fish to grow in the required "natural" environment, as some need the constant current they are used to from the ocean.

While there are different ways in which fish farms can use mechanical protection a full mechanical protection can for a fish farm of average size cost anything from USD 400.000 to USD 750.000 which is a significant investment [9], yet nonetheless, these require maintenance. If this cost is compared to the cost of drones there will be a significant saving for aquaculture installations as a commercial drone currently cost from USD 2.000 to USD 10.000+ which is significantly lower, even if it is assumed that it has a shorter lifetime compared to a mechanical solution [10]. Given the rapid development of drones and associated technology it is safe to assume that this prices in the future will come down as the quality and functionality of the drones improve.

While it is too early to say which design and configuration of drones one would need, e.g. one or a swarm, it will under all circumstances provide a significant saving for the farms. Given the prices above, and taken into account that specialized software might be need, should each farm be able to save more than USD 300.000 when the drones become an accepted substitute for the mechanical solution.

REPAIR AND MAINTENCE DRONE POTENTIAL

To understand the opportunities of this market is it useful to look at the market for inspection drones, as this is significant more developed than the market for repair and maintenance. It can with some reason be expected that the two other markets will follow the same path as the market for inspections has followed, when the right drone solutions become available.

There are various forecast for how big the market for repair, inspection and maintenance will be, with some forecasting a values of USD 60 billion by 2027 [11]. The growth is partly driven by the rapid expansion of offshore renewable energy and an increase demand within the ageing offshore oil and gas industry infrastructure. However, it is yet too early to say how big a share that drones will get of this market. However, there are predictions that the market for use of drones for maintenance repair and inspections can growth with up to 23% CAGR [12].

The main application of drones in the moment is for inspection, where there is a number of advantages, both economic and from a risk perspective. Rather than having to have a team of experts or experienced personnel doing the inspection the drone can do this with the current technology. This also effectively eliminates risks to workers, as it is inherently dangerous to inspect offshore installations, if the operator can be in a safe place while doing the inspection. However, there is a risk that there might be a shortage of experience drone pilots as the demand increases, which might slow down the growth of the segment [12]. The estimates for the savings by using drones for inspection depends on the particular sector, e.g. oil rigs around 90% and wind turbines around 50% [13]. Yet, there are significant issues in one of the potential major applications, the inspection of wind turbine blades, where the technology is not yet reliable enough [14], although there is progress also in this area [15].

The area of repair and maintenance has so far seen less progress than inspection. There are several reasons for this, including lack of drones that can lift a heavy payload which is often necessary in the case of offshore installation. Another issue is of design of the objects of repair and maintence, as the equipment is currently designed and manufactured under the assumption that they are to be repaired and maintained by humans. A more modular setup could increase the ability for drones to operate in that environment. A first step towards drone friendly design would be to use light-weight components to reduce the weightlifting requirements to the extent that drones are able to complete the work.

The advantages from such a change will likely have the same benefits as we are observing in the area of inspection, both economically, in terms of significantly less cost as well as reducing the risk for humans working within this area. However, there are still significant challenges in term of getting the drone to operate reliable in high wind, snow and other adverse weather conditions, which will most likely be solved over time but are currently not available.

DEICING WIND TURBINE BLADES

Of the three analysis in this report, this is the one where there is the most uncertainty. The fact that 6 of the 29 respondents did not think that this will happen is a relatively large number compared to the other studies.

It is also the only study where there are other competing technologies that might be as good or better in some cases, such as mounted heating coils on the windmill blades. There are also other technologies such as a UK developed robot which current focus is on repairing wind turbine blades that could conceivable be converted to this task as well [16].

It is too early to come with any estimates of the cost or potential savings for this technology. It will furthermore depend on how the big manufactures of wind turbines decide to solve this problem, and companies like Vestas who have developed their own technology might be reluctant to change [17].

[01] https://bestdroneforthejob.com/blog/pwc-report-business-use-drones/
[02]https://informedinfrastructure.com/22563/infrastructure-leads-commercial-application-of-drone-technology/
[03] https://droneii.com/money-talks-2019-drone-investments-break-new-records
[04] http://www.fao.org/state-of-fisheries-aquaculture
[05] https://ec.europa.eu/fisheries/cfp/aquaculture/facts_en
[06] https://www.worldatlas.com/articles/top-15-countries-for-aquaculture-production.html
[07] https://www.indexmundi.com/facts/indicators/ER.FSH.AQUA.MT/rankings
[08] Tavares-Dias, M., & Martins, M. L. (2017). An overall estimation of losses caused by diseases in the Brazilian fish farms. *Journal of Parasitic Diseases*, *41*(4), 913-918.
[09] https://www.aquaculturealliance.org/advocate/advice-managing-predatory-birds-part-1/
[10] https://dronerush.com/drone-price-how-much-do-drones-cost-21540/
[11] https://www.globenewswire.com/news-release/2020/06/16/2048499/0/en/Inspection-Repair-and-Mainten
[12] https://www.transparencymarketresearch.com/inspection-drones-market.html
[13] https://www.rolandberger.com/fr/Publications/Drones-The-future-of-asset-inspection.html
[14]https://eicluster.dk/sites/default/files/publications/drones_for_offshore_and_maritime_missions_sdu_spring_2018.pdf
[15]https://eicluster.dk/sites/default/files/publications/drones_for_offshore_and_maritime_missions_sdu_spring_2018.pdf
[16] https://renews.biz/61200/smart-offshore-blade-repair-drones-move-a-step-closer-to-reality/
[17] https://patents.google.com/patent/US6612810B1/en

7 CONCLUSION

For many firms it is hard to estimate the status and feasibility of technology, especially due to its rapid growth and development. This report reports on three studies for smart inspection and maintence by aerial drones for maritime and offshore industries that have been developed (aquaculture, offshore installations, and offshore windmills) and used as prompts for surveys that were distributed online. Aggregating answers from 75 respondents, smart offshore maintenance drones are expected to be implemented emerge between 5-8 years from now, depending on the use case and operational environment. Respondents point to technical and economic feasibility as primary concerns and justifications for their implementation.

Yet uncertainties abound. Just because a problem like the predator bird abatement would be executed by a drone doesn't mean it will automatically be better and birds would not acclimate to those. Moreover, many see the danger to endangered species. This shows that when developing drone applications for nature, the environmental impact must be considered and social acceptance should be garnered.

Secondly, not all potential use cases seem economically viable to every participant and may service a niche only. Nevertheless, even a smaller or bigger niche application can simply process and gain revenue, when the application development is not to cost intensive. This well expressed in the ratings for business potential, which differ from 3.3 to 4.1 (with a maximum of 5).

Thirdly, not all technologies are developed yet to be able to establish all imaginable drone services. As key technologies for the application of offshore maintenance drones survey participants mentioned long endurance batteries, drones that are able to withstand harsh North Sea weather conditions, heavy lifting, but are also still easily maneuverable and precise in their work to the benchmark of current human practices.

Nevertheless, according to the large majority of participants, drones offer an opportunity to increase safety and reduce costs. Ensuring quality levels of current human-based practices provide the benchmark against which drones are judged. Feasibility demonstrations in combination with sufficient funding is needed to kick off the development of each drone. Yet the more industries that can be served and the more tasks a drone can provide seem to indicate the expected speed of its adoption in maritime and offshore industries, but further study is required to constitute this.

8 RESPONDENTS

Respondents identified as acting on this opportunity include:

Aarhus University
Dansk Maritime
Energy Cluster Denmark
Terma

TNO
Ålborg University

Periscope Network

periscope-network.eu