Periscope Network

Market Opportunity Report

Offshore Energy Hubs

Interreg North Sea Region PERISCOPE
European Regional Development Fund
EUROPEAN UNION

PERISCOPE
reaping the potential of the oceans

Dear reader,

This report provides an assessment on the prospects for offshore energy hubs. Four use cases have been developed and evaluated by respondents in a survey instrument for their forecasted time horizon to implementation and their business potential as opportunities for the maritime and offshore industries.

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

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

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.

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

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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 offshore energy hubs and maintenance provides an opportunity to support the accomplishment of these goals. The rapid development in renewable ocean energy generation provide the context for growth.

To support investment timing decisions for enterprises and research policy, an engagement tool was developed around different configurations for the electrification of the seas. This report presents the outcome and analysis of 4 surveys taken by a total of 98 respondents. Responses indicate that:

- Tide-powered hydrogen vessels are expected to become an accepted practice 15 years from now (2035), and respondents rated the business potential at 3,58/5. In order to develop this opportunity, respondents primarily point to economic factors (50%) followed by technological factors (26%). Only 13% and 11% point to political and social factors respectively, while none point to environmental factors in relation to this opportunity.

- Recharging at wind farms is expected to become an accepted practice 8 years from now (2028), and respondents rated the business potential at 3,77/5. In order to develop this opportunity, respondents mostly mention economic factors (40%), followed by technological (26%), social factors (17%), political (11%), and environmental factors (6%).

- Fully electric fish farms are expected to become an accepted practice 10 years from now (2030), and respondents rated the business potential at 3,43/5. In order to develop this opportunity, respondents mostly mention technical factors (40%), followed by economic (33%), political (17%), environmental (7%), and social factors (3%).

- Renewable methanol vessels are expected to become an accepted practice 10 years from now (2030), and respondents rated the business potential at 3,52/5. In order to develop this opportunity, respondents mostly mention economic factors (49%), followed by political and technological (17% each), social factors (10%), and environmental factors (7%).

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 stability and long-term prosperity, new ways are needed to increase productivity, and offshore energy hubs have been proposed. While initiatives, cases, and projects have begun to emerge, questions of what's next, how, and when further applications of offshore energy hubs will develop remain.

To answer these questions, PERISCOPE identified potential next practices for offshore energy hubs and put them to the crowd for assessment and validation. Survey instruments were developed for various use cases that cover new activities to support the electrification of the seas. The use cases ranged from introducing new renewable fuels such as methanol and hydrogen, developing multi-use platforms such as charging at wind farms and incorporating electrification into existing industries such as fish farming, and the production of synthetic fuels. While none of these individually can be considered an "offshore energy hub", they contribute with descriptions of different capabilities that could be implemented at said hubs.

The use cases were developed, 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 the studies are presented, general remarks are made on the business opportunity for offshore energy hubs, and the report is concluded.

3. STUDY A: TIDE-POWERED HYDROGEN VESSELS

With approximately 3000 ships sailing at any one time, the North Sea is one of the busiest shipping areas in the world.[1] Many of the medium-sized vessels require approximately 1 MW for propulsion - for instance ferries, search and rescue vessels, and coastal and inland commercial vessels. These are vessels that can be potentially powered by hydrogen gas.[2,3,4]

New floating tidal power plant designs will allow for their mass production at shipyards, further reducing the costs of clean electricity production. Electricity from tidal is very predictable because it relies on the gravitational pull from the moon, and because the waterways that make good sites for tidal energy are not always easily connected to a mainland electricity grid, producing hydrogen can serve as another way to store the energy.[5,6,7]

Hydrogen is stored in tanks that are about the size of a shipping container, and therefore can be swapped on and off vessels. However, making an existing vessel capable of running on hydrogen fuel cells requires alterations to the ship’s infrastructure, especially concerning the drivetrain.[2] Furthermore, even if there is hydrogen stock available along the route, the availability of hydrogen at ports is still limited.[2]

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 2035. According to the respondents, tide-powered hydrogen vessels will become an accepted practice in 15 years.

When asked for the time to accepted practice, the respondents had to option to choose "will never happen", three of the 32 respondents selected this option, amounting to a total of 9,3%.

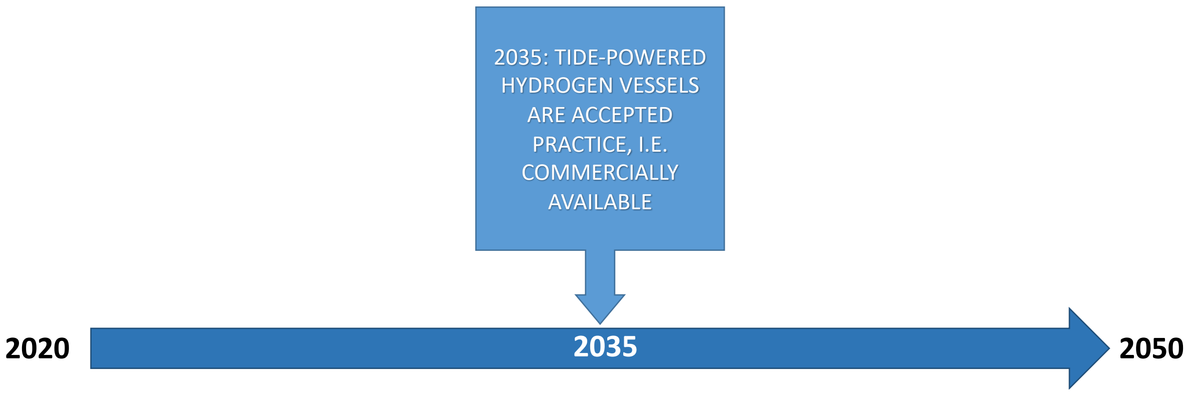

Figure 1: Median estimate for tide-powered hydrogen vessels

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
• Large amounts of political pressure are needed to incentivise companies to make the change. This could be seen as a chicken and egg scenario where unless there are power plants the ships won't be converted and unless the ships are converted the power plants will not be built. This is why external factors such are needed as incentives. • Political pressure, such as an emissions tax.

- Governments may have to help with subsidies. It will take time for the floating tidal power plants to be up and running, and for there to be enough of them to make it successful.
- Political will resulting in channelling investments and entrepreneurial action in the right direction.
- Strict CO2 regulations, starting with CO2 emission costs increasing, and regarding the shipping industry, a ban of specific contaminating technologies used today.
- Technology is becoming increasingly competitive, and regulations should enhance the innovation change.
- Governments offering tariffs to companies that switch to hydrogen fuel cells, to offset the cost of modifying the ship.
- Governmental policies to encourage the use of hydrogen are needed: for example tax-free or low taxes on maritime transport running with hydrogen.

ECONOMIC

- Need to show the CAPEX/OPEX and operational confidence.
- This is indeed a good business opportunity although the limited applicability and high investment cost so far.
- An initial investment in the offshore hydrogen power plants.
- A rise in the cost in traditional fuels for these vessels.
- A lot of hydrogen gas for not high price is needed.
- A lot of money is needed.
- Investors are needed.
- The cost of making it has to go down.
- Converting medium sized vessels to hydrogen sounds financially unviable, so I don't believe this will happen, replacing old vessels with hydrogen cell vessels may be an option but I expect this to be a slow uptake.
- The basic technological systems are there and work at scale, but they are still not economically viable. This use case is too limited in my opinion, both in respect to energy carrier (NH3 is more likely for ships) and the type of vessel chosen (large oceangoing ships will be converting to electro fuels within in the years until 2040 and they will not want a long-term solution based on a carbon free energy cycle).
- The price of traditional marine fuels is far lower than the price of hydrogen. Thus, not commercially attractive for the time being.
- Inexpensive, mass scale, and efficient hydrolysis is needed.
- Cost effective and smaller scale fuel cell and electrolyser stacks are needed.
- Cost-efficient ways of storing hydrogen
- If the gas was cheaper, it could be good.
- Due to the size of the market, the business opportunity for hydrogen is huge.
- A great deal of investment, and vessels will need to be "out of action" for a while.
- An economic floating tidal energy converter system which produces hydrogen in areas with a viable tidal current. At the moment, this does not even exist for the Bay of Fundy, where tidal currents are far more energetic.

• Tidal plants being a reality for starters, there needs to be proper investment in the area which there isn't at the moment. • There would have to be lots of expensive renovations to existing fleet or the actual re-placement of fleets to be able to adopt this. • Alterations in existing ships' infrastructure is not an easy and affordable way. The new produced ships should be compatible. • Hydrogen needs to be made more readily available, at ports and not just at the floating power plants. • Ease and accessibility of the power plants would be vital to outweigh the ease and ac-cessibility of diesel. • Hydrogen gas has to be produced on mass scale to be cheaper. • Hydrogen tank availability is needed. • The availability at ports of hydrogen would need to increase for hydrogen only vessels and it may be advantageous to have some floating power plants near to the ports to increase availability. • More stock availability for vessel is needed. • Fuel cells to be implemented broadly. • It sounds theoretically very good, but it would take a great deal of implementing and would probably be only able to roll out on a small scale to begin with. • A very large investment in infrastructure, onboard storage and fuel cell installations is required in each case, making this solution a very difficult business case, compared to e.g. battery powered vessels, or just engines powered with sustainably produced fuels. • Accelerate the large scale production of hydrogen to become much available and af-fordable.
SOCIAL
• Safety is a large concern with hydrogen production and storage which would improve with investment over time. • I think a shift is needed from an evolution-based algorithm economy (today's capital-ism) to an AI based partially planned economy with a decentralized currency. • People's attitudes and minds would have to be changed to this way of thinking and I think it would take a good few years to be accepted and used. • Strong engineering safety standards are needed. • Making sure everything concerning the hydrogen is safe. • Safe ways to store and distribute the hydrogen need to be ensured. • Safe ways of storing hydrogen
TECHNOLOGICAL
• Fuel cell technology on large scale in ships need some demonstration projects. • Retrofitting capabilities need to be researched. • Prepare the ships for the use of hydrogen, • Alteration of ship infrastructure is needed.

• Final designs, production and development of the power plants. • Better infrastructure is needed. • Revamped ship designs are needed. • Floating tidal power plant designs are needed. • The opportunity may even require new ships to be built with the intention of with hydrogen only or a hybrid of hydrogen and traditional fuel. • Hydrogen is rather difficult to store. Liquid fuels are much easier. I suspect that this transition will happen as a result of liquid synthetic fuels becoming competitive with petroleum-derived ones. • Adjusting existing vessels to use it is needed. • I believe this is already happening, but in small doses due to the alterations that need to be made to carry out the transformation on the vessel. • Previously worked at an Asian based automotive company that extensively researches hydrogen and produces hydrogen fuel cell vehicles. The technology needs several leaps in improvement in almost every area, and batteries are already ahead and continue to move faster in improvement than hydrogen technology. I hope something does change, that breakthroughs do happen, because cases like those stated are valid and should be made zero emissions. But I don't think hydrogen will be the technology that gets us there. • Research is needed. • An improvement in the technology so fuel cells can be stored in ports and the ships can be modified easier is needed. • Technological advancement is needed.
ENVIRONMENTAL
• N/A

The distribution of comments among the 5 categories in the PESTE analysis is depicted in Figure 2 below. This shows that 13% of the comments can be considered political, 11% social, 26% technological and half of the comments (50%) are concerning economic factors. None of the comments were attributed to environmental factors.

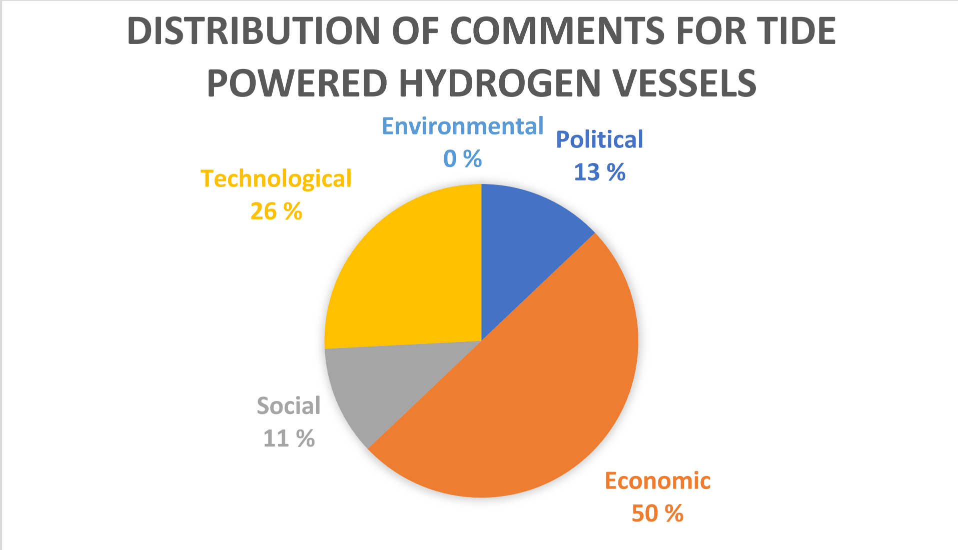

Figure 2: Respondents' comments to tide-powered hydrogen vessels, categorized.

3.1.3 BUSINESS POTENTIAL

On the question of business potential of tide-powered hydrogen vessels, respondents, on average, rated it 3.58 out of 5.

3.1.4 ANALYSIS

This section reviews and provides commentary based on the responses. Respondents identified economics factors as the most important factors to realize this opportunity. These were mixed but many pointed on the extensive investments needed to make this a reality, "There have to be lots of expensive renovations to existing fleet or the actual replacement of fleets to be able to adopt this". Besides the heavy investments needed to adapt the fleet, others pointed at economic viability as "The basic technological systems are there and work at scale, but they are still not economically viable". This economic viability of the opportunity was further emphasised by others who comment that "The price of traditional marine fuels is far lower than the price of hydrogen. Thus, not commercially attractive for the time being". So the economic challenges include both the heavy investments needed, but also the economic benefits of substituting current methods with this opportunity being too low for the time being.

These economic challenges are further supported by the political factors where several comments state a need for political involvement and say that if it should become economic viable "Governments may have to help with subsidies". It is further added that it is not just about making it viable to use the technology, but also a matter of facilitating the switch, and "Governments offering tariffs to companies that switch to hydrogen fuel cells, to offset the cost of modifying the ship" could speed up this process. Others point towards a need for "Strict CO2 regulations, starting with CO2 emission costs increasing, and regarding the shipping industry, a ban of specific contaminating technologies used today", which will also improve the relative benefits of this opportunity compared to conventional practices. In general, "This could be seen as a chicken and egg scenario where unless there are power plants the ships won't be converted and unless the ships are converted the power plants will not be built", emphasising the need for external support.

A big part of the comments also pointed on technological factors and many believe that "Technological advancement is needed." Some say that "Better infrastructure is needed" while other point towards the facts that "Hydrogen is rather difficult to store. Liquid fuels are much easier", reflecting how there are still some practical issues involved in this opportunity even though it might in many ways be technological possible.

Lastly, several social concerns are also raised, which relates directly to the technological factors as several comments call for "Safe ways of storing hydrogen" and in general "People's attitudes and minds would have to be changed to this way of thinking and I think it would take a good few years to be accepted and used."

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4. STUDY B: RECHARGING AT WIND FARMS

Offshore wind farms are playing an important role as Europe transitions to renewable energy. The European offshore wind market will reach an expected annual capacity of ≈14 GW by 2030, and will require an expansion of the fleet of Service Operation Vessels (SOVs) to maintain them.[1] SOVs function as workshops, spare part delivery services, and floating hotels for workers.[2,3] Current SOVs are powered by diesel fuel, diminishing the benefits of renewable wind energy.[4]

Battery or fuel cell powered SOVs that can charge while docking at the wind farm will provide a partial solution.[2,5,6] Here, the concept of “cold ironing,” in which a docked ship is plugged into an onshore power source, could be adapted to electric vessels servicing wind farms. This adaptation is forecasted to reduce fuel costs by 20%, and emissions by 30%.[1,3,7] Furthermore, wind farm owners will benefit from selling electricity to the SOVs, and energy companies would benefit from smoothing out the volatility of electricity production and storage created by wind speed variability.[8]

Ongoing challenges to offshore “cold ironing” include the cost of equipment, such as transformers and modifications to energy storage systems, and the increased risks to human safety.[7]

4.1 RESULTS

4.1.1. FORECAST TO IMPLEMENTATION

According to the media answer by respondents, recharging at wind farms 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", only one (1) out of the 24 respondents selected this option, amounting to approximately 4%, implying that for the overwhelming majority of respondents, it is more a case of *when* recharging at wind farms will occur, rather than a question of *if* it will happen.

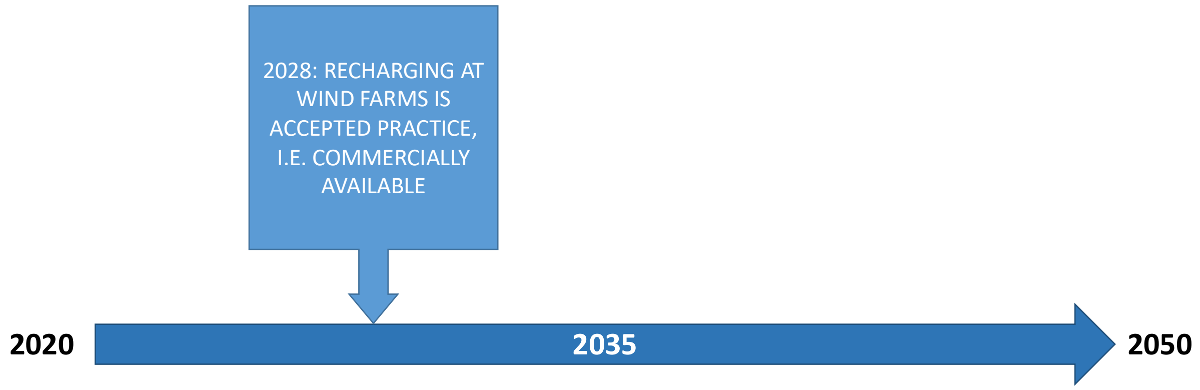

Figure 3: Media estimate for recharging at wind farms

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. Further-more, some comments were split to categorize them accordingly to their parts. These appear in no particular order.

POLITICAL
• I'm not sure the technology already exists to manage this, but definitely something that should be made a priority for any new wind farms, maybe this also needs help with legislation to begin implementing this, so it is available for SOVs in the future. I think the electricity they would receive from the wind farm should be subsidised by the government to allow it to be even cheaper than original diesel costs. • International standards for connectors and cables and uniform ship voltage and frequency. • Investment from governments is needed. • Support from government and tier one companies is needed.
ECONOMIC
• Just investment it seems really - it sounds like a win-win option; cutting costs in the long term. • A reduction in cost compared to using diesel is needed. • Resources, perhaps through sponsorship or funding. • It sounds like this is all viable, it is just a matter of reducing the costs. • Reduced cost of equipment. • I think in the faraway future this is possible. An increased demand in wind energy technology will decrease the costs of course. • Investment to offset the detriments of cost of equipment, such as transformers and modifications to energy storage systems. • To make this happen an incentive need to be in place so that the forecasted reduction in fuel costs and emissions are not just perceived as morally good but also a financially sound investment. • The demand is a factor, if a wind turbine needs servicing once every six months for example, the investment to get the functionality may never be regained before the equipment wears out. This requires replacement especially when this technology may be going onto every offshore wind turbine. Perhaps a fewer number, say one in 4 offshore wind turbines are fitted with the functionality to charge an SOV, that may then be more financially viable. • Proven cost effectiveness. • Cost-effective ways of equipping wind farms and vessels with the capability to deliver/receive energy offshore. • Whilst it sounds like a great improvement from what is currently in place, as a business opportunity it will not be successful as it is too expensive. • The initial costs may have to come down, which they generally do with an increased market. • Funding for the project.

SOCIAL
• A logistical way of charging the vessels which doesn't pose a threat to anyone's safety on the boat. • A good risk analysis is needed. • The health and safety aspect of having personnel on board a charging ship needs to be considered. • Reduce the risks to human safety by using technology to make the repairs, etc. • A greater time period to build solutions and health & safety procedures to deal with the increased risks to human safety. • Awareness is needed.
TECHNOLOGICAL
• The technology needs to be developed to put on the ships to allow them to dock at wind farms to recharge. The power is already there just need to transfer it to the service vehicles. • Using H2 might be a realistic option but electric battery driven vessels are not. The recharging takes much too long, much better would be H2 or another synthetic fuel. • Developed infrastructure. • Adequate infrastructure. • New build CTV designs with battery or fuel cells designed in. • Retro fitting of batteries or fuel cells in existing CTVs. • Adaption of existing monopiles / power export to accommodate plug-ins. • Skua Marine and partners are developing a combined electrical and mooring connection system for wave energy convertors. This would allow quick and safe connection and disconnection of the CTV to the monopile in marginal weather conditions. This would contribute to the cost effectiveness, business case and safety standards required to make this solution feasible. • Improvements in the technology to ensure the safety of persons using the equipment.
ENVIRONMENTAL
• Cutting emissions at a time when it is high on everyone's agenda. • The environmental aspect which is more important can make this happen.

The distribution of comments among the 5 categories in the PESTE analysis is depicted in Figure 4 below. This shows that only 6% of the comments can be attributed to environmental factors, 11% political, 17% social, 26% technological and 40% are concerning economic factors, making this the most attributed category.

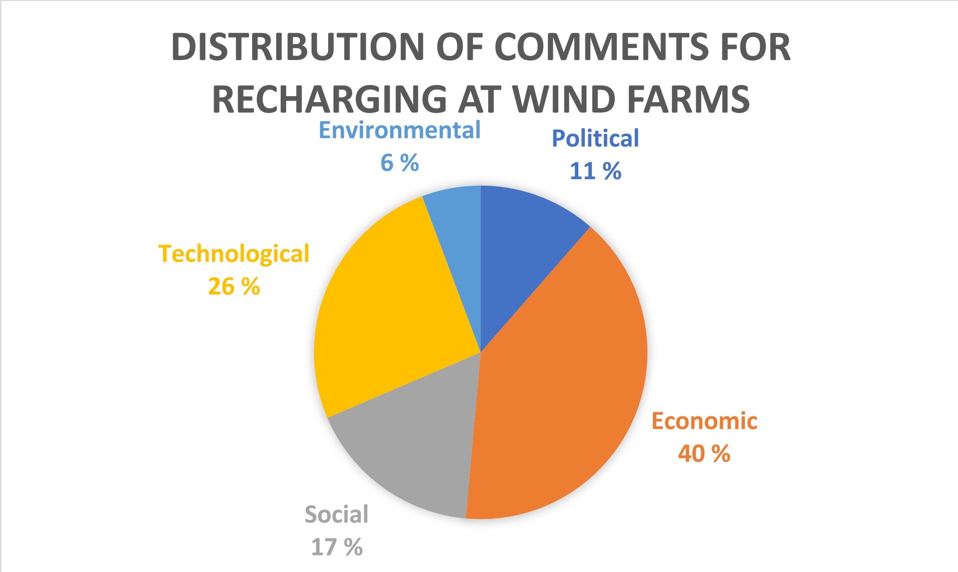

Figure 4: Respondents' comments to recharging wind farms, categorized

4.1.3 BUSINESS POTENTIAL

On the question of the business potential of recharging at wind farms, respondents, on average, rated it 3.77/5.

4.1.4 ANALYSIS

The respondents to this survey opine that economic factors are the most important ones in the way for this opportunity to become a reality. Respondents point to the decreasing costs of electricity production and the equipment needed for creating the electrical infrastructure as important to establish the business case. Criticisms over the flexibility of the energy supply – that the "demand is a factor, if a wind turbine needs servicing once every six months for example, the investment to get the functionality may never be regained before the equipment wears out." Providing the infrastructure with a mobility radius would make installations more accessible to SOVs.

In terms of the opportunity in question, reponses indicate that this may be a case of "just do it" by installing the infrastructure to enable it. However, as one respondent put it, "international standards for connectors and cables and uniform ship voltage and frequency" are needed in order to facilitate the uptake and wider dissemination of the practice. While one use case demonstration would validate the technology, wider industrial dialogue is needed to bring this into common practice..

Yet some respondents suggested alternative solutions to "plugging-in" at windmill monopiles. Swapping hydrogen tanks provides a potential advantage in the time it would take to complete the recharging, as recharging takes "much too long." This would require the installation of an electrolyzer. Another alternative suggested was the co-location of a wave energy converter to be used as a vessel battery charger.

Finally, the comments pertaining to environmental factors demonstrate the apparent urgency of the electrification agenda. The opportunity window to create the political awareness and willingness is open, but may not stay that way.

4.2 REFERENCES TO STUDY B

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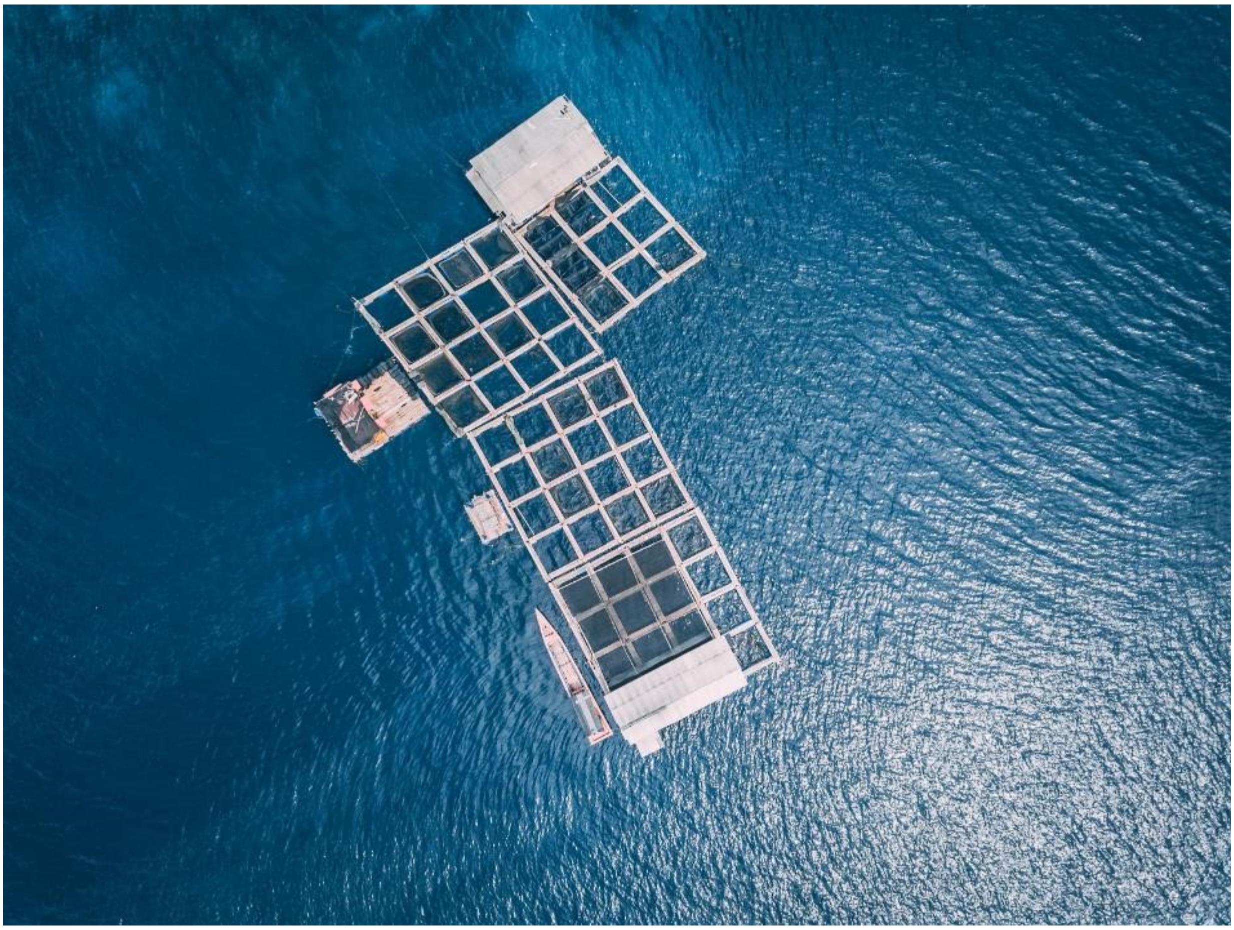
5. STUDY C: FULLY ELECTRIC FISH FARMS

The aquaculture industry currently produces approximately half of the fish for global consumption, and this is expected to reach two-thirds by 2030.[1,2] Given the trends in fish farming, one can anticipate bigger farm facilities that will be located further out to sea. This makes it increasingly infeasible to connect them to onshore electric grids.[3,4]

A typical salmon farm uses about 342 kWh/day and emits 120,000 kg of CO_2 per year.[3,4] Common practice sees offshore fish farms being powered by diesel generators, but recent installations are starting to integrate hybrid power systems that incorporate renewable energy.[3]

Hybrid systems can reduce costs by 16% and emissions by 50%.[3] Fully electric fish farms, powered by wave energy, might not only produce sufficient energy to power their operations, but even excess energy to power the electric vessels that make the voyage to maintain, stock, and extract fish from the farm.[4,5]



5.1 RESULTS

5.1.1. FORECAST TO IMPLEMENTATION

According to the media answer by respondents, fully electric fish farms will become an accepted practice (i.e. commercially available) by 2030 (see Figure 5).

When asked for the time to accepted practice, the respondents had the option to choose “will never happen”, three out of the 21 respondents selected this option, amounting to approximately 14%.

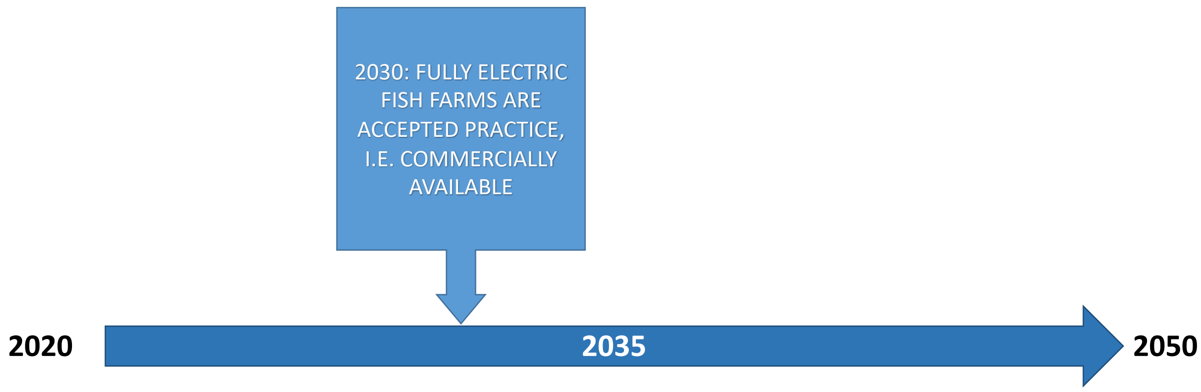


Figure 5: Median estimate for fully electric fish farms

5.1.2 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 4 categories, representing a Political, Economic, Social, and Technological (PEST) analysis. The text in the table are the responses. In some cases, spelling, grammatical improvements, 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
• It is not legal. • Governing bodies need to implement new rules. • Government regulation is needed. • Industry regulation for sustainability is needed.

• Legislation for this type of fish farming is needed.
ECONOMIC
• Companies need to make changes and invest in the technology. • Investment is needed. • The cost and efficiency need to be better than current traditional methods of fish farming. As renewable technology becomes more accepted and cheaper and the infrastructure and knowledge is there, there won't be many barriers in the way of making this opportunity happen. • Economics to be right for industry to invest. • Sufficient long-term demand for product is needed. • The rate determining steps here are the value of the product we are farming, the cost of installation and the capacity of the cells to generate enough power. Provided the latter is proven then it just comes down to a commercial decision based on the value of the farmed product. • I guess nothing is needed except money. Although, it would be beneficial if the farms are powered by wave energy so it could produce enough energy to be able to maintain itself. So money, money, money is needed only. • Bigger farm facilities and capital. • Any offshore wave energy device will be highly uneconomical because of maintenance, installation, mooring etc. I cannot envisage fish farms to be.
SOCIAL
• Collaboration between the energy companies and the aquaculture industry.
TECHNOLOGICAL
• Technology is needed. • Using the waves and motion of the sea it must be viable to harness this and use it to generate the power needed. • Hybrid power systems are needed. • They need to locate a bigger fish farm further out to sea. More planning/research is needed in order for this to happen. • Research into this type of fish farming is needed. • Seems like the technology is there, so really it just needs the installation. • Diesel generators need to be stored. • The technology is ready I guess • Hybrid systems are needed which could be powered by waves. • More research and test in wave energy technology, and better public funding. • Located in areas of high wave energy density. • A tonne of research into fish stocks.

ENVIRONMENTAL
• It is not environmentally friendly. • Worried about overfishing.

The distribution of comments among the 5 categories in the PESTE analysis is depicted in Figure 6 below. This shows that only 3% of the comments can be attributed to social factors, 7% to environmental factors, 17% to political factors, 33% to economic factors, and 40% to technological factors, making the latter the most attributed category.

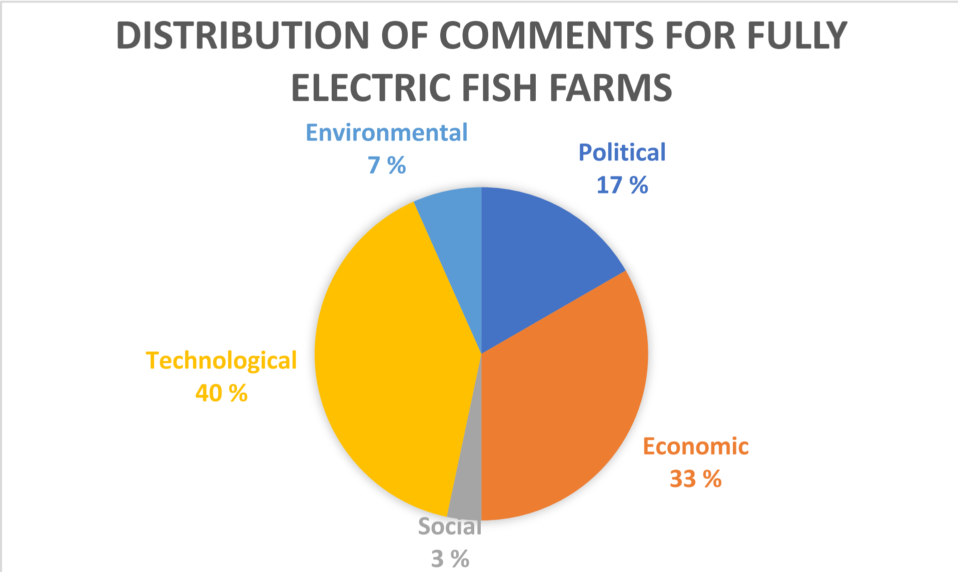


Figure 6: Respondents' comments to fully electric fish farms

5.1.3. BUSINESS POTENTIAL

On the question of the business potential of fully electric fish farms, respondents rated it, on average, 3.43/5.

5.1.4 ANALYSIS

Technological issues occupied the imagination of most respondents. As wave energy was explicitly identified as the energy source, responses indicate that these systems require investment and implementation and adaptation to purpose in order to make it "viable."

Responses pertaining to business economics were the second largest category after technology. Many of the offshore fish farms can be considered simple cages. The electricity requirements can be quite small – for example for the operation of cameras conducting surveillance by taking intermittent photos and transmitting these. In order to improve the business case, "bigger farm facilities" may need to emerge "further out to sea", along with tasks that require more energy, like automated feeding and cleaning systems.

Environmental concerns over fish farming's future is found in the tension between the demand for fish that leads one respondent to be "worried about overfishing" while another is concerned with the reputation of fish farms as "not environmentally friendly." While a renewable and sustainable energy component may enhance the industry's profile that is characterized in "current traditional methods," public concern over the health and lives of the fish will likely remain. With the ongoing challenges to the survivability rate of the fish, one respondent expects a solution to come from the fish themselves, calling for "a tonne of research into fish stocks."

5.2 REFERENCES TO STUDY C

[1] Worldfishing & Aquaculture (2014), Fish farming is still the future
[2] GoodFishBadFish (2020), An Introduction to Open-Pen Sea Cage Aquaculture
[3] University of Stavanger (2017), How to make the fish farming industry more climate friendly
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[5] Eba Gr. (2017), World's First Electric Aquaculture Support Vessel

6. STUDY D: RENEWABLE METHANOL VESSELS

Ambitions for zero emission maritime operations by 2030 require new power sources. Renewable methanol is produced from an electrolysis process, powered from a renewable energy source. The process combines hydrogen with CO2 captured from the air or the emissions from an industry, making it carbon neutral.[1]

Liquid methanol needs neither compression nor cooling, making it easy to handle and cheap to transport. Infrastructure at many important ports has already been established, but it will need retrofitting for refuelling ships.[1,2] Furthermore, although some gas carrying ships and ferries are using non-renewable methanol for a fuel source, large ocean-going ships will need to be built or converted for liquid methanol and the fuel will need to be sourced sustainably.[1]

The amount of renewable methanol needed to power large ocean going vessels would require a scale of production of great magnitude. Electrical grid power is too expensive to produce metha-nol.[3] Solutions could be to locate production alongside nuclear power plants or dedicated wind, solar, or tidal energy farms.

6.1 RESULTS

6.1.1 FORECAST TO IMPLEMENTATION

According to the media answer by respondents, renewable methanol vessels will become an accepted practice in 10 years (see Figure 7).

When asked for the time to accepted practice, the respondents had to option to choose “will never happen”, only one (1) of the 25 respondents selected this option, amounting to 4%, indicating that it is, for the overwhelming majority of participants, more likely a question of *when* renewable methanol vessels will become an accepted practice rather than a question of *if* it will happen.

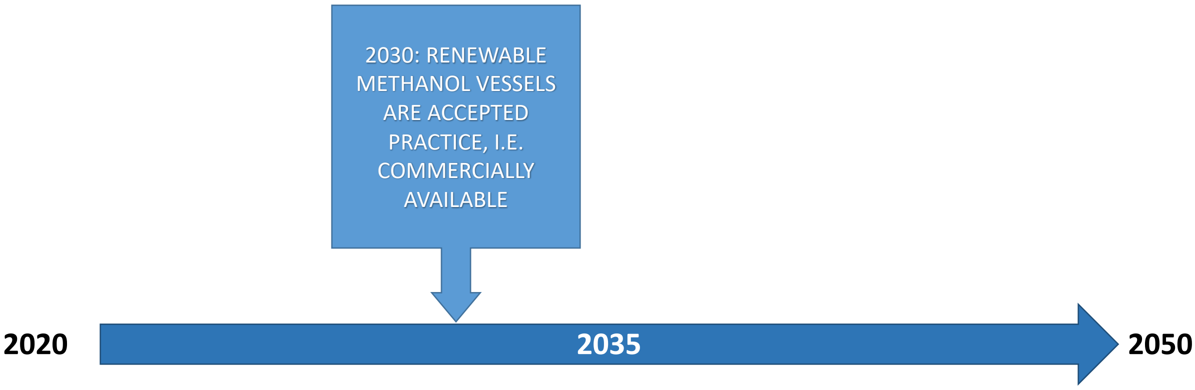

Figure 7: Median estimate for renewable methanol vessels

6.1.2 WHAT IS NEEDED TO MAKE THIS 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
• Primarily regulation of the use of bunker fuel, taxes on emissions. • Governing bodies need to implement new rules. • Legislation that enables the production of liquid methanol on a larger scale that would bring the costs of the fuel down but also make it more widely available for ships/ports. • Subsidised fuel for ships using this system would incentivise its use and that might even help with retrofitting infrastructure for refuelling as its use become more popular.

• Support and subsidiaries from government to make these changes are needed. • More open-minded leaders in politics. • It needs to become a standard in the industry.
ECONOMIC
• Efficiency is still a bottleneck given that ocean vessels burn massive fuel to satisfy their loads while Methanol is a light fuel making thus larger volume will be needed. • Infrastructure would need to be put in place which will probably have a high upfront cost, but that will pave the way for cheaper production and usage, and therefore more people will adopt it. • Companies need to make changes and invest in the technology. • It needs to have both a lower cost and an easier process on how to make it. • I think it is too costly - requires too large-scale production and retro fitting etc. • This technology is innovative - it is taking a 'waste' product so to speak and utilising if for benefit - unlike the other 'opportunities' that are not necessary except for cutting cost under the guise of 'effectiveness'. This won't happen for a while because it is not as profit driven. • Further funding. • As these are still quite contentious and very expensive to research / build. • Renewables need to become cheaper, liquid methanol adds and extra step to an already expensive fuel source. • This seems that it would be very expensive to produce which would be a major barrier in this going ahead. I think other renewable sources will be looked at ahead of this just down to cost. • Cheaper power around the world to produce methanol in large scale. • It needs to become cheaper than heavy fuel oil for companies to be convinced to switch over. • Changing ships is expensive and I don't think shippers want to take risks in these times. • It needs to be cheaper than the alternative and available at enough ports to be reliable. • Price of oil needs to increase, and unit price of renewable methanol needs to decrease. • It needs to become a more efficient and more economical option than the other alternative marine fuels. • Find an economical way to convert existing engines to run on it. • Find an economical way to convert existing bunker infrastructure to deliver it. • Maybe ports could also be helped to link up to their own renewable energy source. • The primary obstacle is to make the fuels competitive.
SOCIAL
• Cooperation from all parties involved. There are a few hurdles that need to be overcome, from agreeing to adopt it and then going forward with it. • They need a place and idea of whole plan to make this with safety obvious.

• People need to recognise the importance of renewable energy. The way we are doing now, we have done years and years. So, it is a bit difficult to persuade people to start doing different and to actually believe in a better solution. However, I think with the RPS (renewable portfolio standard) it becomes more and more known and normal to start thinking about sustainable alternatives. I see it happen already in Europe and more and more in America and Asia. It is a development already starting. • Prove that it's safer.
TECHNOLOGICAL
• The storage technology for methanol in sea environment is rather complicated. • Research. • Electrical power. • Locate the production next to nuclear stations and wind solar or wave farms. • They need to set up facilities to mass produce enough renewable methanol in order to power the ships. • Implementation of alternative fuels in dual fuel combustion solutions offer a market for most liquid fuel types, not just methanol. Also gaseous fuels, which can be in liquid state under pressure, such as LPG, ammonia and others. • Technically, conversion of engines is possible for dual fuel combustion. Technology ready for some engines, more will follow.
ENVIRONMENTAL
• The replacement of bunker fuels offer very obvious advantages in term of reductions in external costs, environmental considerations. • Prove that production and transport on an industrial scale doesn't create other environmental problems. • Even though it is already in use to some extent, to become accepted practice, it must become renewable, if we're looking at making it happen alongside nuclear / energy farms, there is still some way to go.

The distribution of comments among the 5 categories in the PESTE analysis is depicted in Figure 8 below. This shows that only 7% of the comments can be attributed to environmental factors, 10% to social, 17 to technological and political factors respectively, and 49% to economic factors, making the latter the most attributed category.

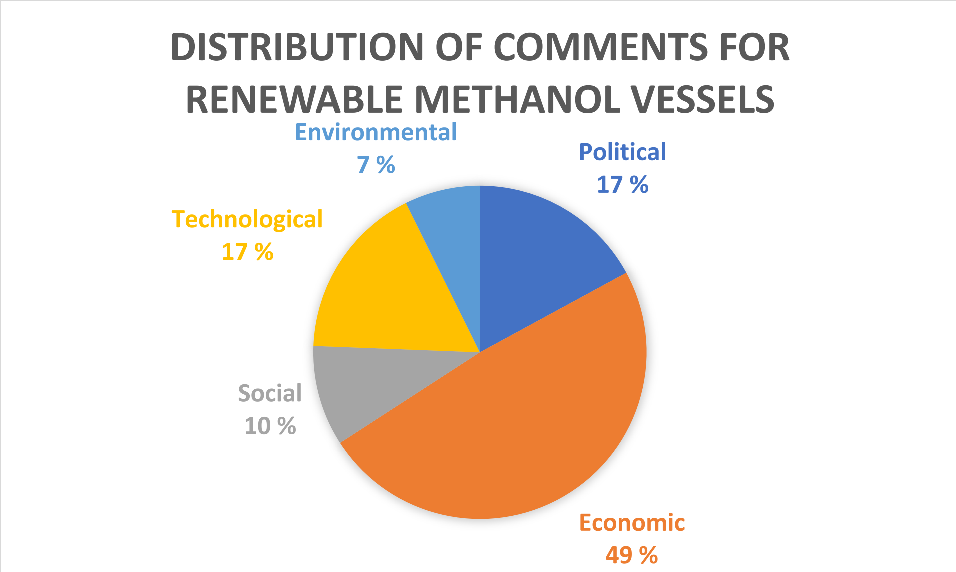

Figure 8: Respondents' comments to renewable methanol vessels

6.1.3 BUSINESS POTENTIAL

On the question of the business potential of renewable methanol vessels, respondents, on average, rated it 3.52/5.

6.1.4 ANALYSIS

Respondents identified economic factors as the most important to realize this opportunity.

A core concern is that the technology is not yet mature enough "to make the fuels competitive" with diesel. Methanol production "needs to have both a lower cost and an easier process on how to make it," in order to close this gap. Beyond the fuel itself, there are issues regarding the "infrastructure [that] would need to be put in place" face challenges since, as another respondent claims, "the storage technology for methanol in sea environment is rather complicated" and tests need to "prove that it's safer."

Respondents identify that the implementation of this opportunity will have a "high upfront cost" and call for "further funding," "support and subsidies," and "rules" from government. Ideas on instruments for the policy mix include "subsidized fuel for ships" and financial "help with retrofitting infrastructure for refueling" and funding for research.

Some, however, question methanol as the proper fuel for the job, and suggest that the "implementation of alternative fuels in dual fuel combustion solutions offer a market for most liquid fuels types, not just methanol." Other synthetic fuels are also currently under consideration, but this prompt specifically focused on methanol.

Among social factors there is a than the alternative, while another state that "people need to recognize the importance of renewable energy. The way we are doing now, we have done years and years. So, it is a bit difficult to persuade people to start doing different and to actually believe in a better solution. However, I think with the RPS (renewable portfolio standard) it becomes more and more known and normal to start thinking about sustainable alternatives. I see it happen already in Europe and more and more in America and Asia. It is a development already starting." So, the opportunity is challenged by the current attitude among people, but this is supposedly changing according to the environmental factors, "The replacement of bunker fuels offer very obvious advantages in term of reductions in external costs, environmental considerations."

Finally, "the price of oil needs to increase, and the unit price of renewable needs to decrease" and there are deeper cultural issues related to the risk appetite of the industry, in that "changing ships is expensive and I don't think shippers want to take risks in these times."

6.2 REFERENCES TO STUDY D

[1] Hobson, C., & Márquez, C. (2018). Renewable Methanol Report.
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[3] Matzer, M., Alhajji, M., Demirel, Y. (2015), Chemical storage of wind energy by renewable methanol production : Feasibility analysis using a multi-criteria decision matrix

7. CROSS-CASE COMPARISON

The data received for each of the surveys was aggregated and analyzed to find the median, the mean, and the standard deviation of the estimates of when the respective opportunities will become and accepted practice. This analysis is represented in table 1 below, which shows the number of respondents, the median, i.e. the value separating the lower and upper half of the data samples, the mean, the standard deviation of the distribution, and the percentage of respondents who answered that the opportunity will never happen. The option, "will never happen", was added to ensure the respondents were able to answer the closed question in agreement to their actual beliefs. The median, rather than the mean, is more valid in forecasting as it prevents the forecast from being skewed by outliers.

	Respondents	Median	Mean	Standard Deviation	Will never happen
Study A	29	15	14,52	9,81	10,34%
Study B	23	8	8,61	4,30	4,35%
Study C	20	10	10,33	6,02	15,00%
Study D	22	10	12,64	6,02	4,00%

8. BUSINESS OPPORTUNITY

This rapid growth in renewable ocean energy generation and the decrease in the costs of its generation are driving the transition towards a sustainable ocean economy. Offshore energy hubs can be viewed through a number of different lenses. Large scale ”hub and spoke” concepts, where wind farms connect to one or several hub islands via alternating current cables, currently dominate North Sea actors' imagination. [1] But questions remain on how these can go beyond electricity generation and distribution in order to contribute to the electrification of the seas. In this report, we focused on a series of configurations and auxiliary services that can be considered alongside and beyond renewable energy generation.

To some extent many of these opportunities can be seen as ”chicken and egg” problems, i.e. should the service come before the users, i.e. supply driven, or should the demand be in place before the supply is made available, i.e. demand driven. This is a classic problem in many technology areas. It is unlikely that any commercial windfarm operator will create the necessary infrastructure without having some (high) degree of confidence that there is a market. Similar to what we have observed with the diffusion of cars using hydrogen as the fuel: The fueling stations will not invest in the necessary equipment to make hydrogen as long as they are not sure that there is a demand. The potential users of hydrogen cars will not buy these unless they are sure that they can actually get fuel when they need it. This is part of the reason while hydrogen cars has so far not been particularly successful.

It is clear that given the drive towards major reduction in emission e.g. the Paris agreement [2] and the EU's goal [3] the solutions discussed here are relevant in trying to reach these environmental goals. While these technologies are still under development we might expect that they will receive more attention and funding from both the EU research frameworks as well as national level support in the future.

TIDE-POWERED HYDROGEN VESSELS

Of all the technologies discussed in this report this opportunity is estimated to be the furthest in the future. The tidal energy sector is still in an emergent phase of development, and has not yet reached a commercial scale. There are test plants which have generated 3GWH over a one year period in Orkney [4], but there is still no clear path to determine which technology will be the most appropriate. The Carbon Trust has estimated that tidal energy has the potential to cover 20% of the UK electricity demands [4], indicating that the technology might have a large potential.

One of the major advantages of tidal energy is its predictability, i.e. it relays on the gravitational pull of the moon on the seas of the world. In contrast to the most common renewable energy sources today wind and photovoltaic which has the disadvantage of being intermittent source, i.e. they do not produce a constant predictable volume of electricity, as it depends on change in the weather conditions [5]. A problem that can only be solved in the moment where there is commercial economic solutions to store electricity or transform it to another media, i.e. Power to X.

Tidal energy furthermore requires a physical location that has strong tidal currents (at least this is the thinking is in the moment): There needs to be sufficient difference in the tide to be able to generate electricity on a sufficient scale [4]. Given this, it will not be ideal in many places.

While the commercial solution is still somewhere in the future, this is a potential area where the EU and the national funding bodies might be able to help create an ecosystem and actors from Universities, commercial actors, and research organizations to accelerate the development.

The second issue in this opportunity is what the future fuel of ships will be. Currently there are large research programs trying to establish alternative fuels and it is far from certain that hydrogen might be the preferred fuel, alternatives could be bio-methane, ammonia, ethanol, etc. [6]. It is not clear if there will be an agreement of which fuel will become the standard fuel, or even if there will ever be one. However, there will potential be infrastructure inadequacies—at least in the short run-- if there are too many different fuel used simultaneously. Secondly, it is likely that shipowners will be cautions as any transition from fossil to new fuels will be costly, and it might not be feasible or possible in some ships.

It is too early to say how big the potential is; but it is likely to eventually be required by regulation, e.g. at EU or national level as a prerequisite for being able to dock at the ports in e.g. the North Sea area.

RECHARGING AT WIND FARMS

This is an opportunity which is already technologically possible, but neither the necessary infrastructure nor the ships with electric engines are adapting. However, there is some potential benefit from offshore windmills parks growth projections, which are set to expand rapidly over the next decade [7].

While the growth in offshore windfarms is due to the policies of reducing emission [2,3] it would be beneficial to think one step broader, and include the maintenance of these off-shore windfarms as part of the attempt to reduce emissions. This could be done as part of the bidding for the construction and operation of the windfarms. This way they would become truly green. The additional cost would be relatively small, particularly as the design and production of support ships would gain some economies of scale.

There are already fully operational ferries running on electricity [8], so it should be feasible to do the same as the support vessels, like a ferry, which have a limited or specified operation radius or route.

FULLY ELECTRIC FISH FARMS

With 15% of respondents claiming that "this will never happen," this opportunity is seemingly the least plausible. On the other hand, there is a forecasted growth in fish farms globally, e.g. the world now produces more seafood from aquaculture than the wild fish catch [9]. With the growing focus on the environment sustainability, particularly beef, the demand for seafood is likely to continue to grow. [10]

There are large aquaculture players in the North Sea region e.g. Norway [11]. It is likely that fish farms will move further from the land, which would not only allow for bigger farms, but also to mitigate some of the other factors as the farms get bigger, i.e. it is necessary have sufficient water circulation.

Fish farms have traditionally used fossil fuel to generate the necessary electricity if they were not close enough to have a connection to land. However there has been a number of experiments with integrating renewable into the system as mentioned earlier [12, 13]. Using a hybrid of renewable and fossil fuel, cost and emission reduction have been demonstrated. However, the intermittency of conventional renewable energy systems, and the not-yet-existing possibility to store electricity in commercially viable ways, remain as barriers for making fish farms fully renewable with conventional renewable sources.

This problem can be solved in at least two ways, a stable renewable energy source or a commercial way to store electricity. Wave energy has identified as a potential source of energy, as it, like tidal energy, is relatively stable. The problem is that this is not yet at a stage in the development where it can be adopted, and again like tidal energy, there are a number of experiments with it but not yet any clear design that can be effectively scaled to the requirements of a fish farm [4] However, even if there was, it is not likely that fish farms are able to use it, as they are normally not located in areas with large waves because these waves can make the fish sick. The other alternative, the possibility of storing electricity, is a more likely solution. Energy storage is an area that is currently attracting significant attention and is expected to create increasingly efficient and cost effective solutions, although it is too early to say when and if these solutions will be possible for the isolated fish farm.

RENEWABLE METHANOL VESSELS

Ocean going vessels are one of the largest contributors to Green House Gas (GHG) emissions. The maritime industry has been characterizes as a traditional one which is slow to incorporate new technologies. Thus, the IMO and other regulatory agencies have been instrumental in incentivizing shipowners to adopt technologies and practices with environmental protection in mind.

As convincing as the case against carbon has been over the recent decades, it still has not been persuasive enough to initiate much of a transition of the existing fleet to low or zero emission shipping. The Heavy Fuel Oil that powers the propulsion of the large ocean-going vessels is inexpensive, and is still available without any tax to price in the negative externalities given that these ships sail most of the time out of the jurisdiction of any government.

This situation is once again an example of the chicken and egg issue, as independent shipowners do not want to overhaul and retrofit their ships before the refueling infrastructure and fuel is available, and the ports and producers will not change to methanol from conventional fuels until the demand is there. Such is the case for regulations make the market through policies that increasingly incentivize shipowners to transition.

It could be that large and influential players can push this transition. For example, Mærsk's new-Center for Zero Carbon Shipping is making significant investments into a set of alternative and synthetic fuels that show potential for use by large vessels. Breakthroughs are needed to mature these technologies, for example, the energy density of methanol is only 49% compared with gasoline, i.e. 1 gallon of methanol has 49% of the energy of one gallon of gasoline.[14] Likewise, improvements are needed across the value chain: In the conversion efficiency, scaling and mass production, safe storage at ports and on ships, refuelling equipment, reconversion efficiency back to electricity, propulsion systems, etc. These issues are often specific and complex for each fuel in question.

The challenges and required investments are significant, but the market potential for such fuels would be enormous as would be the progress towards a more sustainable planet.

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9. CONCLUSION

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 of offshore energy hubs provides an opportunity to support the accomplishment of these goals.

This rapid growth in renewable ocean energy generation and the decrease in the costs of its generation are driving this transition. Large scale ”hub and spoke” concepts, where wind farms connect to one or several hub islands via alternating current cables, currently dominate North Sea actors' imagination. But questions remain on how these can go beyond electricity generation and distribution in order to contribute to the electrification of the seas.

This report looks at some of the potential drone use case in the future that can help stimulate sustainable economic growth. While initiatives, cases, and projects have begun to emerge, questions of what's next, how, and when further applications of offshore energy hubs remain potential next practices for offshore energy hubs and put them to the and validation. Survey instruments were developed for various use cases that cover new activities to support the electrification of the seas. The use cases ranged from introducing new renewable fuels such as methanol and hydrogen, developing multi-use platforms such as charging at wind farms and incorporating electrification into existing industries such as fish farming, and the production of synthetic fuels. While none of these individually can be considered an "offshore energy hub" in itself, they contribute with descriptions of different capabilities that could be implemented at said hubs.

We report on these opportunities to decision processes in enterprises and policy making bodies. The crowd-based assessments forecast tide-powered hydrogen vessels to become accepted practice in 15 years, recharging SOVs at wind turbines in 8 years, fully electric fish farms to emerge in 10 years, and methanol-powered vessels on the sea in 10 years. We furthermore make an analysis of each of these and discuss the opportunities in connection with developing offshore energy hubs.

10. RESPONDENTS

Respondents identified as acting on this opportunity include:

Aarhus University
Central Denmark EU Office
Danske Maritime
DanWEC
Denmark's Technological Insitute
ForWind / University Oldenburg
KF Energieberatung
Skua Marine Ltd
University of Exeter
University of Melbourne

Periscope Network

periscope-network.eu