DEEP DIVE METHODOLOGY

Dear reader,

This report provides an initial overview of the deep dive methodology used in PERISCOPE. This report is produced by the PERISCOPE partnership.

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1 INTRODUCTION

The North Sea Region is a great place to live and work. Education levels are high, institutions are stable, businesses are globally competitive, and interregional collaborations are continually being established to drive innovation. But the region's stability and long-term prosperity depends on finding ways to stimulate sustainable economic growth.

The NSR will undergo transformation and restructuring in the forthcoming decades. The NSR is a crucial area for Europe's Blue Economy with its long history in maritime and offshore, its extensive marine resources, technologically advanced industries, and ever-expanding port infrastructure. However, maritime, marine, and offshore economies are exposed to profound challenges with traditional industries and sectors undergoing significant changes, and new ones emerging.

PERISCOPE is an initiative of the EU Interreg North Sea program, working to use the tools and methods of strategic foresight to catalyse entrepreneurial discovery and promote transregional partnerships that unlock Blue Growth. The project has identified a number of emerging market opportunities and latent markets that are expected to be unlocked by advancements in technological capabilities. The project has the mandate to try to accelerate the development towards the realisation of the opportunities.

The business ideas that the PERISCOPE partnership has collected has generated a vast portfolio of opportunities. Based on assessments by actors in the North Sea Region, some of these have been selected out for further research and investigation. These focus areas are known as deep dives. This paper outlines the methods that are deployed in the development of the deep dives.

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2 PERISCOPE DEEP-DIVE METHODOLOGY IN CONTEXT

PERISCOPE aims to support Interreg North Sea's objectives, first and foremost "Thinking growth" by strengthening cross-sector Blue Growth innovation capacity in the NSR by bringing together the players (businesses, entrepreneurs, clusters/networks, researchers, universities, business angels, incubators, investors and funds, customers/users, regional and local authorities and development/business support agencies) for knowledge sharing, acceleration and launch of new innovation-projects for sustainable business development.

Samenwerkingsverband Noord Nederland (SNN)	4strat GMBH	European Marine Energy Centre (EMEC)
Nederland Maritiem Land (NML)	Global Center of Expertise NODE	Hanze University of Applied Sciences Groningen (HU)
Aarhus University	RISE – The Swedish Research Institute	Offshore Energy Denmark (OEDK)
Business Region Gothenburg (BRG)	Center of Maritime Technologies e.V. (CMT)	South Norway European Office Ltd

Increased collaboration on markets and technologies, and the path into future markets, will help businesses realign from mature and declining markets towards attractive new market segments. Facilitating formation of transregional and cross-sector partnerships to pursue opportunities, has brought together a number of key stakeholders that represent regional capabilities in order to share methods for enhancing future preparedness of NSR actors, especially among the maritime and marine clusters and the firms that constitute their members.

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The PERISCOPE vision is to *establish a permanent strategic foresight platform at the core of the maritime and marine business ecosystem that provides a new way of working for bottom-up knowledge exchange*. This vision delivers an invitation for finance to invest in the future from both the public and private sector. The vision allows for public sector development offices to enhance smart specialization strategies and support businesses and knowledge institutions to take advantage of the opportunities and growth potential identified within the ecosystem. SMEs benefit by gaining access to strategic know-how, resources and new cross- border knowledge partnerships, which may lead to new markets unfolding. Large actors benefit from the harmonization of expectations for the development of the industry and the identification of new actors and competencies from across the region.

The long-term objective of PERISCOPE is to establish itself as the leading Blue Growth ecosystem spurring innovations contributing to the priorities of the Interreg North Sea programme. To accomplish this:

- PERISCOPE will establish an entrepreneurial discovery process to reinforce the knowledge base, identify and valorize innovation ideas, and open up a Blue Growth ecosystem to stimulate industry-driven action on the concrete opportunities ahead.
- PERISCOPE will bring together fragmented and specialized knowledge in a novel entrepreneurial discovery process that will trigger innovations and sustainable business development.
- PERISCOPE will enhance the capacity of 300+ NSR actors within the blue economy, kick start 10+ Blue Growth innovation partnerships within the NSR, accelerate at least two major cross-border innovation projects, and increase understanding of innovation support and conditions for blue business development in the NSR.
- PERISCOPE will link the six NSR countries, also improve trans-regional innovation capacity by working with the public sector and enhanced smart specialization will follow as a consequence of the ecosystem's dialogue platform.
- PERISCOPE will create closer transnational cooperation within the project will lead to better synergies in reaping emerging Blue Growth opportunities, utilizing funds and infrastructures, and creating a platform for sustainable joint innovation actions and investment

	REGIONAL PARTNERS	NETWORK ORGANIZATIONS	CENTRAL TEAM
TREND SCAN	Participate in scanning and assessing on PLATFORM	Run regional TREND JAMS	Build and moderate on PLTAFORM Provide template for WORKSHOPS
OPPORTUNITY SCAN	Submits and votes on ideas on PLATFORM	Run regional IDEA JAMS	
SCENARIO ANALYSIS	Delegates EXPERTS	Supports recruiting of EXPERTS	Run SCENARIO ANALYSIS
DEEP DIVES	Delegates EXPERTS	Supports recruiting of EXPERTS	Run DEEP DIVES
PERISCOPE BOARD	Suggest BOARD MEMBERS	Supports recruiting of BOARD MEMBERS	Recruit and work with BOARD MEMBERS

3 METHOD STRUCTURE

The methodology taken up by the PERISCOPE project consists of four steps.

1. Scanning and scouting the changes on the horizon;
2. Crowd-based evaluation of the opportunities;
3. Selecting opportunities for deep dives;
4. Executing the deep dives.

A brief introduction of the first three steps are described below, whereas the 4th step above, the deep dive execution, will be detailed in section 4. An example of a deep dive is then presented on the topic of offshore vessel charging in section 5.

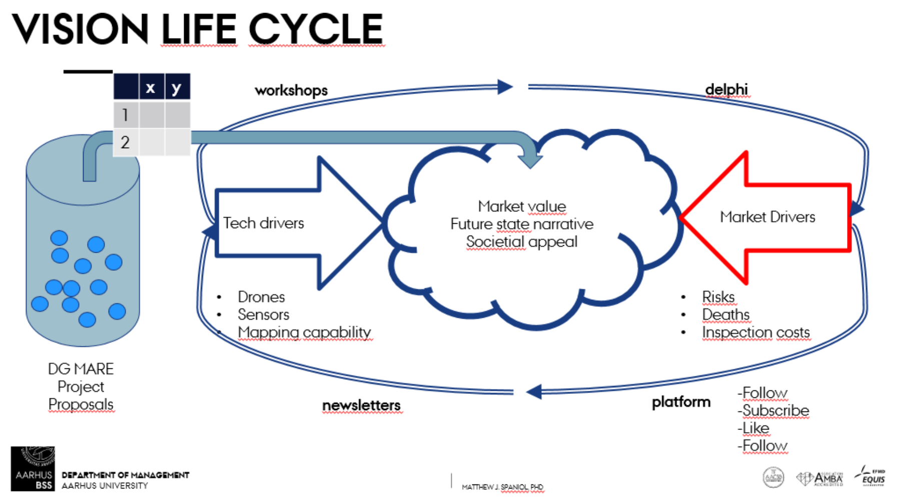
3.1 HORIZON SCANNING AND OPPORTUNITY SCOUTING

Scanning and scouting the horizon for Blue Growth opportunities is undertaken in PERISCOPE by a systematic approach. The premises that serve as a starting point include the notions that maritime and marine industries are difficult areas to innovate in and apply new technologies to because of the harsh conditions of the sea—rough waves, high winds, long distances from shore, the impact of salt on metal, the requirements of capable sailors and appropriate ships and tools, and the lack of infrastructure. Furthermore, special considerations regarding the perceived fragility of the oceans and consumers' motivation to protect and clean up the seas have resulted in the increasingly complex requirements of spatial planning. Likewise, the amount of available space for industrial development on the seas is decreasing, pushing activities further from shore and into deeper waters. This state of affairs have caused a developmental time-lag: The ocean economies are behind compared to on-shore development.

On the other hand, the seas offer unlimited renewable energy. The surplus of wind, wave, and tidal resources can provide sufficient capacity to drive a transition of the electrification of the seas, including the conversion of electricity into renewable fuels, such as hydrogen, ammonia, methanol, and their derivatives. While renewable ocean energy generation systems are a key input for a technology-based system transition, other platforms and infrastructure will drive applications for new solutions. Comprehensive mapping of the sea and seabed, multi-use platforms, and high-speed Internet coverage, will open the space for new developments. These platforms will serve the advancement of applications of robotics and drones, digital services and vessel performance optimization, and improved transparency and oversight of the ocean economy.

PERISCOPE used this understanding of the industry as a building-block framework to search for opportunities. Sources for input included conference presentations, workshops, idea and trend jams, reports by the EU and other experts on the future of the ocean economy, public project descriptions from the DG MARE database, and interviewing industry experts. Opportunities rarely come read-made, but require hypothetical reasoning in order to extrapolate the consequences and applications of emerging technologies into the maritime domain. Here, the tools of strategic foresight are deployed in order to challenge the status quo, help practitioners see beyond the incremental change of the day-to-day, and validate conjecture. This structured reasoning help to match emerging technologies with market applications, leading to the formulation of a research question that asks into the plausibility and potential of opportunities.

The development of discreet descriptions of opportunities that are emerging to challenge the status quo of maritime and marine industries takes time and process, background research, interviews, and iteration, in order to improve descriptions of these future applications.



3.2 CROWD-BASED OPPORTUNITY EVALUATION

Discreet descriptions of emerging technologies and their capabilities allow analysts to evaluate and judge not only their impact on business and development, but also allow for an estimation of when such activities will become accepted practice. These assessments leverage the “wisdom of the crowd” in order to develop a working consensus on expectations for time and impact. These assessments are made and distributed in online surveys.

PERISCOPE sources the informants through the cluster partners who identify those in their extensive network that should have a qualified opinion on the range of different topics. These actors are brought together into virtual discussion over a number of rounds to further develop the descriptions of the discreet opportunities. The evaluation of the business potential of the discreet opportunities gauges the appetite for consortium building. Emerging but latent markets are identified and forecasted and compared against current practices, in order to assess the consortium’s willingness for involvement.

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Furthermore - the logic goes- that once an expected time-to-accepted-practice is identified, these opportunities become more plannable. Technology and new solution roadmaps become easier to develop, and roles that the members of the consortium can take on can be delegates, and the identification of competencies that are still missing in the consortium can be made visible and efforts to plug these holes can be pursued.

3.3 SELECTING OPPORTUNITIES FOR DEEP DIVES

The clusters' and development offices' activities of distributing surveys to their members provides them with insight into their activities and interest areas for development. Reaching out to their members furthermore provides PERISCOPE with an understanding of the topics that regional actors are willing to engage with international partners with. Not all opportunities can be pursued – as is the case in project portfolio management – and so the opportunities are clustered under aggregate themes and rated by the PERISCOPE partners in order to short-list the outputs of the scanning and scouting.

These topics for deep dives selected by regional cluster and business development partners through a rating process where they indicated their preferences across a number of potential areas that could be considered for deep dives. These topics are also considered in line with the strategies of the different EU funding schemes in order to match projects and products to calls for proposals.

OPPORTUNIT	C	ID	Pre-Rank	Priority	Pre-Rank	Priority	Pre-Rank	Priority	Pre-Rank	Priority	Pre-Rank	Priority	Pre-Rank	Priority	Total Pre-Rank
Oil platform decommissioning optimization	O	18	2	7	1		2		1		1	3	2	7	
3D printing for on-site repair and re-design of wind turbine components	O	25	2	13	2		1		1		1	4	2	11	
Offshore vessel charging station	RE	28	1		2		2		1		1	7	2	13	
Autonomous offshore service vessels	AM	64	1		0		2		2		1	1	1		
Underwater Laser Scanner for Hull Corrosion Measurement	MS	3	2	15	1		0		1		1	8	2	15	
Drone & Robotic Maintenance on offshore platforms	MS	4	1		2		1		2		1	6	0		
Tank inspection drones	MS	5	2	8	2		2		1		0		0		
Offshore wind farm repurposing	O	19	2	1	2		2		0		0		1		
Supply drones	AM	59	1		2		0		1		0		2	3	
Modularized shipbuilding	MS	7	2	12	0		2		0		0		2	10	
Lightweight materials for superstructure	O	21	2	10	0		1		1		0		2	12	
Wind farms that move autonomously in the ocean	RE	31	1		0		1		2		0		2	9	
Autonomous barges	AM	62	1		0		2		0		1	2	1		
Next-generation aquaculture	BB	38	0		0		1		2		0		2	8	
lardized data scheme for emissions monitoring, verification, and reporting	MG	72	1		0		1		1		1	13	1		
Robot retrieval and re-utilization of plastic	OM	50	2	3	0		1		0		0		2	1	
100% Renewable energy vessels	VM	55	1		0		2		0		1	11	1		
Fireproof composite hulls	VM	58	2	11	0		2		0		0		1		
Plastic bubble barrier	OM	49	1		0		1		0		0		2	2	
Autonomous port	PO	15	1		0		1		0		0		2	14	
Deep sea mineral mega-mining	SM	48	1		0		1		2		0		0		
Offshore multi-use tourist park, container terminal, and energy hub	X	80	2	2	0		2		0		0		0		
Autonomous harbour bus	AM	63	2	6	0		1		0		0		0		
Open ocean farming	BB	41	0		0		0		2		0		1		
Self-healing hulls and piles	MS	6	2	14	0		1		0		0		0		
Computer-assisted decision verification systems	MS	8	0		1		1		1		0		0		
Internet@Sea	MS	83	0		0		2		1		0		0		
3D imaging of offshore platforms	O	20	2	9	0		0		1		0		0		
Modularized offshore construction and assembly	O	23	1		0		2		0		0		0		

The next section will focus on the deep dive methodology.

4 DEEP DIVE METHODOLOGY

Deep dives are designed to generate future-oriented and prescience knowledge and propositions about emerging business opportunities. Deep dives in the PERISCOPE project, for example, have looked into topics such as offshore vessel charging and drone applications. The core of the process is to widen the application space by mapping the different configurations that future applications could manifest by exploring novel designs and have them appraised by industry stakeholders and

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experts. This section will describe the methodology used in PERISCOPE, including morphological analysis and cross-consistency assessments, the ranking and selection of plausible configurations, their assessment by industry in survey form, and their refinement towards consortium development.

4.1 MORPHOLOGICAL ANALYSIS

General Morphological Analysis (GMA) is a basic modelling method, similar to other scientific modelling methods including Boolean logic, System Dynamics Modelling, Influence Diagrams, and Decision Networks (Ritchey, 2018). GMA is a method for structuring an abstract and complex problem space called a “morphospace” where potential solutions to the problem space are non-quantifiable, non-causal, and synthesized through a process of combinations. The generalized version of GMA was initially developed by the Swiss-American physicist and astronomer Fritz Zwicky (1898–1974) who used it for purposes ranging from astronomy to technological forecasting and social/political problem solving (Johansen, 2018), where causal modelling and simulation do not function well, or at all.

The morphological box describes within itself the morphological field or the problem space of the given problem. Zwicky developed the approach to solve seemingly non-reducible complexity, by using the technique of cross consistency assessment (CCA). The approach allowed for the management of complexity - not by reducing the number of variables involved, but instead by reducing the number of possible solutions through the elimination of the illogical solution combinations in a matrix grid.

The method aims at identifying and structuring all possible aspects and solutions for non-reducible, complex problem spaces which in most cases involve human behaviour and political choice. Morphological modelling is referred to as “totality research” which, in an "unbiased way attempts to derive all the solutions of any given problem" (Ritchey, 2018). It may help us to discover new relationships, configurations or scenarios which may not be so evident and which we might have overlooked by less systematic methods.

The GMA process can be described as a dialectical progression through repeated sequences of analysis and synthesis across five distinct steps (Johansen, 2018). The first step requires an exact as possible formulation of the problem at hand, admitting that a precise description of the problem may be impossible. The second step breaks down a *parameter* set that frames the problem. Each parameter has to be precisely defined and an exhaustive and mutually excluding set of possible shapes, states or *values*, pertaining to each parameter, is then decided.

The third step involves the construction of the morphological box/matrix and contains all solutions related to the problem. A “solution” in this respect denotes a configuration where one value is selected for each parameter. In the example below (see Table 2), the shaded cells represent one such solution. The problem space comprises all solutions that can be constructed on the basis of the parameter set. However, the problem space usually consists of a large amount of “noise” in the form of inconsistent – or impossible – solutions.

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Table 2 - The Zwicky or Morphological boxes will be presented in a matrix grid with the main parameters in the top row and their different values in the columns underneath. A "solution" is represented by the grey shades. The number of combinations is calculated by the multiplication of the the values across the parameter set: 5x5x3x5x4x4 = 6.000 different combinations.

Parameter A	**Parameter B**	**Parameter C**	**Parameter D**	**Parameter E**	**Parameter F**
Value A1	Value B1	Value C1	Value D1	Value E1	Value F1
Value A2	Value B2	Value C2	Value D2	Value E2	Value F2
Value A3	Value B3	Value C3	Value D3	Value E3	Value F3
Value A4	Value B4		Value D4	Value E4	Value F4
Value A5	Value B5		Value D5		

4.2 Cross-Consistency Analysis

The next step requires a consistency analysis of the entire morphological field in order to reduce the amount of noise in order to delineate solution spaces. As with all scientific modelling, General Morphological Analysis (GMA) is based on an iterative process involving cycles of analysis and synthesis (Ritchey, 1991, 2012a). In the analysis phase, parameters (i.e. variables and their respective domains) are formulated which represent the model's initial problem space. In the synthesis phase, connective relationships between parameters are defined. In the case of GMA, these relationships are expressed in terms of mutual constraints between category variables. Such constraints are identified and assigned through what is called a Cross-Consistency Assessment (CCA).

It is important to note that, as a process, the CCA both serves as a check on the integrity and clarity of the concepts being employed and facilitates a deep dive into the nature of the problem space being studied. However, the end-purpose of the CCA is to identify and weed out all internally contradictory or otherwise incompatible relationships, in order to find the set of internally consistent configurations representing a solution space. With proper computer support, such a solution space can be treated as an inference model, which is one of the principal goals of the GMA modelling process (Ritchey, 2015).

In GMA, the Cross-Consistency Assessment (CCA) both serves as a check on the integrity and clarity of the combinations being created and allowed us to identify and remove all internally incompatible relationships in order to reduce the total problem space of the morphological field to a smaller, internally consistent solution space. With computer support from software, the solution space was subject to a heuristic approach with several iterations based on inference and synthesis.

A CCA was conducted to exclude solutions deemed to be impossible on purely logical grounds (internal consistency) and based on real world assessments (external consistency). Each value is rated across the values outside its parameter. Consistency in this context is assessed on the basis of two criteria:

- Logical consistency, i.e. the internal relationships of the concepts involved cannot be mutually contradictory;

* Empirical consistency, i.e. a solution cannot rest on empirically impossible or highly improbable assumptions;

CCA supports of the identification of the top consistency combinations, which are then reviewed. Multiple consistent combinations are selected that 1) cover all parameters and values, and 2) are meaningfully different from one another. These are then developed into solution spaces and matched with markets and customers in order to describe holistic project descriptions to the deep dives – encapsulated by, again for example, the electrification of the seas or drone applications in maritime. These descriptions are then developed into surveys in order to gauge their plausibility and estimate when they will become accepted practice or viable alternatives to status quo.

4.3 SURVEY DEVELOPMENT

Surveys are then developed from the selected combinations. The survey methods follows a logic of the modified Delphi approach. Delphi surveys ask respondents to estimate when technological capabilities will be realized. These methods were popularized after WWII by the RAND corporation that worked with the US department of war to determine when, for example, Hydrogen bombs and intercontinental ballistic missile systems would be ready for deployment.

The opportunities developed through the morphological analysis are developed into descriptions, and the surveys are sent to experts, practitioners, and non-experts to develop a working consensus on the time horizon for viability of the description and the business potential they present. Expertise is assessed in a self-assessment following a likert scale that asks how often the respondent works on the technology or the market in the description.
Once a description reached a certain number of responses, an interim report is produced, including the reasoning that the respondents have given to explain why they have rated as they have. The interim report is then sent to the respondents. In modified Delphi, respondents can then re-rate the time horizon after having reviewed the anonymous comments provided by the other respondents. This second round should lead to a tighter distribution of the answers than in the first survey, given that respondents have access to the reasoning behind the other ratings, and being able to adjust their answers.

It is not uncommon that, based on the feedback, that descriptions of technologies and descriptions are split into separate opportunities, or that separate opportunities are combined into a single one.

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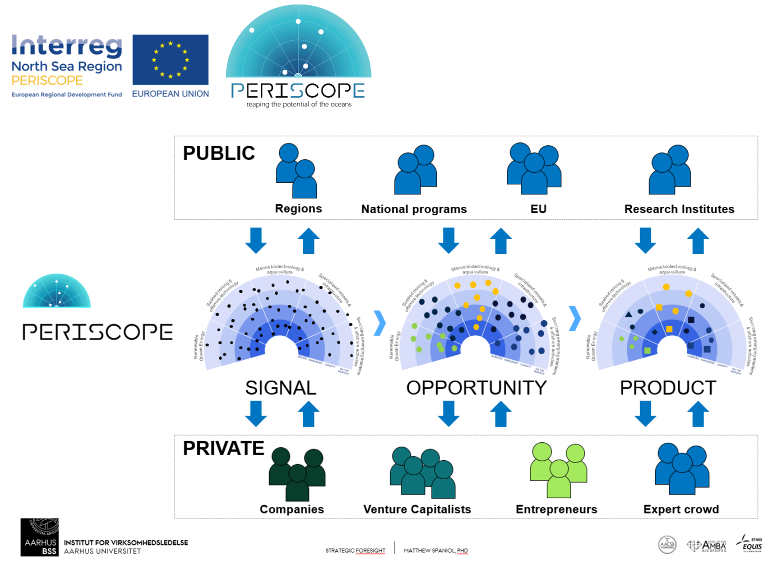
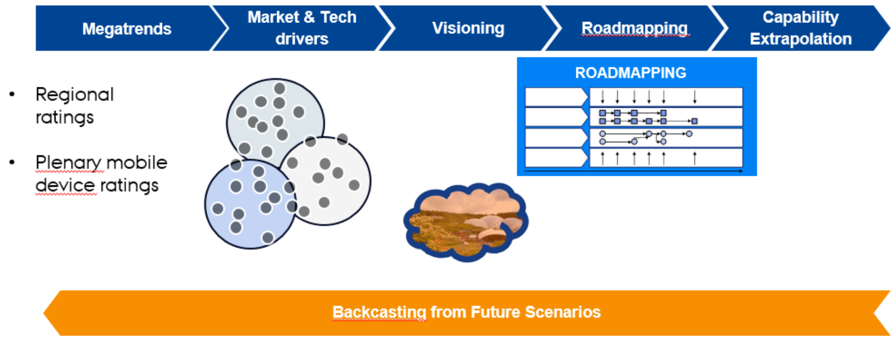


4.4 DEEP DIVE WORKSHOPS

Opportunity development is undertaken in a forwards and backwards process, and at this stage, the process becomes one more of iteration rather than a linear process. Here, additional tools from strategic foresight are used to engage stakeholders that are brought together in workshops.

Responses from the surveys are pre-processed and consolidated into topic areas, and these will also be used to reformulate the original descriptions. At the outset of the workshop, interactive tools are used to re-imagine the opportunity and revisit the topic survey, and workshop respondents are able to see and read in real-time the opinions and assumptions of the other people in the room. Questions such as “what is needed to make this opportunity happen?” and “what other opportunities will this open up?” are, as open-ended questions, effective for starting discussions.

Depending on the opportunity under question, tools are selected in order to fit the purpose. If the opportunity requires the complex integration of multiple technologies, then this can be drawn on a technology roadmap. If the opportunity requires political or social support, then scenario-based strategizing can be effective. In some cases, the development of the opportunity can use both tools. If this is the case, the recomondation is to start with the scenarios and then use them to stress-test the opportunity, and then use those discussions to create a policy innovation roadmap.



4.5 CONSORTIUM BUILDING

The respondents to the survey and the workshop participants should have various backgrounds and diverse functions in order to increase the integrity of the results. While the answers to surveys will be kept anonymous, some respondents have agreed to be listed as actors for this opportunity, and their information being included in the interim report. The interim report contains a section for the logos of the companies/organizations/institutions that have agreed to be listed as actors for this opportunity, along with the name and email of the respondent.

In workshops, it is more difficult to protect the anonymity of the participants, and so it can be a good idea to begin the workshop by informing participants of the Chatham House Rule, that what they say (the content) can be used after the workshop/conference, but it may not be revealed who said it or what organization they represent.

Lists of interested collaborators that are potentially to be developed into a consortium are then brought together to further refine the project proposal applications. If the ideas is to pursue public sector financing, then these partners can independently perform the necessary work to document their involvement over the term of the project. In the cases that there is a lead partner that can support the project, then those discussions can be taken forward as the lead partner decides.

5 EXAMPLE: OFFSHORE VESSEL CHARGING

The deep dive investigated the new uses of the increased offshore activities and infrastructure needed to decarbonise and “electrify” the large industries of the sea, including shipping and service activities. Deep dive research start with a joint understanding of the research team to be at the core, the resources available, and the rationale for the sequencing of the tasks involved, and the delegation of responsibilities. For the deep dive on offshore vessel charging in the PERISCOPE project, the below timeline was used as a starting point to deliberate and help the team develop a shared understanding of where the deep dive was headed and how it was going to be executed.

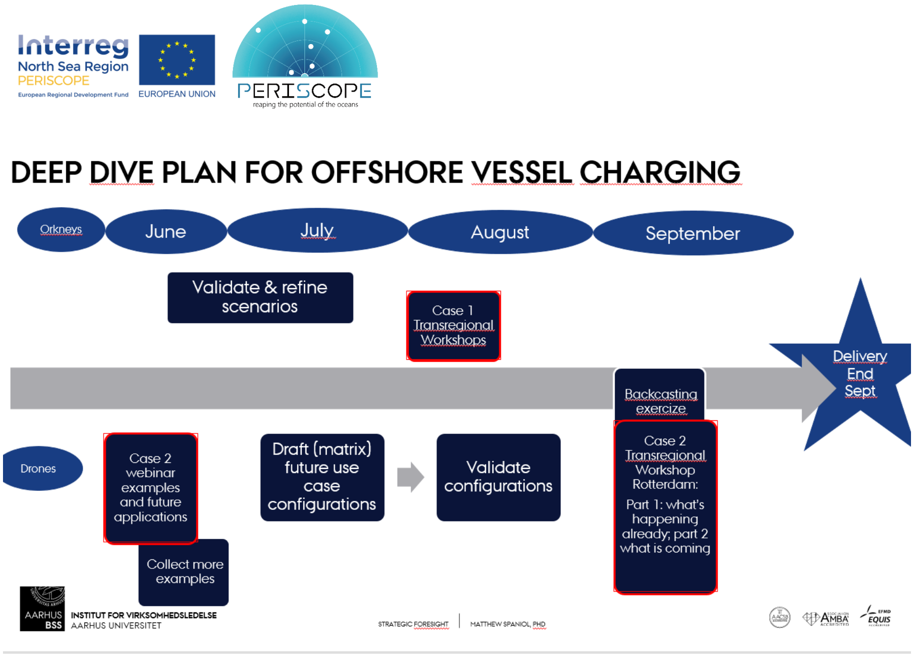
Electrification of the seas has recently captured the imagination of the marine and maritime community. The shipping industry is one of the largest and fastest growing sources of global CO_2-emissions, putting electric and hybrid technologies for marine propulsion and zero emission ships on the political agenda.[1] Costs of construction and maintenance of electric motors are forecasted to be below other propulsion systems because they are less complex and can last three times longer.[2] Sophisticated lithium-ion batteries are powering the first semi-electric ferries in Scandinavia. They reduce CO_2-emissions by 95% and operating costs by 80%.[3] China claims to have produced fully electric ships with a battery capacity of 2,400 kWh, can navigate at a speed of up to 12.8 km per hour fully loaded, and travel up to 80 km on a single 2.5-hour charge.[4]

Conventional approaches for battery charging can be applied to electrically operated ships.[5] However, wireless (inductive) charging is under development- further eliminating the need for onsite support staff and connection cables.[6] Onshore electric supply systems deliver over 3.000 MW for e.g. cruise liners and ferries.[7] In the North Sea, offshore charging stations could be powered by wind energy, where production prices have fallen by 63% in the past six years to 65€/MWh (2018), and have the potential to scale to 2600TWh,[9] making it cheaper than diesel.

Yet, there are technical challenges for large power connectors and operational challenges in electric “bunkering”. Matching the supply of offshore charging to the demands of an electrified mobile fleet gives a chicken-and-egg-problem for ships. Countries with substantial fleets may obstruct changes that would drive forward the electrification of the seas.[2]

5.1 Methodology

5.1.1 Plan for the deep dive



5.1.2 General morphological analysis

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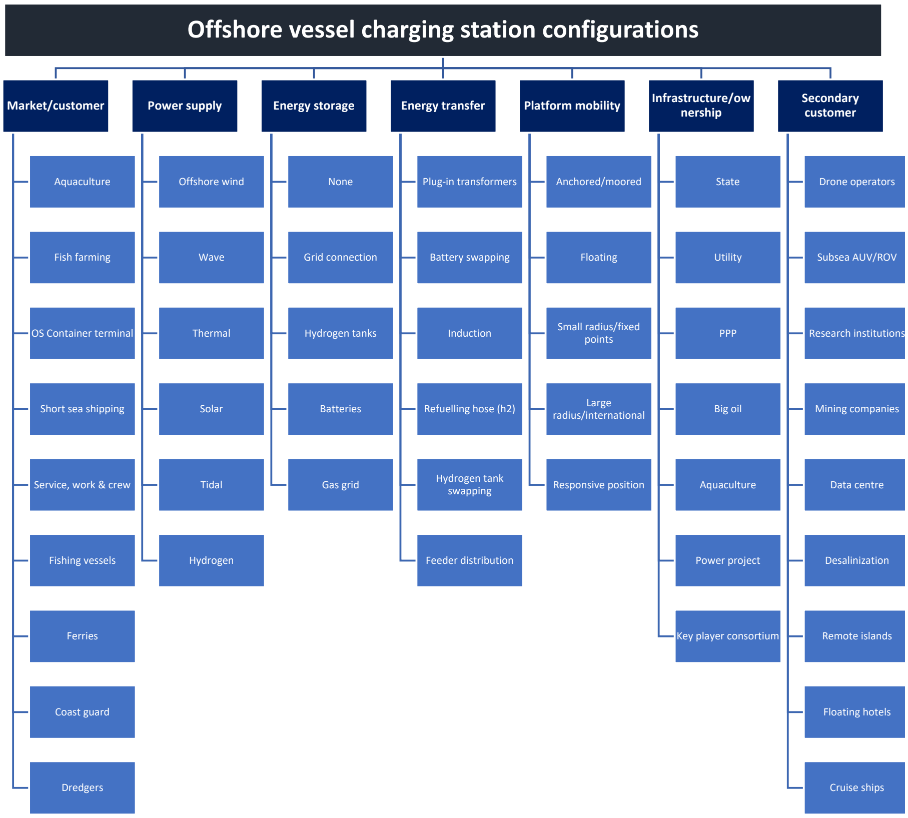
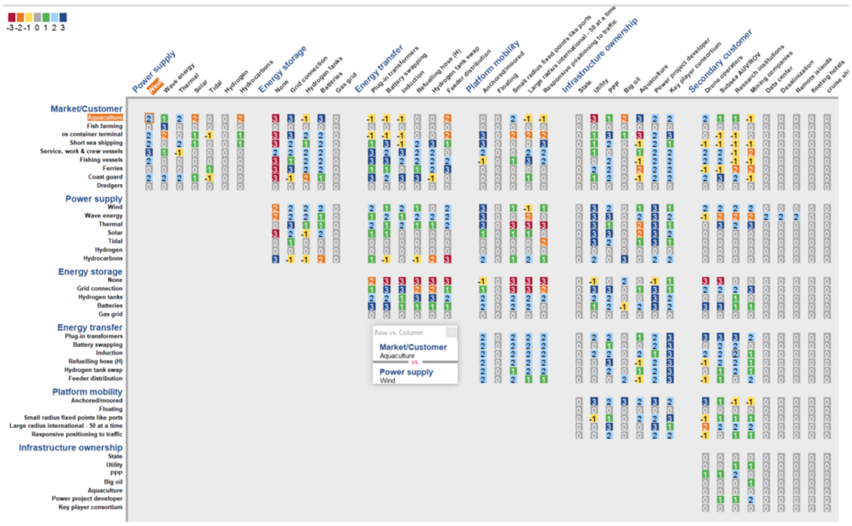


5.1.3 Cross-consistency analysis

A CCA was conducted to exclude solutions deemed to be impossible on purely logical grounds (internal consistency) and based on real world assessments (external consistency).



5.2 Survey on top-rated configurations

Selected configurations are then developed into surveys that are matched with market actors or stakeholders that could be customers or users of the platform. Data collection
Data is collected by consulting literature and conducting interviews with external experts and internal stakeholders.

Surveys for review by PERISCOPE partners

5.2.1 When will it become an accepted practice that electric service vessels will recharge or swap batteries at offshore 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

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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]

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5.2.2 When will a thermal-powered multi-use platform be constructed for the extraction of ocean resources and the autonomous detection of illegal fishing?

Thermal vents on the sea floor provide a source of infinitely renewable power and rare minerals. The value of energy from thermal production is expected to grow from $16 bn in 2018 to $55 bn by 2024.[1] Thermal vents are located along fault lines at difficult-to-exploit depths and distances from shore, including in areas in the North Atlantic.

Another problem that occurs at distances far from shore is illegal fishing. The illegal, unreported, and unregulated (IUU) fishing market is valued at $23.5 bn, with 1 in every 5 fish caught outside of regulatory oversight. [2] Patrolling distant waters is difficult and expensive, but thwarting IUU fishing not only has the potential to increase fish counts, but will also lead to €4 bn in increased value for the regulated fishing economy in the North Sea alone. [3]

Exploiting the thermal energy and mineral abundance from the deep sea, and policing illegal fishing, could be accomplished by the construction of an offshore platform located over these vents. Offshore platforms can harness thermal energy from seafloor vents and surplus energy can be used to produce hydrogen. The energy surplus can be used to power vessels and aircraft that can base and refuel on these platforms. With the rise of autonomous navigation and advanced sensors, these vessels and aircraft can be sent on patrol, and relay data back to coastguards, notifying them of any and all activities detected. [4,5]

Kommentert [RF1]: Needs / needed a link sentence

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5.2.3 When will an offshore container terminal, powered by renewable energy, be installed on the North Sea?

The maritime shipping industry currently transports 90% of the goods traded around the world. [1] The industry is responsible for nearly 3% of the world's CO2 emissions, and this is forecasted to increase by as much as 250% by 2050.[1] The International Maritime Organization has the vision of reducing annual emissions by 50% by 2050, and coalitions of maritime stakeholders are working on zero emission vessels, striving to become carbon neutral by 2030. [2] A partial solution to decarbonizing container shipping is the creation of an offshore terminal powered by renewable energy.

An offshore terminal will provide another node in the network of ports, providing another hub for the rerouting of containers by smaller feeder vessels. Current practice sees large container ships stopping several times to discharge containers along a linear route. An offshore container terminal, powered by offshore wind, will reduce the distance to onshore terminals.[3] Excess wind power can be used to desalinate seawater for hydrogen production, that can provide a power buffer for the terminal. Furthermore, hydrogen can be stored in tanks that can be swapped onto fuel cell-powered feeder vessels.[4,5] This will make transport to and from the terminal emission free.[6]

The challenge remains that hydrogen is still more expensive to produce, especially when taking into account the subsidies that fossil fuels receive. This, in turn, has limited the building of fuel-cell powered feeder vessels.[7]

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5.2.4 When will hydrogen, produced at tidal plants, become a commercially viable alternative for powering 1 MW vessels?

Kommentert [RF2]: Bit tricky this one, as it relies on 2 seperate innovation timelines:
1) cost reduction of tidal energy so it reachs price parity with marine diesel via hydrogen production
2) innovation in vessels so they can be powerd by fuel cells

Suspect your answer will focus on one or the other, but not both. Maybe thats fine!

When will hydrogen, produced at tidal power plants, be a viable alternative to diesel for powering ferries, search and rescue vessels, and other vessels requiring 1MW in the North Sea?

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]

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5.2.5 When will a fully-electric fish farm, powered by wave energy and capable of charging service vessels, be installed on the sea?

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 CO2 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. [4,5,6].

However, to ensure continuous operation, offshore installations will likely require backup systems to provide uninterrupted power for farming the fish.[4]

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6 Deep dive example

Increasing pressure is on the maritime industry and especially ships to take more environmentally friendly measures to reduce their carbon footprint. Offshore vessel charging stations (OVCS) provide an opportunity to realize the electrification of the seas.

While initiatives to develop hybrid and full electric ships have moved forward, limited battery sizes have slowed the progress. The opportunity of offshore vessel charging stations is a way to overcome the weaknesses of battery sizes. A station in the middle of the sea/ocean that can produce electricity and supply it to passing ships is what we define as an offshore vessel charging station. But how can such a station be configured and profitable? And who should it service?

Many questions are still needed to be answered and that's why this deep dive will form the foundation of a technology setup. Thus, the following sections will outline and describe different categories from the figure below, which is a morphological approach to piece together a puzzle of the configuration of an OVCS.

Figure XX

Market/customer	**Power Supply**	**Power storage**	**Power transfer**	**Mobility**	**Ownership**	**Secondary customer**
Aquaculture	Wind	None	Plug-in transformers	Anchored or moored	State	Drone operators
Fish farming	Wave	Grid connection	Battery swapping	Small radius	Utility	Subsea AUV/ROV
Container terminal	Thermal	Hydrogen tanks	Induction	Large radius	Power project developer	Research institutions
Short sea shipping	Solar	Batteries	Refuelling Hose (H2)	Responsive positioning	PPP ??	Mining companies
Service, work & crew vessels	Tidal		Hydrogen tank swapping	Floating	Big oil	Data center
Fishing vessels	Hydrocarbons		Feeder distribution		Aquaculture	Desalinization
Ferries	Hydrogen				Consortium	Remote islands
Cost guards						
Dredgers						

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Figure XXX – OVCS configuration

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Deep dive – Offshore vessel charging station

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2. APPENDICIES

APPENDIX ONE: THE SURVEY

On the sliding scale below, please estimate how many years from now offshore charging stations, will be operational in the North Sea. 0= already here.

0 5 10 15 20 25 30

☐ Will never happen

Why have you answered as you have in the previous questions? Feel free to support your answer with any references or documentation.

What multi-use platform or space combination is the most feasible for offshore vessel charging? Please indicate the ones you believe will be operational by 2025.

- Offshore vessel charging, single-use platform
- Offshore vessel charging & offshore wind/ energy
- Offshore vessel charging & hydrogen
- Offshore vessel charging & fish farms/aquaculture
- Offshore vessel charging & subsea charging of AUV/ROV
- Offshore vessel charging & floating offshore container terminals
- Offshore vessel charging & wave energy
- Offshore vessel charging & a combination of more than one of the above
- Other

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What do you think about the business potential of this opportunity?

How would you rate your expertise on this topic?

Personal expertise

Company expertise

PERISCOPE will produce an interim report based on the answers gathered from this survey. If you would like to receive it, please provide a valid email address:

Would you like to have you and/or your company/organization listed as an actor on this topic? By completing either (or both) of the fields below, you consent to having that information being included in reports and results. Note: all of the answers you have provided above will be anonymous.

Name

Company/Organization + Unit

URL

Submit

TAKE THE SURVEY

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APPENDIX TWO: METHODOLOGY

The survey was developed between the months of November 2018 and February 2019, by a team of research assistants at Aarhus University at the department of Management, Denmark. The survey description and questions were then sent to PERISCOPE partners for review. After the survey description and questions had been updated, a final version was sent out to the PERISCOPE partners. The partners then sent the survey to those in their network they found best fit to answer the survey.

Survey questions

The main survey question is, how many years from now the experts believe the opportunity to be operational in the North Sea? To answer this question the experts had to use a sliding scale, which stretched from 0 to 30 years, indicating 2019 and 2049 respectively. In addition to the sliding scale an option "Well never happen" was added in case an expert believed this opportunity to be unrealistic or unimportant/irrelevant.

Upon answering this question, the experts where asked to support their reason for picking the year with their professional opinion or any relevant references and documents. The experts were also asked to choose the most likely technology to combine with the offshore vessel charging stations. Further, the experts were asked to rank the business potential of the opportunity on a scale from 1-5, where 5 is very high potential, and 1 is very low potential. The experts were also asked to rank their own and their company's expertise within this field in the maritime industry.

Handling the data

Qualtrics is the software used for the survey. Qualtrics stores the data collected in the cloud, and only PERISCOPE partners may be granted access to the raw data. Although, upon request an anonymized primitive data set of the survey results may be granted to any interested reader.

Disclaimer

This survey is produced by PERISCOPE for information purposes only and does not constitute investment advice, and neither PERISCOPE, the EU, nor its collaborators, are responsible for decisions or actions based on any information herein. This survey is developed in Qualtrics, and PERISCOPE is not responsible for storage, use, and analysis, of any personal data or responses by Qualtrics. Visit https://www.qualtrics.com/privacy-statement/ for more information. Data and information provided are the property of PERISCOPE and cannot be distributed without written consent from PERISCOPE. By the partaking in, and sharing of PERISCOPE surveys, you agree to the updated terms and conditions available at http://periscope-network.eu/.

The survey is still available online for who may be interested on Qualtrics[1]. *We would like to encourage all interested in taking the survey for future reports.* This initial market report is based on responses gathered between the 20th of February 2019 and 26th of May 2019.

Notes on Methodology

The median estimation is a valuable measure for skewness of the average estimation. A large negative difference between the median and the mean indicates that a few responses have manipulated the average value, and a majority of the respondents believe the opportunity to enter the market before the mean evaluation. The opposite is true for a large positive difference between the median and the mean estimation. Figure 1 show a one-year difference between the mean and the median, and only one-year difference between the mean and the weighted mean. Both observations are statistically insignificant, since the estimations the respondents could choose were integers, indicating that any number calculated using the data has a standard error of one. There is thus no fear of information asymmetry or skewness in the experts' opinions, regarding this opportunity.

The minimum value represents the optimistic estimation, while the maximum estimation represents the cynical estimation. The average provides a rough estimation of the aggregate perception of the opportunity's time frame. The weighted average provides an even better estimation of the aggregate opinion. The weighted average is the individual estimation multiplied by the individuals own evaluation of expertise in the field. Own evaluation provides a bias to the estimation, but should cancel out, when aggregating the responses. A large difference between the mean and the weighted mean may indicate hidden information in the market opportunity, and the need for better knowledge transfer between the actors in the industry.

Limitations:

To be rigorous, it would only be fair to list some obvious limitations of this report:

- The small sample size of 16 respondents, and only 10 out of these evaluated their personal and company expert level.
- Using bootstrapping to extrapolate the results to the maritime industry.
- Self-reporting/ self-evaluation of expert level.
- Broad questions that may have been interpreted differently by different respondents.
- Choice of answers as integers, i.e. limited possible answers. This means that the variance on the estimation is high.

[1] https://aarhus.eu.qualtrics.com/jfe/form/SV_2h5OafghdHxrsMt

APPENDIX THREE: EVALUATING THE REPORT OPPORTUNTY AND THE RESPONDENTS

1	Perfectly correlated
0.5	Moderately correlated
0	Uncorrelated
-0.5	Moderately negative correlated
-1	Perfectly negative correlated

The opinions and results in this initial market report are only valid as long as our respondents are knowledgeable within the field. The respondents' level of expertise is measured, by asking them: "How would you rate your expertise on this topic?", where the respondent has to evaluate: personal expertise and company expertise. The respondent can pick between one and five stars. 1 star is the lowest choice and 5 is the highest. Respondents have to pick stars in integers, i.e. they cannot pick half stars.

Table 3 represents the results from the self-evaluation of the respondents' personal and company expertise level within the area of offshore vessel charging stations. The respondents tend to estimate their personal expertise higher than their company's. This might be driven by a self-reporting/ self-evaluation bias[2]. It might also be driven by the respondents being experts within the field, and actually knowing on average more than their colleagues, i.e. the survey has been answered by the most informed employee in the respective companies on average. Figure 4 graphs table 3. Visually, it is easier to see that the company expert level is relatively uniformly distributed, suggesting that our sample of responses is from a random distribution of firms. Considering the personal expertise of the respondents, it seems to be either highly experts or average respondents.

Tabel 3: Evaluation of expertise level		
Valuation	Personal	Company
1	1	2
2	1	1
3	4	4
4	0	2
5	5	2
Average	3,64	3,09

but this is not the case in this survey. To learn more about self-evaluation bias, you may read: Gramzow, R.H., Elliot, A.J., Asher, E. and McGregor, H.A., 2003. Self-evaluation bias and academic performance: Some ways and some reasons why. Journal of Research in Personality, 37(2), pp.41-61. Online version: doi:10.1016/S0092-6566(02)00535-4

Evaluating the relevance of the opportunity

The relevance of the opportunity is the correlation between the time horizon and the market potential. This correlation will measure the simultaneous belief that the opportunity is important and that it will happen soon. The relevance of an opportunity is higher the more negative the correlation. A negative correlation means that if a respondent marks the market potential high, they will also mark it imminent (happening soon). Table 4 show that the correlation between the market potential and the time horizon is 25%, which means that respondents who perceive this opportunity having a high market potential also perceive it to be more distant.

Experts vs non experts

Using the data, it is also possible to consider the difference response of experts and non-experts. This is done by considering the correlation between the personal expertise and the time horizon and market potential.

Table 4: Correlation between different measurements

Measure	Time Horizon	Market Potential	Company Expertise
Personal Expertise	26%	-30%	88%
Company Expertise	44%	-42%	
Market Potential	25%		

Table 4 show that the correlation between personal expertise and time horizon is 26 %. It is positive, which means that the more expert the individual, the further in the future they perceive offshore vessel charging stations to be. But, since the correlation is low, it may be argued that there is no significant relationship.

Table 4 shows a - 30% correlation between the personal expertise level and the market potential. It is negative, indicating the more expert the individual, the less they will perceive offshore vessel charging stations as an opportunity with market potential. But, since the correlation is low, it can be argued that there is no significant relationship.

APPENDIX FOUR: EXTENDTED ATTITUDES TOWARDS THE OPPORTUNTIES

Table 1: Arguments for and against high and low market potential	
For:	- "Going all in on electric vessels is a really good business case- big savings for the owners." - "It is a necessity to get the ship traffic on sustainable solutions."

Against:	- "Offshore platforms are very expensive to be installed and maintained, so costs of a charging station will be also relatively high." - "The process towards the first operational system might be significantly influenced by political actions and/or governmental funding schemes for pilot installations."

Respondents' attitude towards the technology

In this section are some of the respondents' argument for and against the technology underlying the opportunity.

Table 2: Arguments for and against high and low the opportunity's technology	
For:	- "From a technical point of view there should be no doubt about the feasibility of offshore charging stations, and there does appear to be some relevant applications that can benefit from such solutions." - "For operations and maintenance of the Offshore wind farms a lot of new vessels will be built in the coming ten years. These kinds of ships are qualified to run on electricity."
Against:	- "It will be very dangerous as there are many failure modes and issues that can occur and are generally difficult to foresee." - "There are no market drivers for this (yet), and there may be easier pathways to decarbonise vessels i.e. using LNG as a fuel."

APPENDIX FIVE: NOTES ON DATA

Visually, the distributions of the market potential results only have one mode, and the shape seem to visually follow a normal distribution. But the distribution is not symmetric, it does exhibit a small negative skewness (-0.17). The negative skewness indicates a higher than average potential for this opportunity. As the sample data is only 16, and the skewness is affected by the sample data, expanding the data through bootstrapping[3] is necessary for evaluating the significance of the skew-

[3] Bootstrapping is a statistical artificial method to increase the sample size. Bootstrapping entails a simulation where the original data is resampled using random sampling with replacements. When bootstrapping the mean of the sample

ness. Expanding the data sample to a million, the skewness diminishing completely, and the distribution can be considered symmetric. The kurtosis of the sample is positive and increases when bootstrapped. This observation may be interpreted as the degree of the respondents' disagreement about the opportunity. It should be noted that the since the sample data is small, little emphasis should be put on the skewness and the kurtosis, but they are never the less relatively informative.

is kept constant. Although, there are definitely many drawbacks of using bootstrapping to simulate answers, most prominently, the sample distribution is equal to the population distribution. We have found bootstrapping to be an optimal method to get around the problem of the the small sample size makes to draw conclusive casual inference results from the data.