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Article

Operationalising Weak Signals and Wild Cards for the Finnish Offshore Wind Industry

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Abstract

Offshore wind development has seen growing interest. Adapting to potential future changes and ensuring a balanced development of offshore wind requires long-term, strategic planning. Using an expert, participatory workshop, we identify and categorise weak signals and wild card events that could impact the sustainable development of Finnish marine space and the offshore wind industry. We use these results to assess how robust an existing global scenario framework (Shared Socioeconomic Pathways) is for analysing the prospects of one specific industry considering these weak signals. This research can support strategic planning for the sector and aid in developing the Finnish marine space in a sustainable manner.

Keywords

Wild Cards, Weak Signals, Scenario Narratives, Renewable Energy Transition, Participatory Planning

1. Introduction

Interest in developing offshore wind energy is seeing rapid growth. 2021 was a record-breaking year for offshore wind development, with 21 GW installed globally, three times more than in 2020. Europe and China are at the forefront of offshore wind development, with Europe (including the United Kingdom) responsible for approximately half of the global total installed capacity of 56 GW (Global Wind Energy, 2022). The European Union (EU) has announced plans to further increase offshore wind power to 30 GW by 2030, and 300 GW by 2050 (European Parliament, 2022).

Offshore wind is a small part of Finland's energy mix. However, demand is increasing and it has the potential to become a major source of renewable energy (Metsähallitus, 2020), if it can be developed sustainably alongside other marine uses. The capacity is approximately 70.7 MW, and this is expected to grow. A maximum capacity of 2.7 GW of development projects are underway (Finnish Wind Power, 2021). Furthermore, prior research has found that offshore wind can be impacted by five driving forces: 1) public acceptance for offshore infrastructure, 2) demand for C02 free electricity, 3) technological developments in offshore wind and competing renewable energy sources, 4) availability of space and wind resources and 5) Nordic and European energy markets and existing infrastructure, including grid connections, transmission networks, and specialised ports and vessels (Jenkins, Malho, & Hyytiäinen, 2022).

The demand for marine space and resources has undergone unprecedented growth (Jouffray,

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Blasiak, Norström, Österblom, & Nyström, 2020). As land-based space and resources are becoming fully exhausted, interest in developing and investing in marine industry is rapidly increasing. The 'Blue Economy' has become an important concept in marine governance, which seeks to understand and limit the negative environmental and social impacts of marine economic development (Voyer, Quirk, McIlgorm, & Azmi, 2018). Marine spatial planning is one important tool to manage and map the often competing and conflicting uses of the marine space and seeks to balance economic development with environmental protection (Schaefer & Barale, 2011). Marine spatial planning is a flexible and adaptive governance tool, but there is an ongoing need for updated and relevant data on environmental and social impacts of blue economy sectors. Furthermore, understanding industry trends and potential future changes is important for effective marine spatial planning (Kitsiou & Karydis, 2017) and identifying potential conflicts that might arise as the industry develops.

The rapid upscaling of offshore wind globally and increased demand means we need to understand, identify, and explore the weak signals already present within the industry that could potentially have a significant impact in the future. We are also interested in exploring how the industry may be impacted from wild card events; highly catastrophic, but low probability events. This research will attempt to support strategic planning for the sector and aid in developing the Finnish marine space in a sustainable manner, while considering the development of offshore energy alongside other uses of the marine space.

To our knowledge, this is the first paper to identify weak signals and wild cards relevant for the offshore wind industry and use these to explore the potential impact on marine sustainable development. These results can be used for strategic planning and understanding the prospects, challenges and conflicts facing the industry. Furthermore, to our knowledge, we are the first to use these results in conjunction with the Shared Socioeconomic Pathways (SSP) framework. We are using the SSP framework as a context to link weak signals, identify which elements comply with the framework, and strengthen and update the established SSP narratives. Additionally, the results can provide knowledge on the limitations on extending the global pathways to a specific national or industry scale.

The aims of this paper are threefold. Firstly, we want to collect expert knowledge on weak signals in the Finnish offshore wind industry and examine their potential impact on marine sustainable development. Secondly, we want to identify potential wild card events that could dramatically alter the development trajectory of offshore wind. Finally, we want to analyse how robust a well-established scenario framework (SSP) is for analysing the prospects of one specific industry considering these discontinuities. The viewpoint in this analysis is intended to be one of a social planner planning the future use of marine space under pressing need to produce more domestic energy but naturally it is a combination of viewpoints of the participants in the workshops.

2. Conceptual and Theoretical Background

The COVID-19 pandemic and Russia's war in Ukraine fundamentally changed the global landscape and revealed the need to better identify and understand emerging trends and develop more robust strategies for potentially catastrophic events. There are a variety of tools available to achieve this, and weak signal and wild card analyses are one. There is no single definition of a weak signal, but they are often described as the first early indicator of a potential larger change or trend (Saritas & Smith, 2011). The main characteristic of wild cards is that they are highly improbable, but highly impactful events that can fundamentally change the development trajectory.

Weak signal analyses were formally developed in the 1970's (Ansoff, 1975), following a global economic shock, to aid in strategic planning. These initial ideas have been developed and used widely across various industries, firms, and research projects to identify potential weak signals and their strategic consequences (Saritas & Proskuryakova, 2017; Takala & Heino, 2017). Weak signals are often faint and fractured pieces of information, and can become lost in mass amounts of other information or "white noise" (Mendonça, Cardoso, & Caraça, 2012). Consequently, identifying and interpreting weak signals can be a difficult undertaking but prove meaningful for identifying important potential changes or provide hints for upcoming wild card events (Heinonen, Karjalainen, Ruotsalainen, & Steinmüller, 2017; Mendonça et al., 2012; Saritas & Smith, 2011).

Wild card analyses are often used to promote creative thinking and aid in strategic planning. Wild cards have extensively been used in the corporate world and can help in introducing and understanding unknown events and their consequences in planning discussions (Saritas & Smith, 2011). The creation of wild card events is limited only by imagination, but the introduced wild card should not be completely destructive, and allow the industry to react (Mendonça, Pina e Cunha, Kaivo-oja, & Ruff, 2004). This also means that calculating the probability of occurrence is difficult but effective scanning and early detection can aid in anticipating potential wild card events (Hiltunen, 2020). Wild card analysis can be an important tool in strategic work to challenge the status quo and our held assumptions about the future (Hauptman, Hoppe, & Raban, 2015). Additionally, the introduction of unforeseen events increases the anticipatory capacity of a system to future shocks and promote adaptive governance (Smith & Dubois, 2010). Wild card analysis is a flexible tool to facilitate discussions and aid in producing policy-relevant strategies for adapting to and mitigating unforeseen events.

Offshore wind is a rapidly growing market and technology is quickly changing. Consequently, it is important to concentrate not only on singular weak signals and wild cards, but also on how these could interact and their potential for larger, fundamental shifts. These interactions can be studied through the concept of discontinuities. Discontinuities have been defined as "*those situations – impacts where over time and extending beyond single events, change is rapid and fundamentally alters the previous pathways or expected direction of policies, events and planning regimes*" (Saritas & Smith, 2011). Wild cards and weak signals form part of the discontinuity process and are useful tools to undercover broader change phenomena (Heinonen et al., 2017). Discontinuity analysis has been used to explore alternative futures of renewable energy and energy security (Heinonen et al., 2017), but has yet to be used to assess the offshore wind energy industry.

An important consideration when undertaking this study was the framing and explanation of discontinuities to the participants, particularly weak signals. There is discussion in the literature around what exactly constitutes a weak signal or wild card (Hiltunen, 2006; Mendonça, Cunha, Ruff, & Kaivo-oja, 2009; van Veen & Ortt, 2021), the best methods for identifying these discontinuities (Hiltunen, 2008; Holopainen & Toivonen, 2012), and how the framing of the exercise can impact the identification and interpretation of discontinuities (Jorgensen, 2012). We are not attempting to provide commentary on these discussions, and for the purposes of this study, we left our framing and definitions of discontinuities open to broader interpretation. We encouraged free and open discussion and creative thinking in the expert groups, leading to a considerable number of identified discontinuities. Consequently, several of the weak signals identified could be considered less of a weak signal, but more of a strong signal, trend or driver of change, a similar result to past research in different sectors (Takala & Heino, 2017). We have made limited distinction between the identified weak signals and retained most of the discontinuities identified in the workshop, with a small number of exceptions that were clearly megatrends or similar enough to be combined.

"Blue Growth" and "Blue Economy" are relatively recently introduced terms to describe the holistic management and promotion of sustainable development of marine areas (Eikeset et al., 2018; Voyer et al., 2018). These terms have been widely adopted in research and policy documents, but there yet remains no generally agreed upon definition (Eikeset et al., 2018). For analysing the potential impact from the weak signals on marine sustainable development, we have adapted the classic definition of sustainable development from the three key pillars: economic, environmental and social (Brundtland, 1987). Economic sustainability was defined as how the trend is expected to effect on sustainable blue economy business opportunities. This can be described in terms of increased or decreased value added from production, increasing income, increased wealth from marine area, resilience of communities to economic fluctuations and risks. Ecological sustainability was defined as the expected contribution to the resilience of coastal and marine ecosystem, and the level of impact on achieving a clean environment with minimum & controlled harmful human impact - in terms of pollution and energy inputs to the sea or extraction of materials, fauna, or flora. Social sustainability was characterized by changes toward, or away, from equal distribution of wealth, equal access to marine areas including tourism and recreation, both for residents and people coming elsewhere and labour opportunities.

The Shared Socioeconomic Pathways (SSP) are a scenario framework that describes five distinct, yet equally plausible, global level development pathways over the 21st century (O'Neill et al., 2017). The pathways combine qualitative narratives with quantitative inputs to describe four extreme narratives, and the "middle of the road" narrative. There are 5 "marker" papers that describe each of the five narratives in detail (Calvin et al., 2017; Fricko et al., 2017; Fujimori et al., 2017; Kriegler et al., 2017; van Vuuren et al., 2017). Many applications have extended the global narratives to a regional or national level to explore developments at specific scales. Extended narratives were developed exploring the future of offshore wind in Finland (Jenkins et al., 2022) and the SSPs have been a useful tool for developing these extended narratives. The SSP framework has been used extensively across many different research topics and has "largely met the immediate needs" of the research community (O'Neill et al., 2020). Prior research has noted the potential for combining weak signal methodology with the SSP framework to further support and strengthen the SSPs (O'Neill et al., 2020). However, this has yet to be undertaken at a regional or specific industry scale. Furthermore, there is a need to understand how relevant the global level narratives are for analysing the development of one specific industry at a national scale.

3. Materials and Methods

To achieve the aims set out in this paper, we organised an expert, co-creative virtual workshop in June 2021, split into two sessions over two half days. We used this approach to gather a range of knowledge and experience from a group of stakeholders and experts interested in energy and sustainability issues.

There were altogether ten committed participants representing a diverse range of stakeholder groups: four researchers, three industry representatives, one union representative, and two think-tank representatives. The registered participants were provided with a preliminary report introducing the project, a brief explanation of wild cards and weak signals, and results from prior research linking to this workshop (Jenkins et al., 2022). We elected to use a participatory, expert method with a representative group of experts and stakeholders to ascertain a broad and diverse range of trends, emerging issues, and potential consequences. High-expertise groups of participants are important for the identification of weak signals and wild cards (Holopainen & Toivonen, 2012). Furthermore, this method was chosen as open-discussion, creativity, open-mindedness and interaction have been emphasised as key traits needed for the detection of weak signals (Hiltunen, 2008).

Both half-day sessions were organised virtually using an online meeting platform due to the COVID-19 pandemic. This allowed us to begin with presentations and discussions as one group and breakoff into smaller groups for more in-depth discussions. We used an online canvas to document the group discussions and allow working and note-taking in real time. These canvases were prepared beforehand, and they included background information and allocated space for documenting the group discussions. A facilitator was assigned to each group to support as needed and help the participants with technical details.

In the first session of the workshop, each group began by brainstorming and collecting weak signals on the pre-built canvas. The participants were asked to freely ideate and discuss potential weak signals, their meaning and potential impact. After the breakout group discussions, all participants returned to the main room and each group presented their results briefly before a shared discussion with all participants. The session ended with a voting session on which weak signal was the most interesting. The participants were asked to write out the weak signals in a voting platform and were given three votes on which they thought was the most interesting. This ended the first session of the workshop.

The second session focused on developing wild card events and discussed the potential and plausible implications and impacts on the offshore wind industry. Proceeding the smaller group discussions, the participants returned to the main room and each group presented their results. The final task of the workshop was to vote, with the same method as the first session, on which wild card would be the most impactful for the offshore industry. With this voting, the second session and the workshop were closed.

Proceeding the workshop, the wild cards were categorised according to the PESTLE (political, economic, social, technological, legal, and environmental) framework. The PESTLE framework is a valuable tool that can provide insights into external factors impacting the industry in question now, and in the future (Basu, 2004; Mäkelä, Parkkinen, Lyytimäki, & Nygrén, 2020; Thomas, Sandwell, Williamson, & Harper, 2021). The framework is useful for qualitative data and categorising the weak signals and wild cards for easier comparison across categories. The overall impact of wild cards is difficult to assess, given their complexity and unpredictability. To overcome this challenge, criteria have been proposed that can be used to assess the impact (Brown, 1997). We have used a similar criterion-led method to assess each wild card. Our criteria included the PESTLE category, duration, magnitude, scope, and industrial impact. The full data set that supports the findings of this study are available from the corresponding author, JJ, upon reasonable request.

4. Results

4.1. Weak Signals in the Offshore Wind Industry

Altogether forty-nine weak signals were identified across the participant groups. From this initial list of forty-nine, after combining and removing some weak signals, an updated total of thirty-three is presented in this paper. Several of the weak signals were similar enough to be combined. Table 1 presents a summary of the identified weak signals categorised according to the PESTLE framework. Many of the weak signals fall into the social category, and more specifically, changing consumer values and preferences. This includes weak signals related to increasing awareness and knowledge of offshore wind and other renewable energy, improvements in education, changes in free-time travel, changes in working arrangements, and increasing harmful misinformation campaigns. Political weak signals include shifts in global and national climate policies, additional requirements for marine spatial plans and more space being allocated to offshore energy and increasing presence of energy issues. Additional weak signals include developments in technology in renewable energy, shifts in corporate social responsibility, and changing forms of energy markets.

Proceeding the workshop, the weak signals were assigned a grade from -2 through +2 for each of the three key pillars of sustainable development and plotted. Figure 1 outlines a graphical representation of the weak signals. This exercise was conducted by two of the authors, that have a background in marine sustainability science, specialising in the Baltic Sea region. This allows for an evaluation of the interconnections and cross-impacts of the weak signals across marine activities. The analysis was conducted separately, and the grade was averaged. The full data set that supports the findings of this study are available from the corresponding author, JJ, upon reasonable request. Further detail on the axis definitions can be found in section 2. The environmental impact is on the horizontal axis. The social impact is on the vertical axis. The impact on economic development is represented through the colours green, red, and black. Red is negative for economic development, green is positive and black is neutral, or dependant on the direction of change.

Observations can be made from this exercise. Firstly, it was found that eleven weak signals contribute toward all three areas of sustainable development. This is one-third of the total weak signal list. These are the weak signals in the top right quadrant in figure 1, that are coloured green or black. There are altogether sixteen weak signals that promote, or are at least neutral, for environmental and social sustainable development while five of these are considered a move away for economic development. The overarching theme for this top right quadrant is political and public values and preference, and technological improvements in offshore wind (and renewable energy). These include weak signals such as combining use of marine spaces, shifts in corporate social responsibility, improvements in educations and improvements in offshore technology and other renewable energy technology.

To contrast these aspects, four weak signals were found to dampen all areas of sustainable development. In the bottom left quadrant, seven weak signals are placed, with three of these contributing to the economic development of offshore wind. These four weak signals include trends involving policy and preference shifts away from climate change mitigation, harmful misinformation campaigns and theories against offshore wind and power concentration in select companies. The remaining three weak signals, which reduce environmental and social development, but increase economic development, include complacency around climate change mitigation, increased conflicts in other renewable energy sources and limited carbon sinks in Finland.

In the bottom right quadrant, which contribute toward environmental development but a reduction in social development, there were found to be three weak signals. These were also found to reduce economic development. Weak signals in this quadrant include increasing value of the land and sea, new pandemics and increasing energy poverty.

The top left quadrant, which contribute toward social development but away from environmental development, there were found to be seven weak signals improving (or at least no movement) toward social development. Six of these were found to aid economic development and one was hindering. There are not any dominant themes represented in this quadrant and issues range from the different forms of energy markets, increasing energy demand and dormant potential of offshore, changing technology and taxation revenue.

The participants voted on the “most interesting” weak signal. The weak signal that received the most votes was “social media influence and its political power.” The participants discussed the unpredictability of this emerging trend, and how it can have strong ramifications for the energy sector depending on which topic is highlighted and by whom. Although this is a highly interesting result and emerging trend, it was excluded from figure 1 as the impact is highly uncertain and depends on the topic. However, it does relate to the “harmful misinformation campaigns and theories against offshore wind" weak signal, which is included, as this has a clear direction of intent.

4.2. Categorising Wild Cards according to their impact on offshore wind

Altogether forty wild card events were developed ranging in scale, impact, and location. Table 1 presents a summary description of the wild cards categorised according to the PESTLE framework. The participants developed several wild card events related to major geopolitical shifts, including national defence shifts, shifts in national independence, and collapse of the EU. Several wild cards were identified related to climate change related accidents and severe weather events, and large-scale accidents in wind farms. Global economic and financial collapse was discussed, along with regional Nordic power market splits, trade embargos and manufacturing bans. Major advances in technology, including in renewable energy and carbon capture technology, were discussed. Other identified wild cards include refugee crises, restricted permitting and licensing, and major travel restrictions.

The impact of each wild card was assessed according to four categories: duration, magnitude, scope, and industry spill over. Duration of impact was sub-categorised as short (0-2 years)-, medium (2-10 years)- and long-term (10+ years) impact. Magnitude of impact was represented as positive, strongly positive, negative, strongly negative or dependant on the direction of change. Scope examined whether the wild card impacts at a national (Finnish) scale, regional scale or international (global) scale. The final category, industry spill over, assessed if the impact was localised to offshore wind only, or the wider energy sector or multiple industries to whole societies.

The majority, fourteen wild cards, are categorised according to the political PESTLE category. This category has the most by far, with technology and economic each having seven, environmental has six, social with four and legal has the least with two. Only five events have a short-term impact, and these were categorised as short to medium term. Twenty-six wild cards have a long, or medium to long, term impact on offshore wind. Nine events were assessed to have a medium-term impact. Twenty-three events shown to have a negative impact on offshore development, five were dependant on the direction of influence after the event, meaning only twelve had a positive impact. Half of the impact would be localised at a national scale, with one-quarter each impacting the regional and international scale. Finally, nineteen of the events would impact several sectors or society. Eleven would solely impact offshore and the remainder the wider energy sector.

The participants voted on which wild card would be the "most impactful" on offshore wind development. The wild card that received the most votes was "major technological advances in other renewable energy sources." This was considered to have the "most clear and direct impact" on offshore wind and the most probable. Many of the other events would have a complex, long-term, and uncertain impact on offshore development.

4.3. Assessing and Linking the SSP framework with Weak Signals

We were interested in how well the global level SSPs narratives are in analysing the prospects of one specific industry at the national Finnish scale. By doing so, we can reveal potential limitations or issues that may arise when using the SSP framework at a nationally extended scale or when developing other specific narrative scenarios. We used the identified weak signals to examine whether they are accounted for in the global SSP narratives. As these weak signals may become more prominent in the future and shape the future of the industry, and lead to potential conflicts, it is important to understand these for other extension applications and narrative development exercises.

To undertake this task, we examined whether each of the weak signals presented in section 3.1

are implicitly or explicitly mentioned in the 4 SSP narratives. Table 2 outlines a summary of the results from the linking exercise. The table shows how many and a summary description of the weak signals that are an element in the SSP narratives. The full data set that supports the findings of this study are available from the corresponding author, JJ, upon reasonable request. We have restricted this analysis to assessing the weak signals as part of the original SSP narratives and the four "marker" narratives that provide more detail to the original SSP narratives. We have not assessed the many additional papers and research that extend or use the SSPs in diverse ways. SSP2 was excluded from this analysis as we are interested in assessing the extreme narratives.

Eight weak signals were identified that are not an element in any of the narratives. The first three of these weak signals are specifically related to offshore wind or specific land use planning. These include weak signals such as combining use of marine space, dormant potential (of offshore energy) and marine spatial plans allocating space for offshore energy.

The final five weak signals are broader issues that can impact the wider society. These include the increasing value of the land and sea, harmful misinformation campaigns and theories against offshore wind, new pandemics, new possibilities of working, power concentration in select companies. Harmful misinformation campaigns and theories against offshore wind was interpreted as any form of campaign that purposely spreads misinformation and theories on the offshore wind industry, or renewable energy more broadly. New possibilities of working were interpreted as any changes in the working habits of the population, including increased remote working, changing work hours and so on. Power concentration in select companies relates to how a small number of companies have market share and therefore power in which services are offered and at what price.

These results suggest that there are eight weak signals relevant for offshore wind development that are not accounted for at the global narrative level. This exercise has revealed some potential limitations and issues relevant at the extended scale that may need to be accounted for during other extension applications or narrative development related to the SSP framework at this kind of very specific industry scale.

Discussion

This paper outlines discontinuities identified in an expert workshop that may have strategic consequences for the offshore wind industry over a long-time horizon. Additionally, we use these discontinuities to examine how well the SSP framework is for analysing the prospects of one specific industry at a national scale. This is the first paper to operationalise weak signals and wild cards and collect empirical data for strategic planning in the offshore wind sector, and for analysing the robustness of an existing scenario framework. Firstly, we found that major drivers of offshore development are also drivers contributing to the sustainable development of marine areas. Secondly, we found that several weak signals may impact sustainable development in opposite directions which may lead to conflicts arising if these weak signals become stronger and form new trends. Thirdly, even though the SSP framework addressed many important aspects relevant for the weak signals mentioned, several (eight) of the weak signals do not make part of the SSP narratives. We found that the global narratives are relevant at this extended national industry scale, but some potential limitations and issues may arise that need to be accounted for when extending the global narratives. Fourthly, we present potential wild card events that could impact the development of offshore wind. Finally, participants were able to identify more weak signals related to gradual changes in values and preferences, compared with weak signals in the geopolitical situation. In contrast, more wild cards were developed relating to major geopolitical shifts.

We present the discontinuities categorised and analysed based on their impact on offshore wind, and the sustainable development of marine areas. We found that over one-third of the identified weak signals broadly contribute to all three areas of sustainable development: economic, environmental, and social development. Furthermore, two overarching themes are common in these weak signals contributing to all three areas of sustainable development; 1) political and public values and preference shifts and 2) technological improvements. These themes have been found to be major drivers for development of offshore wind (Jenkins et al., 2022; Snyder & Kaiser, 2009), and are now revealed to also be weak signals for contributing to the sustainable development of marine areas.

This paper shows that there are weak signals that may impact the three pillars of sustainable development in opposing directions. This may lead to potential conflicts if these weak signals become stronger. An important consideration for marine sustainable development is identifying and developing strategies for mitigating and overcoming potential conflicts early (Kitsiou & Karydis, 2017). Several studies (Chen, Liu, & Chuang, 2015; Lester et al., 2018; Schillings et al., 2012; Virtanen et al., 2022) have found that a potential solution for mitigating these spatial conflicts is the use of iterative, participatory, and detailed marine spatial plans and spatial analyses that can account for, and compromise between, all uses of the marine space. The identification of potential sources of conflicts are evidently case-specific, and the below are examples of such conflicts. There are weak signals that could lead to a rise in the number of land and sea-use conflicts from different users and stakeholder groups. For example, increasing energy demand, particularly when combined with the "dormant potential" of Finnish waters for offshore energy production, combined with the increasing value of the land and sea and the increasing role of biodiversity protection. These weak signals have potentially opposed, and conflicting directions of sustainable development and frictions may arise. As energy demand increases, along with the value of the land and sea, so does demand for marine space (Douvere, 2008). Furthermore, biodiversity protection needs to be accounted for in spatial analyses and planning of marine use to mitigate some environmental impacts (Virtanen et al., 2022). Conflicts may arise between environmental protection, industrial activities, energy resources and social and recreational uses.

The increasing emergence of harmful misinformation campaigns are one of four weak signals considered to contribute to a reduction in all areas of sustainable development. These campaigns can severely impact public opinion on renewable energy projects based on information that may have no scientific evidence. Although no scientific research has yet been produced analysing this phenomenon, there are examples from recent local news of misinformation campaigns hindering wind power development in the US (Gaumer, 2022; Simon, 2022), Europe (White & Mallet, 2021), and campaigns funded via oil companies to sway opinion on offshore wind power projects (Fang, 2021; Kvittem, 2021). Furthermore, misinformation stories can create a snowball effect leading to more misinformation being spread (Wilczek, 2020). Conflicts can arise if misinformation continues to spread and disrupt the planning of marine spaces.

Our third aim was to assess the SSP framework and its applicability at this specific industry scale. Our results, shown in table 2, suggest that there are eight weak signals relevant for offshore wind that are not accounted for at the global level. Three of these weak signals are specific to offshore wind and could have potentially large impacts on the development of offshore in the future. For example, participants in the workshop discussed the idea of combining tourism and other uses with offshore wind parks to improve public perception. The national and specific industry extension of the global SSP narratives could explain why these weak signals are not accounted for at the global scale but are relevant issues to be considered with other extension applications.

The remaining five weak signals could impact the broader society. These can have significant ramifications for society and the economy, for example, the impact felt from the COVID-19 pandemic. Additionally, misinformation campaigns, along with the campaigns mentioned above, have had a serious impact on the spread of medical misinformation (Chou, Oh, & Klein, 2018), including related to the pandemic (Niemiec, 2020) and anti-vaccine messages (Broniatowski et al., 2018). Considering these potentially large impacts on global and industrial developments, we have found the SSP framework to be a relevant tool for analysing the prospects of offshore wind under different global extremes (Jenkins et al., 2022), as the SSPs include many elements and general issues relevant for offshore wind. This finding is like other papers that have developed extended SSP narratives (Lehtonen et al., 2021; Mitter et al., 2019; Zandersen, 2019). Several of these weak signals have become prevalent in the years after development of the SSP framework, for example, the impact that the pandemic has had would be difficult to predict and may provide some basis for updating the SSP framework based on resulting consequences. However, the long-term nature of the SSPs could explain the absence of these issues as over a longer-term horizon their impact may be minimal.

The participants developed potential wild card events that could impact the offshore wind industry, and we categorised these according to their potential consequences. Similar to other papers (Smith & Dubois, 2010), this exercise is not necessarily about examining which wild cards are *likely* to occur, but identifying which wild cards *could* happen. Wild card events can happen more frequently than generally expected (Anderson, Branch, Cooper, & Dulvy, 2017; Jouffray et al., 2020). Prior exercises in developing wild card events (Hauptman et al., 2015; Smith & Dubois, 2010) and exploring their impact have shown that this exercise can be an invaluable tool for exposing potential weak links or blind spots in strategic planning, and uncovers a need for flexible, long-term decision making.

As shown in table 1, more weak signals fall into the social PESTLE category, and more wild cards fall into the changing geopolitical environment category. This result is in line with other papers that reveal that people generally find it easier to foresee gradual changes in values and preferences or societal shifts (Saritas & Smith, 2011), but forecasting gradual changes in the geopolitical situation is more difficult. However, participants find it easier to develop wild cards and catastrophic geopolitical events, such as war, terrorism or dramatic policy shifts, a finding echoed in previous research (Saritas & Smith, 2011). Additionally, there were nearly double the number of negative wild cards than positive wild card events.

The first aim of this paper was to identify weak signals present in the offshore wind industry and examine their potential impact on marine sustainable development, detailed in section 4.1. These results can be used to better understand the potential conflicts, challenges and opportunities facing the development of offshore wind. Furthermore, we increase understanding on the weak signals and potentially larger changes that may arise in the future. Policy makers, business leaders, experts and stakeholders can use this information for strategic planning (Heinonen et al., 2017; Takala & Heino, 2017), adapting to the changing environment and understanding the potential consequences of (in)action, particularly if combined with a traditional SWOT analysis (Hauptman et al., 2015). This increases the capability and flexibility of decision makers to react and adapt to the unknown (Mendonça et al., 2012; Mendonça et al., 2009), and better understand the limits of our knowledge of the unknown and uncertainty.

The second aim of this paper was to develop potential wild card events that could alter the development of offshore wind. We present a total of forty wild card events that could have an impact on the development of offshore wind. An overview of these wild card events can be found in section 3.2 and table 1. The purpose of this exercise was understanding which wild cards could happen, and not necessarily the likelihood of these happening. By identifying potential events and analysing their impact, we can develop robust strategies for adapting to, mitigating, or taking advantage of unforeseen events and reveals the need for adaptive and flexible governance of marine space.

Our third aim was to analyse the robustness of the SSP framework at this extended national scale. The assessment of the SSP framework considering these discontinuities can aid in the updating and strengthening of the framework in upcoming iterations. Furthermore, researchers can better understand the potential limitations of developing narratives and using the SSP framework for analysing a specific industry at the sub-global or sub-regional level.

This paper contributes to the futures literature by providing a methodological example for operationalising weak signals and wild cards for strategic planning at a very specific industrial scale. We have shown that the process of collecting, identifying, and exploring weak signals and wild cards for this specific industry yields fruitful and useful information for strategic planning, understanding the potential future development and adaptive governance and marine spatial planning. This is not the first paper to collect weak signals and wild cards however, this is the first to do so at this very specific scale for an industry that's relatively new and rapidly changing. Consequently, our contribution reveals that using futures methodology can result in worthwhile information for other very specific scales.

We have only provided potential discontinuities relevant for the offshore wind industry. These results can offer insights into how the development of offshore may be impacted under various events and allow for better informed decision making. However, we have not presented any concrete solutions or policies regarding offshore development. Thus, the natural next step in this research is to develop robust strategies for offshore development, given a unified vision for the future of offshore wind. National pathways and roadmaps can be developed allowing for flexible and robust decision making.

This research was conducted before Russia's invasion of Ukraine and during the COVID-19 pandemic. These major global events have led to an immediate impact on the energy market and have caused rapid shifts in the demand for domestic energy sources. The long-term consequences on the energy transition and offshore wind are still unknown, but it is important to note the change in global context from when these results were collected.

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Figures and Tables

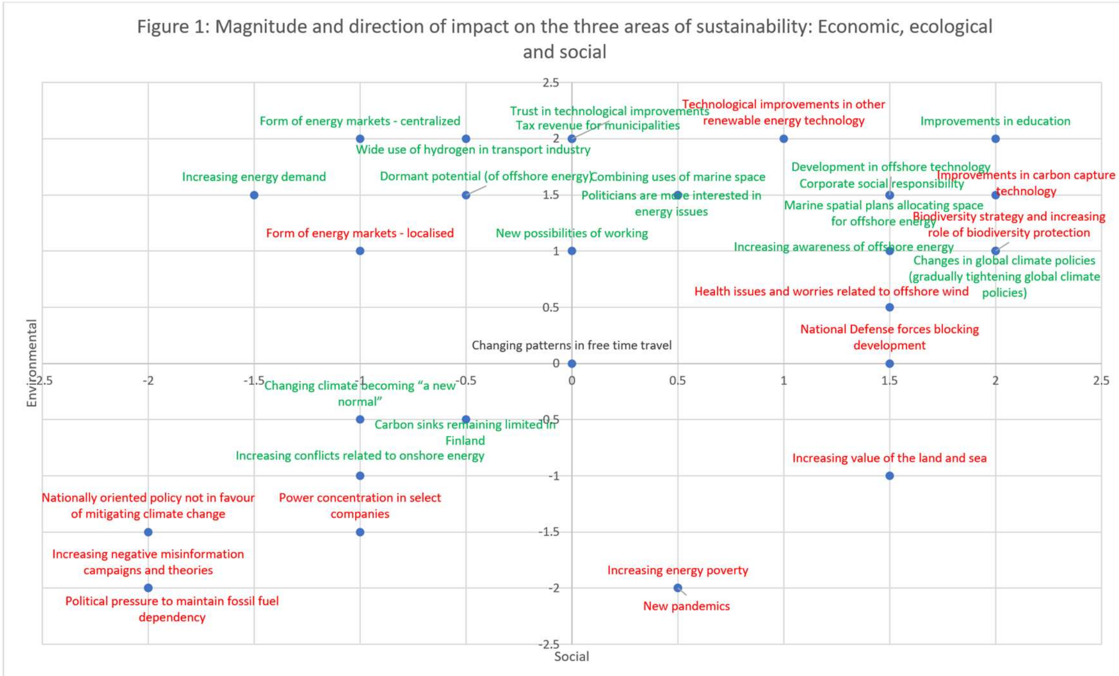

Fig 1: Magnitude and direction of impact on the three areas of sustainability, economic, ecological and social. Environmental impact is on the vertical axis and social impact is on the horizontal axis. The red weak signals are negative for economic development, green are positive and black are neutral.

Table 1: A summary description of the identified weak signals and wild card events categorised according to the PESTLE framework.

PESTLE Category	Summary of weak signals	Summary of wild card events
Economic	Forms of energy markets; combining uses of marine spaces; increasing value of the land and sea; power concentration	Global economic depression; financial collapse; Nordic power market split; manufacturing bans; Trade embargos
Environmental	Dormant potential of offshore wind; limited carbon sinks; increasing biodiversity protection	Major energy-related catastrophes; large scale accidents; catastrophic weather events; major new biological impacts arising
Legal	Corporate social responsibility;	Dishonest & illegal behaviour from industry; limited permitting for offshore
Political	Global climate policy shifts; marine spatial plans; political shifts against climate change mitigation; increased interest in energy issues; tax revenues from offshore wind parks; National Defense forces blocking development	National defence force shifts; gas supply interruptions; terrorist attacks; shifts in national independence; political shifts opposing climate change mitigation; conflicts are resolved; war; The EU crashes
Social	Increasing awareness and knowledge of offshore wind; changing patterns in work and free-time travel;	Refugee crises; power supply interruptions; changing values and preferences; travel restrictions

	increasing energy demand; increasing misinformation campaigns and theories; increasing energy poverty; education improvements; new pandemics; increasing conflicts related to onshore energy;	
Technological	Developments in renewable energy and carbon capture technology; improved trust in technology; increased hydrogen use	Major technological advances in energy and green technologies; drastic change in energy supply and production