MOSES

Maritime, Ocean Sector and Ecosystem Sustainability: Fostering Blue Growth in Atlantic Industries

‘Best Management Plan’ Testing of Case Study Sites

Work Package: 8.2

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Contents

Executive summary

This report presents tailored approaches for pursuing blue growth strategies which promote sustainability for maritime sectors. The analyses here are built upon Case Study scenarios from WP7, utilising a common framework (i.e., 'toolkit') that can be further refined based on geographic and socioeconomic aspects relevant to the specific maritime sector and blue growth targets.

Five scenarios are detailed below: harbour development in Belfast, UK (WP7.1), coastal heritage tourism (WP7.2), aquaculture (WP7.3), commercial fishing (WP7.4) and offshore renewable energy (WP7.6). Each scenario demonstrates the utility of developing blue growth strategies within existing legislative, policy, and sectoral requirements. The scenarios reflect back upon relevant EU legislation, policies, and communications as proxies for examining whether outcomes, as Best Management Practices, encourage or enhance sustainability.

The methodologies employed include:

- Transition Management (WP7.1)
- Local Knowledge and Participatory Mapping (WP7.2)
- Spatially Defined Ordered Weight Averaging (WP7.3)
- Sustainability Factor Modelling (WP7.4)
- Driver Interactions (WP7.6)

Whilst the individual outputs of the case studies in Work Package 7 outline policy advice that countries can follow to achieve sustainable blue growth for each of the case study sectors, scenario outputs here reflect lessons learnt from each of the case studies and individual sectors (i.e. ports and shipping, tourism, aquaculture and commercial fishing, offshore renewable energy).

The Maritime Ocean Sector and Ecosystem Sustainability (MOSES) Project is funded by the EU INTERREG Atlantic V Programme (2014 to 2020) and focuses on examining the environmental pressures and impacts from growing maritime sectors and possible transition paths to sustainable blue growth.

1. Background

In line with both ‘Blue Economy’ and ‘Blue Growth’ frameworks, EU Member States have proposed and implemented planning and management strategies which promote sustainable economic development within their exclusive economic zones (EEZs). The frameworks are informed by legislation, notably the Marine Strategy Framework (MSFD) [2008/56/EC] and Maritime Spatial Planning (MSPD) [2014/89/EU] Directives, as well as policies and communications like the Common Fisheries Policy (CFP) [1380/2013] and COM(2020)248, ‘Towards more sustainable fishing in the EU’. Other EU-level directives, as well as national and regional legislation of Member States, contribute further toward sustainability goals.

The MSFD establishes a framework within which Member States shall apply an ecosystem-based approach ‘*to the management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status (GES) and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services by present and future generations*’[1]. Member States are obliged to determine a ‘set of characteristics for GES’[2] from a list of qualitative descriptors,[3] which allows for a more localised, member-led approach. At the same time, a high level of coordination is expected among Member States sharing a marine region or subregion[4] to establish coherent and comparable GES targets[5] and programmes of measures[6]. The MSFD establishes the future legislative space for the MSPD, requiring Member States to consider the utility of ‘spatial and temporal… management measures that influence where and when an activity is allowed to occur’[7].

The MSPD provides the legislative avenue for economic development concerns to work within the MSFD and its ecosystem-centred priorities. Specifically, the MSPD establishes a planning framework ‘aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources’[8]. Under Article 3, the MSPD directs Member States to oblige to MSFD terms and requirements, including the use of an ecosystem-based approach while preparing plans which ‘promote the coexistence of relevant activities and uses’[9]. The MSPD further incorporates MSFD guidance regarding ‘the main cumulative and synergetic effects’[10] assessments of human activities on the marine environment

[1] Directive 2008/56/EC of the European Parliament and of the Council. Article 1(3).
[2] *ibid.* Article 9(1).
[3] *ibid.* Annex I.
[4] *ibid.* Articles 4(1-2); 5(2-3); 9(3).
[5] *ibid.* Article 10.
[6] *ibid.* Article 13(1,3).
[7] *ibid.* Annex VI.
[8] Directive 2014/89/EU of the European Parliament and of the Council. Article 1(1).
[9] *ibid.* Article 5(1).
[10] Directive 2008/56/EC. Article 8(1)(b)(ii).

by requiring Members States to consider 'relevant interactions of activities and uses'[11] that might challenge objectives for cross-sectoral sustainable development set out in Article 5.

Similarly, the CFP provides guidance that '*fishing and aquaculture activities are environmentally sustainable in the long-term and are managed in a way that is consistent with the objectives of achieving economic, social and employment benefits*'[12] of EU-managed fishery resources. This includes the stated need to apply an ecosystem-based approach[13] and affirm principles of sustainability in both wild-capture fisheries[14] and aquaculture[15] as principal conservation measures. These values are reaffirmed by COM(2020)248, '*sustainable fishing and more selective fishing techniques are constituent elements of a sustainable food system that offers value to producers and consumers, and they are essential requirements to meet if we want to protect and restore biodiversity in our natural environment to the benefit of future generations*'[16].

Viewed as a planning and management framework, these legislative and policy instruments are linked by considerations of 'complexity' and 'sustainability', central tenets to blue growth[17,18,19]. Yet, there is little agreement on what sustainability might even be, much less how it might be achieved and maintained. As Munda (2005, 131) states, 'there is no doubt that there is a lot of complexity and fuzziness inherent in the sustainability concept'[20], a recognition later emphasised by Ostrom.[21] For progress to be made in planning and management, science should not seek a reductionist approach that provides a false impression of reducing complexity and uncertainty, but 'dissect and harness complexity' within 'frameworks, theories, and models'[22].

The over-arching objective of WP8 is to develop scenario models constructed from selected case studies presented in WP7 that test various policy outputs at increasing levels of complexity, embracing Ostrom's call to better understand 'their parts of the complex multilevel whole'[23]. These outputs are then assessed in terms of how well they meet MSFD and MSPD obligations. In particular, this approach presents an opportunity to apply Article 8 of the MSFD as a legislative proxy for 'sustainability' and blue growth in assessing planned marine sector growth in terms of

[11] Directive 2014/89/EU. Article 8(2).
[12] Regulation (EU) No 1380/2013 of the European Parliament and of the Council. Article 2(1).
[13] *ibid.* Article 3.
[14] *ibid.* Article 2(2); 7(1).
[15] *ibid.* Article 34(1)(a-e).
[16] COM(2020)248, 9.
[17] United Nations. 2015. Sustainable Development Goals. https://sdgs.un.org/goals [accessed 4/3/21].
[18] Burgess, M.G. *et al.* 2018. Five rules for pragmatic blue growth. *Marine Policy* 87: 331-339.
[19] Eikeset, A.M. *et al.* 2018. What is blue growth? The semantics of "sustainable development" of marine environments. *Marine Policy* 98: 177-179.
[20] Munda, G. 2005. "Measuring sustainability": a multi-criterion framework. *Environment, Development and Sustainability* 7: 117-134.
[21] Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325: 419-422.
[22] *ibid.* 420.
[23] *ibid.*

both ecosystem resilience – through achieving and maintaining GES – and sustainable economic potential. This is particularly important given ongoing academic debates over definitions of sustainability[24].

2. Assessing Blue Growth Sustainability

Annex I of the MSFD provides qualitative descriptors for determining GES while Annex III list ecosystem elements, functions and processes, anthropogenic pressures, uses and human activities that might affect the marine environment. Case studies from WP7 situate relevant environmental characteristics and economic activities described within Annex III of the MSFD as a proxy for achieving sustainability objectives. For the selected WP7 case studies, scenarios were proposed with hypothetical economic growth against concomitant pressures. Scenario testing sought two mutually related outcomes: whether the scenario achieved blue growth targets while maintaining GES. The approach recognises the unique geographic and socioeconomic challenges planning and development face[25] while seeking reliability in outcomes from a range of single-sector to integrated, multi-sector planning and development options. Scenarios were constructed utilising best-available spatial data along with stakeholder input. Sources include state agencies, private and public sectors, and local stakeholders. Habitats and ecosystem information includes qualitative characteristics outlined by Annex III of the MSFD. The following sections summarise scenario outputs.

3. Scenario – Transition Management for Maritime Sectors (UK)

The work presented reflect on the lessons learnt from the Belfast case study (WP7.1) and will describe in detail the key stages involved in the development of a pathway towards sustainable blue growth in key maritime sectors. The guidance will provide an overview of the main transition ideas and practical tools that can be used to develop blue growth pathways and will be a resource for policymakers, resource managers, maritime businesses and marine stakeholders looking to undertake local transitions initiatives.

Specific objectives are:

1) To guide the transition arena on how to develop a vision of sustainable blue growth.
2) To include several recommendations to help local actors to monitor the development of the recommended steps and actions within the first short-term phase of the transition.
3) To demonstrate that the transition management approach can be used for the sustainable blue growth of maritime sectors.

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[24] Moore, J.E. et al. 2017. Developing a comprehensive definition of sustainability. *Implementation Science* 12: e8.
[25] Tödtling, F. and Trippl, M. 2005. One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy* 34: 1203-1219.

Scenario methodology

Belfast Harbour, in Northern Ireland, UK, was selected as a MOSES case study to critically evaluate the potential opportunities and challenges facing the port and shipping sector in transitioning towards more sustainability. The proposed scenario pathway used a multi-level, iterative perspective to map the potential interplay of actions at the landscape, regime and niche levels to identify political windows of opportunity for new institutional developments. This involved engaging with key stakeholders through online surveys, interviews, meetings and workshops. The study was conducted over three phases:

- **Phase I.** Researchers undertook online questionnaires and conducted a half-day Sustainability Workshop at Belfast Harbour with a range of stakeholders. These data collection exercises focused on identifying drivers and barriers to sustainability in Belfast Harbour over the long term. Following a period of analysing the feedback of stakeholders, it was clear that many stakeholders found it difficult to perceive the way future conditions will shape port operations.

- **Phase II.** This led to the exploration of a Future Pathway Analysis (FPA) approach in Phase II. FPA is based upon the concept of 'change' and the differing ways that ports can respond to change. This process involved analysing future events by considering alternative possible outcomes. This work included identifying change drivers likely to impact the development of Belfast Harbour over the short, medium and long-term until 2050 and refining them as part of future pathways that chart consequences of certain decisions and actions. This was examined by engaging with key stakeholders with an interest in the sustainable development of Belfast Harbour using online interviews. This involved: (i) critically analysing change drivers over the short-, medium- and long-term; (ii) examining potential impacts and responses to change drivers over the different timeframes using a future pathway analysis approach; and (iii) analysing how alternative future pathways can respond to change drivers.

- **Phase III.** As part of Phase III, the stakeholder evaluation of the opportunities and weaknesses of each pathway was used to help identify a potential Blue Growth future pathway for ports and shipping. This was based on input from stakeholders, academic literature review as well as international good practice and ultimately helped to refine the transition pathway.

Scenario outputs

The case study revealed that stakeholders found it difficult to comprehend or imagine how future conditions will shape port operations over the long term. Given that Belfast Harbour had already developed its vision for the next 15 years, MOSES focused the work around a Future Pathways Analysis (FPA), emphasising horizon scanning and the application of innovation and technology to achieve and maintain sustainable blue growth[26]. FPA work identifies change drivers likely to impact the development of Belfast Harbour over the short, medium and long-term until 2050 and refining them as part of future pathways that chart consequences of certain decisions and actions. The drivers were categorised into economy, environment, society and technology, the timeframes were 2025; 2035 and 2050 and the pathways represented three different responses to these drivers over the short, medium and long term. These pathways are – 1) stable future, 2) disruption/ resilience and 3) managed innovation.

In terms of selecting the most suitable pathway for Belfast Harbour to follow, most stakeholders felt that a 'managed innovation' approach is necessary to transition to greater sustainability over the longer term. It was emphasised that this approach should foster resilience and adaptability as well as embracing innovation and technology to flexibly steer long-term change. Moving forward this approach will be informed by transition management and horizon scanning.

Scenario recommendations

FPA was presented to a range of Belfast Harbour stakeholders. In terms of future thinking, there is a reluctance to plan beyond the medium-term (15 years). Future thinking to date has often been based around financial and infrastructure planning cycles and risk management. There has also been a lack of planning or foresight in terms of pandemics or major political events such as Brexit, with responses often being reactive instead of proactive.

With regards to drivers of change, the recent COVID-19 pandemic was considered fundamental to recent transformations. This referred to an increase in demand for usable outdoor spaces, improved human experiences instead of service provision, flexibility in work practices, increased cycling and walking facilities. In addition, the increases in businesses trialling innovation, working with urgency and taking risks in an attempt to leapfrog technological advancements were also emphasised. The Belfast Harbour case study also highlighted a number of other fundamental recommendations that are summarised below.

- **Planning for a greener and more just economy.** In terms of imagining other pathways, an economy that is not dependent on growth but on social and planetary boundaries instead was considered an alternative approach that should be considered over the longer term. A world that is 3-4 °C warmer by 2100 because of climate change was also identified as a pathway to be considered in light of current global CO_2 emissions. A third alternative recommended a globally coordinated approach, a pathway illuminated by the unique challenges presented by COVID-19.

- **Greater adaptation to climate change.** Many stakeholders noted that there was a lack of urgency around managing the impacts of climate change and that adaptation was not at the

[26] Within the timeframe of MOSES, the UK departed the EU and its legislative obligations (e.g., MSFD). The UK continues to abide by MSFD-transposed Marine Strategy Regulations 2010 (S.I. 2010/1627) while working to codify necessary language post-Brexit.

forefront of future/ strategic plans. Despite climate change being considered a threat, paradoxically, many stakeholders felt that it presented an opportunity for ports and shipping to decarbonize and seek zero carbon emissions instead of a transition to a low carbon future. Fiscal incentives should be made available by port and local authorities to help with the transition to zero carbon emission.

- **Addition investment into technology.** The investment was considered necessary for training in new technologies, engineering, manufacturing and design. Belfast Harbour was considered an ideal location to maximize this technology revolution with its proximity to critical infrastructure i.e. third level institutions, R&D hubs, airports, multinational companies and businesses. It was also acknowledged that traditional port businesses are dependent on the port authority implementing innovative changes, e.g. new infrastructure, cranes, greener processes and while technology advancements are being introduced, the capacity/ drive to implement these improvements is uncertain.

- **Increased collaboration between more diverse interests.** Globally there is a growing need for greater collaboration between ports, city administrations, academia, businesses and local communities. According to one stakeholder "Governance systems that are built on collaboration, equality, diversity and mixed gender tend to do better than others". In relation to governance, it became apparent in the Belfast Harbour case study that there is uncertainty over the role of the Harbour in contributing to city-wide social and just transition issues, where traditionally the Harbour operated first and foremost as a Trust Port and more recently as a land developer. Some stakeholders felt that there is a lack of diversity in Belfast Harbour in terms of businesses adapting to change and becoming more resilient. This could be attributed to a hesitancy to grasp innovation and take risks as suggested by some stakeholders.

In terms of future application across different maritime sectors, this work presents ideas and practical hints on how to work towards the vision of sustainable blue growth, providing a useful resource for policymakers, coastal managers, maritime industries and groups looking to develop or rejuvenate a local initiative.

4. Scenario – Blue Growth Pathway for Marine Tourism Trail Development (Ireland)

The scenario (WP7.2) examines the blue growth potential for Ireland's coastal tourism sector. As with other case studies prepared by MOSES, the scenario incorporates stakeholder knowledge to shape planning and development options. The work was conducted in Rathmullan, County Donegal (pop. ~500), a village near the northern terminus of Ireland's 2500-km long Wild Atlantic Way (WAW) coastal touring route. The WAW is the longest uninterrupted coastal touring route in the world, boasting scenic views, culture and experiences unique to the island nation. This landscape serves as a fundamental attraction for visitors, and marine and coastal tourism experiences a significant regional distributive effect in providing economic activity to localized areas[27].

Marine and coastal tourism in Ireland has experienced a steady growth since Fáilte Ireland launched the Wild Atlantic Way initiative in 2014. In 2019, an estimated 11.3 million overseas visitors toured Ireland, resulting in revenue of over €5.8 billion[28]. Despite the increase in visitors overall, overnight stays in the border region (including Co. Donegal) represent only 7% of stay share for visitors. This disproportionate distribution of tourism costs and benefits is reflected in the level of engagement a community is able to provide.

With the tourism industry being heavily impacted by the COVID-19 pandemic (both 2020 and 2021 seasons), communities which rely on the WAW tourism traffic have an opportunity to overhaul their approach to tourism engagement and better align its recovery and future development in more sustainable ways. Community-driven tourism opportunities have the potential to rebalance some of the regionally disproportionate costs and benefits, allowing communities to highlight their unique identities.

As part of EU's Blue Growth strategy, Ireland's tourism sector is one of five focus areas with the potential to foster 'a smart, sustainable and inclusive Europe'. But whilst tourism is economically vital for a wide range of coastal regions across the EU Atlantic Arc, the sector faces increasing sustainability challenges due to increasing demand and the accompanying social and environmental consequences for local communities like Rathmullan.

There is therefore a need to establish a comprehensive understanding of the socioeconomic and environmental impacts of coastal tourism, and to accurately estimate the potential impact of new policy measures aimed at developing the sector. A sustainable blue economy is a transformative opportunity to tackle some of our most pressing development challenges and as the largest industry in the European ocean economy, coastal and marine tourism has a key role to play.

Using Rathmullan and the Fanad Peninsula coast of Lough Swilly as a case study, the blue growth pathway for coastal and marine tourism scenario will:

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[27] Fáilte Ireland. 2021. *Key Tourism Facts 2019*, Dublin.
[28] Tourism Ireland. 2020. *Island of Ireland Overseas Tourism Performance: 2019 Facts and Figures*, Dublin.

1) Identify existing and potential areas that might be attractive for outdoor recreation, particularly walking and hiking, where visitors can enjoy the unique scenery, culture and history of Fanad while reducing potential conflict with other uses and economic sectors.
2) Address landscape and niche pressures identified in WP7.2 and support innovations within the sector to minimise these pressures by locating potential areas of interest to focus growth attention.

Scenario methodology

The Lough Swilly catchment (962 km^2) was subdivided into a 220 km^2 study area from Ramelton through Rathmullan and Portsalon, on to Fanad Head, and across Lough Swilly to Inch Island, Buncrana, and Dunree Head. The extent of the study area was informed through stakeholder interviews and participatory mapping exercises with Rathmullan community members (Figure 1), who focused on cultural attractions and outdoor recreation opportunities in and around Fanad. There are five 'Discovery Points' within the study area, including Fanad Head Lighthouse – one of Donegal's three 'Signature Discovery Points' that anchor the WAW – and Ballymastocker Beach, voted in 2019 as the second most beautiful beach in the world.

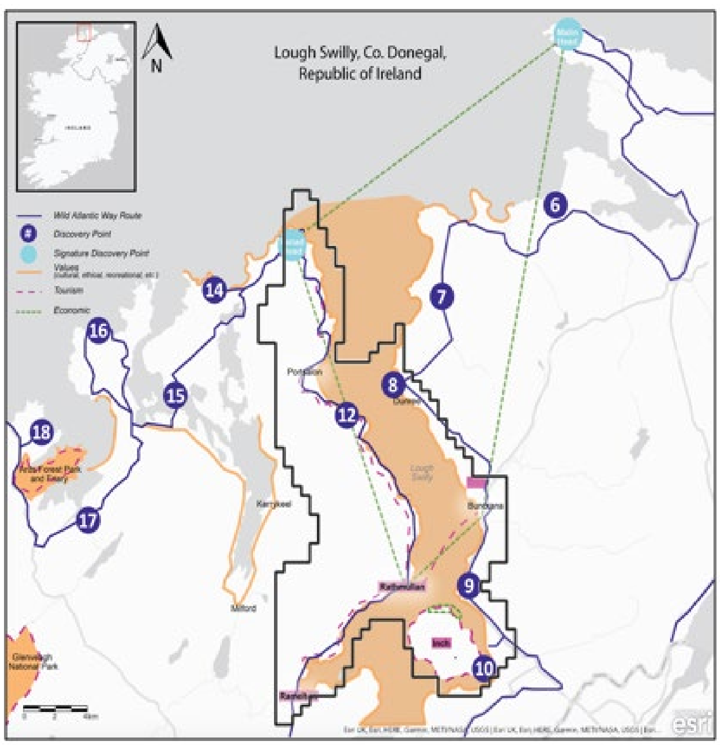

Fig 1. Summarised values map of Lough Swilly catchment, based upon participatory mapping exercises with Rathmullan community members. The 220 km^2 study area is outlined in black while Wild Atlantic Way Discovery Points are numbered according to Fáilte Ireland. The five Discovery Points in the study are: Dunree Head (8), Lisfannon Beach (9), Inch Island (10), Ballymastocker Beach (12), and Fanad Head (13, Signature Discovery Point).

Rathmullan sits along the western shores of Lough Swilly on the Fanad Peninsula, connected to the Inishowen Peninsula by the Rathmullan-Buncrana ferry. The Fanad Peninsula (pop. ~3000) remains largely rural and pastoral, interspersed with forest and a number of ridges, hills and narrow valleys, and small villages. The local populace is relatively older and the entirety of the peninsula is considered to suffer marginal deprivation, as measured by educational attainment and overall employment rates, compared to the national average[29].

Rathmullan is a destination for summer beach holidays, and serves as a central hub for a variety of outdoor recreational pursuits, both on land and water. It is also historically significant, having been the departure point for the famed 'Flight of the Earls' in 1607. A number of historical and cultural attractions surround Rathmullan, including a 16th-century Carmelite monastery, an early 1800s Martello tower and army battery, and the The Devil's Backbone pilgrimage walk along *Cnoc Colbha* (Knockalla Mountain). Lough Swilly itself is popular with recreational anglers and water sports, while also supporting small but vibrant aquaculture and commercial fishery sectors. Other economic sectors include mining, wind energy development, and construction.

Marxan software[30] with the Conservation Land-Use Zoning (CLUZ)[31] software extension was used to conduct complementary ecological and socioeconomic analyses. Marxan is a well-known planning tool whose conceptual core is the 'reserve system' that 'will satisfy a number of ecological, social and economic criteria'[32]. Marxan is most frequently associated with conservation planning and designing marine reserves[33], a strength when considering how best to achieve and maintain GES across a range of habitats and human activities. Marxan possesses functional capacity beyond conservation and nature protection, and has can be successfully applied as a decision support tool for site selection for any defined planning objective[34]. The scenario assessment, as structured for WP8, produces modelled iterations toward blue growth targets (Figure 2)[35]. The iteration that best meets targets in a spatially efficient manner represents the best management plan (BMP) recommendation for blue growth, in line with legislative and policy requirements.

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[29] Donegal County Council. 2016. *The Donegal Local Economic and Community Plan 2016-2022,* Lifford.
[30] Ball, I.R., H.P. Possingham, and M. Watts. 2009. Marxan and relatives: Software for spatial conservation prioritization. In: Moilanen, A., K.A. Wilson, and H.P. Possingham (eds.) *Spatial Conservation Prioritisation: Quantitative Methods and Computational Tools*. Oxford University Press, Oxford, 185-195.
[31] Smith, R.J. 2019. The CLUZ plugin for QGIS: designing conservation area systems and other ecological networks. *Research Ideas and Outcomes* 5: e33510.
[32] Ball, I. and H. Possingham. 2000. Marxan (v1.8.2): Marine Reserve Design Using Spatially Explicit Annealing. Great Barrier Reef Marine Park Authority, Townsville, 70pp.
[33] Smith, R.J., *et al*. 2009. Developing best practice for using Marxan to locate marine protected areas in European waters. *ICES Journal of Marine Science* 66: 188-194.
[34] Göke, C., K. Dahl, and C. Mohn. 2018. Maritime spatial planning supported by systematic site selection: applying Marxan for offshore wind power in the western Baltic Sea. *PLoS ONE* 13: e019432.
[35] Caldow, C., *et al.* 2015. Biogeographic assessments: a framework for information synthesis in marine spatial planning. *Marine Policy* 51: 423-432.

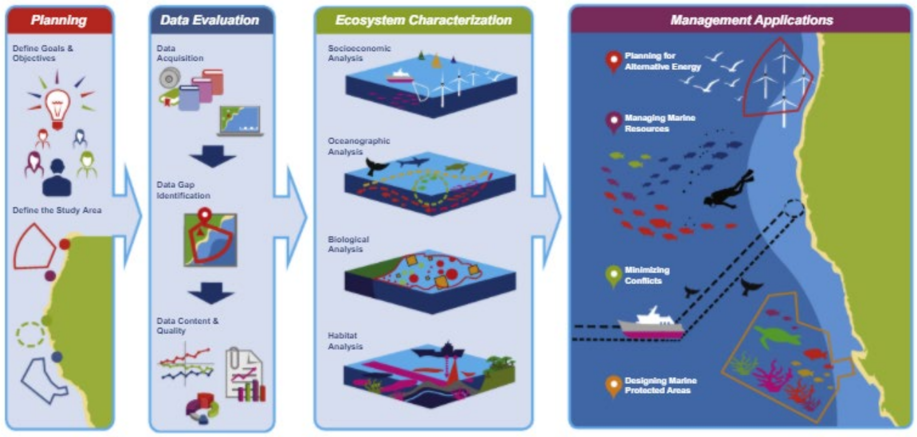

Fig 2. Generalised schematic for scenario assessment. Step 1: Define goals and objectives within the study area; Step 2: Collect and evaluate the quality and breadth of datasets; Step 3: Use QGIS to spatially describe and characterise relevant aspects of the study area, based upon socioeconomic and ecological features; and Step 4: Produce planning recommendations from analytical outputs. From: Caldow et al. (2015).

Scenario outputs

A tourism network map was constructed with Marxan-CLUZ using spatial data within a hierarchical framework (Figure 3). A 0.25 km^2-sized grid produced a 220 km^2 (880 cells) study area covering much of upper Lough Swilly around Rathmullan, Fanad, and the coast of Inishowen.

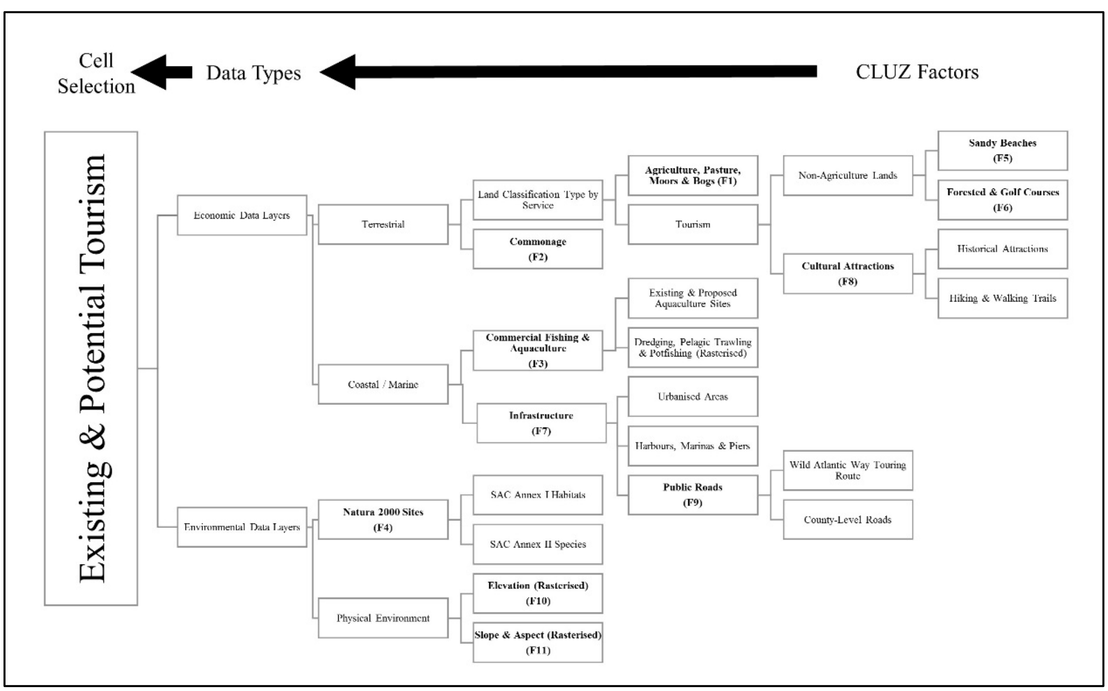

Fig 3. Analytical hierarchy process for construction of tourism network map and scenario assessment, following Caldow et al. (2015). Data layers, including any sub-layers, incorporated into CLUZ planning units are in parenthesis.

Data layer information were incorporated into each grid cell, from which cell selection and prioritisation using the CLUZ extension, was run. Per the CLUZ protocol, each 0.25-km^2 cell is considered a 'planning unit'. Each planning unit works both independently and in relation to neighbours, based on defined characteristics and interactions (i.e. 'penalty factor' in CLUZ), utilising multi-criteria evaluation methods[36]. Factor weights for the scenario were adapted[37] for the included data layers. Results were incorporated into each grid cell, a value recognised by CLUZ as the 'cost' attribute. Cell values were then ordered and ranked within CLUZ to produce a 'summary solution' within Marxan from 'unattractive for tourism' (1) to 'very attractive' (4), as well as all existing cells associated with tourism (5) and a sixth bin flagged as 'unsuitable for tourism' (0). The CLUZ output is based on cell value similarity to existing tourism cells against proximity values for other non-tourism uses. Additional considerations, based on Marxan's Boundary Length and Penalty Factors, affecting planning unit scores include:

- **Positive Factors:** Proximity (within 2 km of a county-level road); Natura 2000 sites; Beach, Golf, and Forest trails; Elevation; Eastern-facing (i.e., Lough Swilly-facing) slopes.
- **Neutral Factors:** Commonage; Urbanised Infrastructure.
- **Negative Factors:** Pasture and Agriculture; Commercial Fishery and Aquaculture Operations.

The results (Figure 4) compose a 74.5 km^2 tourism network where tourism-related activities already exist (190 cells) or are considered to be highly attractive (68 cells), given the interactions of positive factors within those planning unit cells. Conversely, 36 km^2 (144 cells) are considered to be unattractive for tourism. These cells are associated with areas of extensive agriculture, particularly along the less accessible western edge (i.e., inland) of the Lough Swilly catchment. An additional 59 km^2 (236 cells) are unsuitable, 57 km^2 of which are within Lough Swilly. There are three areas of potential interest (from north to south in Figure 3): Murren Hill and Knockalla Mountain, the coastline of Inch Island, and between the Glenalla River and Mill Brook, which both empty into Lough Swilly south of Rathmullan near the village of Ray.

[36] Joerin, F. et al. 2001. Using GIS and outranking multicriteria analysis for land-use suitability assessment. *International Journal of Geographical Information Science* 15: 153-174.
[37] Gimpel, A., et al. 2015. A GIS modelling framework to evaluate marine spatial planning scenarios: co-location of offshore windfarms and aquaculture in the German EEZ. *Marine Policy* 55: 102-115.

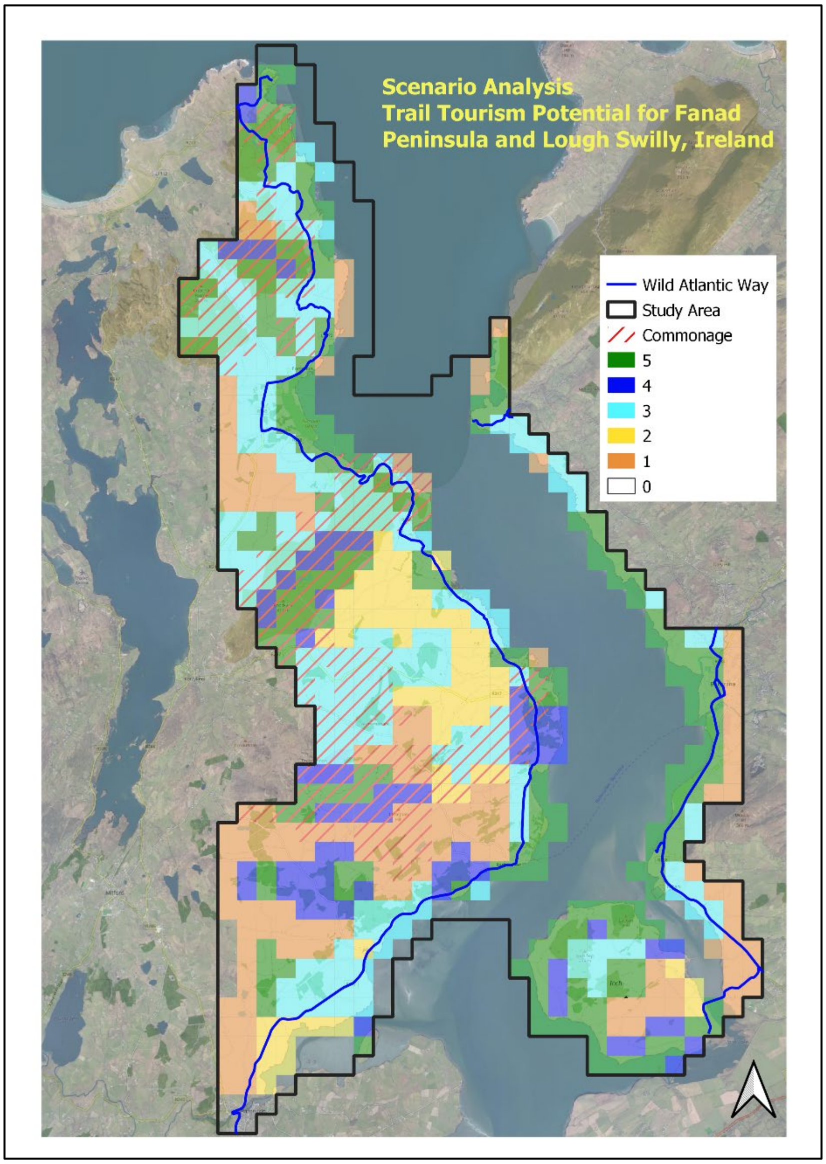

Fig 4. Summed CLUZ solution for blue growth of trail tourism scenario along Lough Swilly and the Fanad Peninsula, Co. Donegal, Ireland.

Table 1. Sum of grid cells from Figure 3 for blue growth in marine tourism within the Fanad Peninsula, Co. Donegal, Ireland.

Unsuitable 0	**Unattractive 1**	**2**	**3**	**Very Attractive 4**	**Existing 5**
236	144	58	184	68	190

Scenario recommendations

Utilising the capabilities of Marxan-CLUZ, the analytical model identified 64.5 km^2 (30% of study area) that is either a current or highly attractive area for Rathmullan-based trail tourism within the Lough Swilly catchment. The network reflects an understanding of environmental and economic inputs while remaining cognizant of MSFD and MSPD requirements. The model produced in Figure 4 prioritises elevated and accessible but undeveloped areas away from agricultural lands and shore-side infrastructures related to commercial aquaculture and fishing. There is a preference as well for proximity to Natura 2000 sites like Inch Island (Lough Swilly SAC and SPA) and Fanad Head (Ballyhoorisky Point to Fanad Head SAC and Horn Head to Fanad Head SPA), which overlay nearly 84 km^2 (335 cells) of the study area. Other potential draws for trail-based tourism include cultural and historical sites along the WAW like Fanad Head Lighthouse, beaches (Ballymastocker, Kinnegar and Rathmullan Bay Beaches), and pilgrimage sites.

The scenario outputs also align with perspectives shared by the Rathmullan community:

- Increase ecotourism ventures for both domestic and international tourists.
- Utilise Lough Swilly as a hub for marine activity in the region, linking land to sea.
- Establish a network of hiking and walking trails with varying length and difficulty.
- Increase specialised local tourism infrastructures (e.g., accommodation, restaurants, etc.)
- Build support for land practices that enhance biodiversity in concert with other uses of commonage (i.e., conservation-led agriculture)[38].

[38] Palm, C., et al. 2014. Conservation agriculture and ecosystem services: an overview. *Agriculture, Ecosystems & Environment* 187: 87-105.

5. Scenario – Blue Growth Pathway for Aquaculture (Portugal)

The proposed scenario (WP7.3) focuses on the Blue Growth potential for sustainable mixed aquaculture development in the Centro Region of Portugal. The National Strategy for the Sea (ENM 2013-2020) identifies aquaculture as one of the five strategic areas of intervention to achieve Blue Growth and calls for the 'promotion of the activity in line with consumption growth and according to a regional development matrix'[39]. With European Maritime and Fisheries Fund (EMFF) support, it is expected that by 2023, the end of the 2014-2020 programming period, an increase in production capacity of 25,000 tons will be achieved[40].

From a spatial planning perspective, above goals will be achieved by the appropriate 'zoning of the identified potential, profitability of platforms and infrastructure and enhancement of the value of the production chain'[41] and by 'facilitating access to space and water that aims to identify spaces with water resources with greater potential for aquaculture and which have lesser environmental impacts, ensuring their compatibility with other uses of those resources'[42].

To deliver these objectives, the Plano de Situação do Ordenamento do Espaço Marítimo Nacional (PSOEM, National Maritime Space Situation Plan) is facilitating the 'identification of potential areas for aquaculture considering in space reserved for the next 10 years, considering the most favourable oceanographic conditions, the distance to the coast and the identification of good practices in the development of the activity' and 'taking into account not only the existing natural conditions but also the interaction of this activity with the other activities that occur in the marine environment'[43].

Scenario objectives to facilitate blue growth in aquaculture in the Centro Region are:

3) Economic Objective: Increase aquaculture production through selection and development of existing and potential aquaculture units as indicated by PSOEM.
4) Environmental Objective: Reduce spatial conflict between incompatible uses of shared, overlapping, and adjacent space; Ensure environmental compatibility by following the standards/thresholds set by marine protection plans of overlapping or adjacent maritime areas.

Scenario methodology

The current area (60.64 km^2) of aquaculture production in Portugal's Centro Region is proposed to be increased over 10 years by 58% (+ 35.25 km^2), giving a total production area of 95.89 km^2.

[39] *National Ocean Strategy (NOS) 2013-2020*. Government of Portugal. Mar-Portugal, 112 pp.
[40] *Strategic Plan for Aquaculture Production (SPAA) in Portugal 2014-2020*. DGRM, 96 pp.
[41] *NOS 2013-2020.*
[42] *SPAA 2014-2020.*
[43] PSOEM 2019.

Areas currently in production are expected to be maintained while accommodating new investment and exploration of potential new areas suitable for aquaculture while remaining aware of other marine uses and sectors. For example, priority areas for the potential development of renewable energy, including an ocean energy test site and two WindFloat Atlantic windfarms with a planned total production of 150MW, have been identified. Blue growth plans will have to navigate how to best balance potential competition for shared space off the Centro Region's coast. It should be noted that the previous round of maritime space planning in 2012 identified 1075 km^2 along the entirety of Portugal's mainland coast that might be suitable for open-sea aquaculture, including approximately 500 km^2 along the Centro coast. Legal uncertainty, however, on how these areas were defined and adequately characterised hindered subsequent development.

Within the Centro Region, there are five potential or existing aquaculture sites operating: off Peniche (bivalves production), a group of 40 lots under licence for bivalve production located in the Área de Produção Aquícola (APA) of Centro, and an experimental unit for assessing Atlantic salmon growth, off the coast of Aveiro. The fourth and the fifth are potential aquaculture sites, identified by PSOEM near Aveiro and Peniche.

Marxan software[44] with the Conservation Land-Use Zoning (CLUZ)[45] software extension was used to conduct complementary ecological and socioeconomic analyses. A fuller description of the approach is provided in Section 4 of this report, Blue Growth Pathway for Marine Tourism Trail Tourism Development (Rathmullan, Co. Donegal, Ireland case study from WP7.2).

Scenario outputs

An aquaculture network map was constructed with Marxan-CLUZ using spatial data within a hierarchical framework (Figure 5). Included in these data are existing and proposed aquaculture sites identified by PSOEM. A 1 km^2-sized grid, extending from shore out to the 100m depth contour, produced a study area of 6000 km^2, composed of 6061 complete and partial grid cells.

[44] Ball, I.R., H.P. Possingham, and M. Watts. 2009. Marxan and relatives: Software for spatial conservation prioritization. In: Moilanen, A., K.A. Wilson, and H.P. Possingham (eds.) *Spatial Conservation Prioritisation: Quantitative Methods and Computational Tools*. Oxford University Press, Oxford, 185-195.
[45] Smith, R.J. 2019. The CLUZ plugin for QGIS: designing conservation area systems and other ecological networks. *Research Ideas and Outcomes* 5: e33510.

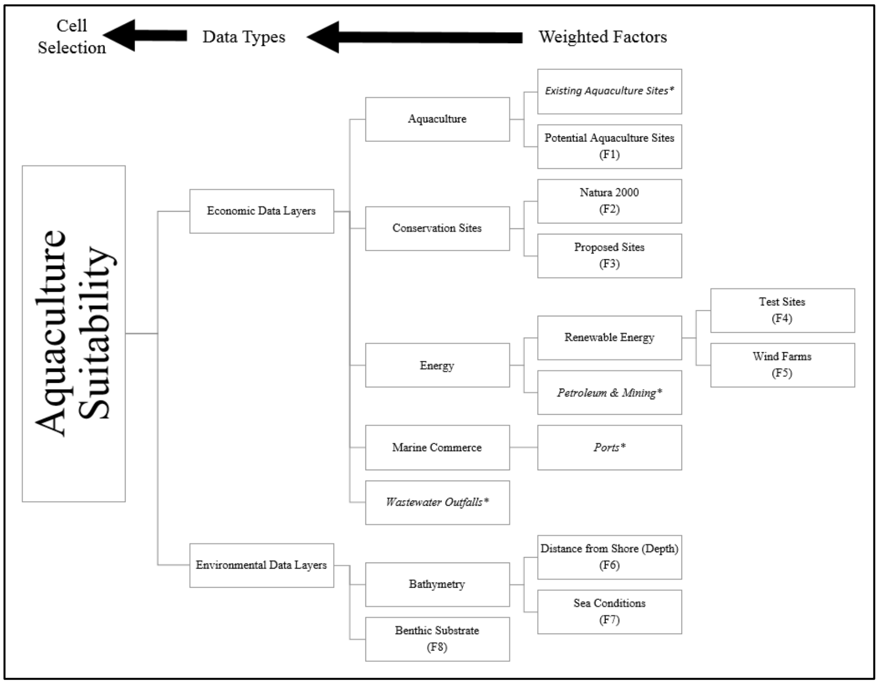

Fig 5. Analytical hierarchy process for construction of aquaculture network map and scenario assessment, following Caldow et al. (2015). Factor codes (for Table 1) are in parenthesis. Those factors excluded from pairwise comparison are indicated with an asterisk.

Data layer information were incorporated into each grid cell, from which cell selection and prioritisation using the CLUZ extension, was run. Per the CLUZ protocol, each 1-km^2 is considered a 'planning unit'. Each planning unit works both independently and in relation to neighbours, based on defined characteristics and interactions (i.e. 'penalty factor' in CLUZ), utilising multi-criteria evaluation methods[46]. Ordered weight averaging (OWA) for cell characteristics and interactions were calculated following[47]:

1) Cells with existing aquaculture must be included in the final network;
2) Cells within 2 km of a port must be excluded in the final network;
3) Cells within 2 km of a wastewater outfall must be excluded in the final network;
4) All other cells were weighted by:

$$OWA_i = \sum_{j-1}^{n} \left(u_j w_j / \sum_{j-1}^{n} u_j w_j \right) z_{ij} \quad (1)$$

[46] Joerin, F. et al. 2001. Using GIS and outranking multicriteria analysis for land-use suitability assessment. *International Journal of Geographical Information Science* 15: 153-174.
[47] Malczewski, J. 2006. Ordered weight averaging with fuzzy quantifiers: GIS-based multicriteria evaluation for land-use suitability analysis. *International Journal of Applied Earth Observation and Geoinformation* 8: 270-277.

where u is a set of regional factor weights compiled through a pair-wise interaction of data layers using both 'join' and 'intersect' modifiers, w is a set of local factor weights reflecting data quality and scale of resolution , and z is produced by reordering the ith grid cell for each factor j in an ascending order. Factor weights for the scenario are adapted[48] for the included data layers, guided by a pairwise comparison matrix (Table 2). Results were then incorporated into each grid cell, a value recognised by CLUZ as the 'cost' attribute. Cell values were then ordered and ranked within CLUZ to produce a 'summary solution' within Marxan from 'lowest priority (1) to 'highest priority' (5) as well as a sixth bin flagged as 'unsuitable' (0).

OWA values reveal that, of the eight considered factors, water depth (F6) provides the greatest weight toward identifying grid cells that best would support aquaculture development[49], followed by other physical features, benthic substrate (F8) and ocean surface conditions (F7). Grid cells that were identified previously by PSOEM as having potential for aquaculture (F1) is similarly positively weighted. Conversely, factors that represent potential 'competitive' uses for the space carry low weights, including Natura 2000 sites (F2), proposed biodiversity and conservation sites (F3), and renewable energy opportunities (F4 and F5).

Table 2. Comparison matrix, with ordered weighted averages of factors for aquaculture site selection. Factors are rated along a continuous scale in a pair-wise consideration of relative factor importance toward support of aquaculture development in the Centro Region. Factor codes are listed in Figure 5.

	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**OWA**
F1	1	3	5	3	1	1/7	1/3	1/3	0.14
F2		1	1	3	1	1	1	1	0.087
F3			1	1	1	1/7	1/3	1/3	0.046
F4				1	1	1/7	1/3	1/3	0.043
F5					1	1/7	1/3	1/3	0.054
F6						1	5	3	0.35
F7							1	1/3	0.13
F8								1	0.16

For the assessment, four spatial data layers were excluded from weighting. As mentioned above, grid cells with existing aquaculture – as provided by PSOEM GIS data – were listed as 'conserved' within CLUZ and were included in the final set. Petroleum and mining data were excluded from the assessment owing to the relative large expanse and subsequent low spatial resolution. Major ports and wastewater outfalls were mapped into the assessment, but were both represented by a 2-

[48] Gimpel, A., et al. 2015. A GIS modelling framework to evaluate marine spatial planning scenarios: co-location of offshore windfarms and aquaculture in the German EEZ. *Marine Policy* 55: 102-115.

[49] The model also established a buffer on all grids adjacent to the coastline.

km buffer where aquaculture could not be developed[50]. With the +58% growth target set, the 96 highest-weighted cells were identified, representing the near-optimal network of cells for blue growth pathway for aquaculture in the Centro Region (Figure 6).

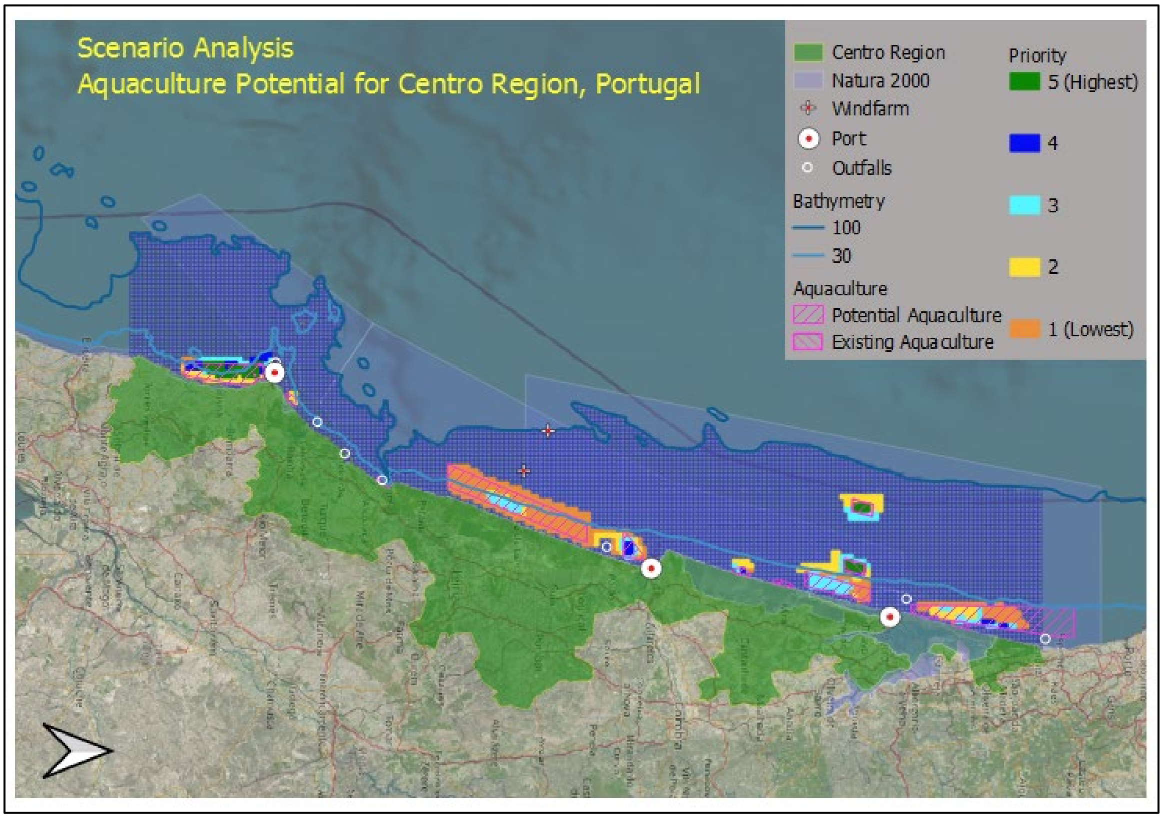

Fig.6. Summed CLUZ solution of aquaculture scenario along the Centro Region, Portugal.

Table 3. Sum of grid cells from Figure 3, by priority bin, for blue growth in aquaculture in the Centro Region, Portugal.

Unsuitable 0	Lowest Priority 1	2	3	4	Highest Priority 5
5353	347	149	116	36	60

[50] FAO. 2017. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Rome, 75 pp.

The network is composed of an efficient network utilising existing and proposed aquaculture sites where PSOEM has established or previously identified its potential development. There are three areas of potential development. From North to South: near Aveiro as well as expansion around existing aquaculture (along the 30m depth contour); immediately south of Figuiera da Foz; and south of Peniche, including an expansion of existing aquaculture operations across a 60-km^2 network of optimal (Bins 4 and 5) grid cells.

Lesser priority cells (Bin 3, light blue in Figure 3) include further expansion of areas described above as well as the proposed offshore site west of Aveiro near the 100m depth contour. The analysis also produced a similar value for cells representing the large proposed aquaculture site south of Figueira da Foz that stretches within 15-km of Nazaré.

As relevant to the analysis is where Marxan-CLUZ identified 'Lowest Priority and 'Unsuitable' grid cells. There were a total of 5700 cells (94% of all cells in the scenario grid) in these two bins. While the vast majority of these cells are located well offshore[51] (i.e., beyond 30-m depth contour), there are cells, including areas identified by PSOEM as potentially suitable for aquaculture. A 4.8-km^2 area identified as potential aquaculture around Nazaré scored poorly owing to buffer restrictions due to proximity to a wastewater outfall and shore. A similarly sized area north of Peniche produced a 5-km^2 grid scored by Marxan-CLUZ at a priority value of two.

Scenario recommendations

The scenario assessment was constructed using a variety of spatially explicit data. Utilising the capabilities of Marxan-CLUZ, the analytical model identified a 36 km^2 (+58%) network of potential in aquaculture that would meet the stated Blue Growth target. The network reflects an understanding of environmental and economic inputs while remaining cognizant of MSFD and MSPD requirements. The model produced in Figure 6 prioritises large swaths of Natura 2000 sites, which overlay approximately 87% of the study area, for conservation rather than aquaculture development. The model identifies areas to expand existing aquaculture within or adjacent to Natura 2000 sites, particularly Peniche-Santa Cruz – where a bivalve aquaculture site is in production – and Maceda Praia da Vieira SACs, and Aveiro-Nazaré SPA.

Lesser priority cells include further expansion of areas described above, as well as a proposed offshore site west of Aveiro near the 100-m depth contour. Importantly, aquaculture expansion south of Figueira da Foz toward within 15-km of Nazaré is largely considered low priority by the assessment, excepting a 14-km^2 area scored within bin three. Similarly, the Marxan-CLUZ output identified an extensive 30 km^2 area (bin three) that is three kilometres inshore of an existing 13-km^2 bivalve aquaculture site immediately south of Aveiro. While this set of grid cells lies within a

[51] *ibid.*

Natura 2000 complex (i.e., Maceda-Praia da Vieira SAC; Aveiro-Nazaré and Ria de Aveiro SPAs) the Marxan-CLUZ output ranks grid cells based on a combination of proximity to shore, and distance from other activities (i.e., ports and wastewater outfalls), as well as considering conservation obligations. Notably, this area is described as having a high sea energy, which may present development challenges for any sector. It is worth noting that the existing Aveiro bivalve aquaculture site, as well as 7-km of high priority (bin four) grid cells are situated outside of this high energy area.

Considerations will be necessary for types and intensity of aquaculture within these Natura 2000 sites, owing to Features of Interest and established conservation objectives. Within the aquaculture development network produced by Marxan-CLUZ, the assessment elevated physical parameters associated with existing aquaculture sites. This includes siting aquaculture operations in mixed sediment and sandy areas, avoiding areas of high sea energy, and balancing the benefits of proximity to ports and shore-side infrastructure while minimising exposure to other claims and uses of shared marine space. Further balancing of development priorities will need to further explore possible interactions between aquaculture development and other sectors. In this scenario, this means better expressing potential spatial incompatibilities between commercial aquaculture and marine renewable energy development. Additionally, efforts to achieve and maintain MSFD GES targets in the coastal zone of the Centro Region should be furthered documented within spatial datasets. This will, in turn, support Portugal’s effort toward meeting MSPD objectives.

6. Scenario – Blue Growth Pathway for Commercial Fishing (Spain)

The work presented reflect on the lessons learnt from the Bay of Biscay, Spain case study (WP7.4), taking into account the impact of Basque's commercial fishing activity on the marine ecosystem and resulting sustainability of fish stocks. The work identifies the economic impacts of commercial fishing on the delivery of ecosystem services.

Specific objectives are:

1) To combine the blue economic pressure index 'P_{kr}', developed in WP5.3 with a Sustainability Factor for targeted fish stocks to assess the sustainable delivery of ecosystem services.
2) To test a scenario based on reducing fuel consumption and therefore the CO_2 emissions by a 10%, by the trawlers and inshore purse seiner segments.
3) To provide recommendations for inshore and offshore fishing fleets that better promote the sustainable delivery of ecosystem services.
4) To expand perceptions of sustainability so that the commercial fishery sector can better align concerns regarding stock status, the carbon footprint of fishing activities, and vulnerability of fishing grounds to ecological damage related to fishing intensity.

The study is composed of five different fishing segments, including inshore and offshore fleets. Inshore fleets target different species, many of which have not been assessed. Offshore fleets target a smaller number of species under a set total allowable catch (TAC), although the total catches may be as high as those of artisanal fisheries. The Basque fishing fleet, like the majority of EU fleets operating in the Atlantic under the Common Fisheries Policy (CFP), are managed to achieve and sustain fish stock sizes at levels best approaching the Maximum Sustainable Yield (MSY). Stocks are scientifically assessed and a quota-based system, based upon a determined TAC, is designed to reach the MSY for fish stocks and fleet segments.

The Sustainability Factor (SF) index takes into account that diversification of the fishing portfolio is not necessarily the best option for achieving fishery sustainability when total allowable catches or other management measures are in place. If the portfolio is changed in response to a raised SF, fishing effort efficiency may fall, in turn resulting in potential higher impacts on the sustainable delivery of ecosystem services through changes within the impact index P_{kr}. Therefore, P_{kr} and SF must be considered jointly in order to analyse the blue growth pathway for commercial fishing in the Bay of Biscay. This deliverable brings together the sustainability approach promoted by the European Commission for all EU fleets, with the pressure impacts of fishing activity on ecosystem services. The blue growth pathway for commercial fisheries necessarily should combine both.

Scenario methodology

This work focus on the case of the Basque fleet operating mainly in the EU Atlantic Area (ICES Areas 8abd, 8c, 7, and 6, Figure 1) but also, in the Indian and Pacific Ocean. We based our work in the impact index P_{kr} developed under the WP5.3, adapting it to account for a SF which is applied to each defined fleet segment. Each fleet segment (i.e., by fishing gear employed) is assessed in isolation then compared against other segments and fishing grounds.

The three inshore fleets:

- **Artisanal fleets** use a variety of passive gears, resulting in a multipurpose catch composition.
- **Purse seiners** deploy a sequential fishery, fishing mackerel, anchovy and sardine using the purse seine, then moving in the summer and autumn to tuna using live bait.
- **Inshore trawlers** target hake, blue whiting, mackerel and horse mackerel within the Cantabrian Sea (ICES Division 8c).

The three offshore fleets:

- **Otter trawlers** target a mix of mainly demersal (e.g., hake, megrim and anglerfish) within the Bay of Biscay, as well as some pelagic species like mackerel and horse mackerel.
- **Pair trawlers** target hake within the Bay of Biscay, accounting for 95% of the total catch.
- **Tropical purse seiners** target several species of tuna (e.g., skipjack, bigeye) in the tropical basins of both the Atlantic and Indian Oceans. Note that for this segment, Pkr is not calculated.

The scenario methodology is fully described within WP5.3 and WP7.4. Fish stocks captured by the Basque fleets are evaluated according to their stock status[52,53,54]. A scoring system was developed according to stock status (Table 3 in WP7.4) while P_{kr} was created by building a sector-pressure-socioeconomic-ecological component linkage[55] which introduces pressure assessment criteria under both socioeconomic and natural capital systems. The socioeconomic system assesses blue growth using traditional business indicators, employment and other proxies along with considerations on the size and scale of fishing effort in terms of those business outputs. The natural capital system incorporates habitat vulnerability and the delivery of a range of ecosystem services (i.e., provisioning, regulating, and supporting services).

[52] ICES. 2019. Report of the working group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE), 3-10 May 2019, Copenhagen. ICES Document CM 2018/ACOM: 12, 642 pp.
[53] ICES. 2019. Report of the working group on southern horse mackerel, anchovy and sardine (WGHANSA), 26-30 June 2019, Copenhagen. ICES Document CM 2019/ACOM: 17, 597 pp.
[54] ISSF. 2021. Status of the world fisheries for tuna. https://iss-foundation.org/about-tuna-status-of-the-stocks.
[55] Knights, A.M. et al. 2013. Identifying common pressure pathways from a complex network of human activities to support ecosystem-based management. *Ecological Applications* 23; 755-765.

Scenario outputs

The scenario (Figure 7) demonstrated that reductions in CO_2 emissions affects SF proportionally. However, this proportion is not the same on each fleet segment, and will depend on fishing pressure that each segment has on the environment relative to their fuel consumption intensity, as embodied by the P_{kr} calculation. For the Basque trawler fleets, a 10% reduction in fuel consumption produces a 9.5% lowered impact on the CO_2 ecosystem service. However, for the purse seiner fleet, which consume less fuel in comparison to trawlers, a 10% reduction in fuel consumption produces only a 5.5% reduction in the CO_2 ecosystem service. On average this reduction in the Basque overall fleet will create a reduction of 4.5% in the total pressure on the environment. This result implies that in the sustainability path of the blue growth of the fishing activity, averages cannot be considered as a reference and that the analysis and therefore the management actions for this sustainable growth have to be considered at fleet segment.

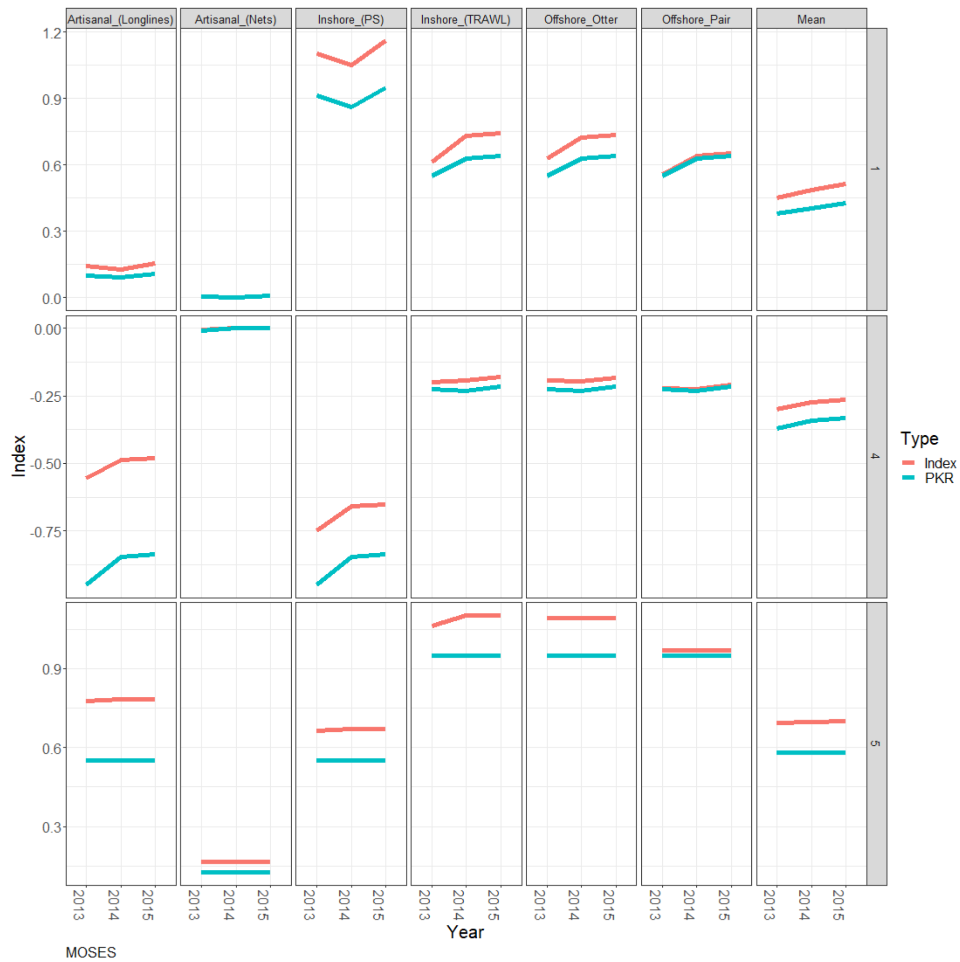

Fig 7. Sustainability index and P_{kr} compared for each segment and ecosystem service impacted by fishing activity (top row: provisioning; middle row: cultural; bottom row: CO_2), Basque commercial fleets, 2013-2015.

Scenario recommendations

- Fleet segment-specific environmental pressures from fishing activities shows differences than an overall fleet analysis. These differences extend how particular ecosystem services respond.
- Both P_{kr} and SF must be considered jointly in order to analyse the blue growth pathway of commercial fishing within the Bay of Biscay.
- The SF is based on the status of stocks conforming to the catch portfolio of each fleet segment. Further diversification of the portfolio may not always improve efficiency[56]. Therefore, when the catch portfolio is changed to increase SF, fishing activity increases to maintain fleet efficiency, leading to a higher impact on some marine ecosystem services.
- Management should be aware of the limits of simplifying a fishery through averaging exercises. Average levels do not provide a good overview on the resulting environmental pressures, at least at the level of specific ecosystem services. This means that fishery management does not have a specific action or metric that can be employed to determine effects of fishing pressure on ecosystem services or benthic habitats. When considering habitat vulnerability, cumulative effects may have less of an impact than any particular pressure, given timing, intensity, duration, and repetition of the pressure.
- Stakeholder perceptions of sustainability remain quite narrowly defined. Stakeholders should be encouraged to expand the definition by jointly considering stock status, fishing intensity, carbon footprint, and impact on the delivery of ecosystem services. In this way, improved future blue growth pathways for commercial fishing may be achieved.

[56] Carmona, I. et al. 2020. Measuring the value of ecosystem-based fishery management using financial portfolio theory. *Ecological Economics* 169: e12.

7. Scenario Assessment – Offshore Renewable Energy (France)

A case study (WP7.6) on offshore renewable energy (ORE) development was conducted in the Atlantic Area of Brittany, France. Outputs focused on providing guidance for best management practices (BMPs) that would lead to a determination on the best mix of fixed wind farms, floating wind farms, and marine current turbines. BMPs will ultimately be influenced by national, regional, local, and technico-economic drivers, as well as Multiannual Energy Programmes (MEPs), which are 5-year energy supply and demand documents[57] that guide France toward achieving carbon neutrality by 2050.

The ORE sector is a set of different technologies designed for electricity generation, and include offshore wind turbines (both fixed foundation and floating), tidal range and tidal stream energy, wave energy converters, ocean thermal energy conversion, and osmotic gradient energy. Of these technologies, only wind power and tidal range energy have matured to a commercial stage. Europe is a world leader in offshore wind energy production, with 75% of the total installed global offshore wind capacity as of 2019. Growth of ORE in Europe is guided by the EC communication on blue growth[58], the Atlantic Action Plan[59], which emphasises the need to accelerate the sustainable deployment of OREs if carbon reduction targets are to be met by 2050.

Specific Objectives are:

1) To determine the best of mix of ORE in Brittany, France, taking into account the levelised cost of energy.
2) To determine the commercial sustainability of ORE given varying levels and types of support.

Scenario methodology

The case study is presented in WP7.6. As France has yet to install any offshore wind capacity, the scenario seeks to recommend blue growth pathways for the sector going forward toward 2050. A central consideration for determining the best mix of ORE is the levelised cost of energy (LCOE), which are the total discounted cost of an energy production plant throughout its lifetime, from investment and installation to dismantling. These drivers shape MEPs in a variety of ways:

[57] Ministère de la Transition écologique et solidaire. *Synthèse. Programmation pluriannuelle de l'énergie, 2019-2023, 2024-2028*. Paris, MTES, 2019.
[58] COM(2012) 494 of 13 September 2011. 'Blue growth opportunities for marine and maritime sustainable growth'.
[59] COM(2013) 279 of 13 May 2013. 'Action plan for a marine strategy in the Atlantic Area: delivering smart, sustainable and inclusive growth'.

National Drivers

- National drivers include the need to meet the MEP objectives for 2028 and further, in terms of renewables capacity. To get to the 2028 step, OREs will compete with onshore technologies.
- National drivers also include technological and commercial competition for developing floating wind solutions. A range of companies, benefitting from state support, are moving toward competition, including in several European states, Japan, China, etc. National projects enable companies to gain experience in this context.

Regional Drivers

- Regional drivers include regions' willingness to mitigate Brittany's major energy deficit and to develop technologies using natural assets and local sources. These include Brittany's strong marine winds and currents and the region's objectives to develop ORE technologies.
- Regional drivers also include the (high or low) potential for ORE industry supporting facility building, principally dedicated terminals in regional ports to facilitate short distance logistics.

Local Drivers

- Local drivers include competition between ports or between local industrial clusters for attracting ORE related equipment and facilities. Such competition may take place in one region or between several regions. Such competition does not seem to be strong in Brittany.
- Local drivers also include competition for coastal space and possible eviction effects whereby local industries such as fisheries or tourism may be negatively impacted by ORE development through space use or environmental disturbances. There is some suggestion that marine aquaculture may be exempt from major impacts from ORE equipment.

Technico-Economic Drivers

- At the present development stage, LCOEs are significantly lower for fixed turbines than for floating ones, while marine current turbines remain very costly. Developing the two latter technologies will require public support.
- In the near future, LCOEs may vary as a result of the increasing size and power of floating turbines: new units reach 14 or 15 MW, as compared to 5 MW a few years ago. This means that fewer turbines will be needed for a given amount of overall power.
- LCOEs do not include any external effect on, and possible compensations due to, impacted activities or communities, which would increase the overall cost of fixed turbines as compared to alternative, less impacting, technologies.

Scenario outputs

The case study identified blue growth pathways for ORE. These pathways are shaped by a number of interrelated aspects that can inform future MEP iterations. Specifically:

- A range of ORE technologies are being developed in the EU but wind energy is, by far, the most important one. Offshore and onshore wind projects have reached a commercial phase, although they still depend on specific support tools such as buy-back prices paid by the grid. Thanks to investment cost decrease, several new projects are expected to be commercially sustainable without any specific support.
- Except tidal plants, other technologies are either less advanced or still costly, and pilot projects critically need public funding. Tidal plants are commercially sustainable but have significant environmental impacts. No project of this type is planned in the EU at the moment but prototypes are being tested, especially in the UK.
- Owing to France's lag in terms of offshore wind development, related projects are currently in a start-up phase.
- The short term steps of a pathway for Brittany are in line with the current MEP and cannot be changed.
- BMPs for ORE in Brittany must therefore be discussed terms of medium- and long-term steps.

Table 3. Short-term steps of ORE development in Brittany.

ORE Projects	Location	Pressures on Maritime and Coastal Activities
Fixed wind farm, 500 MW, 62 turbines, 75 sq.km, 16.3 km to the shore. Construction due to start 2021, operation due to start 2023.	Brittany, North Coast	Regulated access to the waters of the farm Impacts on fisheries Installation of an onshore station Visual impacts
Eolfi – Floating pilot farms. Three 9.5 MW units, 60m depth. Installation in 2021. Operation due to start 2022.	Brittany, South Coast	Pilot project *Impacts to be studied.*
Two floating wind farm projects, due to be in operation by 2030. A 250 MW project tendered in 2021, followed by a 500 MW project due to be tendered in 2024.	Brittany, South Coast	Regulated access to the waters of farms Fisheries prohibited in the area Sanctuary effects Installation of an onshore station Installation of several marine and seabed cables Visual impacts
Sabella D10 - Submarine current turbine pilot project : a second prototype to be installed and tested, similar to the 500 kW prototype in operation	Brittany, West Coast	Economic impacts due to high investment cost Unknown local impacts on fish Unknown local impacts on currents if many units are installed

Medium-term steps for ORE in France, and the specific case of Brittany

As the MEP procedure is in a starting phase, two programmes, 2018-2023 and 2023-2028, have been jointly planned. Seen from today, the scope for ORE technologies for Brittany is limited, for environmental impact and investment and maintenance cost reasons. Brittany's ORE projects are less determined by regional electricity demand than by MEPs and the local supply potential in terms of technical feasibility, costs and acceptability. Over the medium-term:

- Fixed wind farms have a higher profitability potential but, due to water depth conditions, must be installed close to the shore, with inevitable impacts on coastal populations, fisheries and tourism.
- Floating wind farms give a broader location flexibility and can be installed far away from the shore, but with higher installation and maintenance costs. Impacts on fisheries and tourism are not avoided. However, fishing sanctuary effects may be beneficial to biodiversity.
- Marine current turbines have apparently neither tourism nor fisheries impacts but have much higher investment and maintenance costs. They are not profitable at the moment and critically need state support. Brittany offers exceptional marine current spots that can be exploited using such technology.

Table 4. Main medium-term steps for ORE development in France.

<table>
<tr><th></th><th>2021-2022</th><th>2023</th><th>After 2024</th><th>2028</th></tr>
<tr><td>Renewables installed capacity objectives</td><td></td><td>73.5 GW</td><td></td><td>118 GW</td></tr>
<tr><td>Offshore wind capacity objectives</td><td></td><td>2.4 GW</td><td></td><td>5.2 to 6.2 GW</td></tr>
<tr><td>Tendering dates for fixed wind turbines</td><td>500 to 1,000 MW, South Atlantic, LCOE: EUR 60/MWh</td><td>1,000 MW, LCOE: EUR 50/MWh</td><td rowspan="2">1,000 MW/year, fixed or floating, depending on prices and sites, with tendering price targets nearing fixed wind market prices.</td><td></td></tr>
<tr><td>Tendering dates for floating wind turbines</td><td>250 MW, South Brittany, LCOE : EUR 120/MWh. 500 MW, Mediterranean, LCOE : EUR 110/MWh</td><td></td><td></td></tr>
<tr><td>Marine current turbines</td><td colspan="4">No tender during the MEP period. The running of pilot demonstrators and the performance of the technology will be monitored.</td></tr>
</table>

Source: Ministère de la Transition écologique et solidaire. *Synthèse. Programmation pluriannuelle de l'énergie, 2019-2023, 2024-2028*. Paris, MTES, 2019.

Table 5 summarises the assessment of the three main technological options. It is based on the WP7.6 case study on ORE in Brittany, the abovementioned drivers and Table 4. Finally, Table 5 includes the outline of a BMP for Brittany. This BMP has some relevance only after 2024 (medium- and long-term investment decisions).

Table 5. ORE technology options for Brittany's BMP.

Drivers and Metrics	Fixed Wind Farms	Floating Wind Farms	Marine Current Turbines
Technology readiness level*	9	7 to 8	7
Estimated overall unit costs (LCOEs)	~EUR 50/MWh	~EUR 110/MWh	~EUR 300 to 500/MWh
MEP objectives	Major technology to meet carbon neutrality objectives	Technology used depending on tender prices and sites, with costs progressively nearing those of fixed farms	Foreseen to remain at prototype stage
Brittany Region's priorities		Objective to take a lead position in floating wind technology competition	Objective to take advantage of natural assets and energy potential
Regional facilities and logistics means	Port of Brest marine energy terminal for logistics, construction and maintenance of ORE equipment		
Pressure on other coastal activities	Impacts on coastal populations, tourism and potentially fisheries. More feasible option for English Channel waters.	Potential impacts on fisheries Mitigated impacts on tourism More preferable option for Brittany and Atlantic waters	Sites in strong current zones No significant impacts on fisheries, aquaculture and tourism
Outline of a BMP for Brittany	**Low priority**	**High priority** ~1,000 to 1,500 MW calls for tender until 2030	**Medium priority** 500 to 1,500 MW until 2030

*EU version of TRL from original definition by the US Department of Defense. Source: European Commission, C(2014)4995, 22 July 2014.

Scenario recommendations

If it is assumed that investments are largely determined until 2024, a BMP should be examined in terms of investment decisions to be taken after this date. It must be kept in mind that this BMP proposal is perhaps environmentally acceptable but certainly costly. If similar options were to be taken for the other coastal regions of the country, this would lead to high overall energy costs, largely above those of fixed wind and conventional electricity plants.

Given that the MEP leave some scope for the location of wind projects, and subject to state and region support being made available with sufficient amounts, the case study recommendations for developing a blue growth pathway for ORE in Brittany are:

- A BMP for Brittany should prioritise floating wind farms and, to a lesser extent, marine current turbines.
- Planning for floating wind farm should pursue a capacity of 1500 MW. A 750 MW capacity floating wind farm off the south coast of Brittany is already being discussed, with 250 MW already being secured for development. As the growth in ORE capacity would be through a mature sector, such investment would carry small risk.
- In terms of marine current turbines, 500 to 1000 MW of capacity should be put out to tender, based on the Brittany Region's objectives, but within a wide margin. The reason for that lies in the unknowns of the technology in terms of LCOE decrease as a result of series effects as well as in terms of public support being available.