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DELIVERABLE D2.1

D2.1 – Description of the Social Ecological Systems in the Three Demonstrators

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Executive Summary

SEADOTs (Social-Ecological Ocean Management Applications using Digital Ocean Twins) aims to advance holistic, just and sustainable ocean management by integrating predictive socio-ecological components into comprehensive Digital Ocean Twins (DOTs). These DOTs will integrate human activities into digital twins of the ocean (DTOs) by combining social-ecological and socio-economic data with physical ocean and ecosystem data, and a variety of models. By developing and demonstrating applications in the Norwegian North Sea, the Southern North Sea and the Baltic Sea, SEADOTs aims to facilitate and inform political decision making, marine spatial planning and adaptive management to help safeguard ocean ecosystems, promote sustainable resource use, and enhance social and economic well-being.

The project builds synergies with EU Mission and Green Deal projects including Iliad, EDITO, OLAMUR and CLIMAREST, and demonstrates Ocean Management Applications with Digital Ocean Twins on the EU Digital Twin Ocean infrastructure and other platforms for socio-ecological, socio-economic and political endpoints. A key ambition is to provide spatially-explicit social-ecological data beyond the project's lifetime and to strengthen long-term data interoperability.

This deliverable (D2.1, Description of the social ecological systems of the three demonstrators) applies a common theoretical grounding to understanding and explicating the social-ecological systems (SES) of the three demonstrator cases, drawn from Elinor Ostrom and colleagues' seminal work developing the SES framework. Using the framework, we systematically describe the resource system, resource units, actors, governance arrangements, and key interactions shaping system outcomes. This common grounding further provides a foundation for the development of demonstrator-specific models for input into SEADOTs digital twins (D2.2, forthcoming); in this context, D2.1 connects the SES of each case to the data that will feed into the modelled SES relationships and identifies where data are lacking. The SEADOTs app is under development to provide updating data to address data poverty re: perceptions and social acceptance.

In the Swedish Baltic case, SEADOTs partners apply the SES framework to analyze interactions between pelagic fisheries and offshore wind farm (OWF) development in the central Baltic Sea, with a focus on waters around Gotland. The analysis describes interactions between mobile fisheries operating across large spatial scales and multilevel governance arrangements, including fisheries management and offshore energy planning. By making cross-scale interactions and cumulative pressures explicit, the SES framing supports structured analysis of fisheries–OWF trade-offs and discussions on integrated MSP.

In the German Bight case, partners use the SES framework to analyze the possibility of establishing low-trophic aquaculture at an existing OWF, Meerwind Sud | Ost. The analysis describes interactions between future climate change, wind power generation, and potential aquaculture growth rates, including analysis of future profitability of both wind and aquaculture. In this case, the SES framing supports precise delineation of opportunities for multiple sectors to cooperate to achieve economic sustainability, moving beyond spatial conflict and into true co-existence.

In the Norwegian North Sea case, partners apply the SES framework to analyze interactions between the social sustainability of Norway's smallest municipality (Utsira) and the proposed development of the world's largest floating OWF at the nearby Utsira Nord site. The analysis describes connections between social sustainability of the community of Utsira, social perceptions of development, and potential OWF impacts on ecosystems and cultural heritage. Relatedly, this case engages with the ethical implications of development and discourse on just transitions.

D2.1 links to WP1 through identification of data sources and by laying groundwork for formalizing data flows (systematizing and documenting data inputs and outputs to and from models and DOTs). The deliverable links to other tasks in WP2 by describing the SES systems within which modelled relationships occur (T2.2), and by identifying variables and outcomes for which indicators will need to be developed (T2.3). The deliverable contributes to WP3 and WP5 by identifying specific actors and governance organizations of relevance to each case, thereby identifying both sets of potential DOT users and potential targets of training and communications and dissemination activities. Lastly, D2.1 links to WP4 by setting the conditions and variables that underpin demonstrator testing and validation.

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Definitions, Acronyms and Abbreviations

Acronym/Abbreviation	Title
WP	Work Package
DOT	Digital Ocean Twin
SES	Social-Ecological System
OWF	Offshore Wind Farm
EU CFP	EU Common Fisheries Policy
MSP	Marine Spatial Planning
MPA	Marine Protected Area
ICES	International Council for the Exploration of the Sea
MW/MWh	Megawatt/Megawatt hour
GW/GWh	Gigawatt/Gigawatt hour
TW/TWh	Terawatt/Terawatt hour

1 Introduction

1.1 Objectives of the deliverable

This deliverable (D2.1) explores how certain components of social-ecological systems (SES) contribute to addressing SES questions related to offshore wind. Although this deliverable identifies and defines these components according to the specific research questions being examined in SEADOTs, they address global issues associated with offshore wind development, namely: competing uses and access to ocean areas, including ramifications of offshore wind development for existing activities (Baltic demonstrator case); opportunities, logistics, and potential benefits from co-location of other industries with existing offshore wind infrastructure (Southern North Sea demonstrator case); and social perceptions and acceptance, and community sustainability, in coastal communities impacted by offshore wind development (Norwegian North Sea demonstrator case).

Within SEADOTs, D2.1 lays the foundation for the work in WP2 by presenting Elinor Ostrom and collaborators' social-ecological system (SES) framework (McGinnis et al., 2014; Ostrom, 2007, 2009) and applying it to the three SEADOTs demonstrator cases. Applying the SES framework facilitates comparability of diverse demonstrator contexts, ensures a structured, systematic understanding of complex cases, and clarifies connections between the SES, data, and the applied models under development for input into the Digital Ocean Twins (DOTs). This shared foundation for understanding the three cases integrates the work of SEADOTs partners into a cohesive whole despite partners' different focus areas and variety of approaches to DOT development. In so doing, D2.1 provides a living reference document (to be updated in D2.4) that allows the demonstrator cases, work packages and partners to share a language and a frame of reference.

D2.1 also furthers the work begun in D1.1 by mapping data sources to SES variables across the three cases, with a focus on data necessary to model the relationships reflected by the three DOTs under development. In this context, D2.1 also identifies how the SEADOTs app will be used for data collection. Lastly, as part of the exploration of the Norwegian North Sea case, D2.1 engages with ethical questions about the distribution of costs and benefits of wind power development through a deep dive into community perceptions, hopes, and fears in Utsira, Norway.

1.2 Structure of the deliverable

Section 1 of this deliverable provides the objectives and previews the structure of the document. Section 2 orients the reader to the SES framework. Section 3 applies the SES framework to each case. In-depth examination of each demonstrator case's SES 1) tells the larger story of the case; 2) allows identification of the most relevant components of the SES, given the lead partners' research focus; and 3) allows specific - and where appropriate - consistent variable operationalization. Section 4 takes the research foci identified in Section 3, and the data identification work begun in Deliverable 1.1, to

connect each relevant variable to the data source that will provide the data underpinning the development of each DOT. We conclude with a summary of results in Section 5.

2 The SES Framework

This section presents an overview of Ostrom and colleagues' SES framework (McGinnis et al., 2014; Ostrom, 2007, 2009). In general, the social-ecological system approach delineates social and ecological processes, components, and actors that are connected via multiple interactions. All natural resource systems can be considered social ecological systems, due to close coupling between natural systems, the ecosystem benefits humans derive, and the ecosystem effects of human activities.

The SES framework has been widely applied as a structured way to understand complex interlinkages between human resource use, human institutions, natural resources, and bio-geophysical systems (Partelow, 2018) across varied geographies and research domains (e.g., Crosman et al., 2019; Du et al., 2025; Dwyer et al., 2018). The framework splits social-ecological systems into four primary domains (Figure 1): resource units, resource system, actors and governance system. Resource Units (RU) are the resources that humans extract or use from the environment, defined by characteristics including their distribution in space and time. Resource units are embedded in Resource Systems (RS), spatially explicit areas where resource extraction and/or use takes place, with characteristics including a specific location and more-or-less clear boundaries. Resource Units also connect to Actors (A), the people who extract or use the resources in question. Actors are characterized by, for example, their history of resource use and their shared norms. Earlier work (Ostrom, 2007) conceived of this category as Users – only those actually extracting resources – but here we follow later work that expands Users to Actors and includes those who extract, use or consume resource units (McGinnis et al., 2014). Actors and their activities are governed by Governance Systems (GS), which include the organizations and institutions governing or influencing governance of the resource system and extractive/use activities. Governance systems are also influenced by the constraints imposed by the resource systems and the characteristics of the resource units. Actors further influence each of these domains by their own actions. Indeed, the framework includes Action Situations – Interactions (I) and Outcomes (O) – to explicitly identify the links between domains – links like harvesting, lobbying, networking, and conflict, and outcomes like environmental and social sustainability. Lastly, the whole SES is influenced both by Related Ecosystems (ECO) - the larger ecosystems in which the focal resource system is embedded – and the broader Social, Economic and Political Settings (S) in which governance and actor behavior take place.

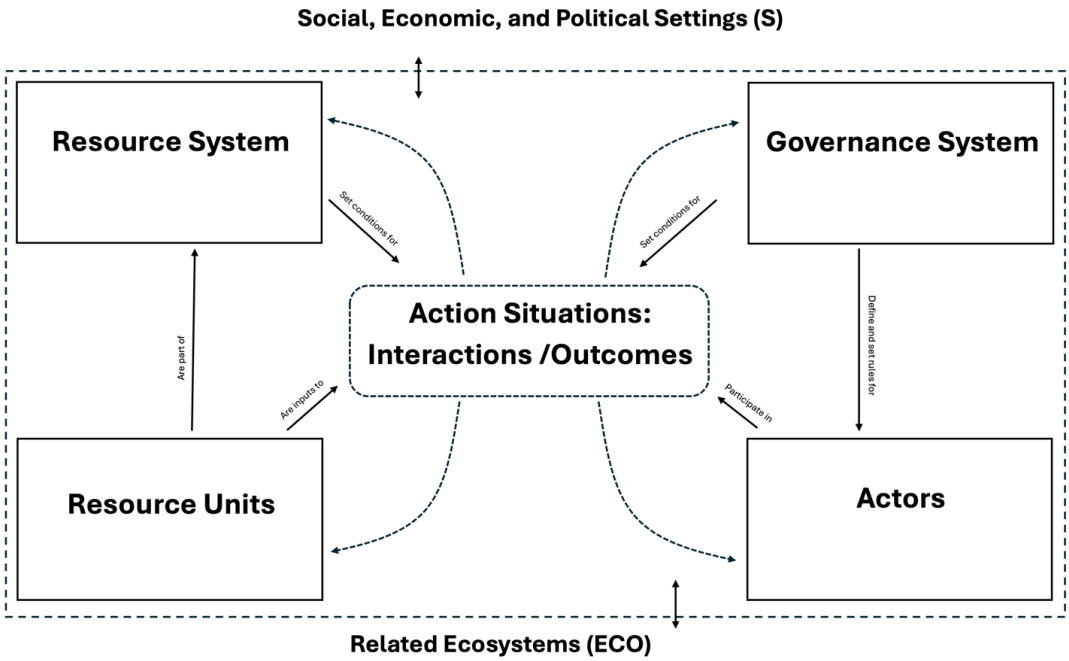


Figure 1 General schematic of the Social-Ecological Systems Framework (adapted from McGinnis and Ostrom 2014)

Applications of the SES framework vary widely in the subject areas of focus, the system domains of greatest interest, and the operationalization of variables (Partelow, 2018). Indeed, the generality and flexibility of the framework are among its greatest strengths (McGinnis et al., 2014). Across SEADOTs' diverse demonstrator cases, the common conceptual grounding provided by the SES contributes to consistent operationalization of shared variables, consistent use of data sources, and comparability across the cases.

3 Demonstrator Cases

This section applies the SES framework to the three SEADOTs cases (the Baltic (Central Baltic), the Southern North Sea (German Bight), and the Norwegian North Sea (Utsira)). The cases share a focus on offshore wind energy production, although the research questions, variables and interactions of interest vary. The Baltic case focuses on fisheries and offshore wind trade-offs; the Southern North Sea case focuses on co-location of aquaculture and offshore wind; and the Norwegian North Sea case focuses on social acceptance of offshore wind development and sustainability of affected communities.

3.1 The Baltic (Central Baltic)

Trade-offs between pelagic fisheries and offshore wind development

The Central Baltic demonstrator case examines interactions between pelagic fisheries and offshore wind farm (OWF) development (Figure 2). For this case, the SES provides a structured approach to explore ecological dynamics, governance arrangements, actor behavior, and their interactions in a context characterized by environmental change and increasing competition for ocean space (McGinnis & Ostrom, 2014; Nagel & Partelow, 2022; Reckermann et al., 2022).

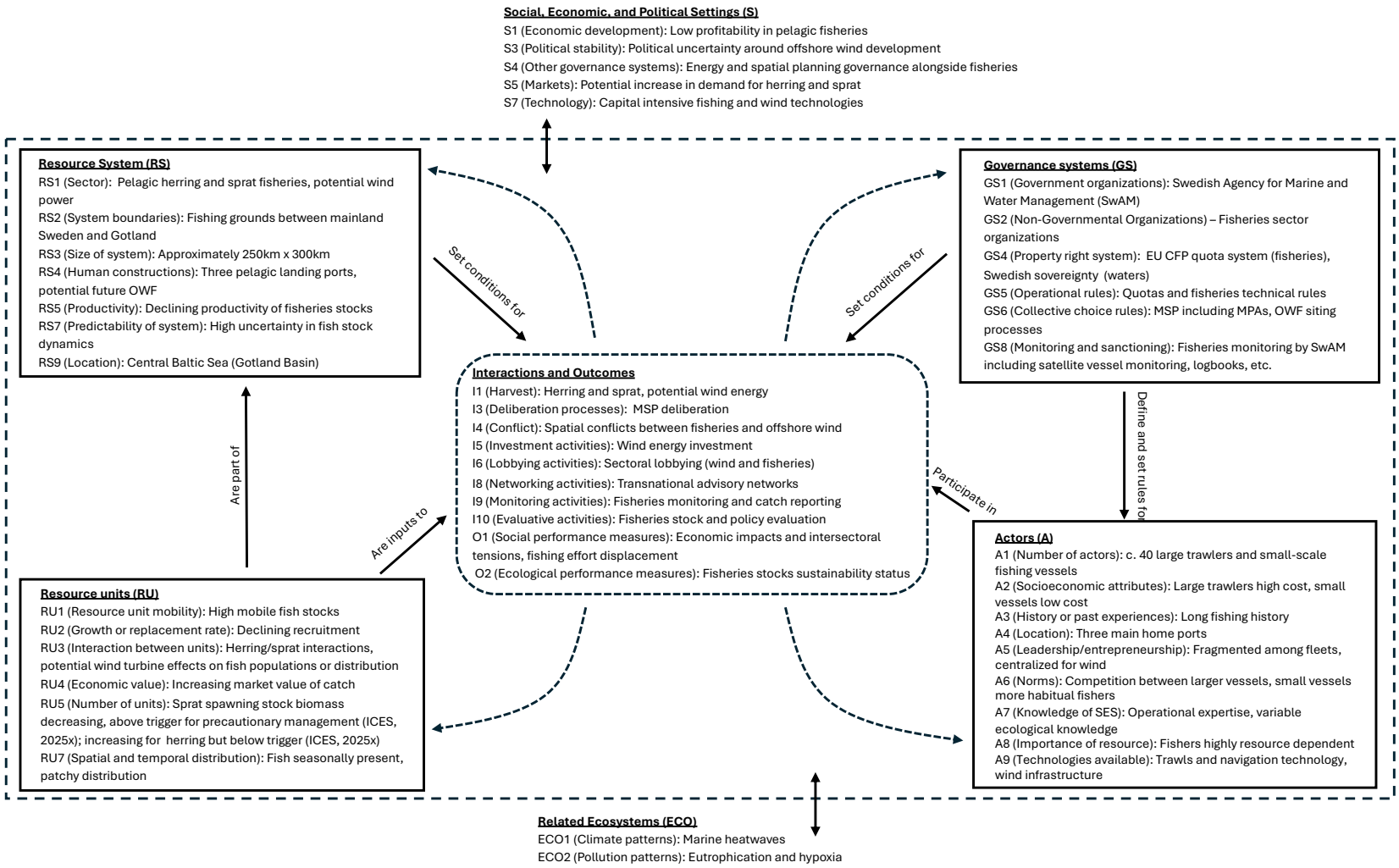


Figure 2 Conceptual model of the SES of the Baltic case

Resource system (RS)
The resource system of the Central Baltic case comprises pelagic fishing grounds in the western Gotland basin, spanning the waters between mainland Sweden and Gotland. System boundaries are defined by the administrative borders and planned OWF around Gotland (~latitude 56-59, ~longitude 16-21), covering approximately 250 × 300 km^2 (Figure 3). The area also includes three key landing ports as well as the locations of the proposed wind farms.

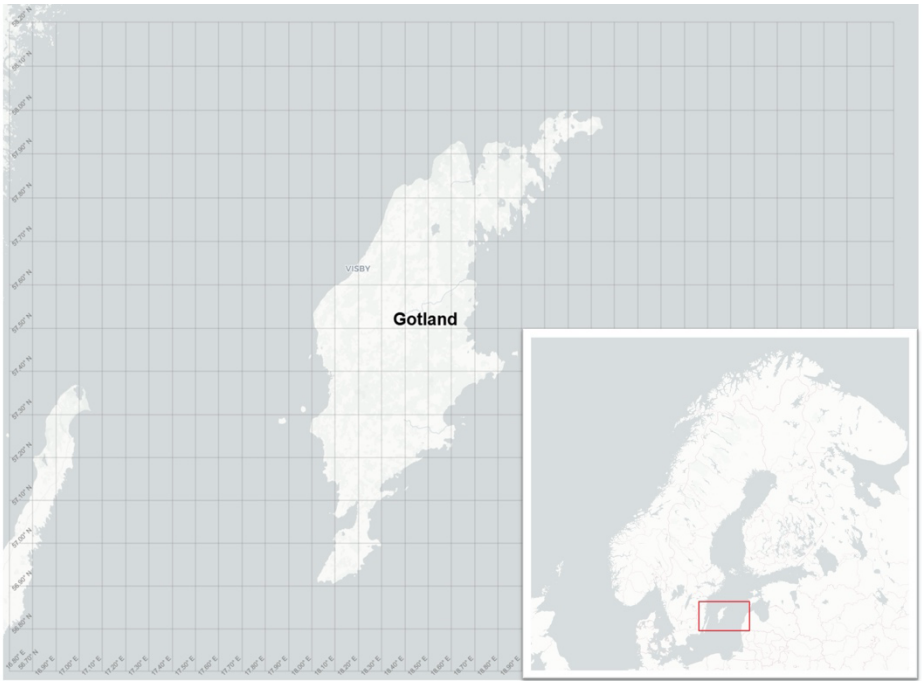


Figure 3 The case study area for the Baltic case

The resource system includes herring and sprat populations. The size and productivity of these fish stocks have declined over time. ICES stock assessments indicate reduced biomass and recruitment for both herring and sprat in several Baltic sub-basins, with growing uncertainty in future stock projections under changing climatic conditions (ICES, 2024, 2025a, 2025c). These dynamics reduce predictability of the herring and sprat resource system and complicate both management and strategic decision-making.

Resource units (RU)
The primary resource units are herring and sprat catch (caught as a mixed fishery). The total allowable catch recommendations from ICES in 2025 were: 125,344 tons for central Balic herring (ICES subdivisions 25-28, excluding 28.1), and 164,947 tons for sprat (note that sprat is managed as a single stock across ICES subdivisions 22-33, so not all of the sprat catch will be captured within the case resource system) ('Overview - ICES advice on Baltic Sea fishing opportunities', 2025). These species are highly mobile, schooling pelagic fish with spatial and temporal distributions that vary seasonally and interannually, typically across ranges of 100–300 km (ICES, 2024).

At this resource-unit level, economic value is expressed through market prices for pelagic fish. Broader economic outcomes—such as profitability or value added—

emerge only through interactions between harvesting intensity, spatial access, fuel costs, and regulatory constraints, rather than being intrinsic properties of the resource units themselves.

Secondary (potential/future) resource units include the wind energy produced in the event of future wind development. Three parks will potentially be developed: Aurora, planning for 370 turbines generating ca. 24 TWh electricity per year; Ran, 90–121 turbines generating ca. 8 TWh electricity per year; and Pleione, 42–70 turbines generating ca. 5 TWh electricity per year (Region Gotland, 2024).

Actors (A)
The main resource users of interest are vessels comprising large-scale pelagic fishing fleets, consisting of approximately 200 trawlers operating under multiple national flags, including those of Sweden, Finland, Poland, Denmark, and Germany (STECF, 2024). These fleets are capital intensive and strongly reliant on continued access to the fishing grounds. Pelagic fishing in the region has a long history, resulting in accumulated operational knowledge and strong path dependency in spatial fishing practices. Small-scale vessels are also important for socio-cultural reasons and are struggling to maintain their fishing activities due to declining fish stocks, high costs, and unfavorable regulations (Björkvik et al., 2020).

Offshore wind developers are another influential actor group; these actors are typically centralized and corporate. Both fisheries organizations and offshore wind developers actively engage in lobbying and consultation processes at national and EU levels, seeking to influence marine spatial planning and permitting outcomes (Bengtsson, 2025; Hooper et al., 2015; Orach et al., 2017).

Governance system (GS)
Pelagic fisheries and offshore wind farms (OWFs) in Sweden are governed through multi-level, sector-specific institutional arrangements. Fisheries are regulated under the EU Common Fisheries Policy (European Commission, 2025) and implemented nationally by the Swedish Agency for Marine and Water Management (HaV), which is responsible for quota allocation, fisheries regulations, and marine spatial planning, with monitoring and enforcement carried out in cooperation with the Swedish Coast Guard (HaV, 2023). Scientific assessment of stock status and advice on harvest levels is provided by ICES.

Offshore wind development follows a separate governance pathway, with national energy policy set by the Government of Sweden and project-level permits issued under the Environmental Code by the Land and Environment Courts with support from relevant national authorities. At the subnational level, the County Administrative Board of Gotland coordinates consultation and environmental assessment processes, while Region Gotland participates in regional development and coastal planning. Marine spatial planning provides a formal arena where fisheries and offshore wind interests are considered alongside other marine uses (Janßen et al., 2018).

Social, economic, and political setting (S)

The social and economic context of the SES is shaped by persistent economic pressure in the Baltic pelagic fishing sector. Herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) fisheries have experienced declining profitability in recent decades, driven by reduced stock productivity, fluctuating markets, and rising operational costs, particularly fuel costs (ICES, 2024; JRC, 2024). These pressures heighten the sensitivity of fishing fleets to additional spatial constraints and increase vulnerability to displacement.

Offshore wind development in the Central Baltic takes place within a contested political setting. While offshore wind is central to European and national energy transition strategies, recent years have seen increasing hesitation and delays in Swedish offshore wind permitting, linked to security concerns, environmental considerations, and conflicts with existing marine uses (STECF, 2024; Swedish Government, 2024). Fisheries governance and energy governance operate through partly separate institutional systems, creating a context in which sectoral objectives are not fully aligned. Market dynamics further complicate this setting, as future demand for small pelagic species for feed and food may increase, which could lead to intensifying pressure on the already stressed stocks (HaV, 2023).

Related ecosystems (ECO)
Related ecosystems include ecological processes operating at broader spatial and temporal scales that have significant influence on the SES being studied. In the Baltic Sea, influences of interest include a) increased frequency and intensity of marine heatwaves, reflected in long-term climate warming and rising sea surface temperatures, and b) hypoxia and eutrophication. Together, these ecological drivers exert substantial pressure on pelagic fish populations and ecosystem functioning, shaping stock productivity and spatial availability of the resource (Dutheil et al., 2022; Reckermann et al., 2022; Viitasalo et al., 2022).

Interactions (I)
Core interactions include extraction of fish from the ecosystem, spatial planning decisions, and cross-sectoral competition for marine space. Offshore wind farms introduce spatial exclusions that displace fishing effort, increase travel distances, and raise fuel costs – mechanisms consistently identified in the literature as primary pathways through which OWFs affect fisheries (HaV, 2023).

Conflict and lobbying are prominent interactions, as both fisheries and wind energy actors seek to shape planning and policy outcomes. Information sharing and evaluation occur through scientific assessments and consultation processes, but these mechanisms do not necessarily resolve underlying trade-offs or distributional impacts (HaV, 2023; Negro et al., 2020; Swedish Pelagic Federation Producentorganisation, 2023).

Outcomes (O)
Key outcomes of interest center on social and ecological sustainability of fisheries, including altered profitability across fishing fleets, changes in pelagic stocks and their

dynamics, and displacement of fishing activity. Electricity production and OWF value-added are potential outcomes that will become relevant if OWF development occurs.

3.2 The Southern North Sea (German Bight)

Potential multi-use of existing offshore wind farm for low-trophic level aquaculture at Meerwind Süd | Ost

The Southern North Sea demonstrator focuses on the multi-use potential of existing offshore wind infrastructure at the Meerwind Süd | Ost wind farms in the German Bight, specifically the physical and economic potential of co-locating mussel aquaculture with wind turbines (Figure 4). For this case, the SES framework provides a foundation for integrating large-scale environmental change, localized environmental change from human-built infrastructure (e.g., alteration of local ocean currents), and the introduction of novel uses (e.g., shellfish growing), in order to maximize and diversify the benefits associated with OWFs.

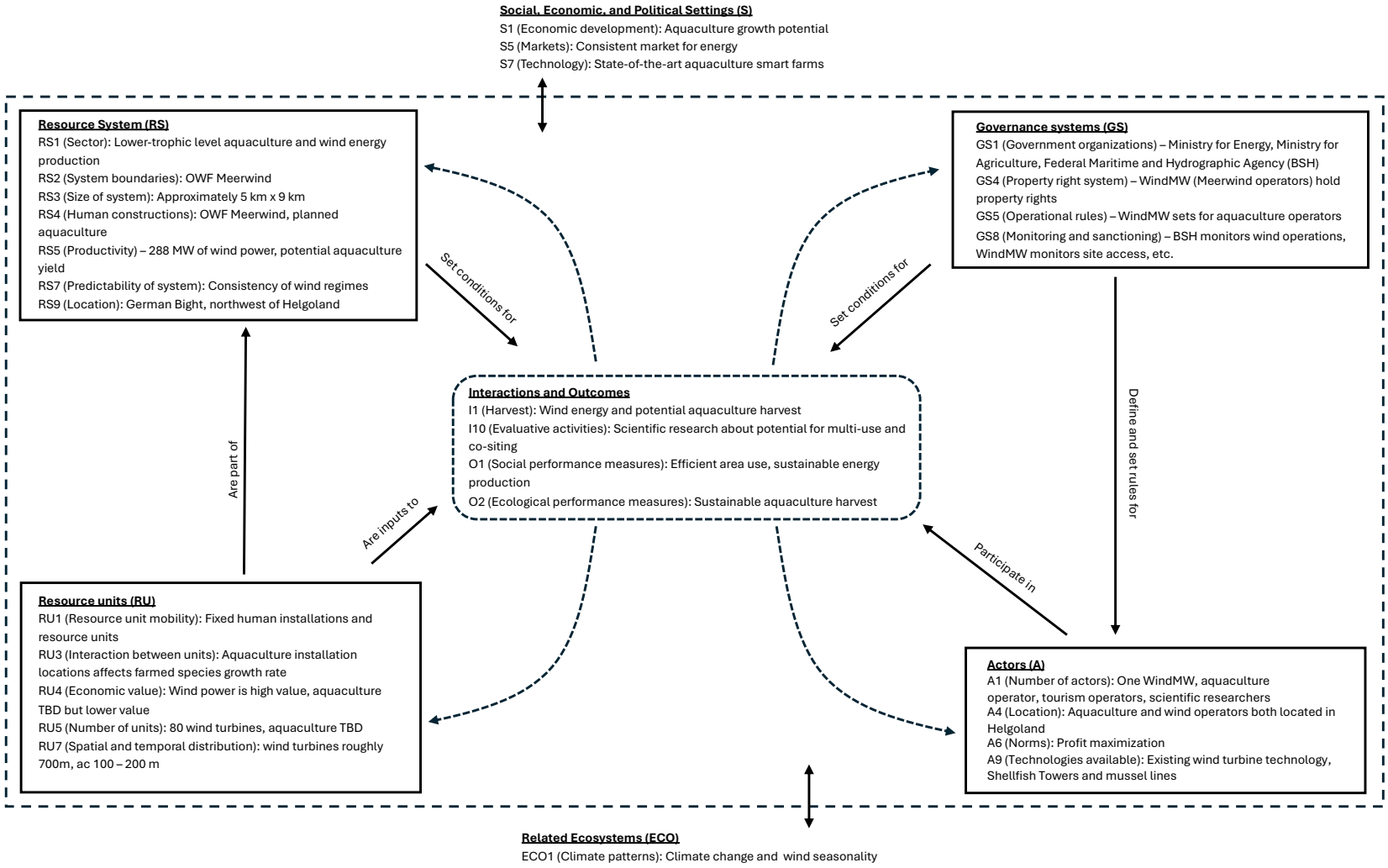


Figure 4 Conceptual model of the SES of the Southern North Sea case

Resource system (RS)

Meerwind Sud | Ost wind farms (collectively Meerwind) are northwest of the island of Helgoland in the German Bight; the farms include a total of 80 3.6 MW-class offshore turbines, set along approximately 700m x 700m grid squares. The wind farm itself is approximately 43 square km. The boundaries of the existing wind farms set the location, size and boundaries of the resource system (Figure 5). In the future, the productivity of the wind may decrease slightly due to climate-change driven reduction of regional winds (Warder et al., 2025).

Aquaculture installations under consideration for installation in the wind farm area include mussel lines and Shellfish Towers, developed and tested in New Zealand for installation at exposed sites (Heasman et al., 2021). These installations need to be spaced at intervals of 100-200m. The optimal configuration of aquaculture installations is under examination in SEADOTs, as are predictions for aquaculture productivity.

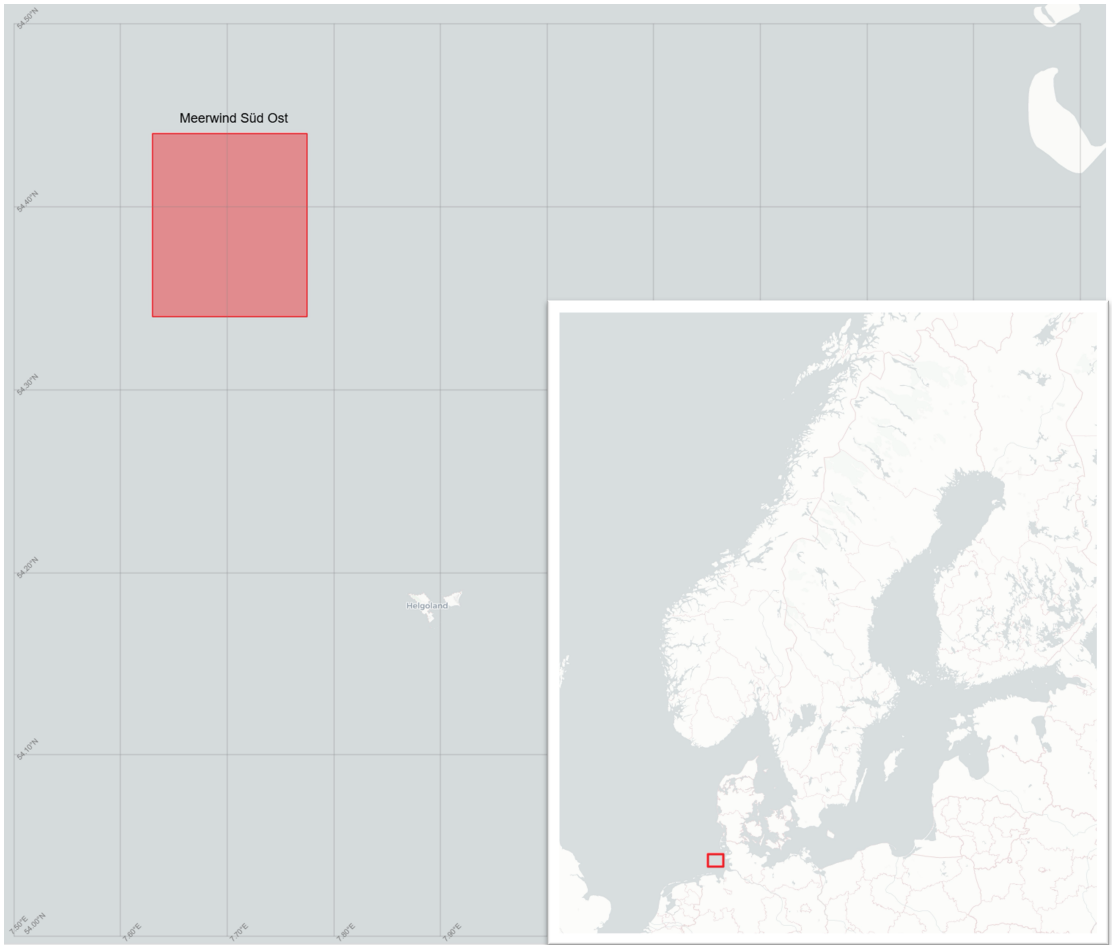


Figure 5 The case study area for the German Bight case

Resource units (RU)

The primary existing resource units are the (up to) 288 MWh produced annually by Meerwind Süd | Ost. The windfarm consists of bottom-fixed turbines; the stability of power production depends on the stability of the area's wind patterns over time (projected to decrease, as noted above). The market value of the electricity produced is determined by market price and power output; however, the former of these is driven in

large part by market forces and geopolitical developments external to the resource system.

The mussels harvested from potential co-located aquaculture facilities are secondary (potential) resource units. Mussels are sessile species that grow in place on lines (or otherwise mostly stationary installations). The economic value of shellfish harvest is dependent on the species grown and market prices.

Actors (A)
Primary actors of interest in this case include WindMW, the company that operates MeerWind, and aquaculture operators, who see expansion opportunities in the potential co-location of low-trophic aquaculture and OWFs. Both actors share the goal of profit maximization; furthermore, for WindMW, allowing diverse uses of OWF space may help maintain social license to operate. Additional actors include tourism operators, who may benefit from new opportunities associated with interest in wind farm and aquaculture operations, further increasing public benefit, while researchers play a role in advising aquaculture operators on the physical constraints and opportunities for co-location (through, e.g., projects OLAMUR and SEADOTs).

Governance System (GS)
Although the Federal Ministry for Economic Affairs and Climate Action (BMWK) determines where wind farms should be built and some access regulations (e.g., active fishing bans within wind farms, buffer areas around turbines and cables) (Bonsu et al., 2024; Zeth, 2025), once licensed, operators have primary jurisdiction over their area. Current German law does not preclude passive fishing or the establishment of aquaculture facilities. Thus, it is the wind farm operators themselves who determine whether, and the extent to which, aquaculture development is allowed within the boundaries of the facility.

Social, economic and political settings (S)
The German federal government has set ambitious targets for offshore wind. The German Offshore Wind Energy Act, passed in 2017 and reformed in 2023, sets a target of 30 GW of offshore wind capacity by 2030 and 70 GW by 2045 ('WindSeeG - nichtamtliches Inhaltsverzeichnis', 2017). Meerwind Süd | Ost sits within the context of these ambitious goals.

The 80 offshore turbines at Meerwind Süd and Ost have been operating since September 2014. Multiuse of the wind farm area, specifically the possibility of shellfish aquaculture, is in the conceptual stage. Scientists and local shellfish farmers are combining their knowledge to understand the feasibility and potential of state-of-the-art multiuse aquaculture-offshore windmill installations. In Germany, commercial low-trophic aquaculture currently only exists onshore, but offshore possibilities have been the topic of study for almost a decade (Buck et al., 2017; Maar et al., 2023).

Related ecosystems (ECO)
Related ecosystems' influence on the SES of the German Bight include climate change and seasonal effects. Climate change and wind wake studies show that the production

of offshore wind power will be slightly reduced in the future, with wake effects noticeable in the shorter term and of greater magnitude than climate change effects, but with interactions between the two (Warder et al., 2025). Models show that seasonal variability in the wind resource will increase over time, with less wind in the summer and more in the winter (Hahmann et al., 2022), which will lead to greater seasonality of energy supply.

Interactions (I)
WindMW prioritizes maintenance access, legal compliance, and operational safety; these values drive the interactions and opportunities available to aquaculture operators, as the wind operator acts as a *de facto* private property owner regarding access to the OWF area. Aquaculture operators also prioritize access to whatever aquaculture infrastructure is installed, profitability, and access to data, but are constrained by the willingness of the wind operator to support their enterprise (Schupp et al., 2021; Stelzenmüller et al., 2016).

Outcomes (O)
Meerwind Sud | Ost produces 288 MW per year and forms part of Germany's ambitious sustainable energy strategy. The harvest potential of the mussel lines and shellfish tower, and associated profits, are under examination in the SEADOTs project. The ecological and social sustainability of co-location will consist of the ability to sustainably grow, harvest and sell the aquaculture yield.

3.3 The Norwegian North Sea

Developing the world's largest floating wind farm next to Norway's smallest municipality, Utsira
The Norwegian North Sea case focuses on the proposed development of the world's largest floating offshore wind farm at Utsira Nord, a designated wind development area located near Utsira, an island that is home to Norway's smallest registered municipality (Figure 6). For this case, the SES framework provides a foundation for exploring the social acceptance, local impacts and ethical implications of large-scale development on local resource users who may or may not directly benefit from that development.

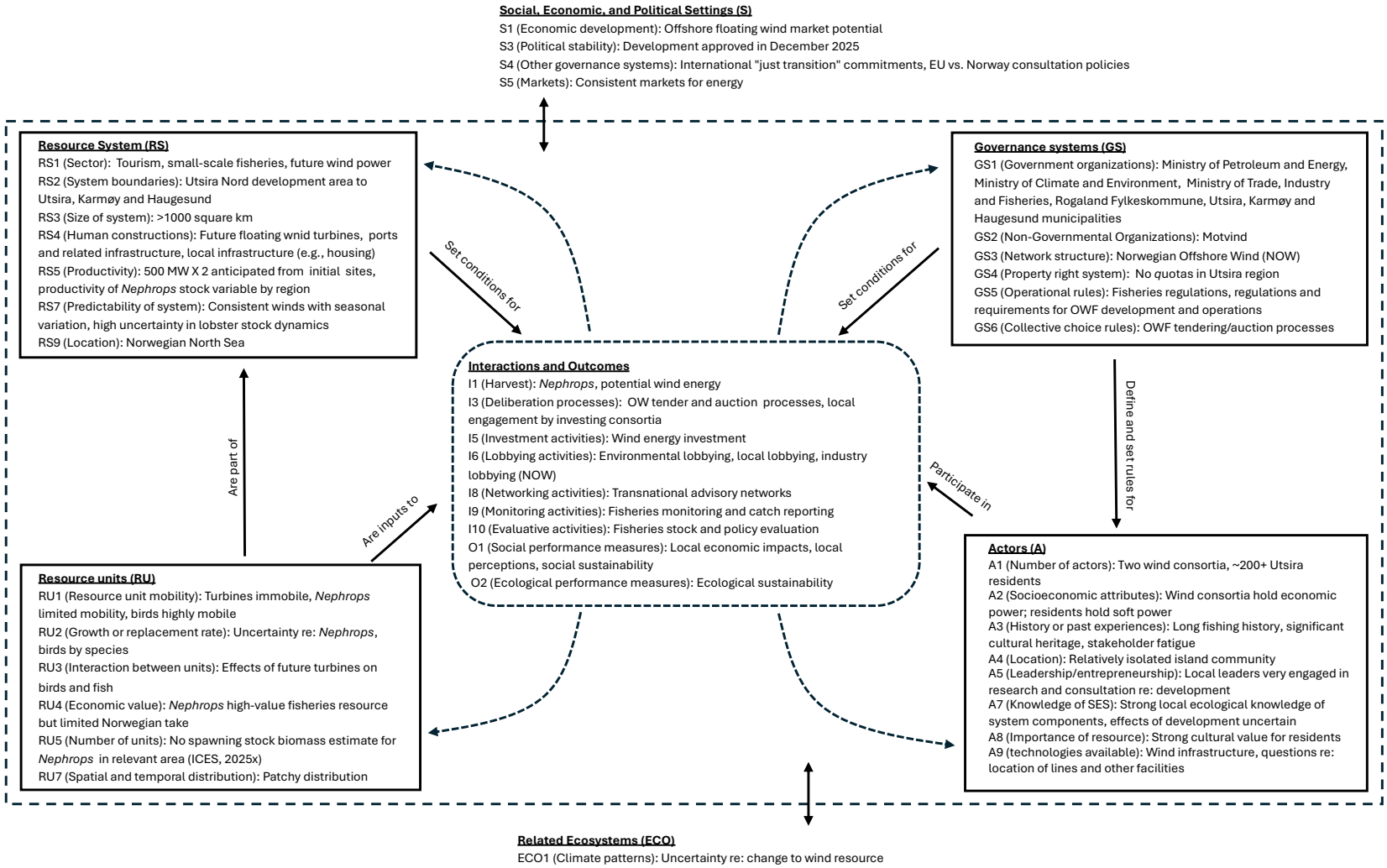


Figure 6 Conceptual model of the SES of the Norwegian North Sea case

Resource system (RS)

Utsira Nord is a designated floating offshore wind area of ~1000 km^2 with depths 185–280 m, located west of Utsira Island, Norway, in the Norwegian North Sea (Figure 7). The first supported projects, approved in December 2025 for two of the three identified development areas, will generate 500 MW each (potential full development of up to 1.5 GW). Wind energy development in this area is attractive due to high and consistent wind regimes. However, Utsira is located in a significant bird migration corridor (Cordes et al., 2024), the area is a hotspot for rare bird species, and interactions between turbines and birds is a possible concern. Furthermore, residents will experience viewshed effects, and OWF development may impact small local fisheries for the Norway lobster (*Nephrops norvegicus*), a high value species that is fished locally at a limited scale. Biomass estimates for *Nephrops* are subject to significant uncertainty but the Norwegian Deep population closest to Utsira is believed to be currently overfished (ICES, 2025b).

Proposed development will include turbines, subsea cables, assembly/port infrastructure on the mainland (Haugesund/Karmøy) and, potentially, local support facilities (e.g., port and breakwater upgrades). Wind energy production will be variable and require storage facilities for steady supply.

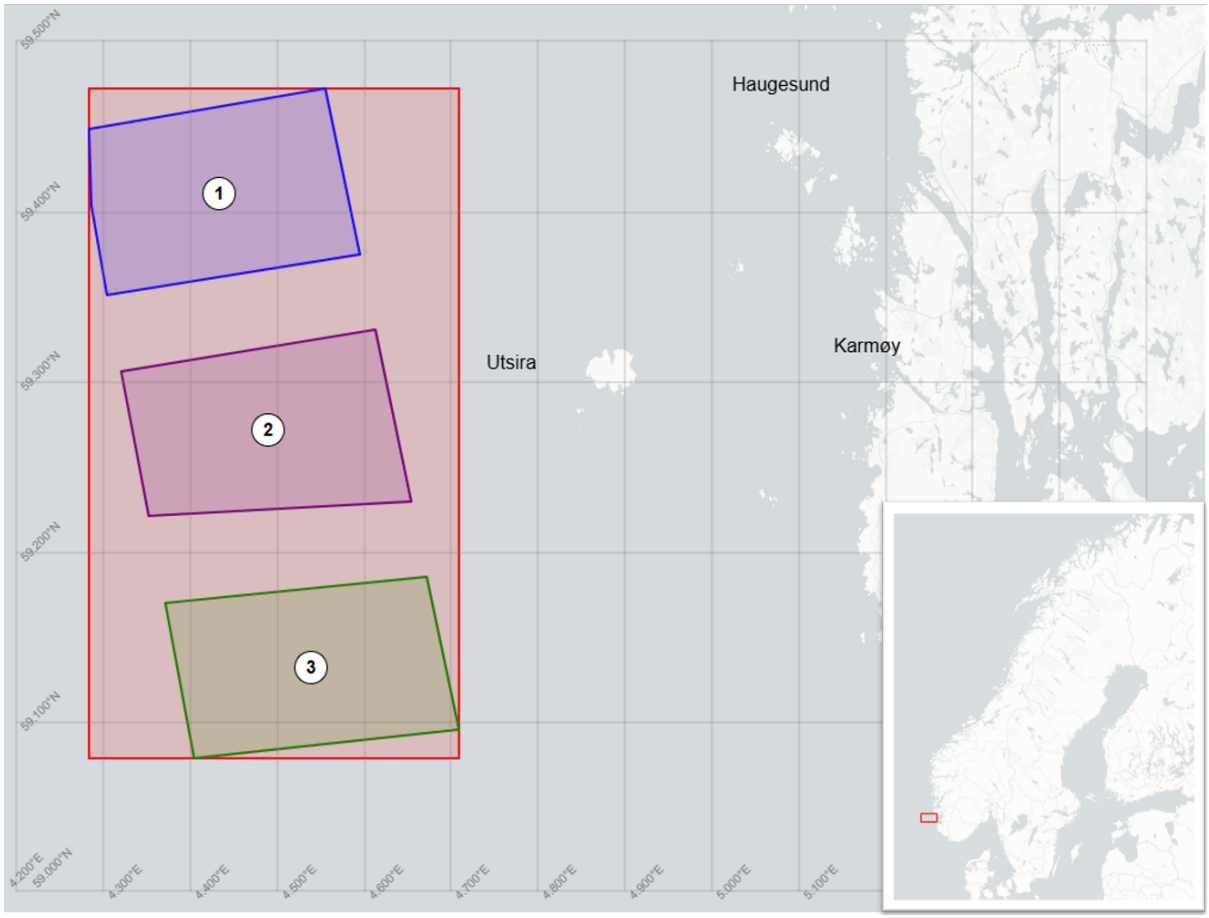


Figure 7 The case study area for the Norwegian North Sea case. The red area indicates the overall area open for development. The three labelled boxes are the three specific project development areas for Utsira Nord, to be developed in two phases.

Resource Units (RU)

The primary existing resource units are the Norway lobster catch, which is a source of income for some residents. ICES recommends a maximum catch of 53 tonnes of Norway lobster in the entire Functional Unit of the Norwegian Deep for 2026 (ICES, 2025b). Residents of Utsira report deriving significant cultural value from fisheries, bird life, and the general landscape and nature. Uncertainties remain concerning the impacts of wind development and associated noise, electromagnetic frequencies, and lighting on marine ecosystems; those uncertainties extend to the impact on the ecosystem services derived from existing uses. Utsira also receives economic benefits from nature-based tourism.

The initial 1 GW and eventual 1.5 GW of wind energy derived from Utsira Nord are significant future resource units. Stability of wind power generation depends on stability of wind patterns, which are highly uncertain according to recent climate change research (Hahmann et al., 2022). Economic value of wind energy depends on larger economic and geopolitical patterns.

Actors (A)
Wind developers are represented by two separate consortia (Equinor/Vårgrønn and DeepWind Offshore/EDF Renewables), each of whom have been approved to develop one 500 MW area within Utsira Nord. Related industries include port authorities for Haugesund and Karmsund and associated businesses related to cables, moorings, assembly, installation and maintenance of the floating wind turbines. The civil society group Motvind represents opposition to wind energy throughout Norway. Residents of Utsira (~200+) express views on Utsira Nord ranging from cautious optimism to outright skepticism.

Governance System (GS)
The regulatory environment, including rules on marine use and safety as well as Environmental Impact Assessment requirements, are set at the national level by, variously, the Norwegian Ministries of Energy; Climate and Environment; Trade, Industry and Fisheries; the Norwegian Water Resources and Energy Directorate; and the Norwegian Maritime Authority. Rogaland county and affected/ interested municipalities including Utsira, Haugesund, and Karmøy engage in planning interfaces – and local governments in Haugesund and Karmøy seek to benefit from the infrastructure development sure to follow development.

The Utsira Nord investment support scheme is Norway's state aid framework for developing floating offshore wind off the coast of Rogaland. The government has set a maximum support frame of NOK 35 billion (2025 price level), provided as investment aid and awarded through a competitive auction. Only one project will receive support, and the winner is the developer that can build the project with the lowest required state subsidy per installed megawatt. The scheme aims to accelerate technology development, cost reductions, and industrial learning in floating offshore wind, while contributing new renewable power and positioning Norway as a location for a future offshore wind industry.

Networked governance brings together industry consortia, NGOs, research institutes, and regional port authorities that both compete and coordinate decisions over construction and supply-chain siting. These interactions shape how infrastructure, capabilities, and investments are distributed across regions.

In Norway, stakeholder engagement in offshore area development is subject to different legal framework than on land. Offshore areas are not governed by the Planning and Building Act; instead, engagement is mandated through sector specific legislation and Environmental Impact Assessment (EIA) requirements. For activities such as offshore wind, petroleum, carbon capture and storage, and seabed minerals, EIAs are legally required and must include public consultation and opportunities for affected stakeholders to submit comments before decisions are made. These processes are state-led, formal, and consultative, ensuring transparency and input from stakeholders

(e.g. fisheries, NGOs, industry, regional authorities), but they provide less local influence and no co-decision rights compared to onshore planning processes.

Related ecosystems (ECO)
Climate change is expected to influence atmospheric circulation across the North Atlantic–Nordic Seas region, but current peer-reviewed research indicates that large-scale wind resources in northern Europe, including the Norwegian North Sea, are not projected to change dramatically (Hjelmeland and Nøland 2023). Multi-decadal analyses (Semedo et al., 2014) and high-resolution reanalysis datasets (Solbrekke et al. 2021) show no strong long-term trends toward declining wind energy potential in the Norwegian sector of the North Sea.

Social, economic and political settings (S)
Broad global agendas include extensive attention to "just transitions" (International Labour Organization (ILO), 2015), requiring that the needs of those affected most by decarbonization are met during societal transformation. Similarly, global development plans and practice recommend broad participation to ensure social equity in the distribution of costs and benefits of development (Hamad et al., 2014; OECD, 2020). This is also the case in wind development more specifically (Armeni, 2016; Cowell et al., 2011; Houghteling et al., 2024). Furthermore, public perception and participation in offshore wind siting and development is distinct from those of onshore wind but follows similar patterns (Wiersma et al., 2014). Norway has no comprehensive MSP regime offshore: stakeholder engagement occurs project-by-project through EIAs and sectoral processes rather than through a single spatial plan.

Interactions (I)
The core interactions in this case concern the development and eventual harvesting of offshore wind power. Contention over who gets what from floating offshore wind develops within the framework of uneven distribution of risks and power.

Residents and local leaders are passionately interested in what the wind park will mean for their community but have only limited soft power to influence processes and outcomes. The role that local voices play to influence the development of Utsira Nord thus remains uncertain. There is anecdotal evidence of consultation fatigue in stakeholder engagement processes, but residents and local government remain deeply concerned about the distribution of costs and benefits of wind development. Residents recognize that they will pay costs, not least in terms of an obstructed west-facing viewshed – in return, they seek fairness in development processes and outcomes, jobs, and other concrete local benefits (e.g., reduced energy prices, improved emergency services, development of local facilities). Local business and industry (including tour operators and small-scale fishers) are also expected to be affected by development, although the nature and magnitude of effects are uncertain. Calls for coordinated, neutral research, robust monitoring and stakeholder involvement recur frequently in the Utsira Nord public debate, reflecting persistent concerns about the need for

credible involvement of the local community in the development and planning process and long-term oversight of the marine environment.

Cross-level interactions further complicate the picture. At the regional level, investment in Utsira Nord is an opportunity to compete for the development and supporting industry necessary to enable large-scale floating offshore wind. Furthermore, local and regional interactions occur in the context of national- and international-level political agendas and lobbying, in the form of both decarbonization commitments and contestation over wind energy. Wind developers include economically powerful industry actors with deeply institutionalized ties to high-level political decision-makers.

Outcomes (O)
Core outcomes that may be of interest in this case include the socio-cultural and economic impacts of wind development on residents. Potential socio-cultural and economic costs include the decline or loss of traditional lifestyles (e.g., fishing) and cultural heritage, effects on tourism, and changes to Utsira's Western horizon viewshed. Potential socio-cultural and economic gains may come from development that attracts new residents to the community and provides opportunities for youth, who might otherwise relocate to areas with more economic opportunities, as well as from the potential development of new community facilities. The extent to which Utsira Nord development is experienced as equitable and legitimate by Utsira residents may influence the project's social sustainability.

3.3.1 Social-ethical components of the Utsira case

The Norwegian North Sea/Utsira case focus on social perceptions, acceptance, and sustainability of offshore wind development contrasts with the focus on spatial tradeoffs and behavioral choice in the Baltic case and the focus on co-existence and economic benefits in the Southern North Sea case. Because of this research focus, and the peculiarities of Norwegian offshore wind governance, the Norwegian North Sea case sheds special light on the socio-ethical dimension of OWF development.

International and national commitments to renewable energy development and green shifts are ambitious. Norway's stated energy goals, for example, include area designated for 30 GW of offshore wind development by 2040 (Ministry of Climate and Environment, 2023). Multiple coastal communities can expect to find themselves in a similar situation to the one Utsira now faces. However, communities do not always welcome renewable development with open arms. In the past, this opposition has often been dismissed as simple NIMBYism (that is, support for development in principle, as long as it is 'not in my back yard'). Recent findings from Norway have challenged this framing, finding that Norwegian opposition to wind development does not exhibit the classic signifiers of NIMBYism and that opposition is related more to environmental values and place attachment (Olve et al., 2025). Consistent with these findings, Utsira

residents exhibit a range of attitudes towards the development of Utsira Nord, with different social groups expressing different priorities, values and fears (Figure 8).



Figure 8 Ethnographic personas representing Utsira residents' views of wind development (Images: Byanthropologene)

Utsira residents and leaders express deep concern over the continued sustainability of their community and are clear about the potential costs and benefits of Utsira Nord. For a community that derives economic benefits from tourism, and that deeply values their natural and cultural heritage, loss of an unobstructed view of the western horizon and potential negative effects on bird life and fisheries are of deep concern. Yet many residents also recognize the economic potential associated with wind development. The establishment of new permanent jobs is of primary concern for maintaining the community over the longer term.

The role of power in influencing the distribution of costs and benefits from OWF development should not be underestimated. As noted above, in Norway, affected communities have no statutory rights to influence decision-making about development more than 12 nautical miles offshore. The consortia developing Utsira Nord include actors with very high levels of economic and political power in Norway, and development aligns with both Norway's energy ambitions and ambitions to develop and deploy cutting-edge floating wind technology. Calls for just transitions insist that the needs of those affected by development must be met during development processes. Utsira's ability to influence development trajectories, and to obtain binding commitments that direct benefits from development to the local community, is inextricably intertwined with government and developers' commitment to ethical, not merely profitable, OWF development.

3.4 Case comparison

Although all three cases focus on offshore wind, they are at different phases in the development process and seek to answer different research questions, thus they focus on different components of the SES framework. In the Central Baltic, plans for major offshore wind development are in political limbo due to changing political priorities; SEADOTs partners focus primarily on pelagic fisheries, including fish populations and the relevant fisheries actors most likely to be affected by possible future wind development. In the German Bight, existing offshore wind facilities are being explored as potential sites for low-trophic aquaculture, with a focus on physical and economic viability of aquaculture installations within wind park boundaries. In the Norwegian North Sea, the world's largest floating wind farm is in the earliest stage of development, with two projects approved in two of three possible development areas. Here SEADOTs partners focus on the impacts of development on the social sustainability of Norway's smallest municipality, with its unique and rich cultural heritage.

Most of the broad components of the SES are important across cases. For instance, although resource systems and resource units vary, they form critical context in all cases, setting the conditions and determining the ecological and economic sustainability of pelagic fishing in the Baltic, determining feasibility and profit in the Southern North Sea, and mediating the impacts of wind development on the local community in the Norwegian North Sea. Relatedly, the resource system is most narrowly bounded in the Southern North Sea case and more broadly bounded in the

Baltic and Norwegian North Sea cases. Actors are also critical for understanding each case, and although their identities vary, wind developers and operators, as well as those with whom OWFs co-exist or compete, are represented across all three cases.

It is notable that the role of governance systems varies across the three cases. In the Southern North Sea, where the operator of an existing OWF has jurisdiction over other activities within wind park boundaries, the larger governance system provides important context but has less immediate impact on the interactions and outcomes of interest. In the Baltic, where competing pressures from different governance levels (e.g., the EU, the government of Sweden and varied agencies therein, and Region Gotland), the governance system creates uncertainties over whether OWFs will be developed at all. Lastly, in the Norwegian North Sea, Norwegian governance of offshore wind follows another path entirely.

In the EU, MSP Directive 2014/89/EU requires integrated spatial planning of sea areas, with early and systematic stakeholder participation in the preparation of binding maritime spatial plans that balance multiple uses (e.g., energy, fisheries, transport, nature protection). EU MSP is anticipatory and coordinative, shaping where activities should occur in advance through cross-sectoral planning and structured participation By contrast, Norway lacks a legal mandate for MSP in offshore areas. As a result, engagement is more centralized, consultative, reactive, and focused on assessing impacts.

4 SES Data

Social-ecological systems, as defined by the SES framework, are interwoven, multi-faceted, and complex. Variables included in the framework include stocks (e.g., fish stocks), flows (e.g., economic benefits), constraints (e.g., regulatory environments), and actors (e.g., fishers and wind energy developers). While the framework provides a comprehensive overview of the parts and connections that define any SES, it is primarily a holistic way of understanding the system. As a result, a full SES in all its complexity is not tractable to mirroring in a DOT. However, the examination of each demonstrator case's SES undertaken above allows identification of key components for which data are available, as well as identification of SES variables that are less relevant to the question at hand and/or which provide only contextual information, given the research focus within the case. In this section, relevant SES variables, as operationalized for each case, are connected to the data sources that will provide the data underpinning DOT development.

Data coverage of the variables of primary interest for DOT development is generally good. Table 1 presents data sources for modellable SES components for each case – note that although high-level data sources are presented in the table, specific links to each data source as well as metadata are being collated in conjunction with WP1. Data are not uniformly available for all variables of interest. For example, interactions between pelagic fisheries and OWFs are far from completely documented, and data on wind energy produced by wind farms under development are naturally not available. Unavailable data will be supplemented as necessary through modelling/imputation approaches and/or expert consultation.

One variable for which data are notably lacking is social acceptance of wind development. This is especially relevant to the Utsira case, which explores social acceptance in relationship to social sustainability. Given reports of local stakeholder fatigue, the case lead elected to engage a subcontractor to compile baseline information on social acceptance and perceptions of wind development in Utsira from previously collected ethnographic data. The case lead also convened an in-person workshop with local leaders (with another forthcoming May) in which baseline analysis results were ground-truthed. The SEADOTs app, under development, will allow ongoing collection of social acceptance and perceptions as Utsira Nord development continues. The app will be distributed widely through QR codes posted at sites nominated by local leaders (e.g., the lighthouse, one of the island's prime tourist attractions) as well as distributed through print and online outlets. The app will include a short survey designed to provide updating input on perceived connections between SES components of particular concern to local residents and visitors. In addition to closed-ended items, free text responses will allow sentiment analysis, allowing tracking of how acceptance evolves with changing information and conditions. This approach represents a novel approach to social acceptance research, which is normally measured as a snapshot at a single moment in time.

Table 1 Variables by case, as derived from the SES framework; data sources are provided only for those variables that will (or will potentially) be included in the models developed to drive the DOTs

SES framework variable	Variable(s): Germany	Data source (if applicable)	Variable(s): Sweden	Data source (if applicable)	Variable(s): Norway	Data source (if applicable)
RELATED ECOSYSTEMS						
ECO1: Climate patterns	Seasonal hydrodynamic variability	Hydrological simulation output (river discharge data, riverine nutrients load)	Predicted sea surface temperature over time	Input data (Copernicus)	Sea surface temperature over time	Input data (Institute of Marine Research; Copernicus)
-	Seasonal atmospheric variability	Hydrological simulation output (ERA5)	-	-	-	-
-	Seasonal wave climate	Hydrological simulation output (calculated based on atmospheric and hydrodynamic input)	-	-	-	-
ECO2: Pollution patterns	Eutrophication	-	Extent of hypoxia; level of eutrophication (chl-a)	HELCOM	Ecological status class and chlorophyll proxies for adjacent coastal water bodies	Input data (Vann-Net /Vannmiljø official status; Rogaland fylkeskommune)
ECO3: Flows into and out of focal SES	Nutrient fluxes	Input data (Federal Waterways and Shipping Administration (WSV))	Species (herring, sprat) and fishing effort flows	Global Fishing Watch (fishing fleet movement)	Shipping density intersecting Utsira Nord buffer	Input data (BarentsWatch; Kystdatahuset)

-	Aquaculture harvest	Input data (Royal Netherlands Institute for Sea Research (NIOZ))	-	-	Seasonal relative use for key bird species (kittiwake, puffin, guillemot)	Input data (SEAPOP/SEATRACK)
SOCIAL, ECONOMIC, AND POLITICAL SETTINGS						
S1: Economic development	Economic growth potential in aquaculture	-	Low/declining profitability in pelagic fisheries	-	-	-
S2: Demographic trends	-		-		Local population size	Input data (Statistics Norway (SSB))
S3: Political stability	-	-	Political uncertainty around offshore wind expansion	-	Utsira Nord process status; rights-holders; support scheme	Input data (Norwegian Water Resources and Energy Directorate (NVE); Regjeringen)
S4: Other governance systems	-	-	Energy and spatial planning governance	-	Coastal/marine protected areas & sensitive sites intersecting cable landfalls	Input data (Miljødirektoratet)
S5: Markets	Steady/increasing demand for energy	-	Potential increase in herring/sprat demand	-	Fisheries landings values	Input data (Fiskeridirektoratet)
S6: Media organizations	-	-	-	-	-	-
S7: Technology	Mussel lines	-	Capital-intensive fishing and wind technologies	-	Floating turbine technology class planned	Input data (Government auction/tender documents;

						developer communications)
RESOURCE SYSTEM						
RS1: Sector	Offshore wind, low-trophic aquaculture	-	Fisheries, offshore wind	-	Offshore wind, fisheries, tourism	-
RS2: Clarity of system boundaries	Clear: Defined by wind park boundaries	-	Fishing grounds between mainland Sweden and Gotland	-	Development area boundaries to Haugesund and Karmøy, including Utsira	-
RS3: Size of resource system	43 km^2	Input data (WindMW)	Approx. 250 × 300 km^2	Input data (GIS map from EMODNet)	1000+ km^2	Input data (Energidepartement et)
RS4: Human-constructed facilities	-	-	-	-	-	-
Wind development	Turbines (existing)	Input data (WindMW)	Turbines (existing and potential)	-	Turbines (future)	-
Ports and related infrastructure, landing sites	Aquaculture landing and processing sites, Helgoland harbor	-	Three main fisheries landing ports	Input data (GIS map from EMODNet)	Cable landing sites, construction/maintenace home ports (future)	-
Local infrastructure related to development (e.g., co-benefits)	-	-	-	-	Utsira cable landing site, investment in community facilities	-
Aquaculture farms	Aquaculture installations	-	-	-	-	-

RS5: Productivity of system	-	-	-	-	-	-
Wind power productivity	Power generated by MeerWind	Input data (WindMW)	Existing and potential power generated	-	Annual energy output (TWh) per project area (500 MW) using CF range (45–55%) from NORA3 wind climatology	Input data (MET Norway NORA3; NVE/Regjeringen)
Fisheries catch biomass	-	-	Herring/Sprat catch	Input/ validation/ calibration data (ICES)	Nephrops catch: FU32 B/BMSY and catch advice (t)	Input data (ICES)
Aquaculture production	Mussels produced	Hydrological simulation output (calculated based on nutrients flow)	-	-	-	-
RS6: Equilibrium properties	-	-	Climate-related tipping points	Output data (agent-based model)	Regional Nephrops biomass estimates below levels necessary for stock maintenance since 2008	Input data (ICES)
RS7: Predictability of system dynamics	Predictability of aquaculture harvest	Hydrological simulation output (calculated based on nutrients flow)	Uncertainty in stock dynamics	-	-	-
RS8: Storage characteristics	-	-	-	-	-	-
RS9: Location	7.63 - 7.775 E , 54.34 - 54.44 N	-	Central Baltic Sea (Gotland Basin)	-	Norwegian North Sea	-

GOVERNANCE SYSTEMS						
GS1: Government organizations	-	-	-	-	-	-
National level	Federal Martime and Hydrographic Agency (BSH), German Federal Ministry for Economic Affairs and Climate Action (BMWE), Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety	-	Swedish Agency for Marine and Water Management (HaV), Swedish Coast Guard, Government of Sweden (Regeringen), Land and Environment Courts	-	Ministry of Energy, Norwegian Water Resources and Energy Directorate, Ministry of Climate and Environment, Ministry of Trade, Industry and Fisheries, Institute of Marine Research	-
Regional/local level	-	-	County Administrative Board of Gotland (Länsstyrelser)	-	Utsira, Karmøy and Haugesund Municipalities	-
IGOs	EU, OSPAR		ICES, EU, HELCOM	-	OSPAR	-
Industry decision-makers	WindMW	-	-	-	Equinor/Vårgrønn + Deep Wind Offshore/EDF	-
GS2: NGOs	-	-	Fisheries organizations, environmental NGOs	-	Environmental NGO (Motvind)	-

GS3: Network structure	-	-	Multilevel governance linking national authorities, EU institutions, and sectoral actors; fisheries organizations	-	Industry coalitions, Norwegian Offshore Wind	-
GS4: Property-rights systems	Primarily private property rights assigned to WindMW	-	Quota-regulated access under the EU Common Fisheries Policy	-	No collective or private property rights beyond 12nm offshore	-
GS5: Operational-choice rules	Wind farm regulations	-	Trawling limit (nm from coast, tonnes), TAC	Input data (EMODnet)	Area-based measures: trawl and trap limits, closures, MPAs relevant to North Sea	Input data (Fiskeridirektoratet)
GS6: Collective-choice rules	-	-	Marine spatial planning, MPAs, trawling limits, and offshore wind farm siting decisions	-	Limited requirement for public consultation for offshore wind outside 12nm	-
GS7: Constitutional-choice rules	-	-	EU Common Fisheries Policy and national energy legislation	-	Steps/timelines for Environmental Impact Asessment (EIA) and hearings	Input data (NVE)
GS8: Monitoring and sanctioning rules	-	-	VMS, logbooks, landing controls, and compliance mechanisms	-	-	-
RESOURCE UNITS						

RU1: Resource unit mobility	Fixed	-	Fish adult spillover	Input data (POSEIDON model)	Adult and larval Nephrops mobility	Input data (McGeady, Lordan & Power, 2019)
RU2: Growth or replacement rate	Aquaculture species growth rates	-	Possible decline in recruitment, normal growth rate	-	Nephrops recruitment and growth	Input data (Aguzzi et al., 2023)
RU3: Interaction among resource units	Mussel growth rates vary with location relative to turbines	-	Effect of OWF/SST on herring and sprat growth rates	Input data (indirect modeling based on food availability and regional SST from regional SST prediction models (Meier et al., 2019)	Effect of turbines and development on birds, Nephrops	Input data (Hutchison, Secor & Gill, 2021)
RU4: Economic value	Market value of aquaculture yield	-	Market value of fish catch	Input data price of fish (EUMOFA)	Market value of catch, market value of energy	-
RU5: Number of units	288 MW; simulated 200m mussel line	Input data (WindMW)	Herring and sprat biomass	Output data (agent-based model)	Nephrops biomass, catch advice; estimated TWh	Input data (ICES; energy data not yet developed)
RU6: Distinctive characteristics	-	-	Schooling species	-	Identifiability of bird species	-
RU7: Spatial and temporal distribution	-	-	Spatial distribution of fish stock density	Input data: biomass per species per subregion (HELCOM) Output data biomass per species per subregion simulated over time using the (agent-based model)	Presence/absence & timing for key bird species	Input data (SEATRACK/SEAPOP)

ACTORS						
A1: Number of actors	-	-	-	-	-	-
Windfarm operators/ developers	WindMW	-	-	-	2 consortia: Equinor/Vårgrønn, Deep Wind Offshore/EDF	-
Aquaculture companies	1 company	-	-	-	-	-
Fishers	-	-	+/- 40 fishing vessels (small <24m and large>=24m)	Input data number of large and small scale fishers in the focus area (Global Fishing Watch)	2 Nephrops fishers	-
Local residents	-	-	-	-	200+ Utsira residents, 9 households of part-time residents, visitors	Input data (SSB, visitor data not yet developed)
Non-governmental researchers	1 (Alfred Wegener Institute)	-	1 (Sveriges landbruktuniversitet)	-	-	-
A2: Socioeconomic attributes	-	-	Capital-intensive large-scale; lower-cost small-scale	-	-	-
A3: History or past experiences	OWF operating since February 2015	-	Long fishing history - strong path dependence	-	Stakeholder consulation fatigue	-
A4: Location	7.63 - 7.775 E , 54.34 - 54.44 N	Input data (WindMW)	Three main home ports	-	-	-

A5: Leadership/ entrepreneurship	-	-	Fragmented fisheries leadership; centralized wind actors	-	Utsira Offshore Wind Center	-
A6: Norms/ social capital	-	-	Competitive large-scale; habitual small-scale norms	-	Tight-knit local community with long-term leaders	-
A7: Knowledge of SES/ mental models	-	-	High operational knowledge; variable ecological knowledge	-	-	-
A8: Importance of resource	-	-	Dependence on pelagic stocks and spatial access	-	Cultural heritage value assigned to local landscapes, ecosystems, and species	Input data (Utsira workshops)
A9: Technologies available	-	-	-	-	-	-
INTERACTIONS						
I1: Harvesting	Energy, mussels	-	Energy, herring and sprat	-	Annual energy output (TWh) by project; fisheries landings by species	Input data (NVE/ Regjeringen; Fiskeridirektoratet)
I2: Information sharing	Consultation between scientists and aquaculture operators	-	Scientific assessments, consultations, and planning processes	-	Consultation between industry and Utsira kommune	-
I3: Deliberation proceses	-	-	Marine spatial planning consultations and sectoral dialogues	-	Tender evaluation and selection process, local	-

					engagement by investing consortia	
I4: Conflicts	-	-	Spatial conflict between fishing activities and offshore wind farms	-	AIS-based fishing & shipping intensity overlays with project buffers	Input data (Kystverket/ BarentsWatch)
I5: Investment activities	-	-	Offshore wind farm development and related infrastructure investments	-	Investment in wind, local co-benefits, grid connection alternatives & milestones	Input data (Statnett Environmental Impact Assessment; NVE)
I6: Lobbying activities	-	-	Lobbying by fisheries organizations and offshore wind developers at national and EU levels	-	Lobbying by local interests, environmental interests, and wind developers at regional and national levels	-
I7: Self-organizing activities	-	-	Limited collective organization across fleets	-	-	-
I8: Networking activities	-	-	Transnational coordination via advisory and industry organizations	-	Floating Wind Days	-
I9: Monitoring activities	-	-	Vessel tracking, catch reporting, and compliance monitoring	-	-	-

I10: Evaluative activities	-	-	Stock assessments and policy evaluations	-	Environmental Impact Assessment requirements	Input data (NVE; regional port/industry)
OUTCOMES						
O1: Social performance measures	Aquaculture and wind operator costs and profits	Generalized model output	Distributional economic impacts and sectoral tensions, vessel fuel costs, income from fisheries and wind power	-	Permanent local jobs, community sustainability, social acceptance of OWFs at Utsira Nord	Input data (Utsira workshops; SEADOTs app); output data (fuzzy cognitive model)
O2: Ecological performance measures	-	-	Changes in herring and sprat biomass and stock structure, fish stock sustainability	-	Trend in FU32 Nephrops B/BMSY; seabird seasonal exposure score	Input data (ICES; SEATRACK/SEAPOP) ; output data (fuzzy cognitive model)
O3: Externalities to other SES	-	-	Displacement of fishing effort to adjacent regions	-	-	-

5 Conclusion

This deliverable applies Ostrom and colleague's SES framework to the SEADOTs' demonstrator cases in the Swedish Baltic, the German Bight, and the Norwegian North Sea. It systematically describes each case using consistent framing and terminology, thereby allowing comparison and developing a common understanding of system components and dynamics across diverse cases. The deliverable identifies similarities and differences between the three case SESs, especially regarding the stage of wind development and the role of the governance system in influencing interactions and outcomes.

This deliverable also presents specific data sources for the key SES variables that will input into the models underlying DOT development. Although we lack comprehensive data for all SES components, existing data provide good coverage of the key variables of interest for DOT development in each case. Nonetheless, as noted in Table 1, certain data will need to be provided via modelling or expert input. As discussed in Section 3, the SEADOTs app will be used to gather updating social acceptance data for the Norwegian North Sea/Utsira case, allowing tracking of local perceptions of OWF development as conditions change. This is particularly salient given the socio-ethical dimensions of development manifest in the Utsira case, and the role of competing priorities, power relations, and the distribution of costs and benefits.

Deliverable 2.1 does not include discussion of the applied models under development for input into the DOTs. Those models will be presented in Deliverables 4.1 and 2.2. Refined understandings of the SES, or changed SES variables or conditions, will be updated in Deliverable 2.4, the final version of this document.

D2.1 links to WP 1 through identification of data sources by SES component and laying groundwork for formalizing data flow (Task 1.2). The deliverable links to other tasks in WP2 by formalizing the systems in which model development occurs (T2.2), and by identifying variables and outcomes for which indicators will need to be developed (T2.3). The deliverable contributes to WP3 by identifying specific actors and governance organizations of relevance to each case, thereby identifying sets of potential DOT users, allowing for definition of functional and non-functional requirements (T3.1) and eventual user interface co-development (T3.4). D2.1 links to WP4 by setting the context for development of and validation of demonstrators (T4.1). Lastly, D2.1 links to WP5 by identifying actor groups within each demonstrator case, thereby contributing to identification of targets for communication, dissemination, and training activities (T5.1 and 5.4).

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