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Large-Scale Multi-Use Realisation of Low Trophic Aquaculture with Offshore Wind Farming or Fish Farming

Øivind Bergh, Institute of Marine Research, Norway

European Commission

EUROPEAN UNION
EU MISSIONS
RESTORE OUR OCEAN AND WATERS

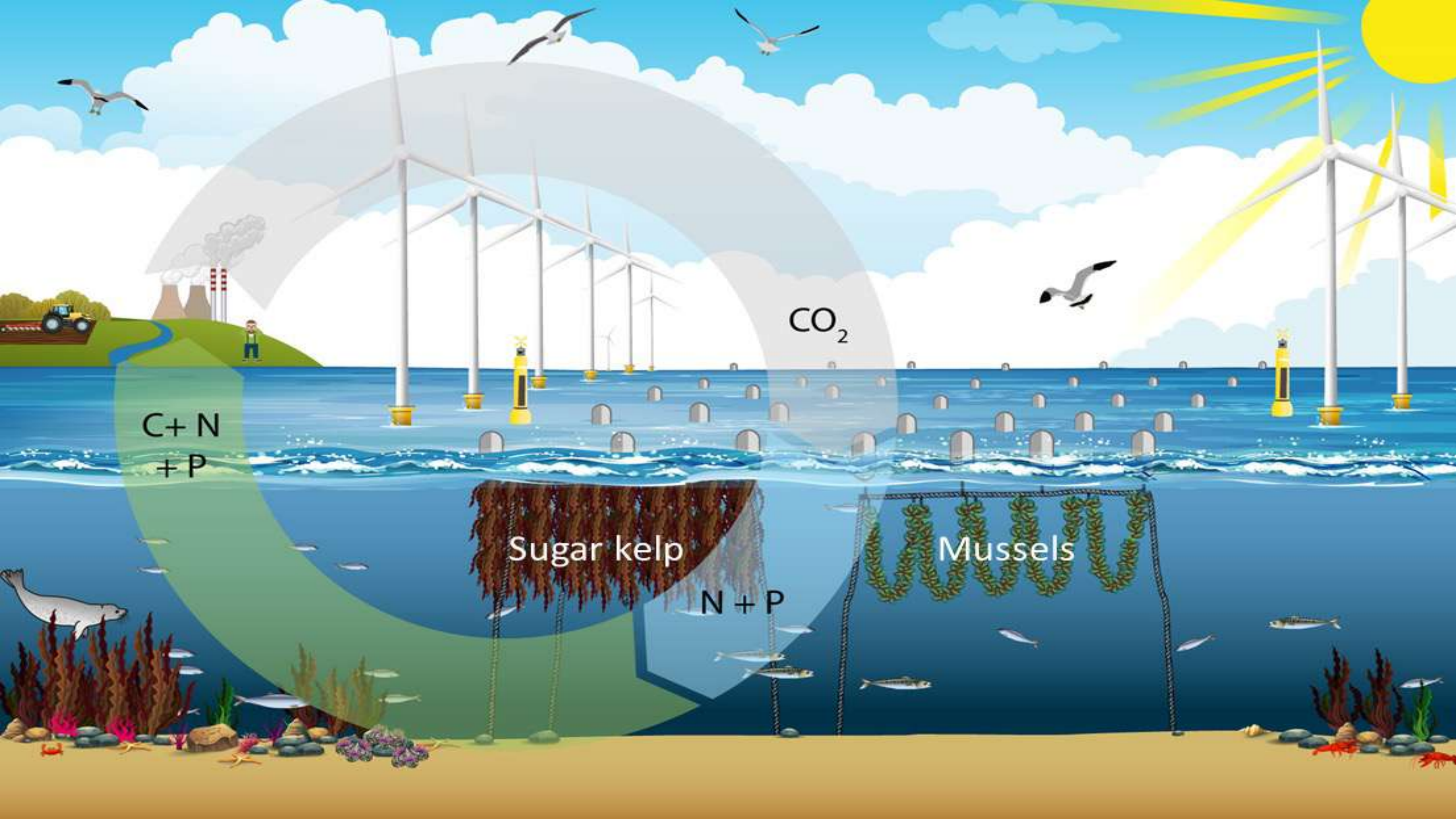
EU grant 101094065
1st Jan **2023** – 31st Dec **2026**

Photo: Vattenfall

Coastal zone

- Many maritime uses
- Stress on coastal ecosystems
- Demand for space is increasing
- Spatial conflicts and inhibition of development
- Often single use management

https://muses-project.com/



CO_2
C+ N
+ P
Sugar kelp
Mussels
N + P

Multi-use of ocean space

- Spatial efficiency
- Sharing:
  - *data management*
  - *Infrastructure*
- Reducing conflicts

- Mitigating:
  - *Restore ecosystem*
  - *Nutrient/carbon capture and utilization*
  - *Improve water quality*
  - *Energy security*
  - *Food security*

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Photo: Vattenfall

Challenges of multi-use

- Licensing (variable among countries/counties/states)
- Hydrodynamics
- Competing use (transport etc)
- Salinity (Low in the Baltic)
- Nutrient status
- Suitability
  - Wind/wave conditions
  - Growth potential mussels
  - Growth potential seaweeds

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Photo: Vattenfall

European Aquaculture
Technology and Innovation Platform

Policy Linkage:

- European Green Deal & F2F Strategies
- Sustainable Blue Economy & EU Strategic Guidelines (COM 2021 – 240 & 236)
- Sustainable EU Algae Sector (COM 2022 – 592)
- EU MSP Platform
- EU4Algae Platform
- Aquaculture Assistance Mechanism
- Aquaculture Advisory Council
- Mission Ocean Charter
- Blue Economy Smart Specialisation
- Horizon Europe Framework Programme

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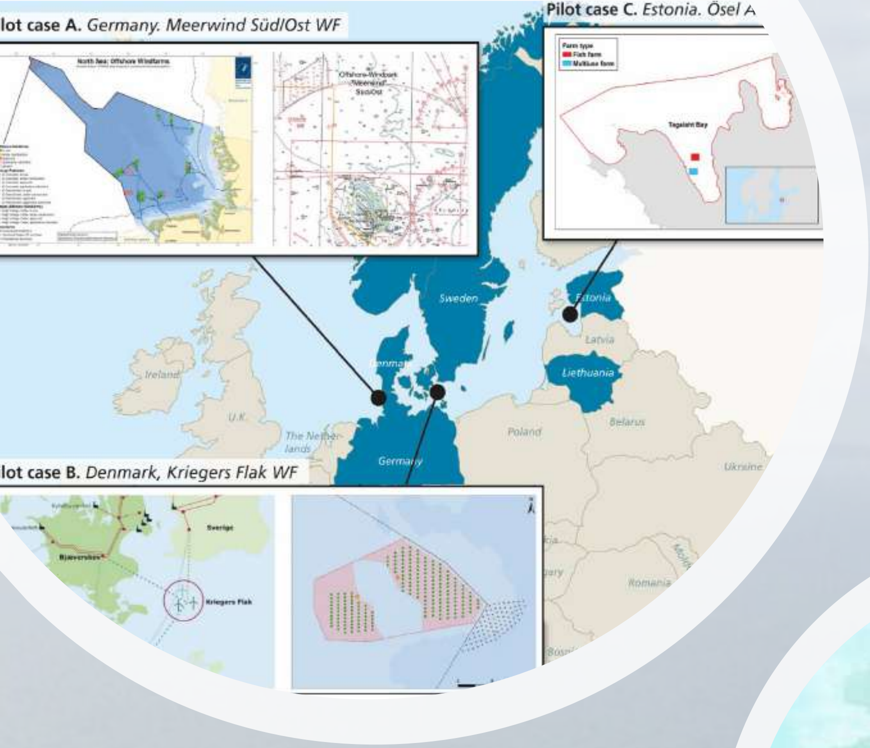

Large EU project on kelp and mussel farming within offshore wind farms

Ambition

OLAMUR will address and solve key bottlenecks hampering the development of commercially viable and sustainable offshore low-trophic aquaculture (LTA) in wind farms or fish farms and thereby enhancing a **sustainable LTA production in the EU**.

Photos: Vattenfall
IMR (Erling Svensen)
WindMW, BSH

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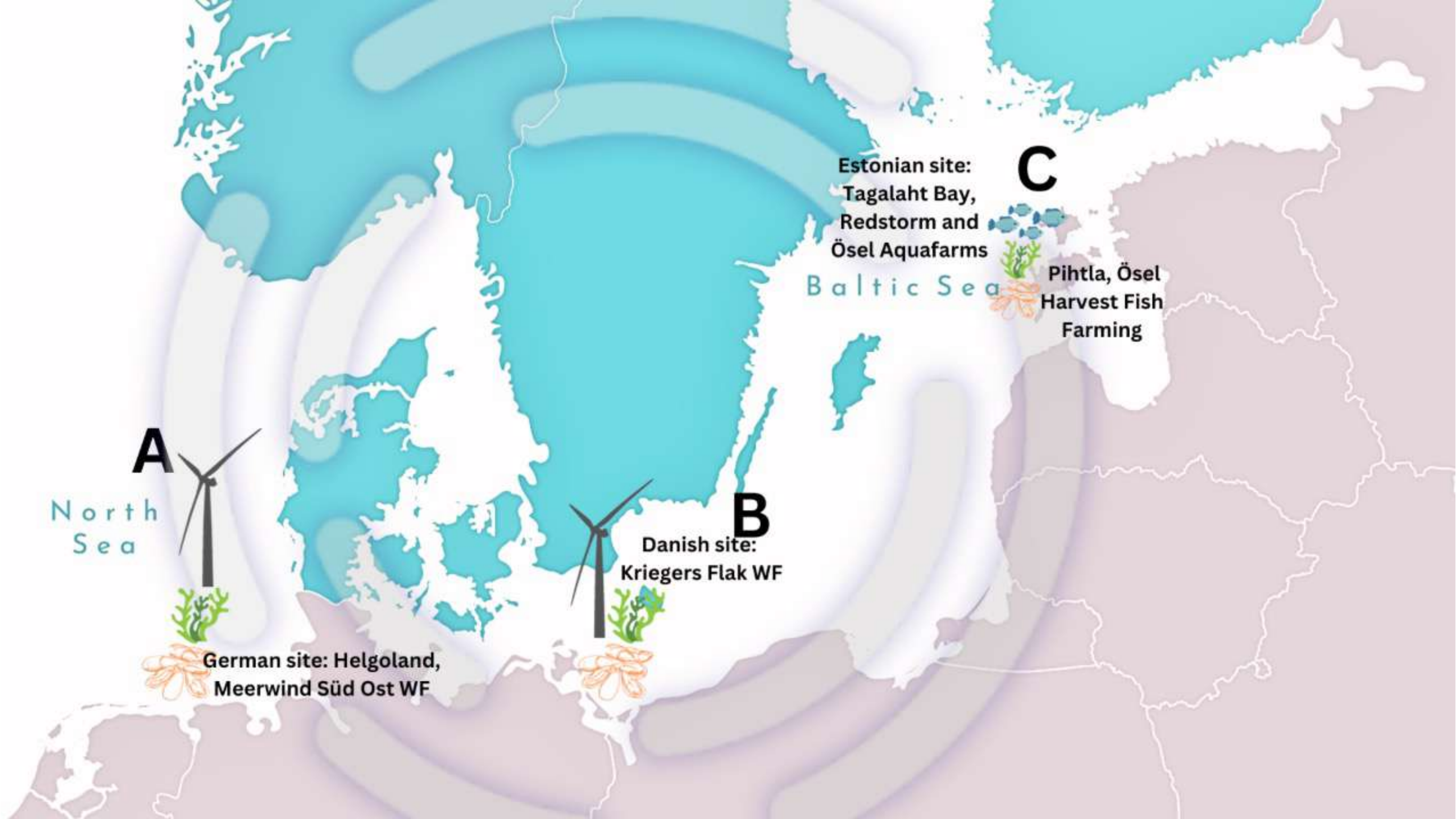
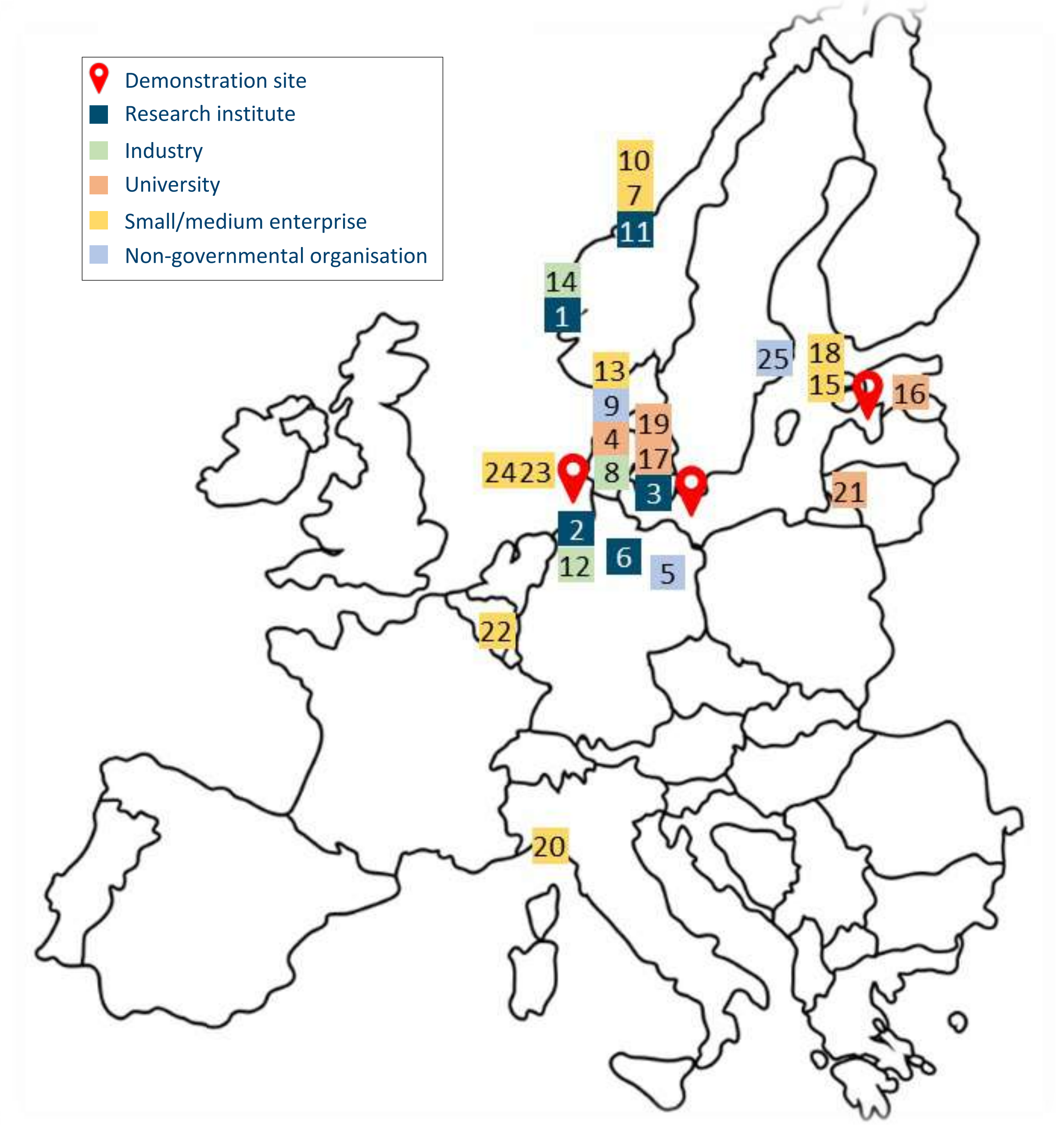

Estonian site:
Tagalaht Bay,
Redstorm and
Ösel Aquafarms
C
Baltic Sea
Pihtla, Ösel
Harvest Fish
Farming
A
North
Sea
B
Danish site:
Kriegers Flak WF
German site: Helgoland,
Meerwind Süd Ost WF

25 partners from research, organisations and industry

1 Havforskningsinstituttet , Norway
2 Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research , Germany
3 Danmarks Meteorologiske Institut , Danmark
4 Aarhus Universitet , Danmark
5 GCF - Global Climate Forum EV , Germany
6 Helmholtz-Zentrum Hereon , Germany
7 Maritime Robotics AS , Norway
8 Vattenfall Europe Windkraft AS , Danmark
9 Kattegatcentrets Driftsfond , Danmark
10 Skarv Technologies AS , Norway
11 SINTEF Ocean AS , Norway
12 WindMW GmbH , Germany
13 Kerteminde Seafarm Aps , Denmark
14 Lerøy Seafood Group ASA , Norway
15 RedStorm OÜ , Estonia
16 Tartu Ulikool , Estonia
17 Danmarks Tekniske Universitet , Danmark
18 Ösel Aquafarm OÜ , Estonia
19 Københavns Universitet , Danmark
20 ETT Spa , Italy
21 Klaipedos Universitetas , Lithuania
22 Platforme Technologique et de l'innovation de l'aquaculture Europeenne ASBL , Belgium
23 Nordfriesische Seemuschel GmbH , Germany
24 Wyk 8 Muschelfischereibetrieb GmbH , Germany
25 Stiftelsen Voice of the Ocean , Sweden



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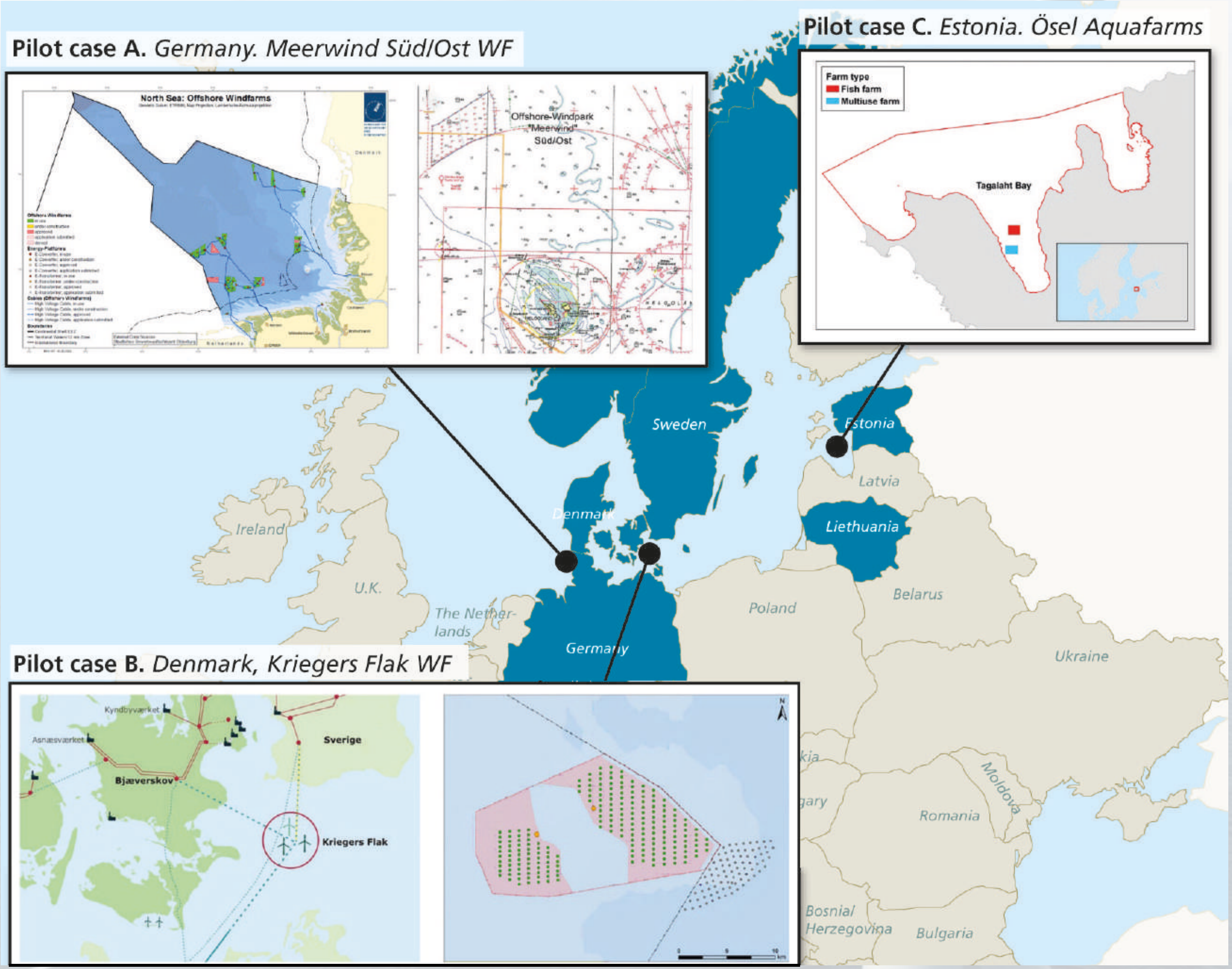
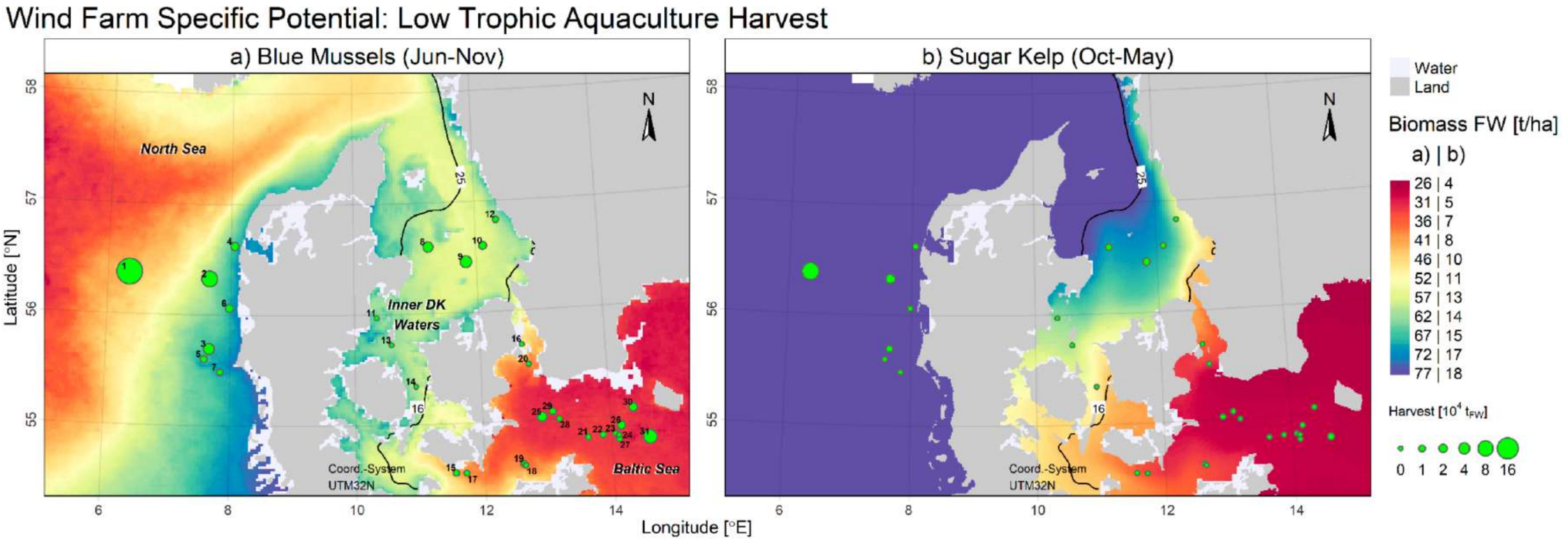
Establishment of 3 pilot **demonstration sites** where **seaweed** and **bivalves** will be farmed within

- an offshore wind farm (Germany/North Sea and Denmark/Baltic)
- in combination with finfish aquaculture (Estonia/Baltic)



Harvesting potential

Average 35 t-FW/ha (seaweed+mussels) salinity >16



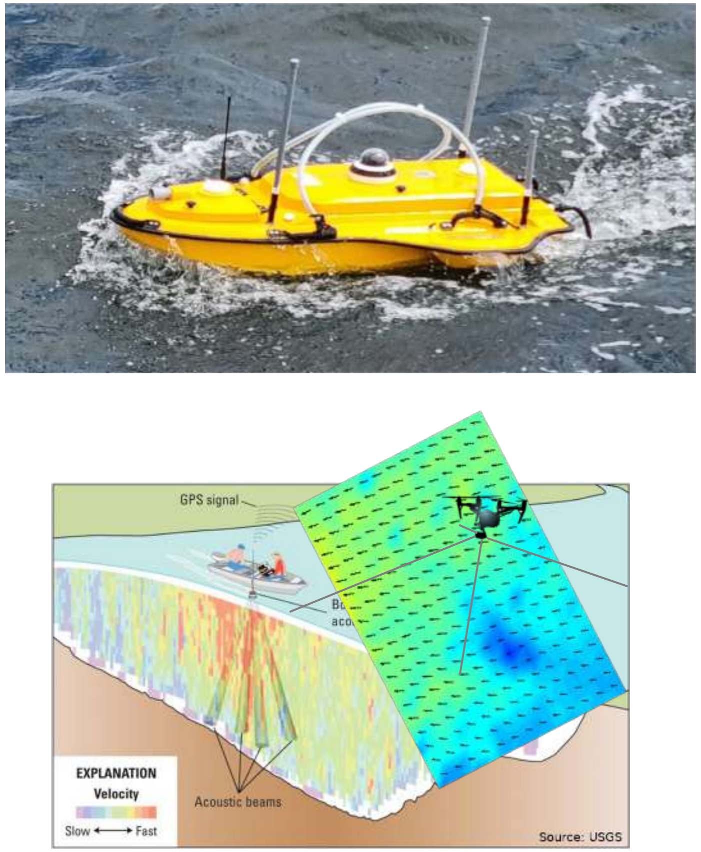
Develop and optimizing robotics-based monitoring technology: Integrated offshore farm monitoring technology (HEREON)

Unmanned Aerial Vehicle (UAV) surface currents monitoring: using CopterCurrents software to retrieve surface currents from the UAV video data

Autonomous Surface Vehicle (ASV): A small ASV Apache 4, 1.2m, equipped with an ADCP (Sontek M9) for acquiring current profile data. The AUV is normally operated in rivers and lakes and therefore adjustments have been made for operations in open waters.

The first in-situ experiment was conducted in July 2024: ASV-ADCP+UAV

A **Ferrybox** has been installed on a **Crew Transfer Vessel (CTV),** to collect temperature, Salinity, Ph, Oxygen, Chlorophyl A (fluorescence) And Colored Dissolved Organic Matter.



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Develop and optimizing robotics-based monitoring technology: ASV+LARS (Corax 60 and Otter X) with UUV

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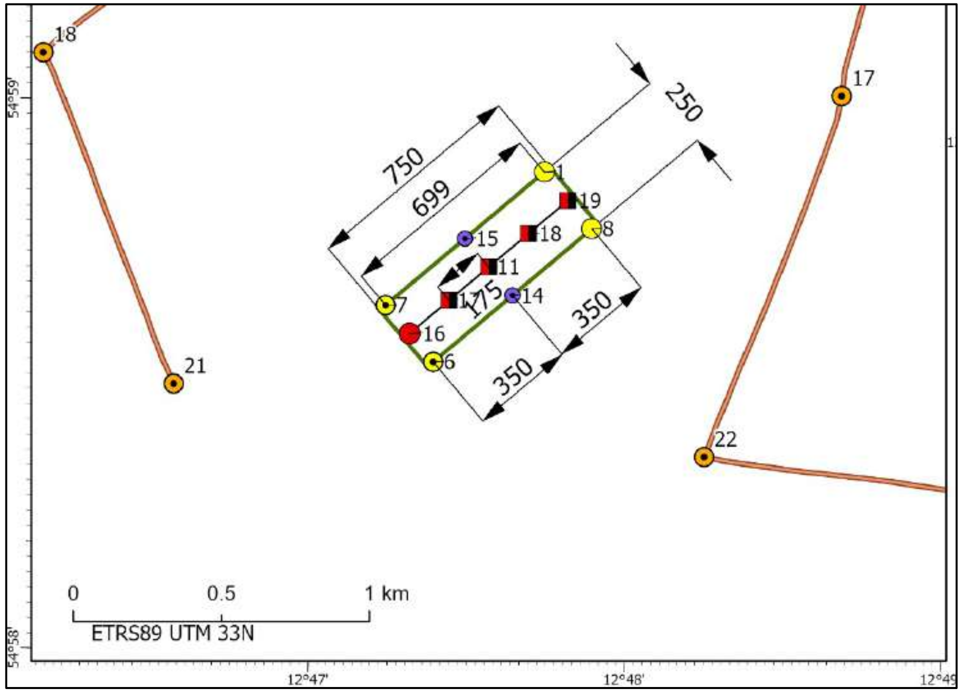
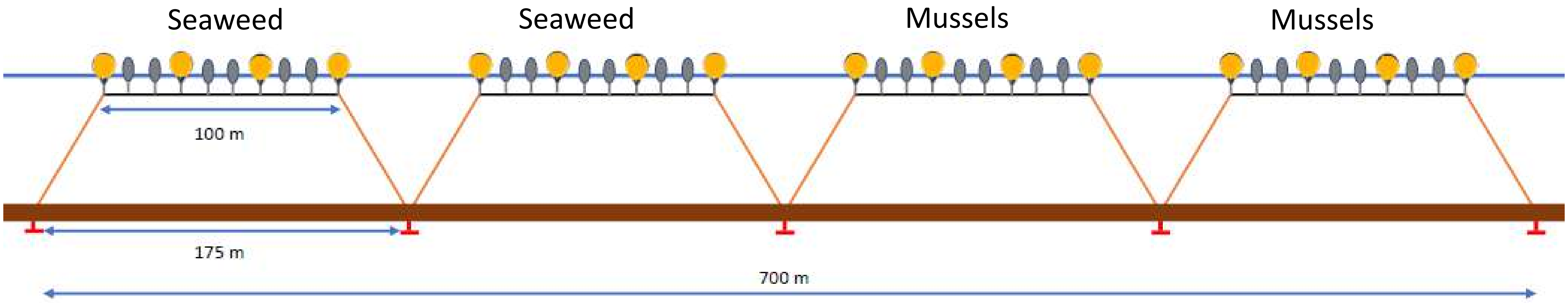
A: German Case Study: Meerwind Süd|Ost

AWI Nordfriesische Seemuschel GmbH (NFS) Wyk 8 Muschelfischereibetrieb GmbH WindMW hereon orcaflex

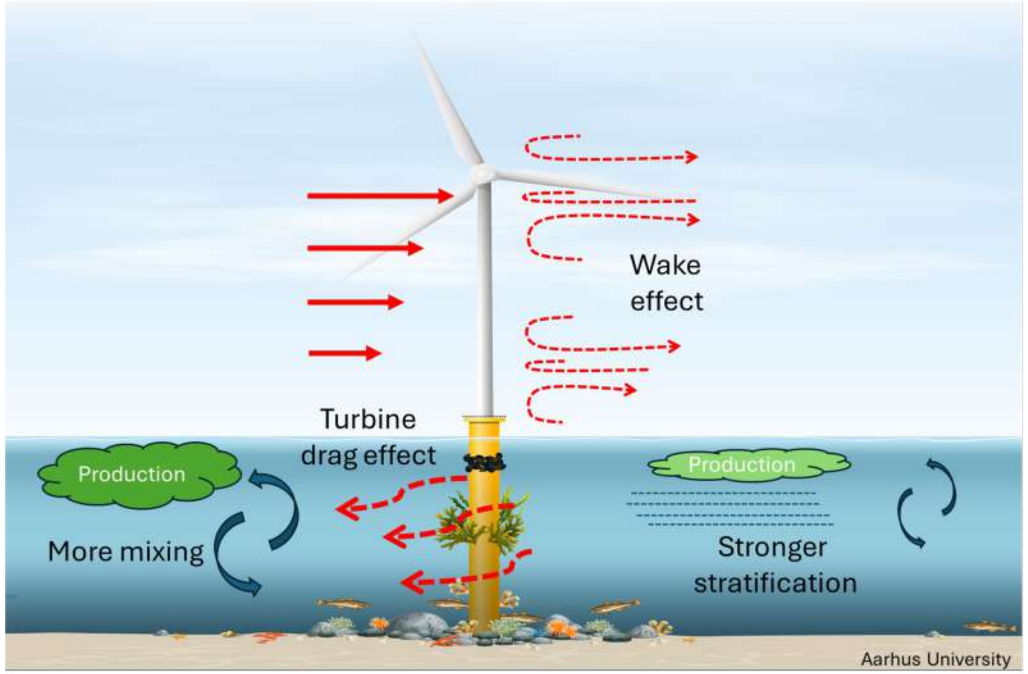
Case Study B – Danish Kriegers Flak – rig design

- 1 x Drill Anchor 3 - 6m in the seabed and 4 × 3 ton concrete blocks
- 4 x 100m main line 3-strand 18mm Polysteel.
- 8 x 50m anchor line 3-strand 20mm Polysteel.
- 175m between each drill anchor.
- 18 liter buoys on each ML with 4 pc. yellow or red Polyform A3 marker buoys.





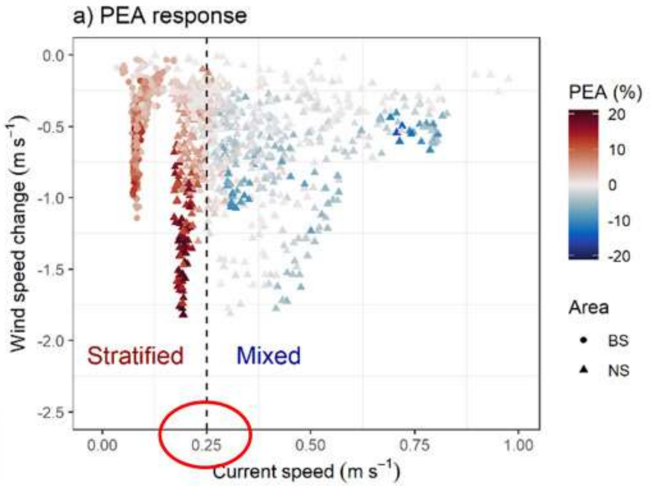
Modelling of spatial impacts of offshore wind on stratification - PEA (AU)



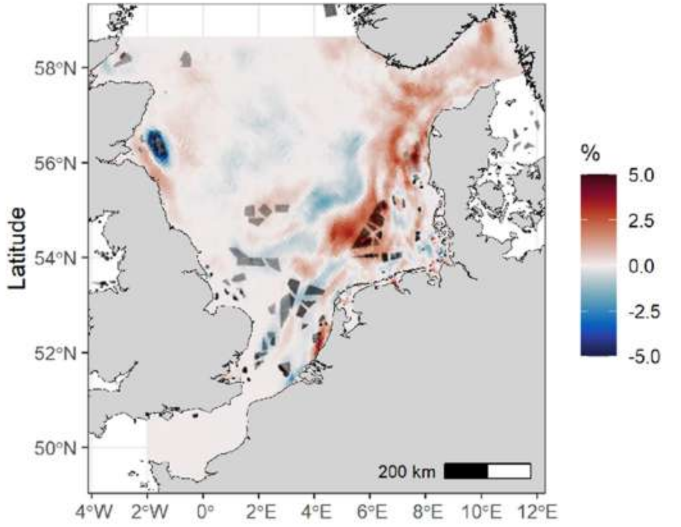
Potential Energy Anomaly (PEA).decreases (more mixed=blue) at current speeds >0.25 m/sec.

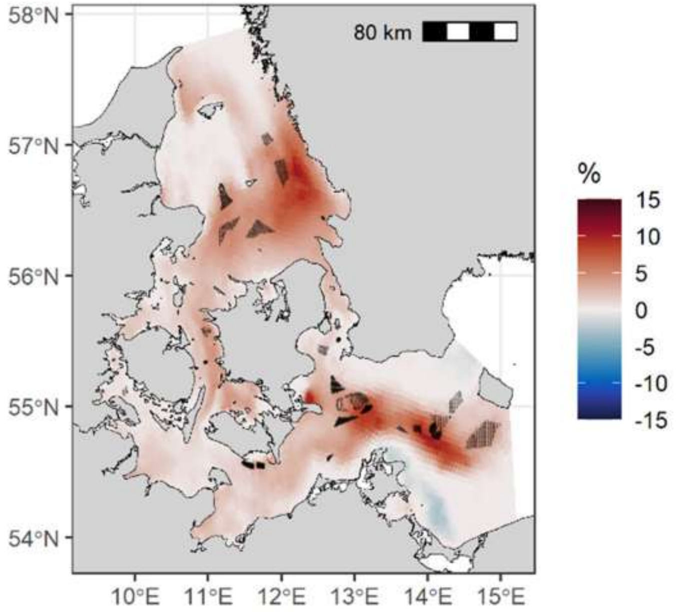
AARHUS UNIVERSITET

Maar et al. submitted



Impacts of offshore wind farms on Potential Energy Anomaly (PEA). Top: North Sea; Bottom: W Baltic Sea





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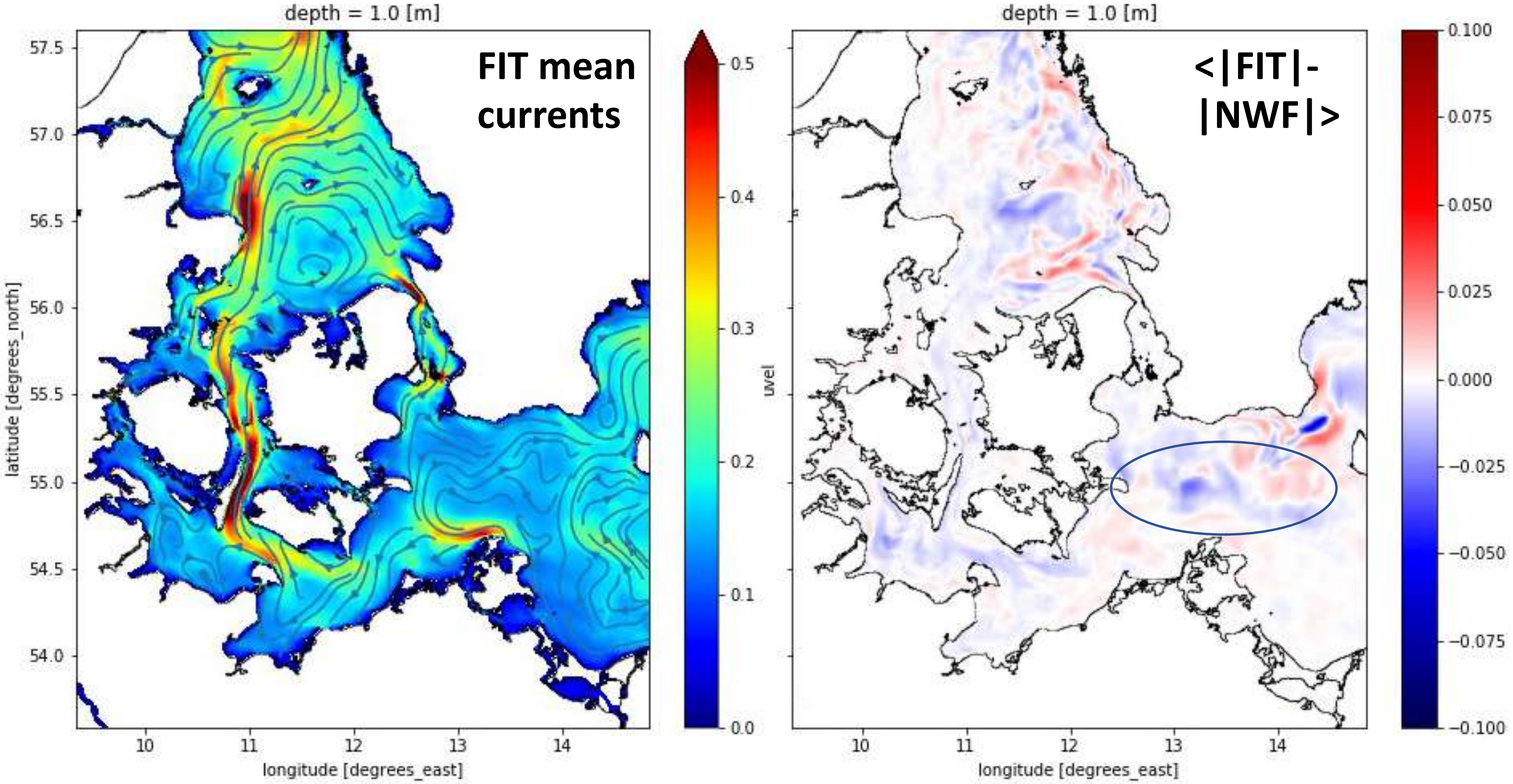
HBM forced by Fit vs NWF: IDW surface currents



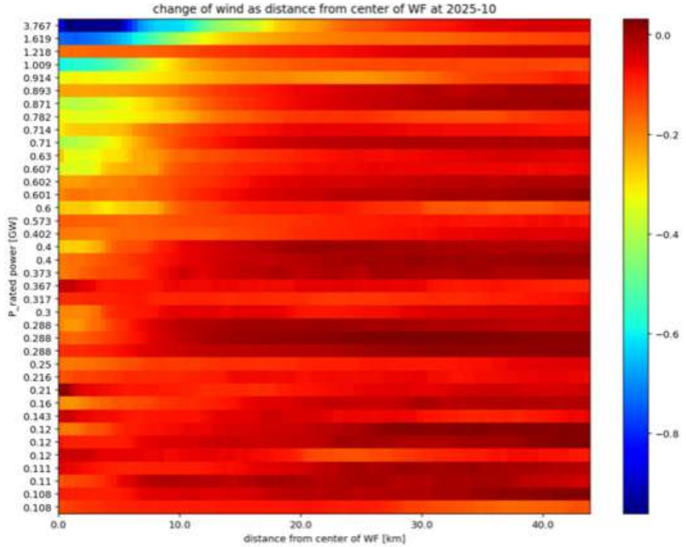
Left: average surface currents [m/s] forced by FIT winds; Right: averaged surface currents speed difference [m/s] between HBM tuns forced by FIT and NWF winds

Model development for forecasting and impact assessment: large scale weather and ocean models (DMI)

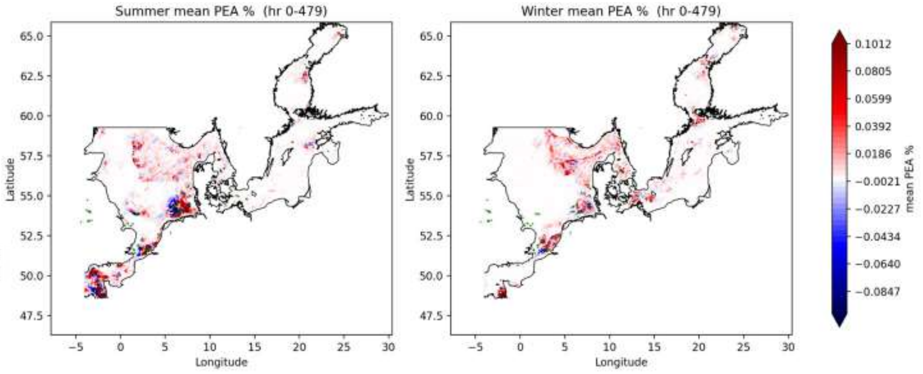
DMI
Vejr, klima og hav

$$k_t' = V_k + P + B - \epsilon + \frac{F_i}{\rho_0} u_i,$$

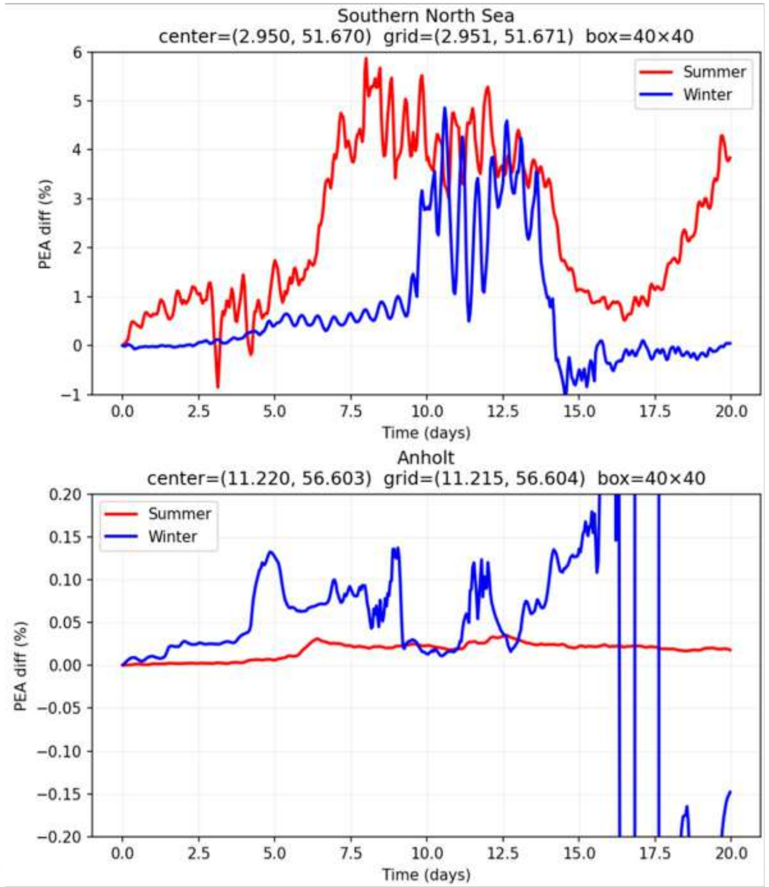
$$\omega_t' = V_\omega + \frac{\partial \omega}{\partial k}(C_1 P + C_3 B - C_2 \epsilon) + \psi \frac{F_i}{\rho_0} u_i,$$



Wake effects on 10m wind related to designed power of offshore wind farms (NWP model HARMONIE)



Impacts of turbine foundation on Potenteial Energy Anomaly (PEA). Left: Aug. 2022; Right: Fe. 2020



Impacts of turbine foundation in South North Sea and Danish waters (Annholt). Left: PEA; Right: energy spectrum using DMI ocean model HBM

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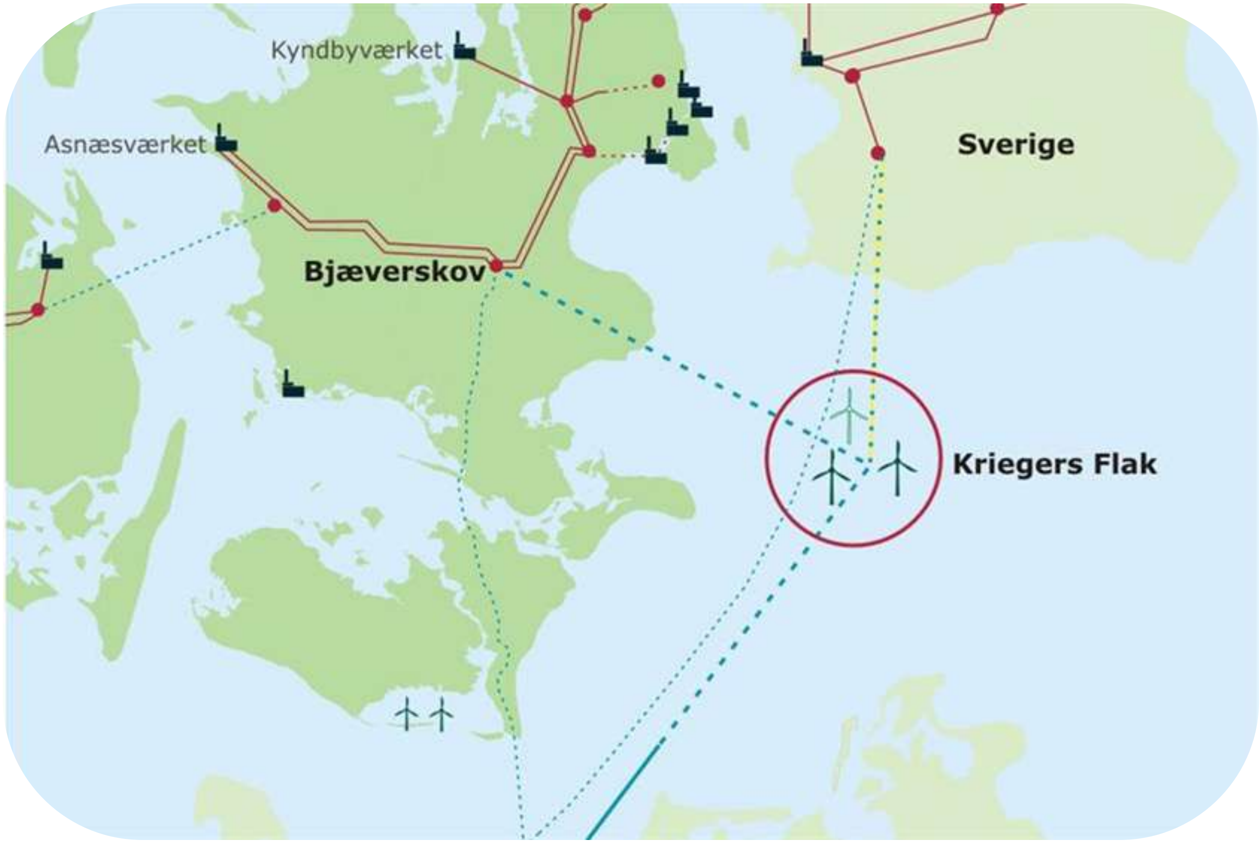
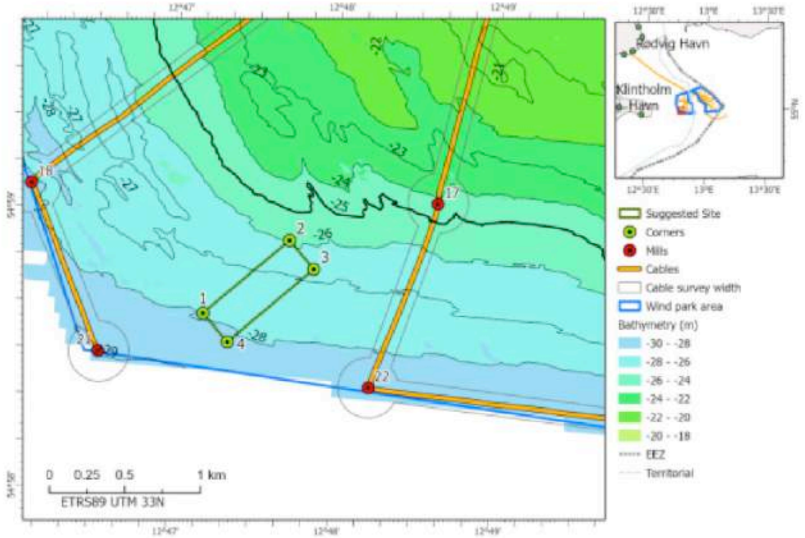
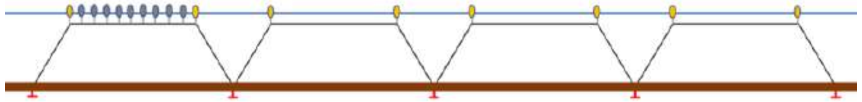
B: Danish Case Study: Kriegers Flak





Rig design

- Drill anchor 3 - 6m in the seabed.
- Main Line (ML) 3-strand 18mm PP rope.
- 150m between each drill anchor, which gives a total of 4 x 100m ML in the Surface.
- 20-50 pcs. 18 liter buoys on each ML and 5 pcs. at each end to keep the line tight.
- 15 pcs. concrete weights of 40 kg on each ML.



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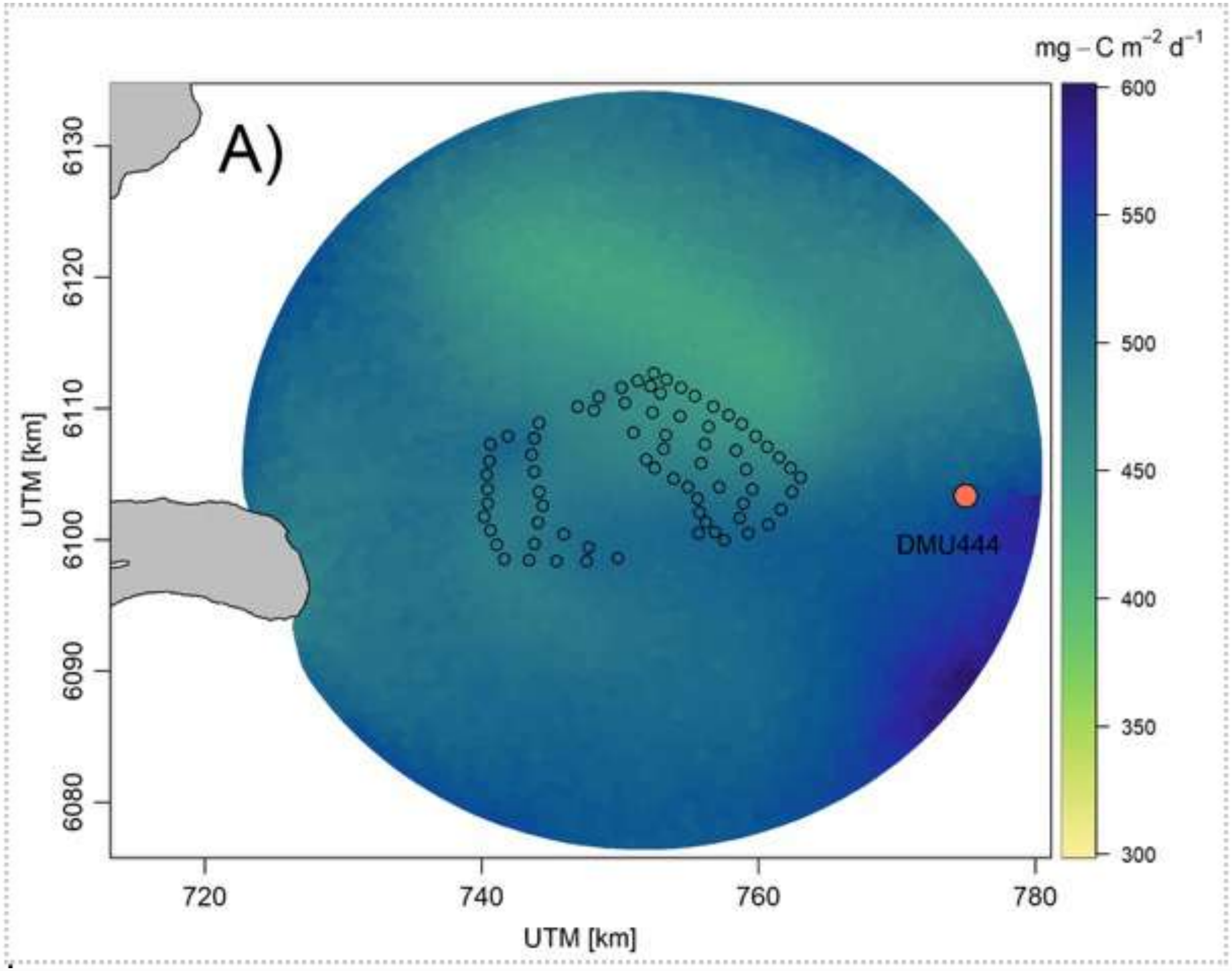
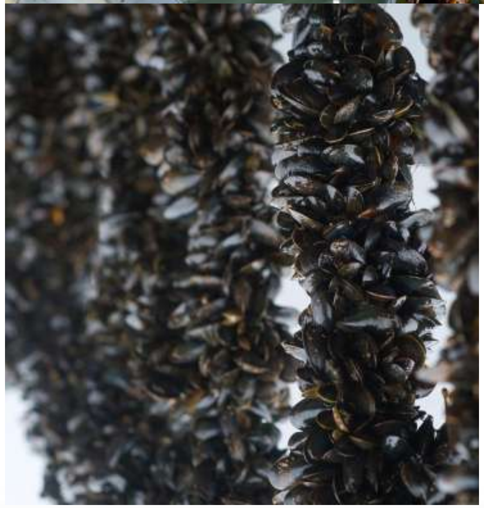
T3.1 Low Trophic Aquaculture performance





source: Vattenfall//Godfisk

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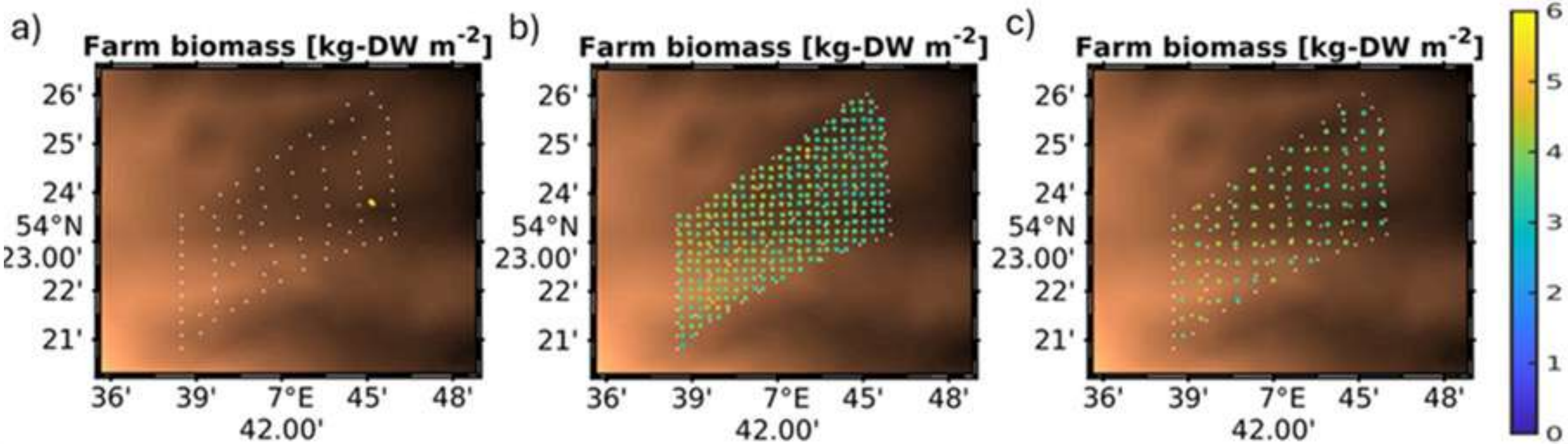
T3.1 Low Trophic Aquaculture performance

Scenarios for 3D ecosystem models

➢ Pilot A Meerwind Süd/Ost: Model only for mussels

Scenario	Description	Feedback to BGM
M	Farms in all cells	x
M1	Farm placed only in pilot farm location	✓
M2	Farms placed 350m distant from one another	✓
M3	Farms placed 700m distant from one another	✓



BGM: 3D Biogeochemical model

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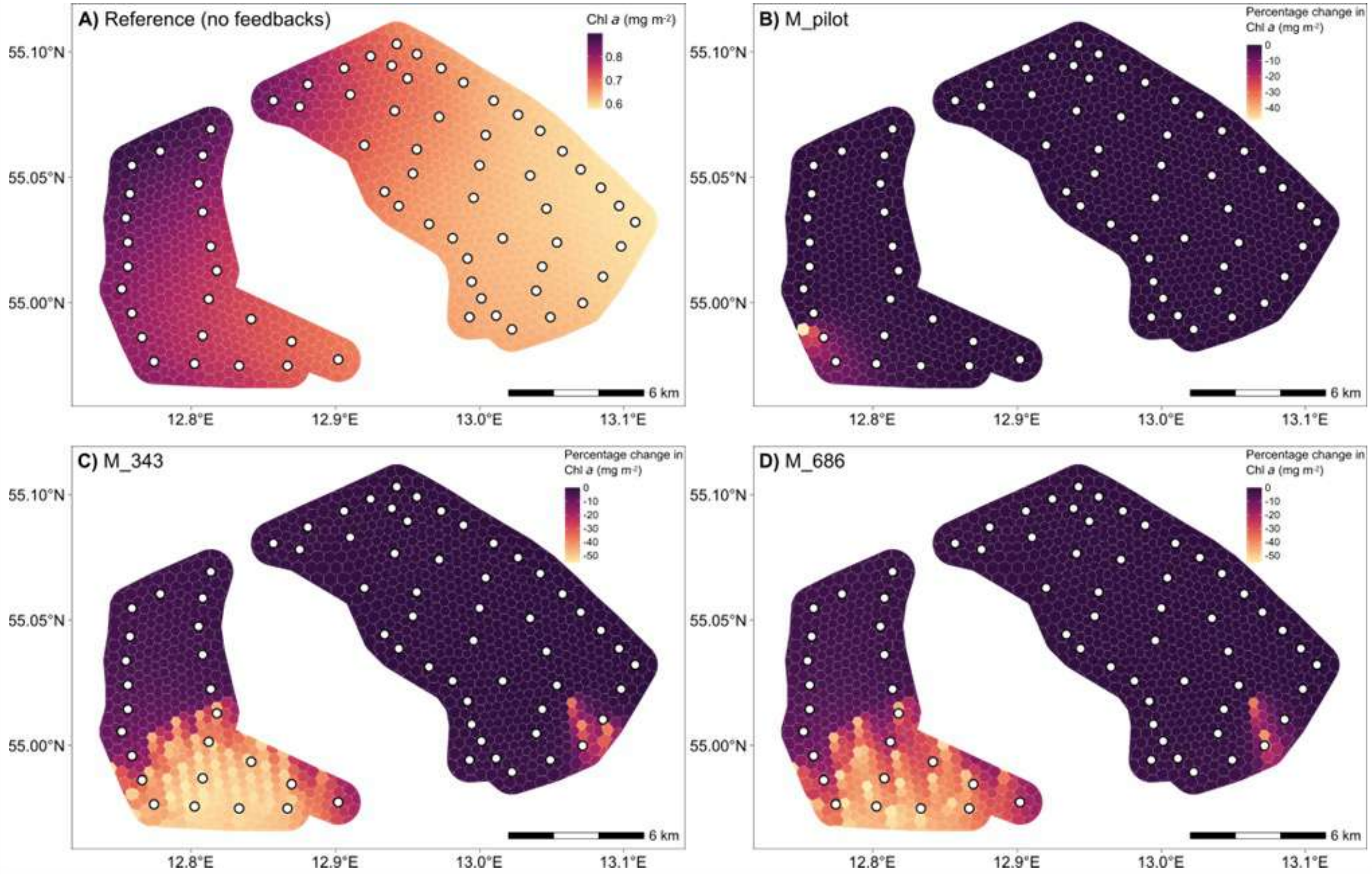
T3.2 Quantification of ecosystem services of Low Trophic Aquaculture

Pilot B: Danish Kriegers Flak (AU)



*Spatial differences in **water clarity** at the surface for the different mussel farming scenarios, measured as percentage difference in Chlorophyll a from the reference screening scenario in which there were no feedbacks from the mussel model to the biogeochemical model. A) Surface Chl a (mg Chl a m-2) in the reference screening scenario; B) Percentage change in Chl a in the M_pilot scenario (single farm in pilot location); C) Percentage change in Chl a in the M_343 scenario (42 farms placed 343 m distant from one another); D) Percentage change in Chl a in the M_686 scenario (22 farms placed 686 m distant from one another).*

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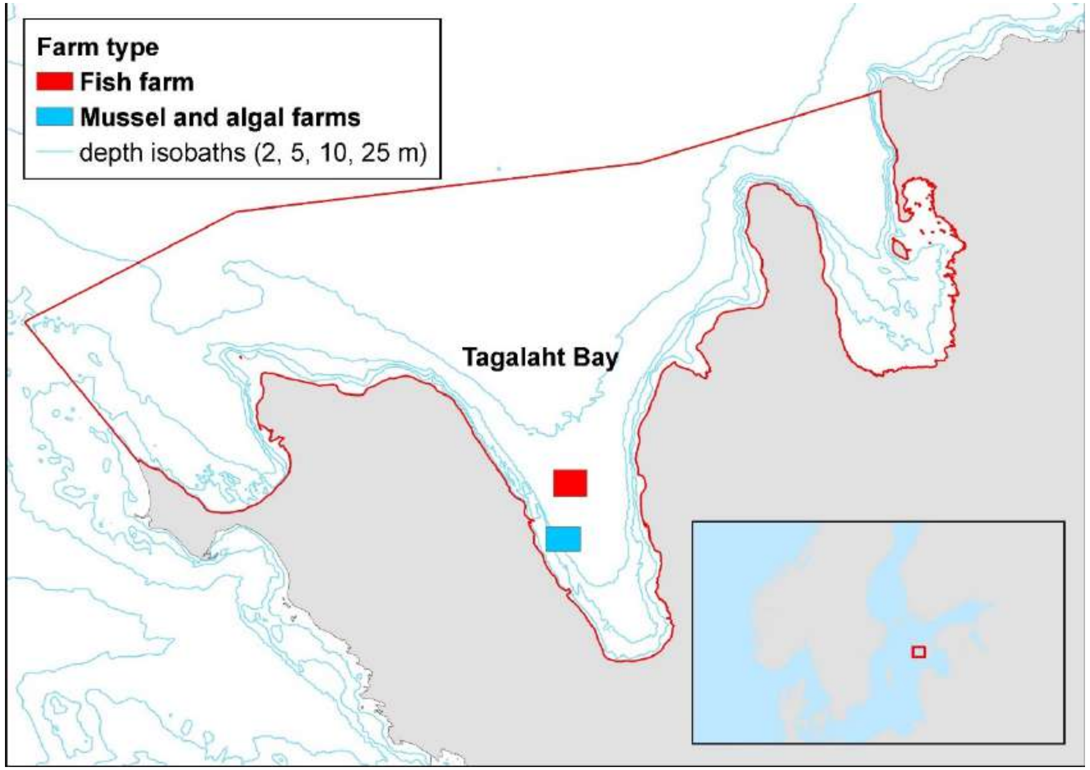
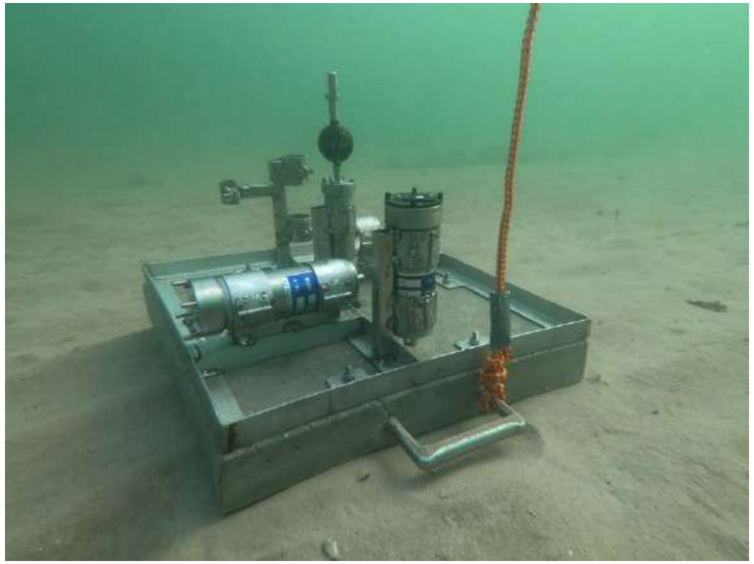
C: Estonian Case Study: Saaremaa





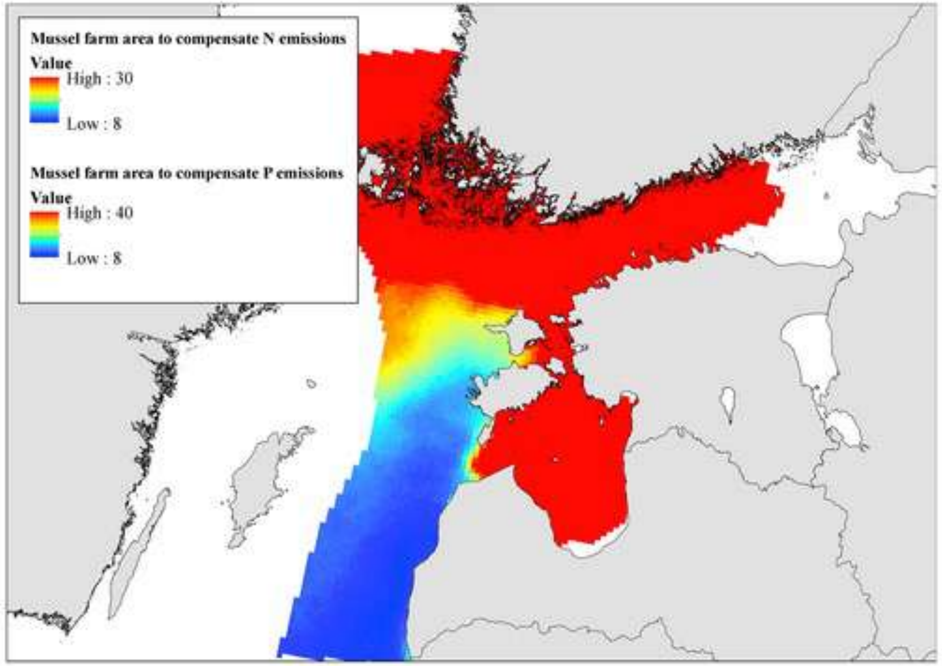
REDSTORM OU

Photos Jack Royd Hall
University of Tartu

T3.1 Low Trophic Aquaculture performance

Pilot C: IMTA at Tagalaht Bay (UT, IMR)

- IMTA trout, mussels and seaweed (*Fucus/Ulva*)
- Developed DEB models for fish, mussels (Kotta et al. 2023)
- DEB model for *Fucus* are being calibrated.
- Current model (trout+mussels) are integrated in an IMTA using forcing data from NEMOv4.0 ocean model and ocean color.
- Integration of seaweed when DEB-IBMs are calibrated.



Spatial variability in the required surface area of a mussel farm (ha) to fully compensate nutrient emissions at a finfish farm. As the spatial patterns of nitrogen (N) and phosphorus (P) compensation potential were exactly the same, we have used a single figure to show the values for N and P.

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Target audience

- Regional, national and EU agencies
- LTA farmers and wind farm operators
- Technology providers
- 5 associated regions
- Climate research community

Photo: Vattenfall

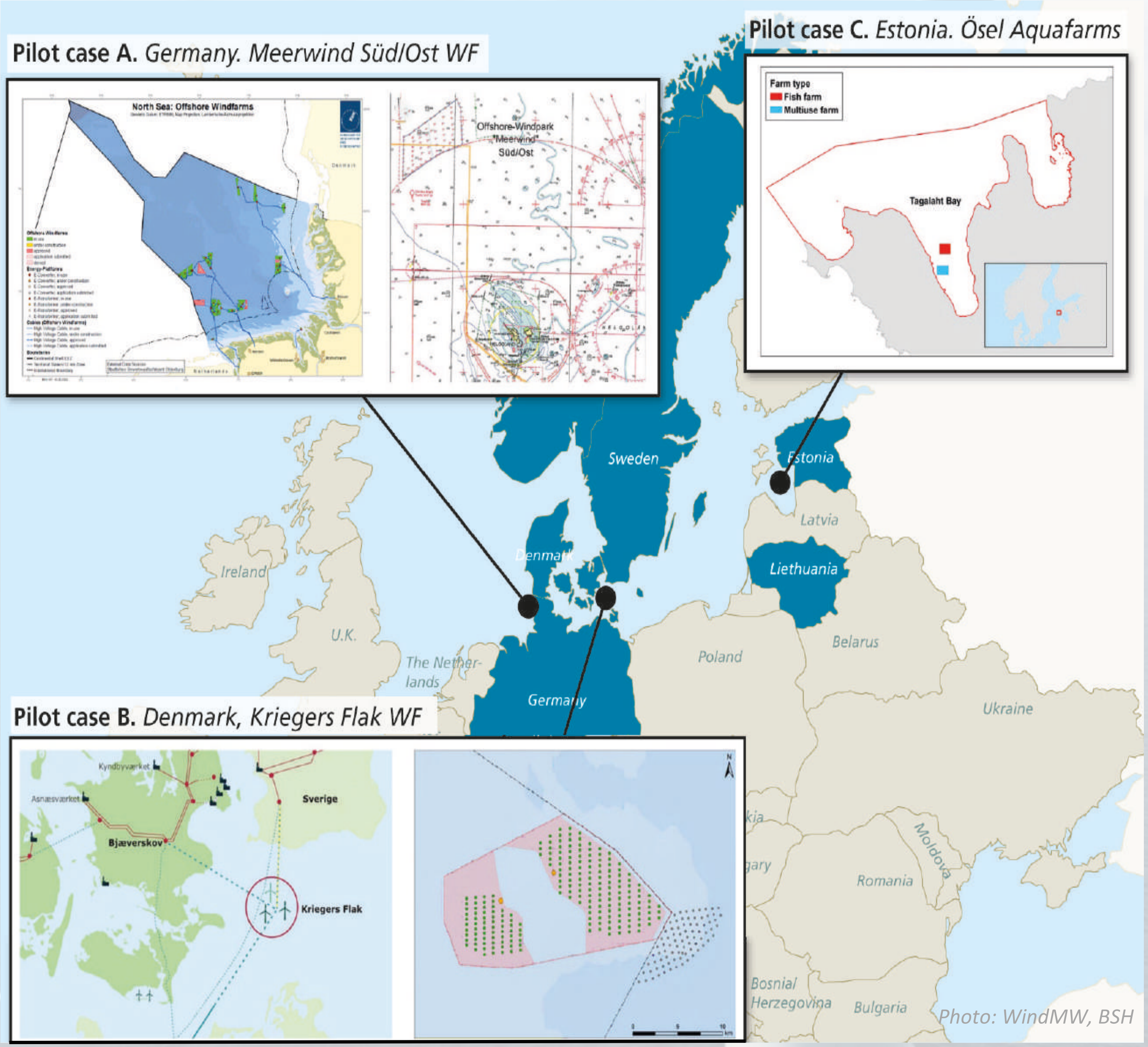

Photo: WindMW, BSH

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SDG Wizard and the Quadruple helix – the science-policy-industry-community interface

How are the 3 OLAMUR Case Studies relevant to the United Nation’s SDGs?

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WP7 Task 7.1: SDG Target Relevance-Tracing: Kriegers Flak Multi-Use Demo

October 2023, Roskilde

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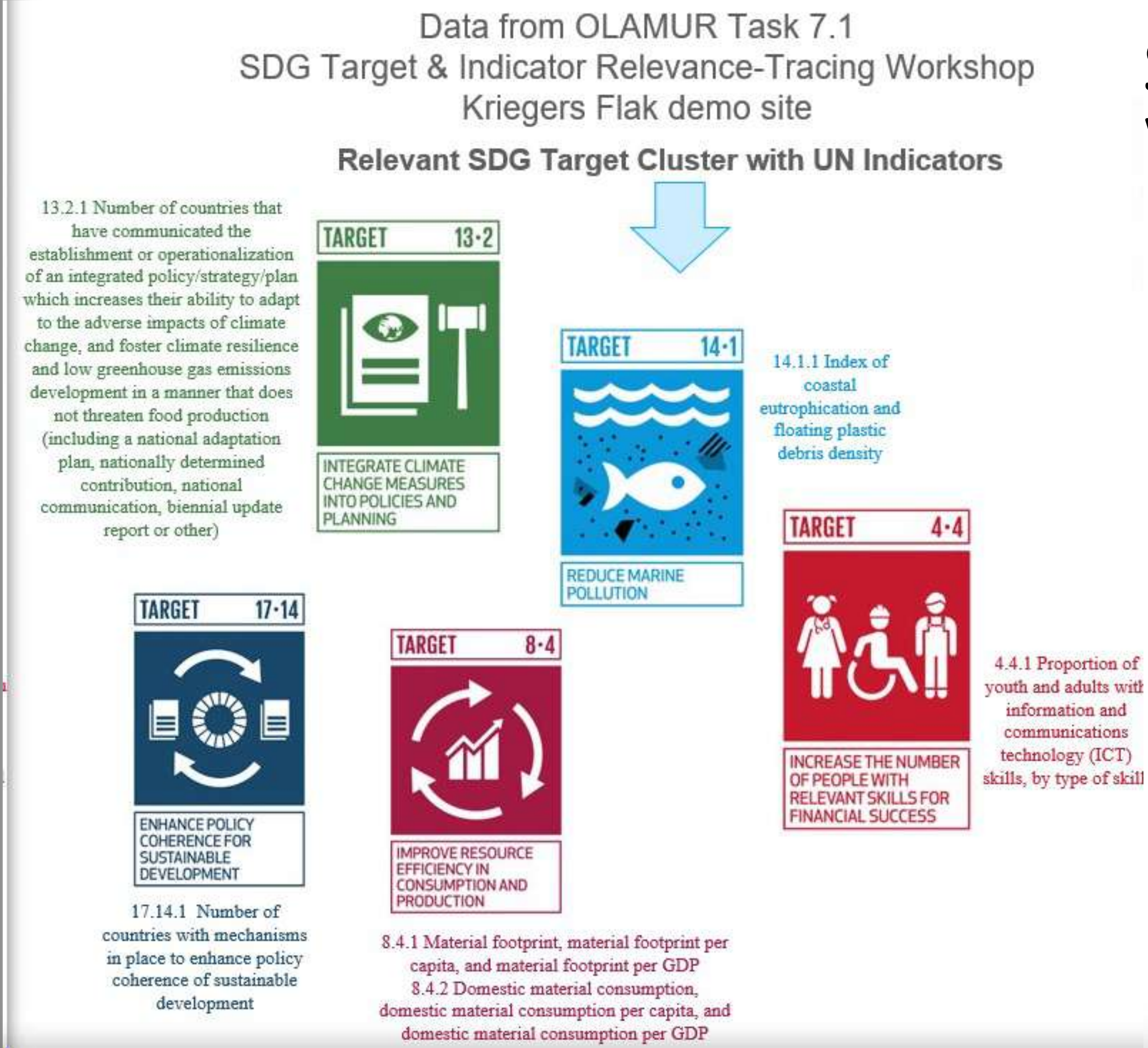
T7.1
SDG Target Relevance-Tracing Workshop



- To identify which of the 169 Targets and associated indicators are relevant for each OLAMUR demo sites

Results:
- Workshop report/joint results publication with WP6 – M28

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Photos: Vattenfall, IMR (Erling Svensen)