North C Neutral

Optimisation and decision support toolkit for marine spatial planning on sea basin level

ORG

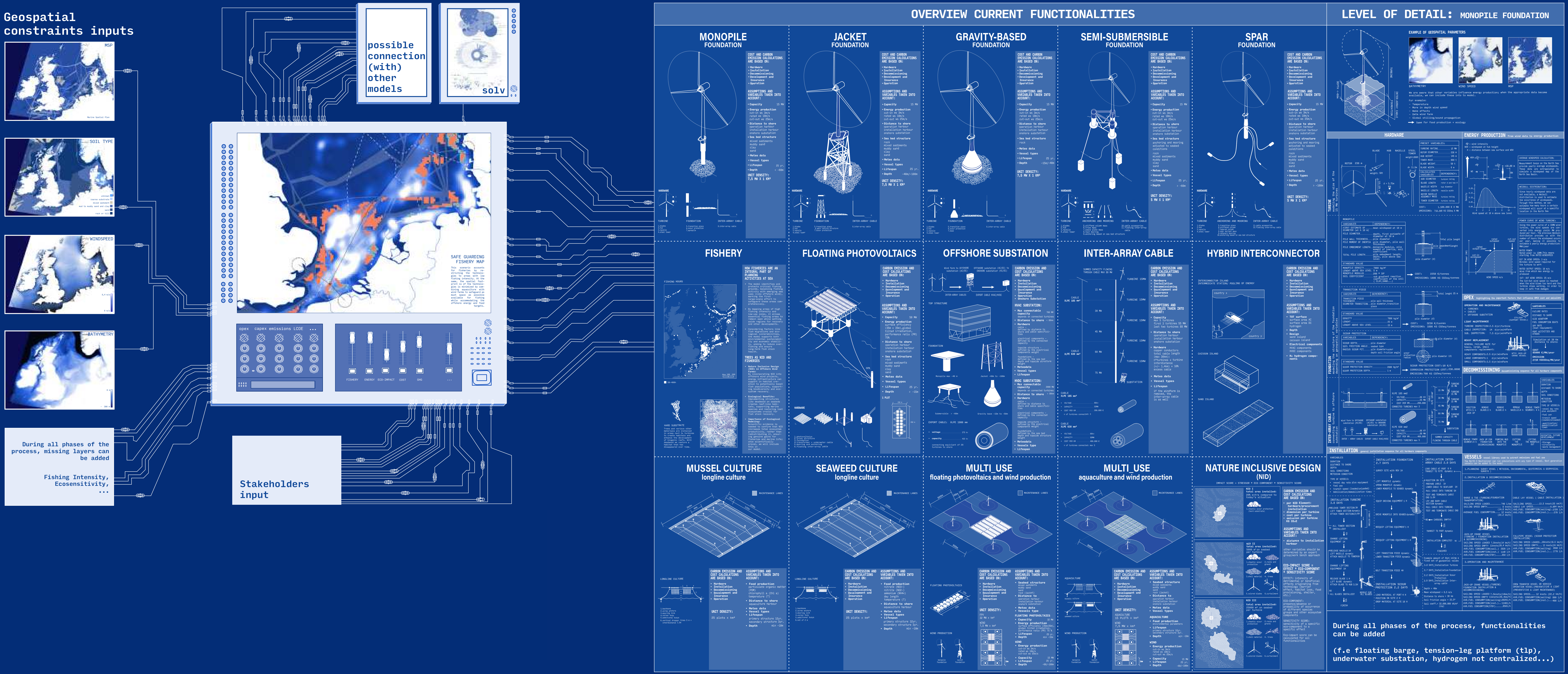
info@orgpermod.com
www.orgpermod.com

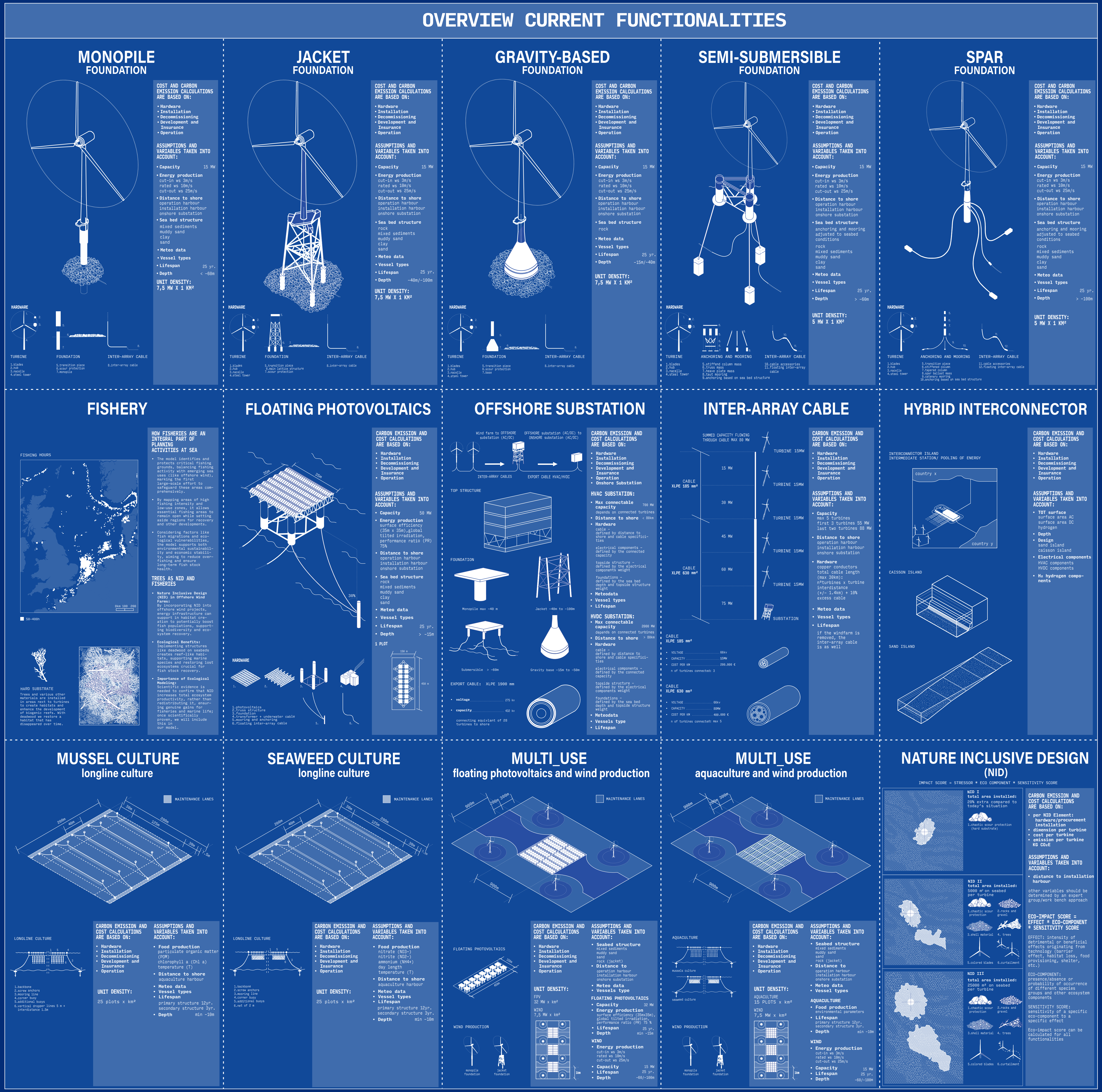
CONTACT

Timothy Vanagt
t.vanagt@orgpermod.com

Marijn Rabaut
marijn@i-marine.expert

North C Neutralizer
Georeferenced Optimization Model





North C Neutralizer

Current functionalities

Energy

Fishery

Aquaculture

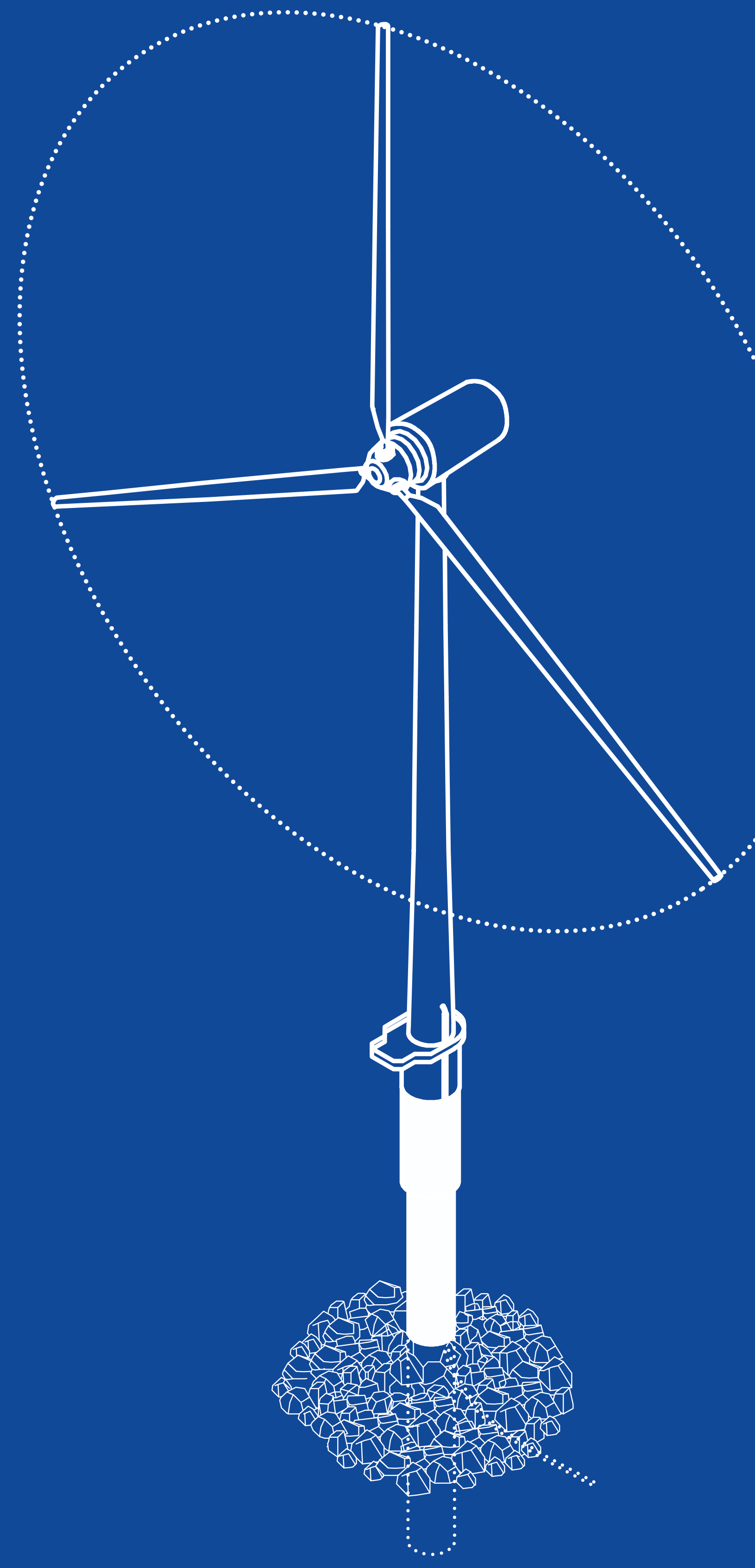
Multi-use

Ecology

New funtionalities can be added throughout the process

North C Neutralizer
ex Monopile
Hardware, Installation, Energy Production, Opex, Decommissioning, Type of Vessels

MONOPILE
FOUNDATION



COST AND CARBON EMISSION CALCULATIONS ARE BASED ON:

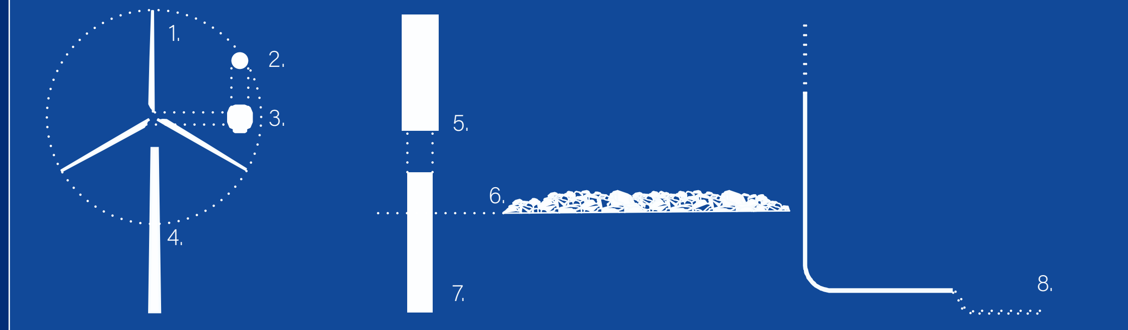
- Hardware
- Installation
- Decommissioning
- Development and Insurance
- Operation

ASSUMPTIONS AND VARIABLES TAKEN INTO ACCOUNT:

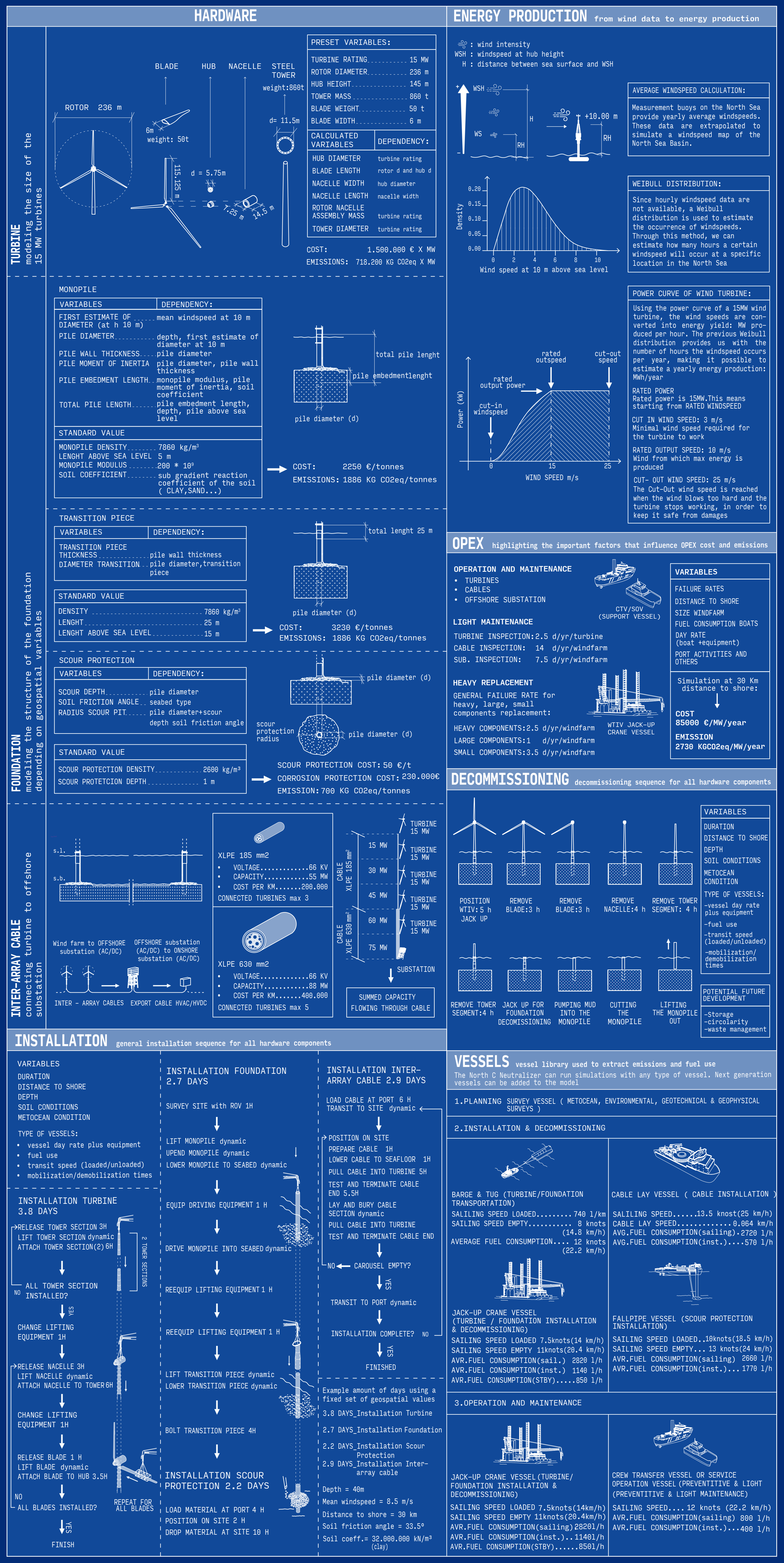
- **Capacity** 15 MW
- **Energy production**
  cut-in ws 3m/s
  rated ws 10m/s
  cut-out ws 25m/s
- **Distance to shore**
  operation harbour
  installation harbour
  onshore substation
- **Sea bed structure**
  mixed sediments
  muddy sand
  clay
  sand
- **Meteo data**
- **Vessel types**
- **Lifespan** 25 yr.
- **Depth** < -60m

UNIT DENSITY:
7,5 MW X 1 KM²

HARDWARE



TURBINE	FOUNDATION	INTER-ARRAY CABLE
1.blades 2.hub 3.nacelle 4.steel tower	5.transition piece 6.scour protection 7.monopile	8.inter-array cable

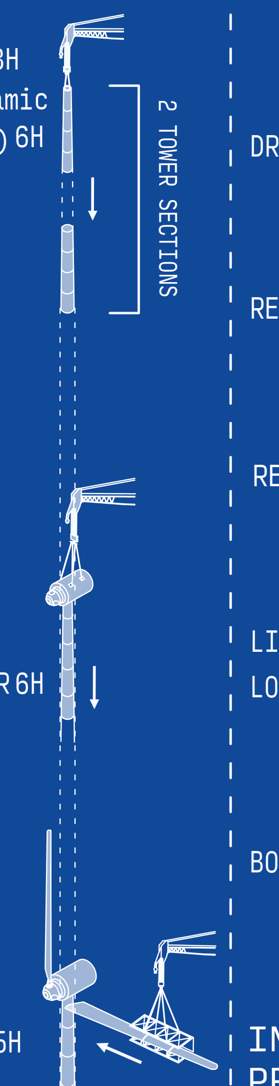


VARIABLES
DURATION
DISTANCE TO SHORE
DEPTH
SOIL CONDITIONS
METOCEAN CONDITION

TYPE OF VESSELS:
- vessel day rate plus equipment
- fuel use
- transit speed (loaded/unloaded)
- mobilization/demobilization times

INSTALLATION TURBINE
3.8 DAYS

→RELEASE TOWER SECTION 3H
LIFT TOWER SECTION dynamic
ATTACH TOWER SECTION(2) 6H
↓
NO ALL TOWER SECTION INSTALLED?
↓ YES
CHANGE LIFTING EQUIPMENT 1H
↓
→RELEASE NACELLE 3H
LIFT NACELLE dynamic
ATTACH NACELLE TO TOWER 6H
↓
CHANGE LIFTING EQUIPMENT 1H
↓
RELEASE BLADE 1 H
LIFT BLADE dynamic
ATTACH BLADE TO HUB 3.5H
↓
NO ALL BLADES INSTALLED? REPEAT FOR ALL BLADES
↓ YES
FINISH

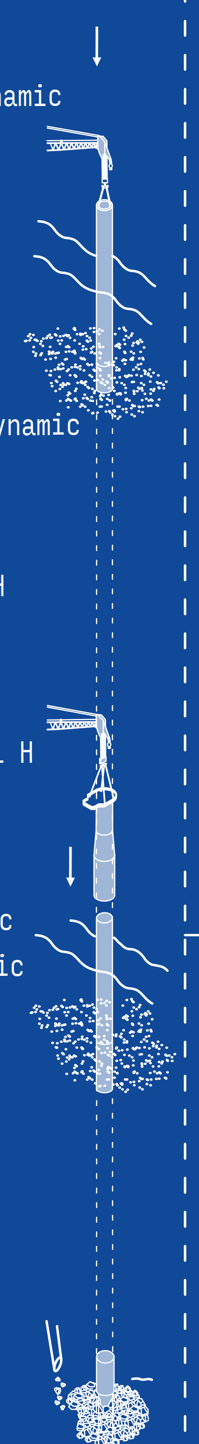


INSTALLATION FOUNDATION
2.7 DAYS

SURVEY SITE with ROV 1H
↓
LIFT MONOPILE dynamic
UPEND MONOPILE dynamic
LOWER MONOPILE TO SEABED dynamic
↓
EQUIP DRIVING EQUIPMENT 1 H
↓
DRIVE MONOPILE INTO SEABED dynamic
↓
REEQUIP LIFTING EQUIPMENT 1 H
↓
REEQUIP LIFTING EQUIPMENT 1 H
↓
LIFT TRANSITION PIECE dynamic
LOWER TRANSITION PIECE dynamic
↓
BOLT TRANSITION PIECE 4H

INSTALLATION SCOUR PROTECTION 2.2 DAYS

LOAD MATERIAL AT PORT 4 H
POSITION ON SITE 2 H
DROP MATERIAL AT SITE 10 H



INSTALLATION INTER-ARRAY CABLE 2.9 DAYS

LOAD CABLE AT PORT 6 H
TRANSIT TO SITE dynamic
↓
→POSITION ON SITE
PREPARE CABLE 1H
LOWER CABLE TO SEAFLOOR 1H
PULL CABLE INTO TURBINE 5H
TEST AND TERMINATE CABLE END 5.5H
LAY AND BURY CABLE SECTION dynamic
PULL CABLE INTO TURBINE
TEST AND TERMINATE CABLE END
↓
NO ← CAROUSEL EMPTY?
↓ YES
TRANSIT TO PORT dynamic
↓
INSTALLATION COMPLETE? NO
↓ YES
FINISHED

Example amount of days using a fixed set of geospatial values

3.8 DAYS_Installation Turbine
2.7 DAYS_Installation Foundation
2.2 DAYS_Installation Scour Protection
2.9 DAYS_Installation Inter-array cable

Depth = 40m
Mean windspeed = 8.5 m/s
Distance to shore = 30 km
Soil friction angle = 33.5º
Soil coeff.= 32.000.000 kN/m³ (clay)

BUSINESS AS USUAL

In this scenario, we describe the "business-as-usual" case for marine spatial planning.

Each country places its offshore technologies as it sees fit, with no regard for cross-border optimization or even optimization within its own region. We assumed that all currently operational wind farms are repowered, under-construction/ approved wind farms are completed, and planned farms are realized.

To meet the final 2050 target, the North C Neutralizer placed the remaining required capacity. This capacity could only be placed in areas identified by countries as development zones for the offshore wind industry. The placement of these wind farms was economically optimized within these zones.

MAIN PARAMETERS

- COST
- ENERGY PRODUCTION

COOPERATION:

NO — YES

LEGEND:

TECHNOLOGIES

- construction approved farms + producing windfarm
- planned farms
- development zones
- monopile
- jacket
- semi-submersible

- PORTS

ENERGY COST

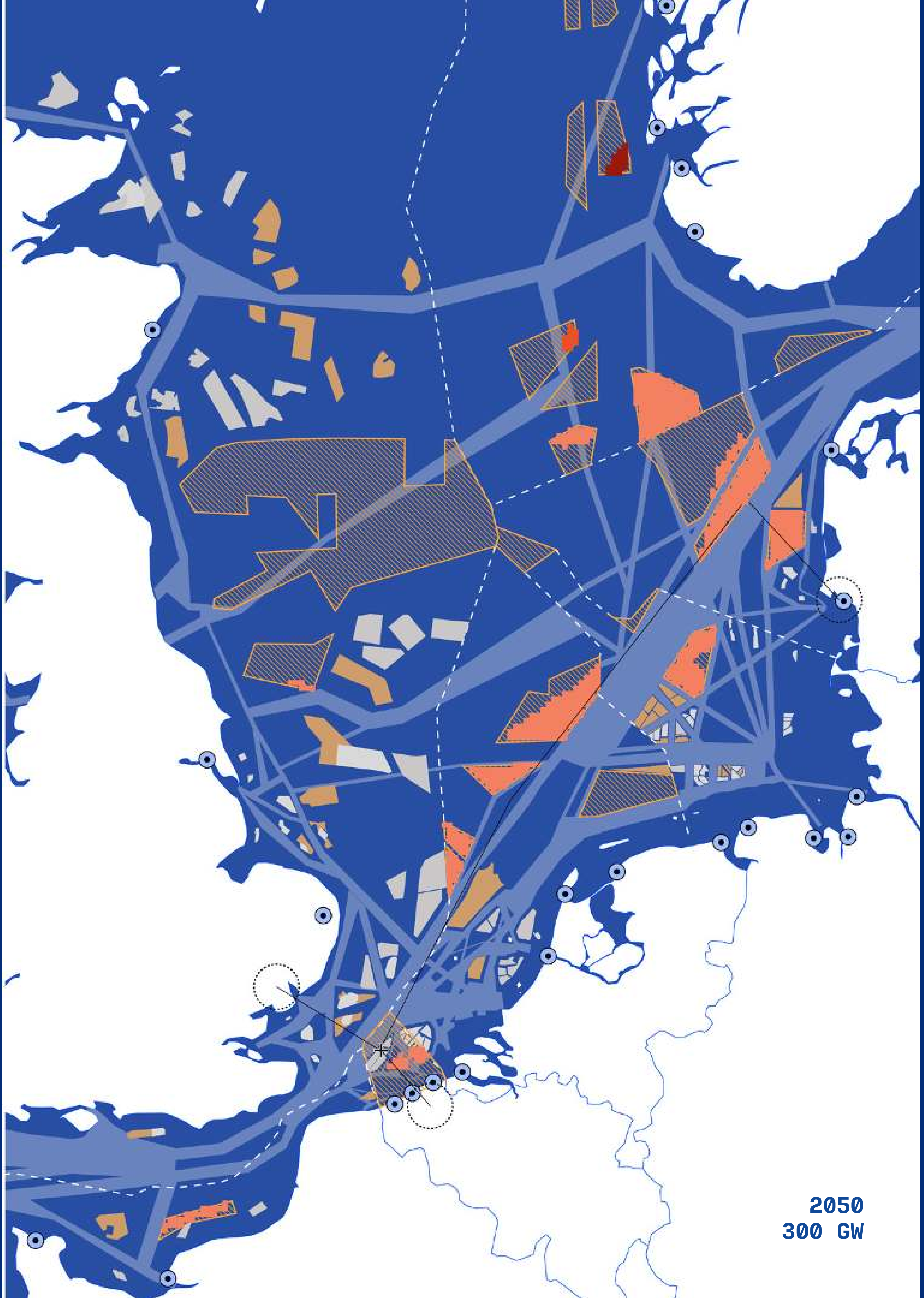
ENERGY PRODUCTION	1,4 M GWh/y
OPEX	35,2 B €/y
Total CAPEX	1,4 T €/y
System-LCOE	115,3 €/MWh
LCOE	**75,4 €/MWh**

CLIMATE CHANGE IMPACT

GHG EMISSION	16,4 M t/y
GHG MITIGATION	238,7 M t/y
NET MITIGATION	222,3 M t/y

(GHG = Green house gas)

ECO IMPACT 1692



COOPERATION OPTIMIZING FOR ECONOMY

To capture the economic benefits of cooperation, we allowed the North C Neutralizer to achieve the 300 GW target through economic optimization.

The difference with previous scenarios is that the only restriction is the energy's final destination: each country must meet its energy target, but the placement of their wind farms is unrestricted by borders. For the year 2050, we only consider the approved and under-construction wind farms; we assume that the planned ones are subject to review and potential improvement.

Harbours for installation and OPEX of the farms are treated as international entities available for use by any stakeholder.

MAIN PARAMETERS

COST

ENERGY PRODUCTION

COOPERATION:

NO YES

LEGEND:

TECHNOLOGIES

- repowered farms
- construction approved farms
- monopile
- jacket

PORTS

ENERGY COST

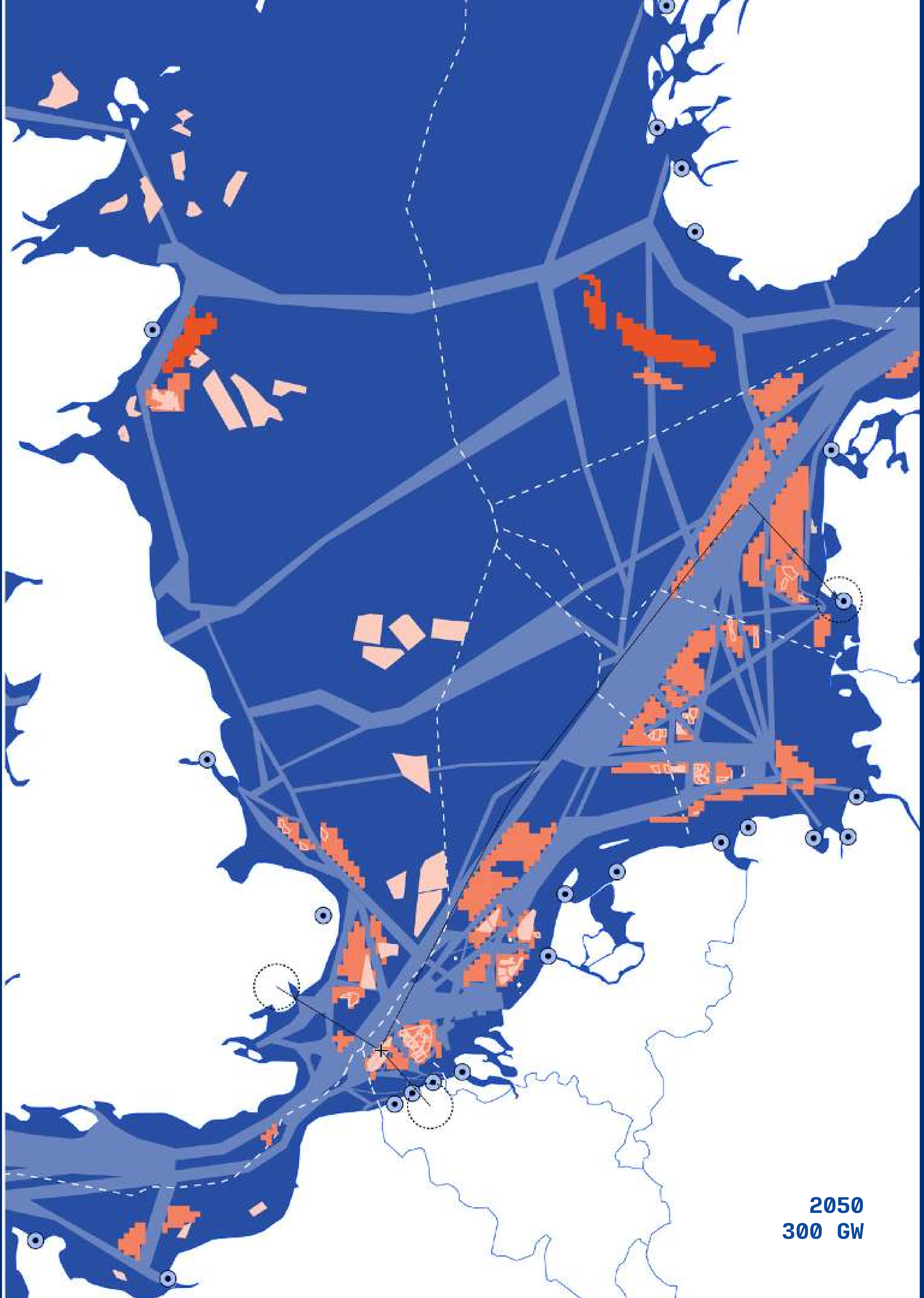
ENERGY PRODUCTION	1,5 M GWh/y
OPEX	33,8 B €/y
Total CAPEX	1,4 T €/y
System-LCOE	107,6 €/MWh
LCOE	**72,3 €/MWh**

CLIMATE CHANGE IMPACT

GHG EMISSION	17,3 M t/y
GHG MITIGATION	257,1 M t/y
NET MITIGATION	239,8 M t/y

(GHG = Green house gas)

ECO IMPACT 2003



FISHERY

Competition for space in the North Sea is becoming an increasingly pressing issue, especially in light of the ambitious goals for offshore renewable energy development. Traditional activities face the risk of losing access and operational freedom, with the fisheries sector being particularly vulnerable. Fisheries require extensive sea areas to operate effectively, and new uses could significantly impact the availability and accessibility of fishing grounds.
For this scenario, we have incorporated a number of measures into our model to safeguard critical fishing areas from encroachment by energy and aquaculture projects:

- **Protecting vital fishing areas:** Energy and aquaculture activities are limited to zones with low fishing intensity, ensuring the preservation of areas critical to North Sea fishing fleets.
- **Optimizing spatial use:** We minimize the footprint of economic activities by integrating energy and aquaculture into multi-use projects.
- **Enhancing ecosystems:** We promote habitat restoration in areas designated for wind and aquaculture activities, contributing to overall biodiversity and supporting the recovery of commercial fish stocks

ENERGY COST

ENERGY PRODUCTION	1,5 M GWh/y
OPEX	34,3 B €/y
Total CAPEX	1,6 T €/y
System-LCOE	123,1 €/MWh
LCOE	**83,3 €/MWh**

CLIMATE CHANGE IMPACT

GHG EMISSION	22,9 M t/y
GHG MITIGATION	249,8 M t/y
NET MITIGATION	226,8 M t/y

(GHG = Green house gas)

FOOD PRODUCTION 1,1 B kg/y

ECO IMPACT 1932

MAIN PARAMETERS

ECO-IMPACT

WAKE EFFECT RESTRICTION

COOPERATION:

NO YES

LEGEND:

TECHNOLOGIES

- monopile
- jacket
- spar
- multiuse: Monopile+mussels
- multiuse: Monopile+seaweed
- multiuse: Jacket+seaweed

HUBS

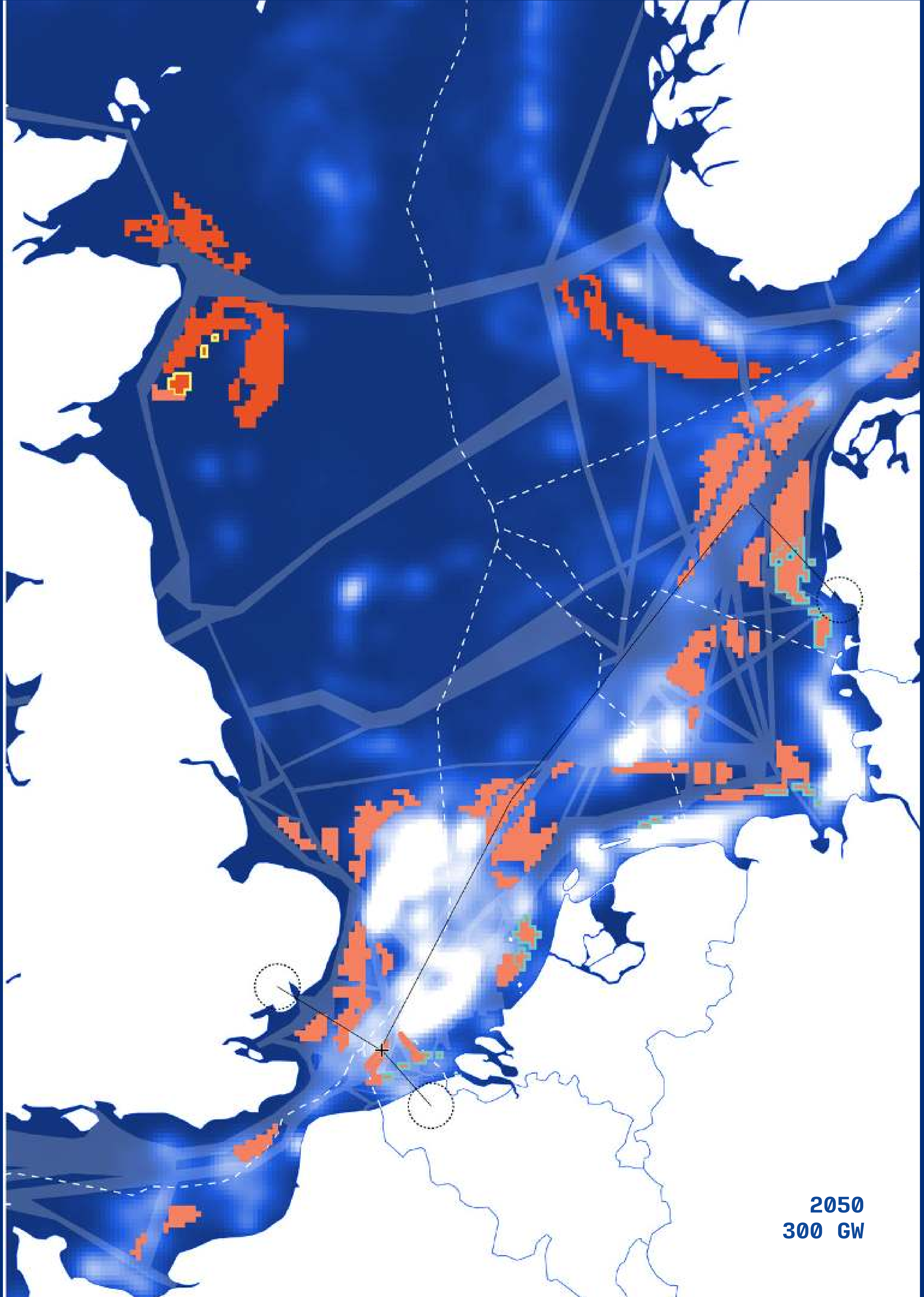
- "Princess Elisabeth Island"
- potential grid connection zone
- energy fluxes

PORTS

FISHERY INTENSITY

high intensity

low intensity



A FULLY INTEGRATED OFFSHORE GRID

In this scenario, we optimized the placement of wind turbines in the North Sea, considering that energy hubs would serve as their sole connection points. These hubs function as the electrical landfall for energy produced by the wind farms while also serving as the OPEX bases for the connected wind farms.

The hubs were strategically placed with a specific purpose: to leverage insights into wind correlations, minimizing the effects of ‘dunkelflaute’ while arranging the individual wind farms to reduce wake effects between them. This approach ensures optimal energy generation and a stable energy supply.

This setup provides Transmission System Operators with greater control over managing the international supply and demand for energy.

ENERGY COST

ENERGY PRODUCTION	1,4 M GWh/y
OPEX	29,1 B €/y
Total CAPEX	1,8 T €/y
System-LCOE	131,7 €/MWh
LCOE	**70,5 €/MWh**

CLIMATE CHANGE IMPACT

GHG EMISSION	21,7 M t/y
GHG MITIGATION	244,0 M t/y
NET MITIGATION	227,5 M t/y

(GHG = Green house gas)

ECO IMPACT 1636

MAIN PARAMETERS

- COST
- ENERGY PRODUCTION
- WAKE EFFECT RESTRICTION
- WIND CORRELATION

COOPERATION:

NO **YES**

LEGEND:

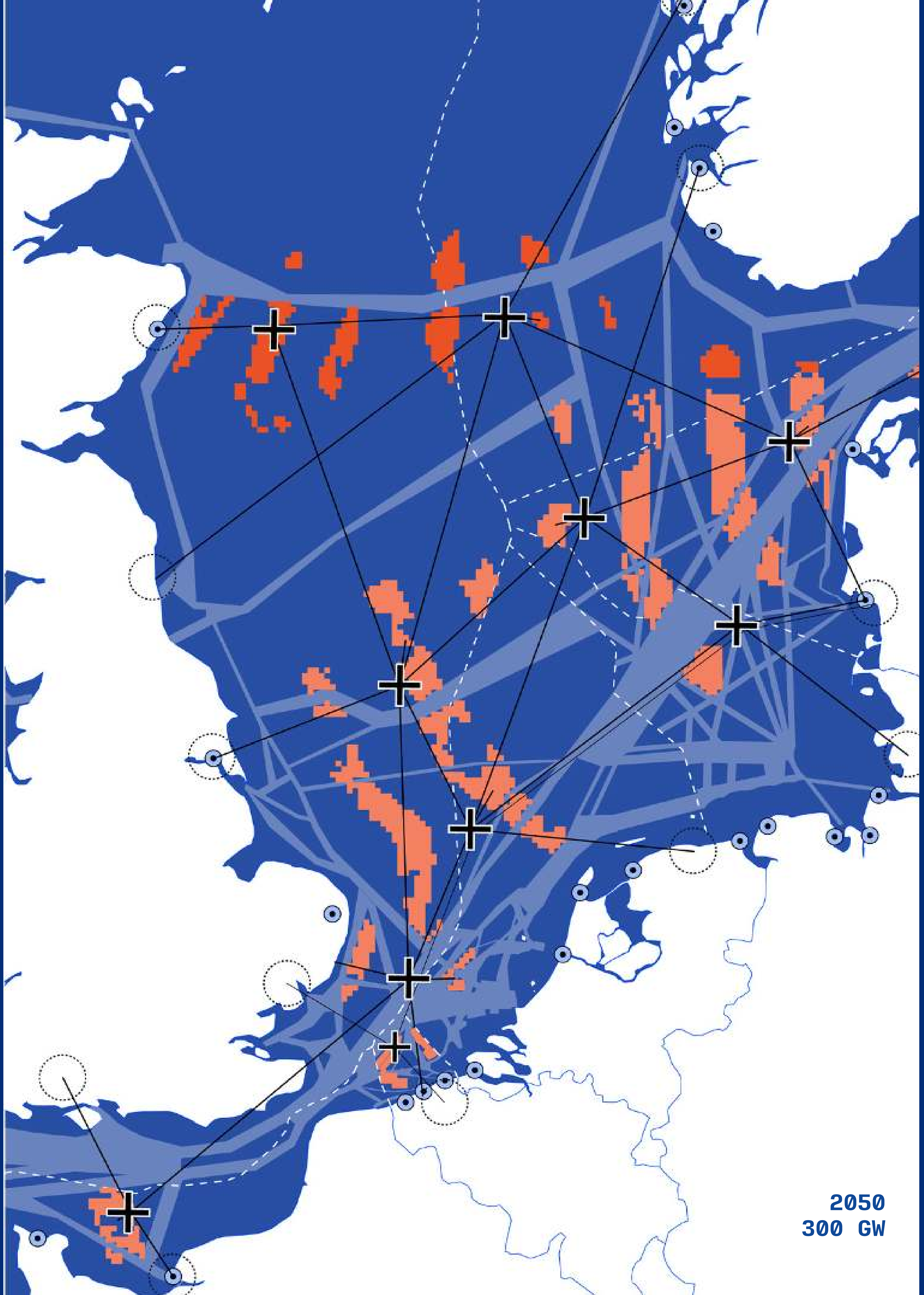
TECHNOLOGIES

- monopile
- jacket

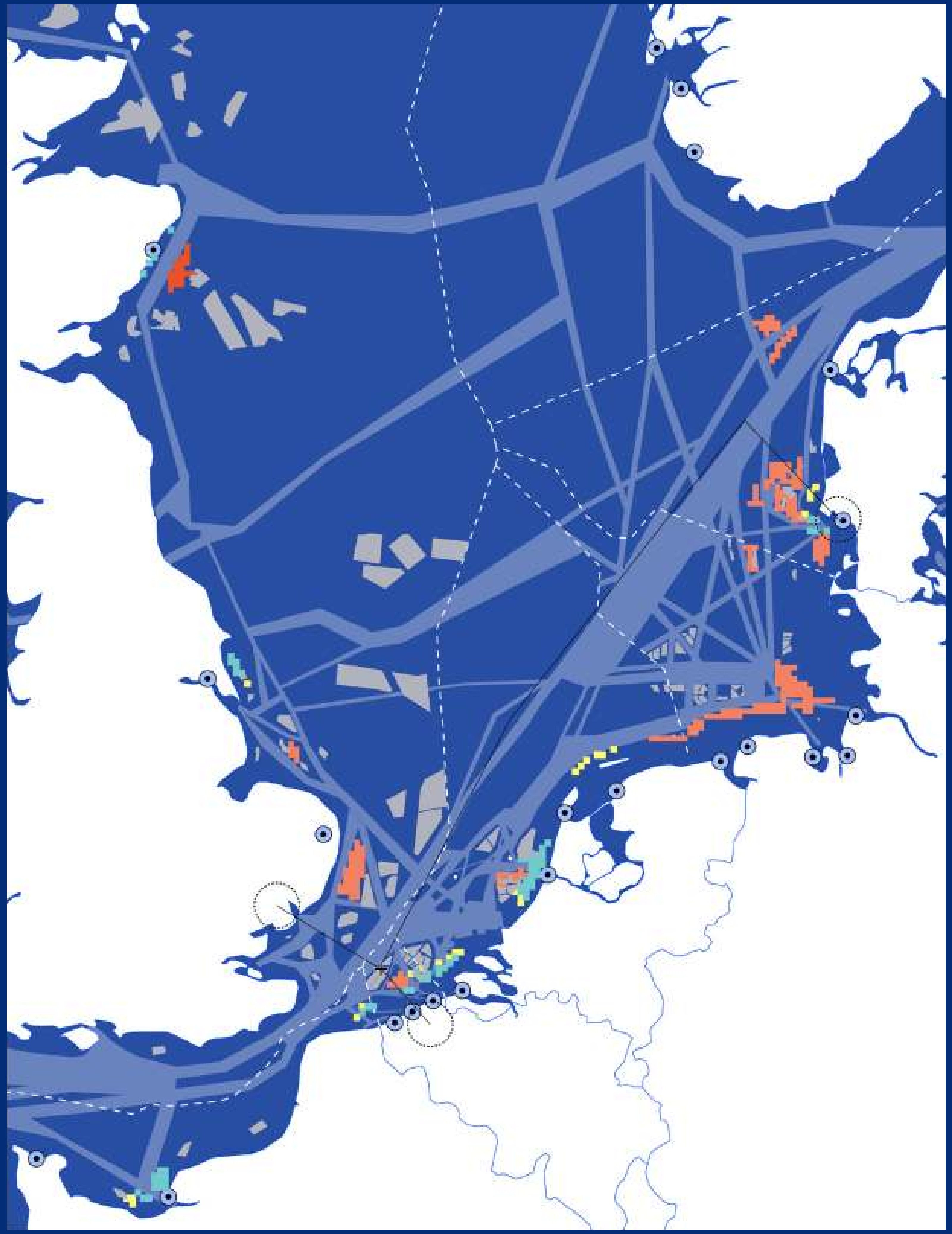
HUBS

- potential hub location
- potential grid connection zone
- energy fluxes

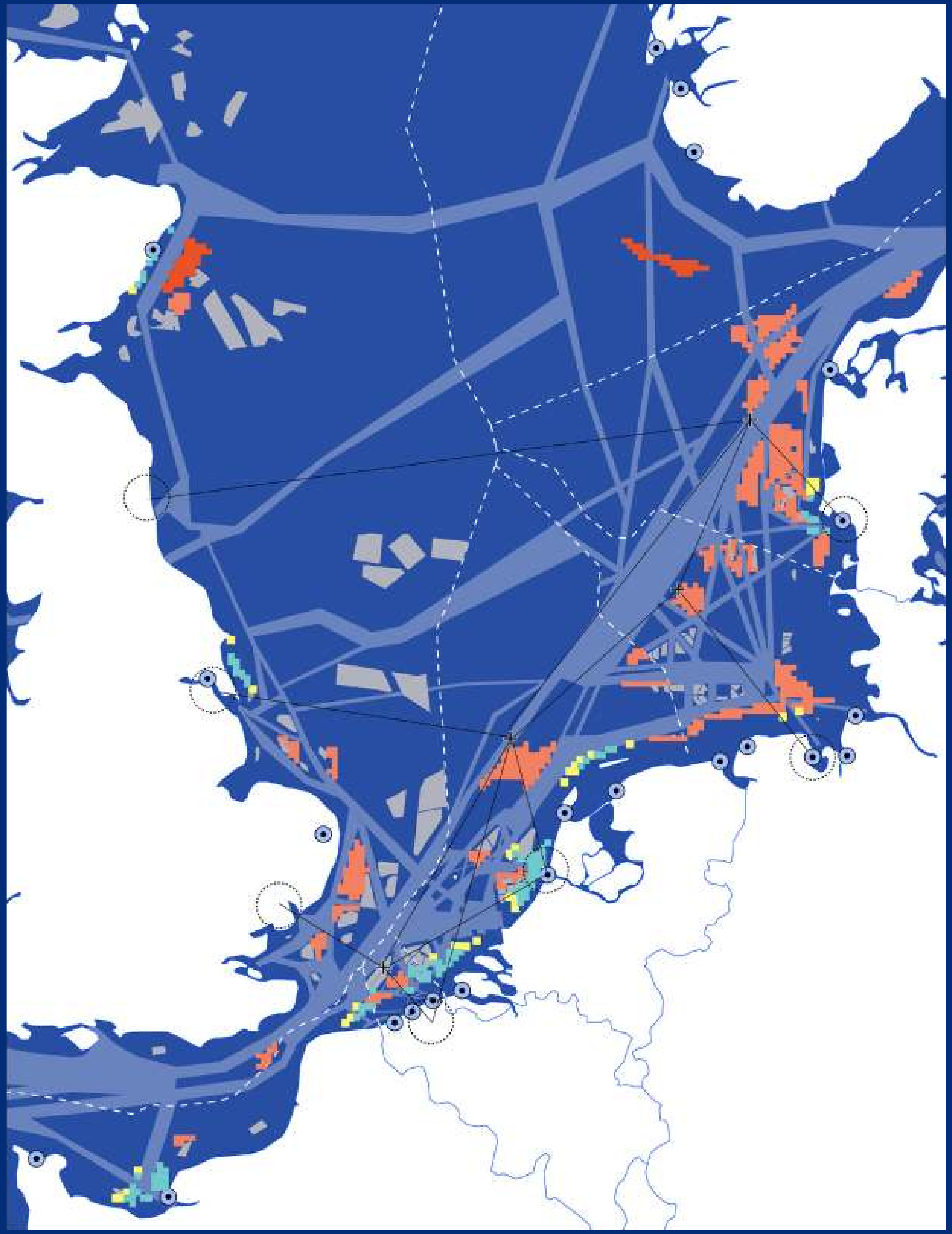
PORTS



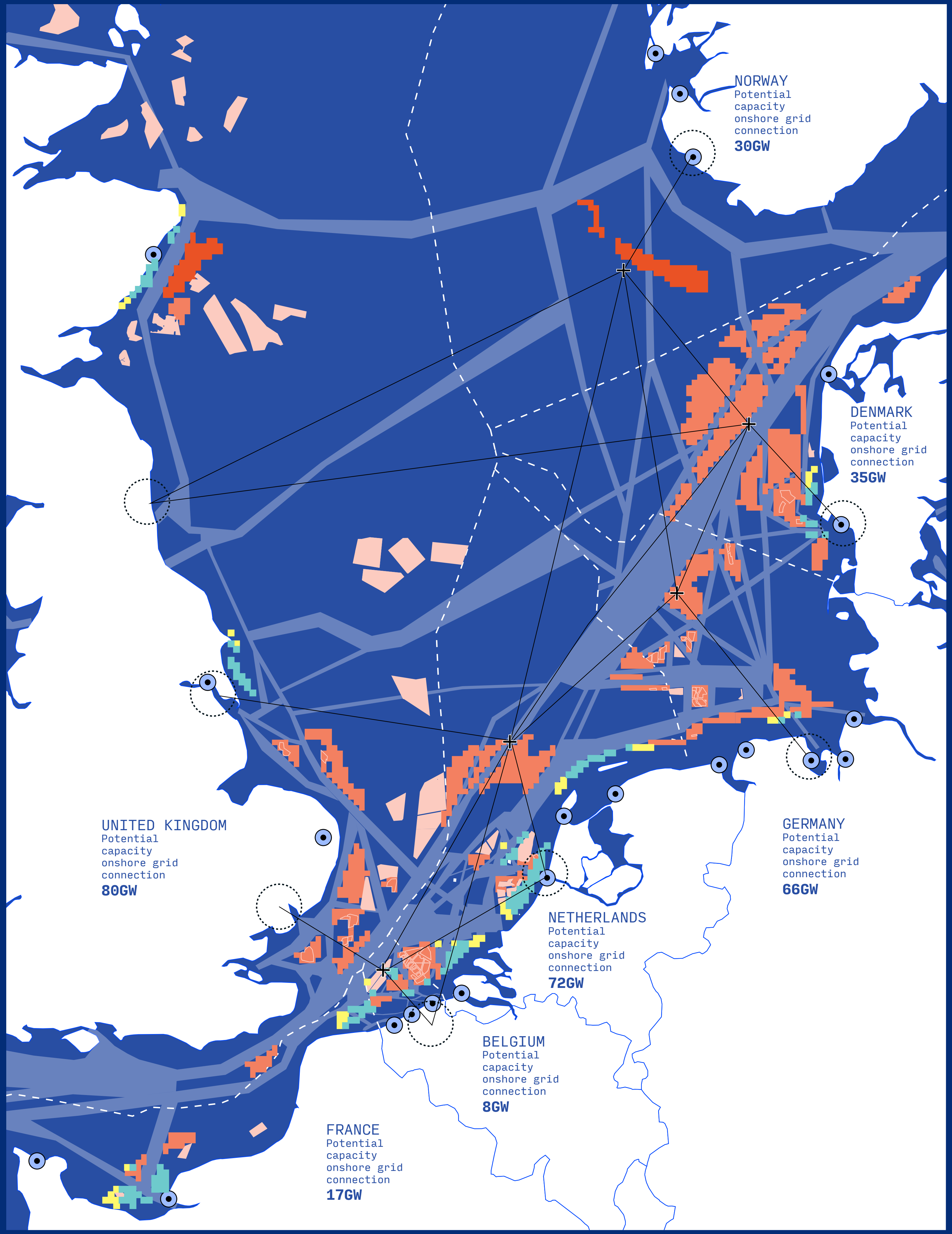
Roadmaps
Over time



2030



2040



2050

Roadmaps

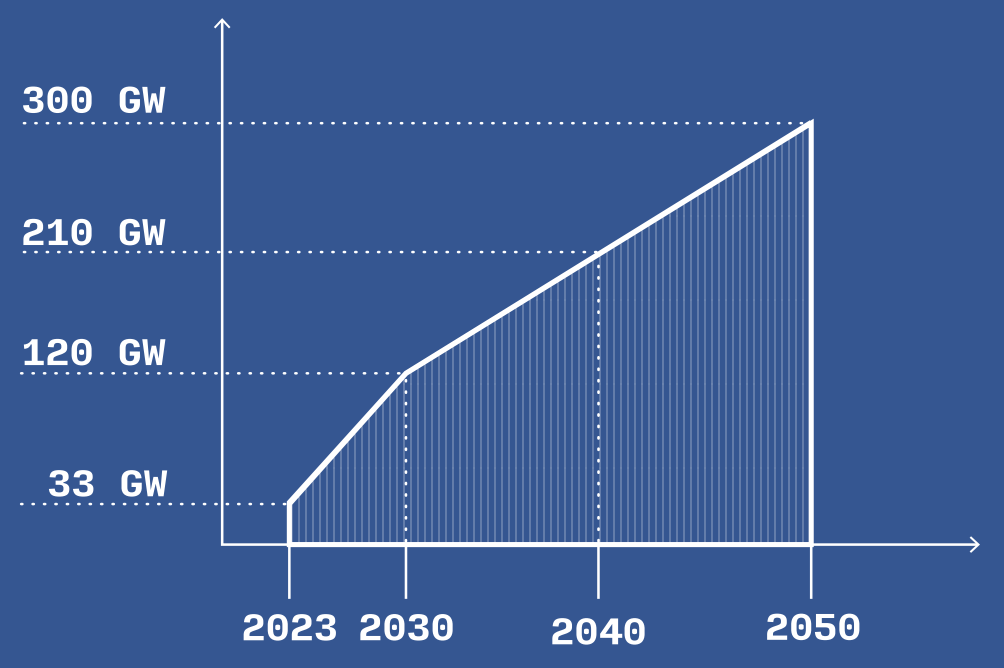
f.e. what about the hardware (monopile)?

ANNUAL DEMAND COMPARISON 2024 / 2050

annual demand of wind turbine	2X
annual demand for cables	2X
demand convertors	3X
steel and iron demand	8X
copper	8X
fibreglass	7X
rare earth metals	8X

CAPACITY GROWTH

This is according to the Ostend declaration (April 2023)



CUMULATIVE DEMAND 2023 → 2050

	2023	2030	2040	2050
total steel needed (tonnes)	7.002.600t	25.464.000t	44.562.000t	63.660.000t
total fibreglass (tonnes)	330.000t	1.200.000t	2.100.000t	3.000.000t
total scour protection (tonnes)	8280800t	30112000t	52696000t	75280000t
total inter-array cable length (km)	3.080km	11.200km	19.600km	28.000km

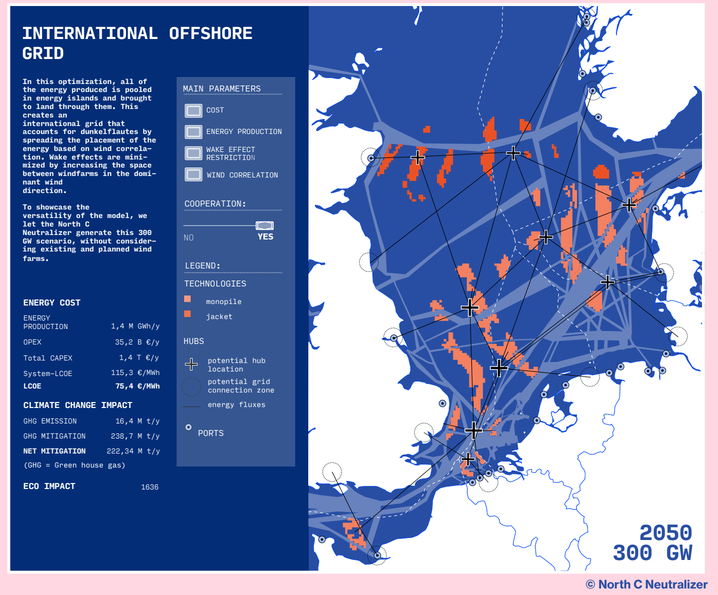
North C Neutral
Optimisation and Decision Support Toolkit
Greater North Sea Basin

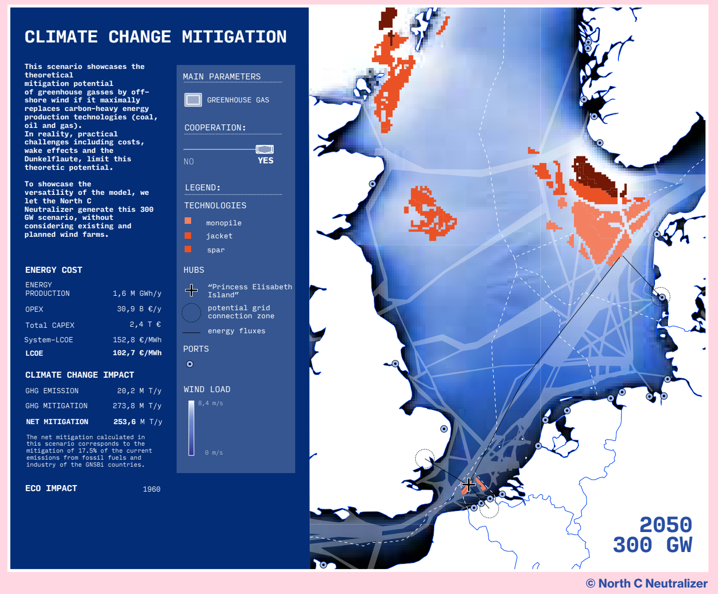
North C Neutralizer

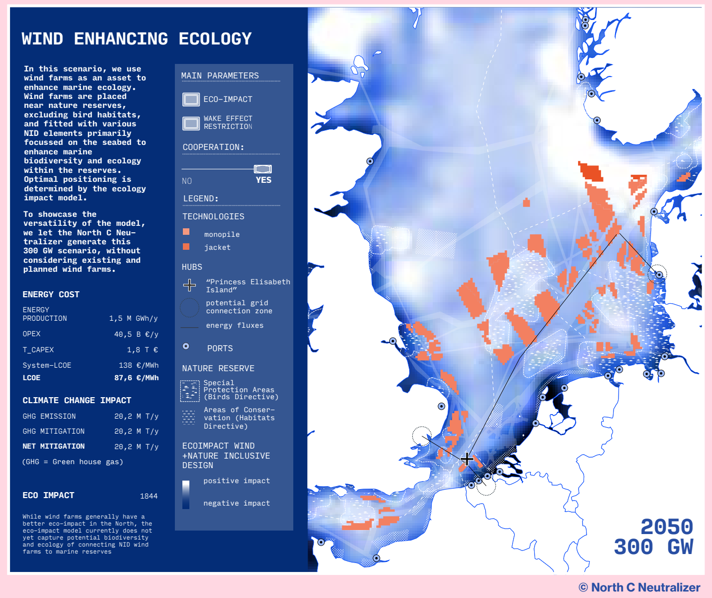
Greater North Sea Basin optimization model

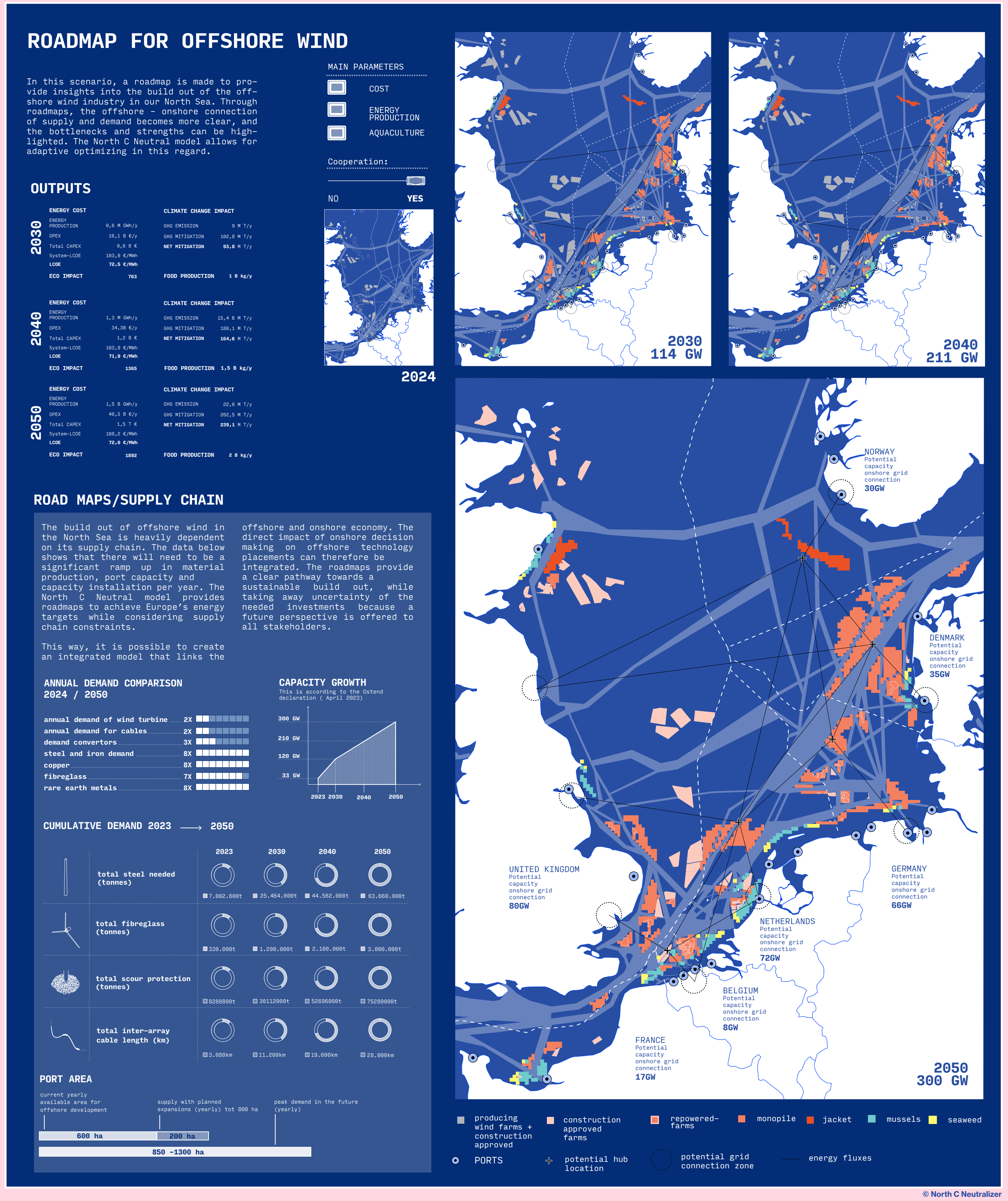
The North C Neutralizer is an innovative and unique optimization model developed for GNSBI. Operating at the sea basin level, it integrates stakeholder interests, leverages the best available data, and builds on existing marine spatial plans. For each desired stakeholder scenario, it seeks an optimal balance across various marine sectors.

Through visualizations and quantitative analyses, the North C Neutralizer clarifies impacts at all levels – from the Greater North Sea Basin to national and even onshore scales, including harbors and energy cable landing points. The detailed roadmaps it generates provide a robust foundation for supply chain planning and financing strategies.









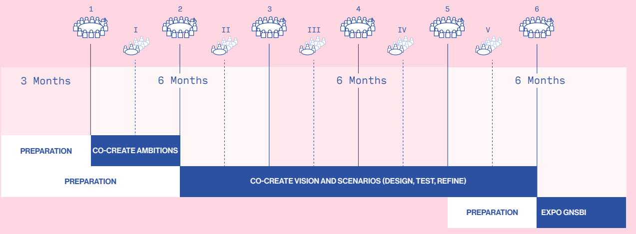
Co-creation

Harvesting Collective Intelligence

To leverage the best available knowledge and assist GNSBI stakeholders toward a unified Greater North Sea Basin strategy, we have designed a dynamic, 1.5-year co-creative process.

In collaboration with GNSBI stakeholders and supported by leading independent experts, we co-create, evaluate, and refine alternatives until we reach a feasible and widely supported set of options for policymakers.The co-creation methodology is designed to include experts from various GNSBI member states, enabling GNSBI to evolve into a truly pan-European project at all levels.

At the end of the process, we envision a traveling exhibition to share the results with citizens across participating countries.



Spatial design

Activate Joint Fact Finding

To "materialize" the outputs of the North C Neutralizer and initiate the joint fact-finding process, we further develop these outputs through spatial design.

In designing at various scales, we reveal hidden aspects, seek solutions, and identify synergies. Opportunities and challenges for each stakeholder group are highlighted, ensuring a transparent process that is easily and continuously accessible to all stakeholders.

Feedback loops between spatial design and the North C Neutralizer make the entire process increasingly adaptive, resulting in more robust solutions.

CONTACT

Timothy Vanagt
t.vanagt@orgpermod.com

Marijn Rabaut
marijn@i-marine.expert

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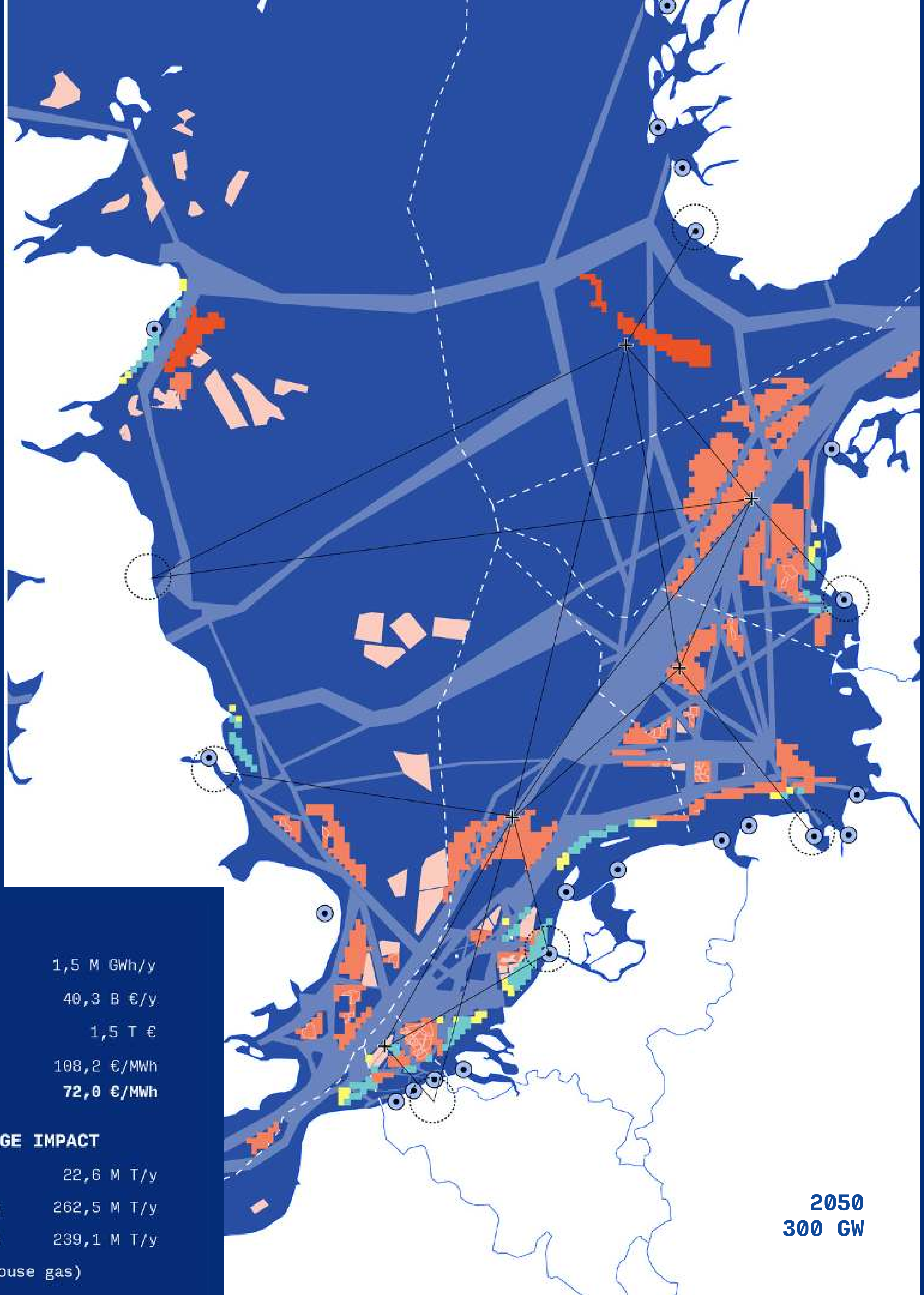


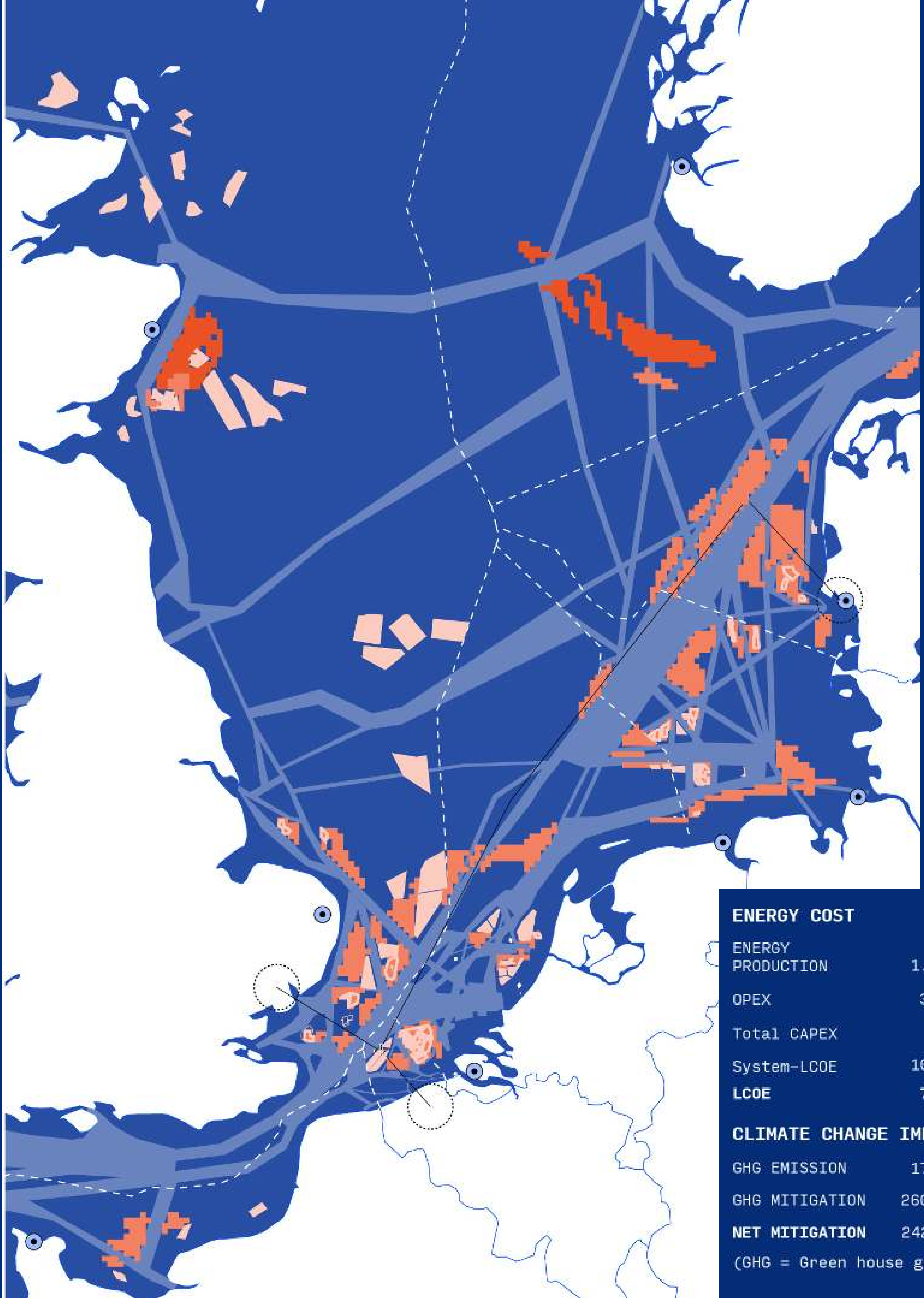
ENERGY COST

ENERGY PRODUCTION	1,5 M GWh/y
OPEX	40,3 B €/y
T_CAPEX	1,5 T €
System-LCOE	108,2 €/MWh
LCOE	**72,0 €/MWh**

CLIMATE CHANGE IMPACT

GHG EMISSION	22,6 M T/y
GHG MITIGATION	262,5 M T/y
NET MITIGATION	239,1 M T/y

(GHG = Green house gas)



ENERGY COST

ENERGY PRODUCTION	1.52 M GWh/y
OPEX	36.62 B €/y
Total CAPEX	1.43 T €/y
System-LCOE	109.12 €/MWh
LCOE	**74.41 €/MWh**

CLIMATE CHANGE IMPACT

GHG EMISSION	17.64 B kg/y
GHG MITIGATION	260.39 B kg/y
NET MITIGATION	242.75 B kg/y

(GHG = Green house gas)