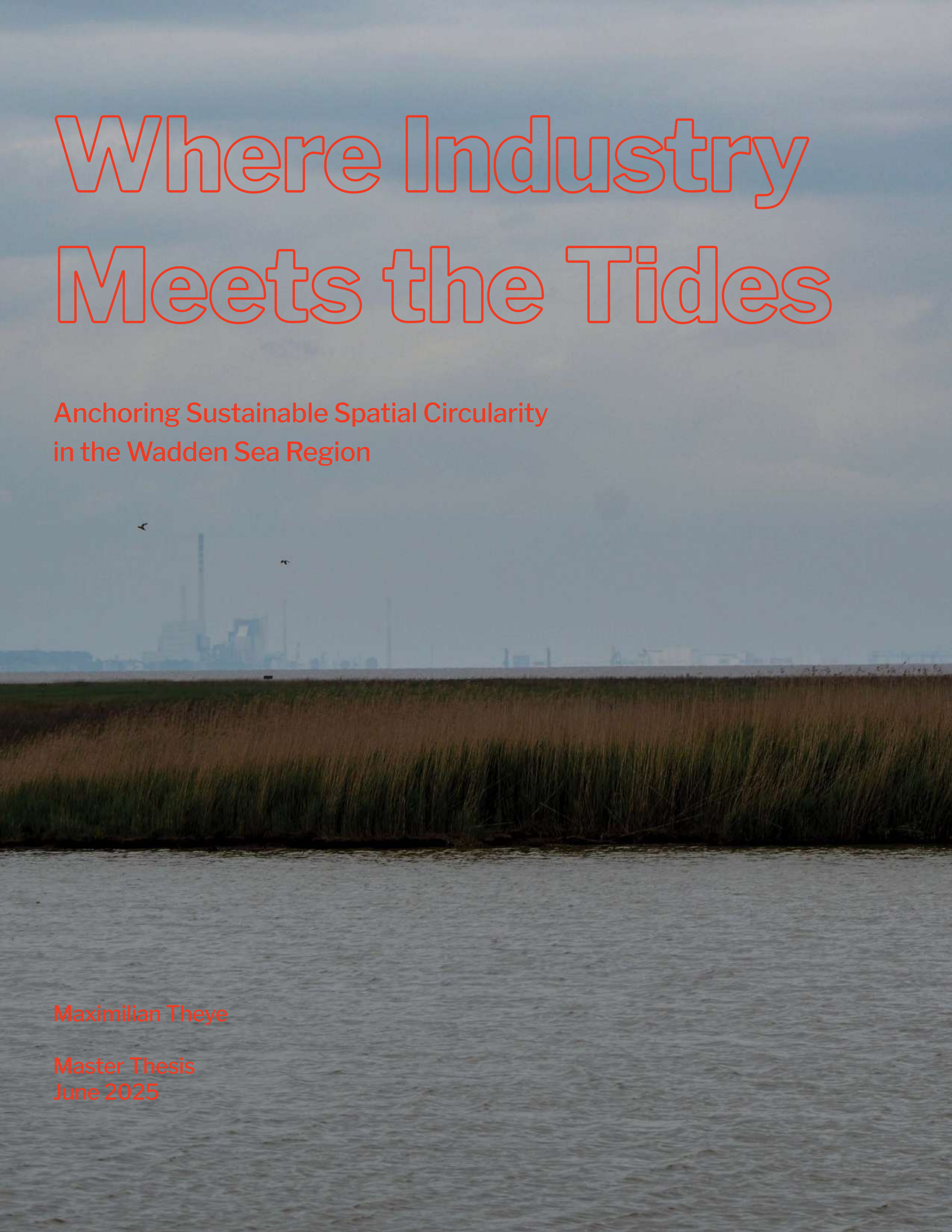

# Where Industry Meets the Tides

## Anchoring Sustainable Spatial Circularity in the Wadden Sea Region

Maximilian Theye

Master Thesis
June 2025

Master Thesis – Final P5 Report
MSc Architecture, Urbanism and Building Sciences – Track Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology

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Metropolitan Ecology of Places

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Author:
Maximilian Theye
Student number:
6067751

Supervisors
First Mentor:
Dr Alexander Wandl – Section of Environmental Technology and Design

Second Mentor:
Teake Bouma – Section of Urban Design



TU Delft
BK Bouwkunde

# Where Industry Meets the Tides

Anchoring Sustainable Spatial Circularity in the Wadden Sea Region


Jade Bay, June 2025

**Abstract**
This thesis investigates how the industrial system of the Wadden Sea region can be spatially transformed towards Sustainable Circularity. As a semi-peripheral and ecologically fragile territory, the region operates as an operational hinterland for Europe where extractive industries intersect with vulnerable landscapes and dispersed communities.

Using the theoretical lenses of metabolism and territorialism, the research explores four key questions:
(1) it maps the regional spatial-industrial history,
(2) examines how territorial and metabolic processes co-shape current regional dynamics,
(3) identifies leverage points and spatial pathways for systemic transition and
(4) proposes strategic design interventions on the regional and the local scale.

The methodology combines diachronic mapping, territorial capital analysis and spatial flow readings, not to quantify, but to reveal underlying spatial organisational principles and systemic logics. These are synthesised into three structuring motors: productive, protective and ecological. Based on these, the thesis formulates a vision for a sustainable, cross-border metabolism, that is explored through scenarios. The resulting findings are structured and made actionable through an adaptive strategic framework. A zoom-in on the city of Emden illustrates how baseline spatial interventions can anchor long-term transitions.

The work contributes to current discourse on circular economy, regional transformation and design-led planning by offering a spatially explicit and theoretically grounded approach. It situates industrial sustainability in policy, process and simultaneously in the fabric of the landscape and the design of territorial futures.

*Keywords:* Circular Economy – Research by Design – Territorial Metabolism – Regional Design – Sustainability Transition –
Wadden Sea Region

**Managementsamenvatting**
Dit afstudeerproject onderzoekt hoe het industriële systeem in de Waddenzee-regio ruimtelijk kan worden heringericht richting circulariteit. Als ecologisch kwetsbare en economisch semi-perifere zone fungeert de regio als 'operationeel achterland' binnen Europese industriële netwerken. De studie koppelt inzichten uit territoriaal metabolisme en planetary urbanisation aan ruimtelijke analyse, scenariodenken en ontwerp. Via kaarten, systeemlezen en een lokale ontwerptoepassing in Emden worden spanningen blootgelegd en handelingsperspectieven ontwikkeld. Het resultaat is een adaptief strategisch kader dat duurzame industriële transitie koppelt aan concreet ruimtelijk ontwerp en bijdraagt aan de discussie rond circulaire economie en regionale ontwikkeling.

**Projektüberblick**
Diese Masterarbeit untersucht, wie das industrielle System der Wattenmeerregion durch räumliches Design in Richtung Zirkularität umstrukturiert werden kann. Die Region ist ökologisch sensibel und wirtschaftlich semi-peripher: ein „operatives Hinterland" innerhalb europäischer Industrieverflechtungen. Aufbauend auf Ansätzen zum territorialen Metabolismus und zur planetaren Urbanisierung analysiert die Arbeit räumlich-systemische Dynamiken und entwickelt Szenarien für zukünftige Transformationen. Eine vertiefte Entwurfsstudie in Emden zeigt konkrete räumliche Handlungsansätze. Das Ergebnis ist ein adaptiver strategischer Rahmen, der industrielle Nachhaltigkeit mit landschaftsbezogenem Entwurf und regionaler Planung verknüpft.


Outer dike in the Eemshaven, January 2025

## Acknowledgements

This was an intense journey. I put everything I could into it – ten months of deep learning, stubborn persistence and not a small amount of ctrl+z. I owe many thanks to those who accompanied, challenged, grounded and occasionally rescued me along the way.

To my mentors: thank you for navigating this process with me. Alex, you always had the next step in sight before I had even finished the current one. This kept me on my toes and pushed the project forward faster than I thought was possible. Teake, you brought calm curiosity, sharing my fascination for the region and opened up the space for deeper thought and long conversation, while reminding me, when needed, that rest is part of the work. With the two of you, I was well covered.

To the MEP studio: thank you for being the kind of environment where good humour and good feedback go hand in hand. The right tools, timely tips, and a steady stream of opinions: I would not have had it any other way.

To my fellow Urbanism students: thank you for the innumerable coffee breaks (arabica > robusta), the collective worry spirals and the last-minute slide reviews. Special thanks to Janne, Jasmin, Moritz and Paulina for their sharp insights and reliable edits; to Lisa for the final sprint; to Luisa and Sophie for layout wizardry; to Laura for energy advice; to Thijs for sparring over Emden with a designerly mindset; and to Alina and Fruzsi for pushing the conceptual edges. And to my housemates: thank you for the laughter, the food and for not thinking I was completely crazy when I said “I’m almost done with my project” for the twentieth time.

I would also like to thank the experts and interview partners on both sides of the border. Your generously shared insights grounded this project and connected it to the real-world stakes it was always meant to address. I deeply appreciated how seriously you engaged with my scenarios: with attention, critique and genuine interest.

And finally, to my parents (and Elly): thank you for being the constant in all this. Your love, support, patience and the knowledge that I always had a place to return to made more of a difference than I can put in a paragraph.

# Contents

**Colophon**
This report summarises the final results of my graduation project on the industrial system in the Wadden Sea region and its potential circular transformation. The process that is represented in this document took place from September 2024 until June 2025 and took place as part of the graduation studio Metropolitan Ecology of Places.

Results from the Studio Essential and the Focus & Integration intensive form part of the contents, while tutoring sessions with Alexander Wandl and Teake Bouma guided the development of this overall product.

The report is set up as follows:
Firstly, the Foundation sets the scene and introduces the topic and the related problems and approach. The Inventarisation contains the results of the analysis of the region, while the Projection translates them into an investigation into future circular pathways.


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Park
MAIN
ENTRANCE
3300-3350

1

# Introduction

# Shared Landscapes, Shared Pressures

## Initial Fascination

**1.1 Kanal mit gelber Brücke by Franz Radziwill, 1928. Collection of Hamburger Kunsthalle**

What first drew me to the Wadden Sea region was the sharp contrast: vast, open landscapes that are interrupted by clusters of intense industry. This tension is not new. Almost a century ago, painters from both sides of the border captured it: Franz Radziwill in Germany (Fig. 1.1) and Jan Altink in the Netherlands (Fig. 1.2) each painted the regional landscape with industry intruding on the pastoral surroundings. Their work showed me something crucial. Despite the national border, the whole region shares one common spatial condition: the overlap of ecology and industry. This realisation became my starting point.

1.2 Dijk langs het Reitdiep by Jan Altink, 1927. Collection of Groninger Museum.


1.3 The Niedervieland area of Bremen in 2025, where Landscape and Industrial System come together

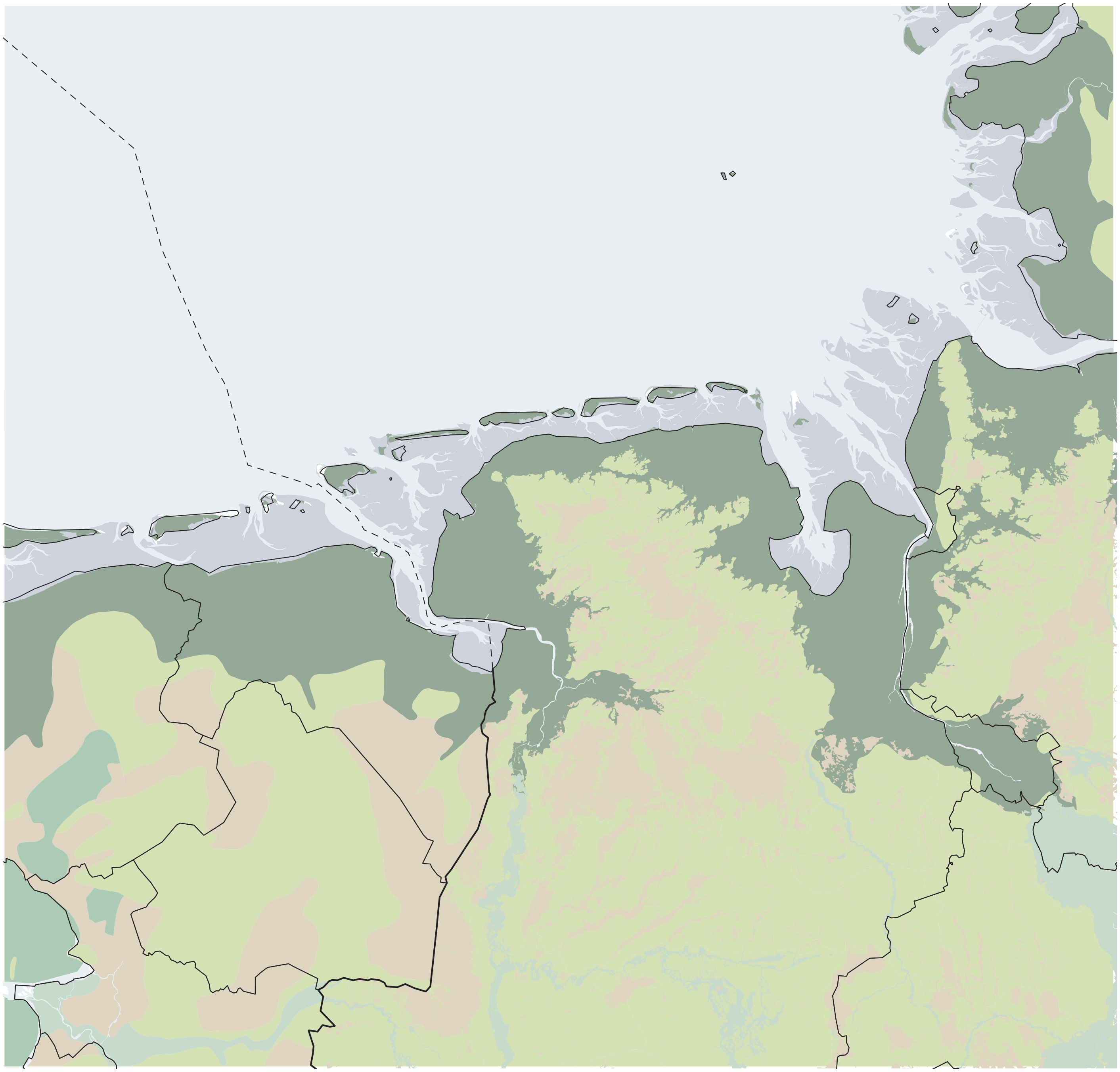
Fig. 1.3 shows how this duality still exists today. In the Niedervieland area of Bremen, steelworks and high-voltage lines, just like in Radziwill's painting, dominate the horizon, while the foreground remains a quiet marsh landscape. The following pages zoom out to show aerial views of other regional industrial sites, where this same uneasy overlap is manifested.

This page
▲1.4 Nordenham and Bremerhaven
◄1.5 Eemshaven

Next page
▲1.6 Wilhelmshaven
►1.7 Bremen

# Reading the Ground

## Landscape Types as Contextual Foundation



- Intertidal wetlands (Wadden)
- Marshland
- Fluvial landscape
- Sandy uplands
- Peat colonies / landscape
- Reclaimed land
- — NUTS 3 area boundaries

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0 10 20 km N

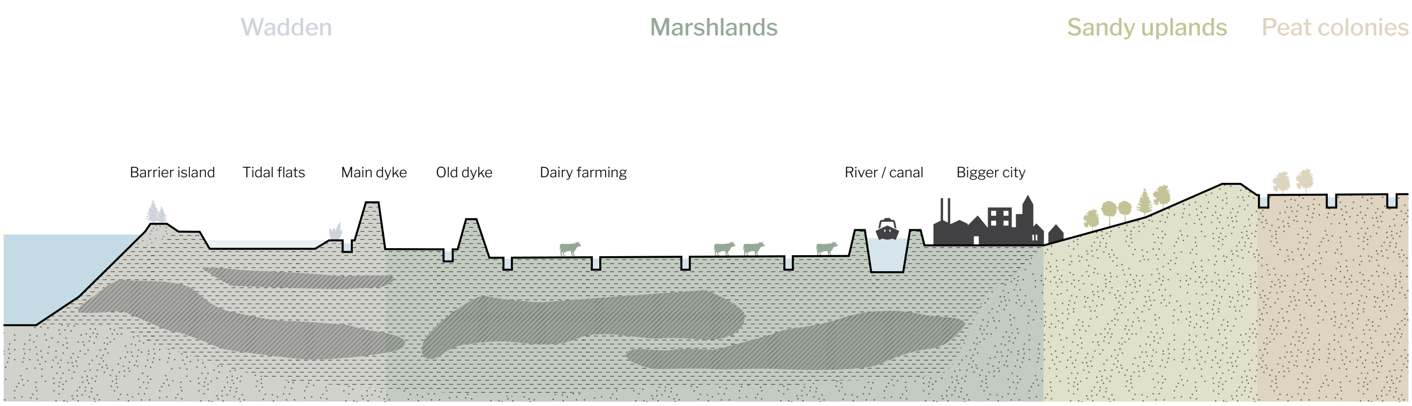
1.8 Landscape types in the study area

Understanding the Wadden Sea region begins with reading its terrain. The area is a layered landscape shaped over millennia by both natural processes and human intervention. From the tidal flats and marshes to the geest and peat colonies, these landscapes tell the story of survival, adaptation and engineering. The Frisian people once shaped these lands with waterworks that spread across Europe and the remnants of that ingenuity still structure the region today.

Mapping this terrain was not straightforward, as no shared landscape database across the Wadden Sea countries exists. Therefore, national typologies are used: CultGIS Landschap for the Netherlands (RCE, 2005), and the Bundesamt für Naturschutz (2011) and LBEG Niedersachsen (2025) for Germany. These sources do show parallels however and reveal four dominant landscape types, whose typical sequence is showed in Fig. 1.8 and 1.9:

- Wadden Area (tidal flats and salt marshes)
- Marshlands (embanked polders and low peat)
- Sandy Uplands (geest)
- Peat Bogs (veenkoloniën)

These types are further explained on the following pages.




**1.9 Section showing the relation of the landscape types with each other and the settlements**

Wadden Sea

Marshlands

Sandy uplands (geest)

Peat bogs

◀ 1.10 Wadden Sea close to Emden, Germany

The Wadden Sea stretches seaward of the main dike or high-tide line in the Northern Netherlands, Northwest Germany and Southastern Denmark and is a globally unique tidal flat and barrier island ecosystem. Its sandy-muddy tidal system creates a habitat of remarkable scale and diversity, earning it UNESCO World Heritage status (CWSS, 2017). Home to the largest coherent tidal flats and salt marshes in Europe, it is one of the most productive saltwater ecosystems globally and has a critical ecological role for invertebrates, fish and birds, including feeding, breeding and resting grounds (OBN Natuurkennis, n.d.).

For centuries since the middle ages, diking, land reclamation and poldering have drastically altered its coastline and created a relatively stable boundary compared to its historic fluctuations. (CWSS, 2017).

◀ 1.11 Marsh landscape in Bremen, Germany

The Marsh landscape emerged from the combination of natural processes such as flooding, peat formation and clay deposition, with peat and clay also being the main soil types. From the 10th century onward, dike construction transformed tidal marshes into drained, cultivated lands, making use of large-scale technical systems of polders, ditches and sluices, many of which still exist today (CWSS, 2017). This engineering marked a shift from reliance on natural gradients to controlled water levels, maintained by windmills and pumps, also leading to subsidence of the land (OBN Natuurkennis, n.d.). However, the balance was fragile, as storm surges often led to land loss (CWSS, 2017).

◀ 1.12 Geest landscape in the Drentsche Aa, Netherlands

The sandy uplands, which are also called "geest" in Germany – stemming from the Frisian term "gust" for barren land (UBA, n.d.) – are situated higher than the marshes, sometimes exceeding 50 meters.

These glacially formed landscapes, such as the Hondsrug south of Groningen and the Hohe Lieth near Bremerhaven, are composed of nutrient-poor, sandy soils that retain little moisture and are prone to acidification. Originally, they were covered by a diverse mosaic of oak-beech forests, heathlands, and dry grasslands.

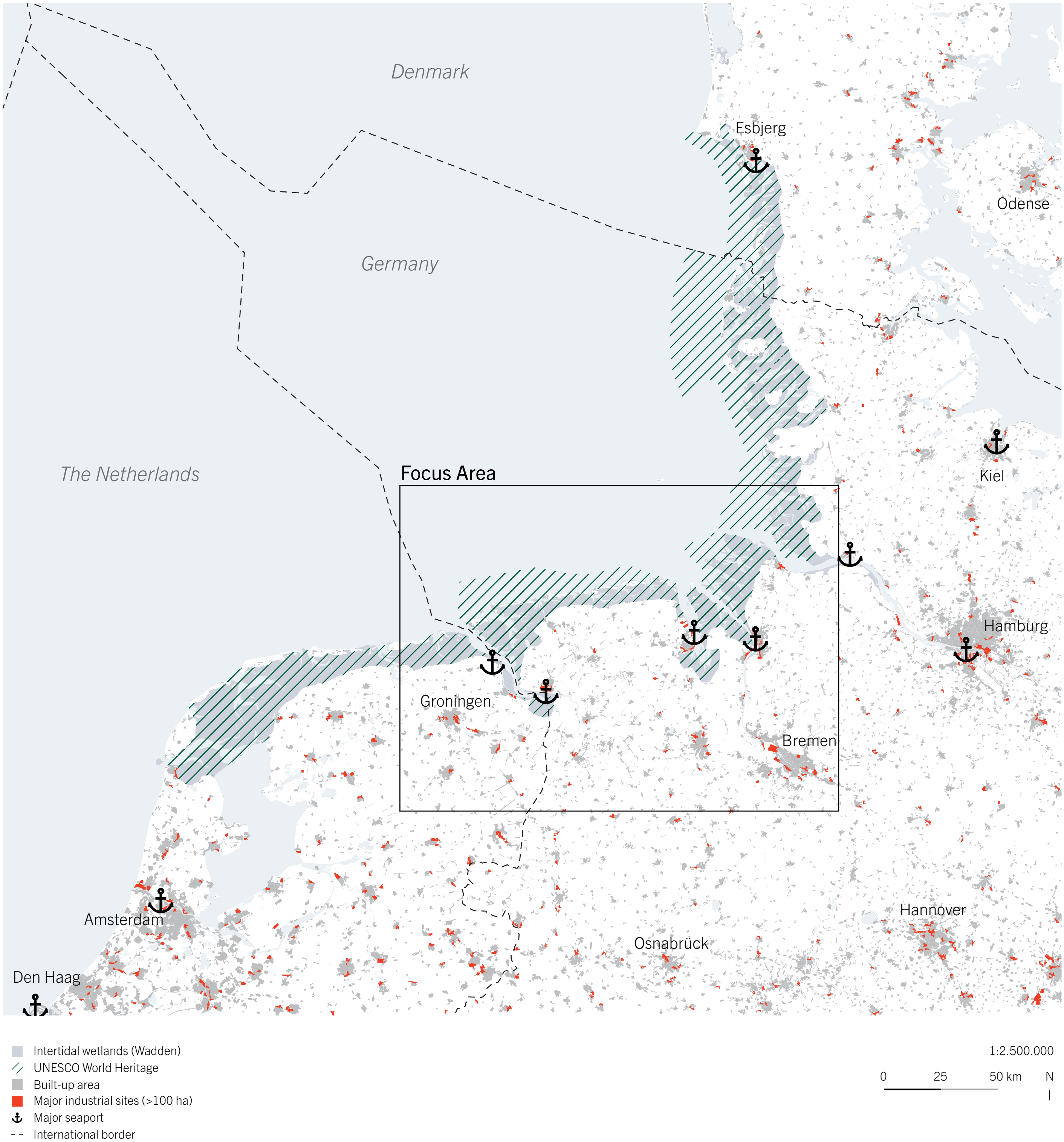
Over time, large areas have been replaced by plantations of conifers and deciduous trees as well as by agricultural fields (OBN Natuurkennis, n.d.). These uplands share cross-border similarities in their topography and ecology.

◀ 1.13 Former peat area in Jheringsfehn, Germany

The peat colonies, most notably the Bourtanger Moor between the Hondsrug and the sandy dunes near the Ems, which once formed the natural border between German and Dutch areas, were historically inaccessible and served as natural barriers for transport, reinforcing the semi-peripheral character of the region (RUG, n.d.). These upland bogs, formed after the Ice Age due to water surplus and a cool climate, were nutrient-poor, wet, and unsuitable for early settlement. Dutch settlers who brought their water management expertise, played a pivotal role in the planned colonisation of these areas from the 17th century onwards. Linear patterns of canals, ditches, and settlements characterise the Veenkoloniën of Groningen and Drenthe, as well as similar German colonies (in Ostfriesland, but also elsewhere like the Teufelsmoor), again illustrating cross-border parallels in topography and development. (LBEG Niedersachsen, 2023; OBN Natuurkennis, n.d.; Provincie Groningen, 2021).

# Where Industry Settled on Fragile Ground

## Localisation of the Focus Area

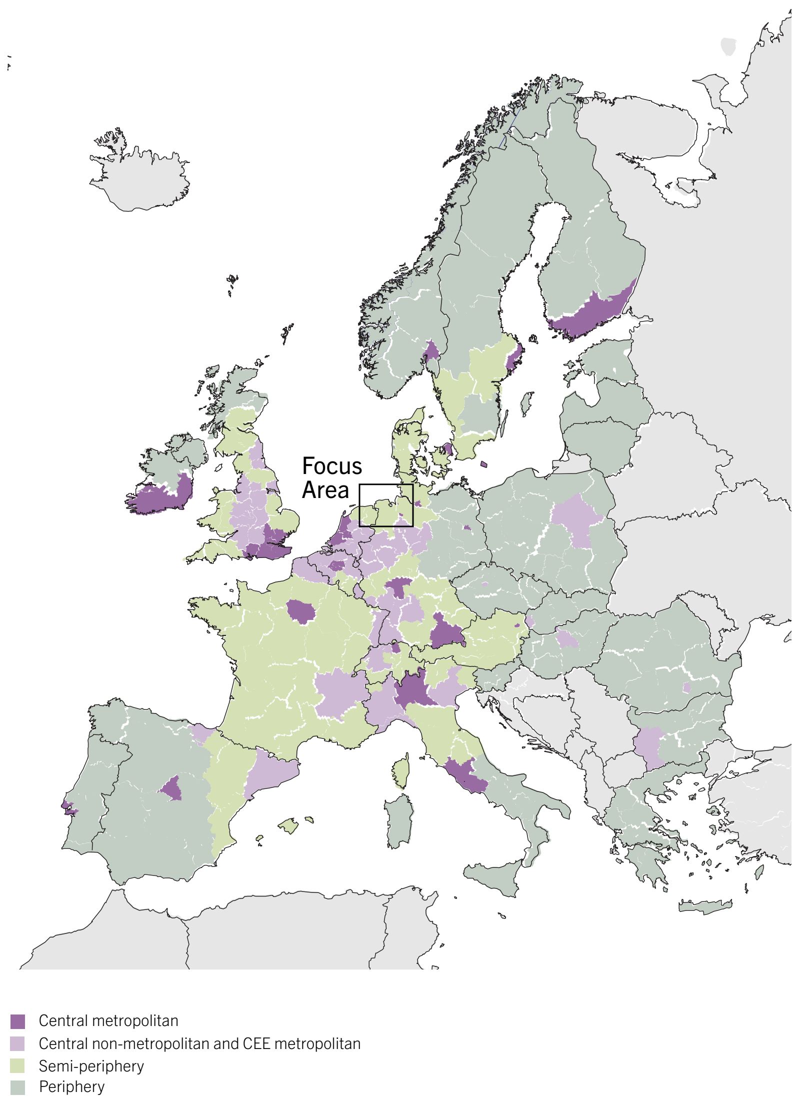



1.14 Localisation of the focus area within the Wadden Sea UNESCO area.

The Wadden Sea stretches along the coasts of the Netherlands, Germany and Denmark. It forms a dynamic ecosystem that is recognised by UNESCO for its global ecological value. But zooming in, something unexpected becomes visible: clusters of large-scale industry that are located right next to this sensitive landscape. Ports, power plants and factories are all concentrated around the river mouths of the Ems, Weser, Jade and Elbe (Fig. 1.14).

This seemed peculiar, as the region does not form part of the European economic core. In fact, when seen through Grasland & van Hamme's (2010) economic typology that is depicted in Fig. 1.15, it clearly sits in the semi-periphery: participating in value chains, but not driving them. Why, then, is so much industry here, in a place that, on the surface, appears relatively remote and ecologically vulnerable?

These spatial, economic and ecological tensions became the first interrogation of this thesis.



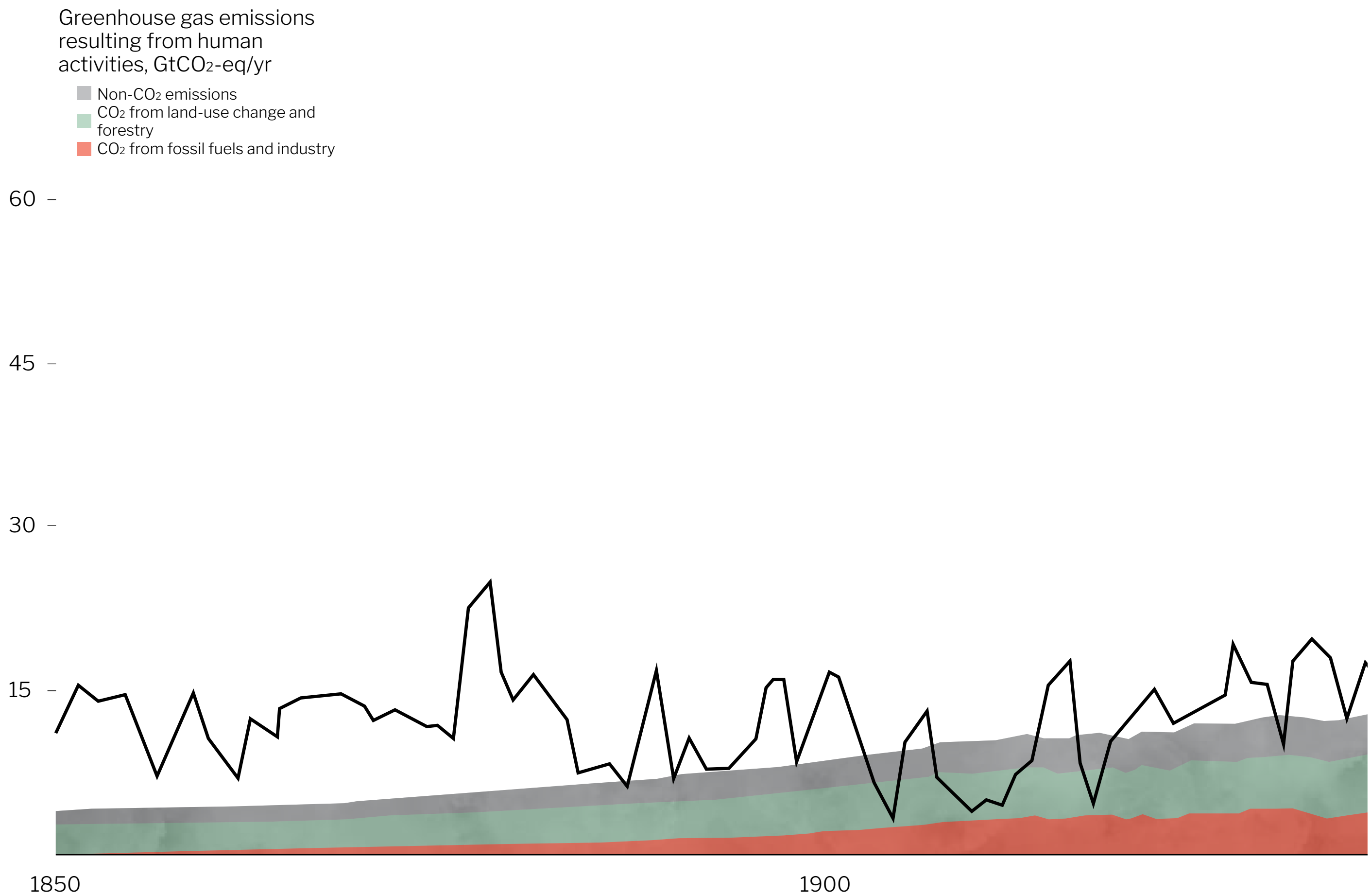

**1.15 Focus area within a typology of European economic areas as coined by Grasland & van Hamme**

# Climate Pressure, Local Tensions

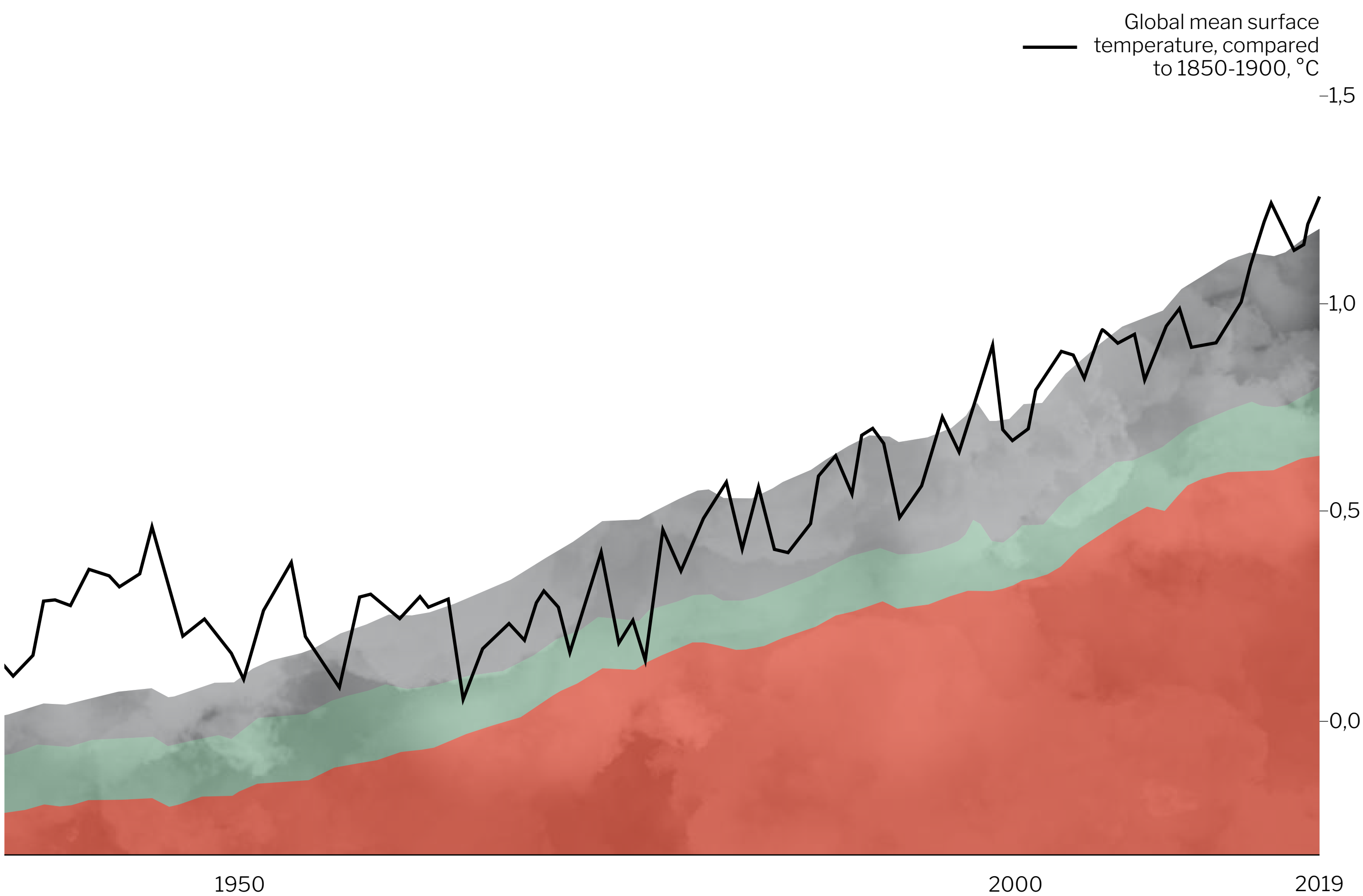
## Context of a Global Climate Crisis

In the Wadden Sea region, climate change is not a distant abstraction but a direct reality (CWSS, 2017). Sea-level rise threatens the delicate balance of tidal flats, barrier islands and dykes. More frequent storms put pressure on the coast and the hinterland alike. These are not just environmental problems. They are spatial ones, too, that have consequences for infrastructures and land use.

Globally, the situation is clear. Fig. 1.16 shows the steep rise in greenhouse gas emissions and global temperatures since 1850 with industry and fossil fuels as the dominant drivers. The science is unequivocal: every fraction of a degree matters. Holding warming to 1.5°C, rather than 2°C, means less coastal flooding, fewer heat extremes, and significantly lower risks to biodiversity and human health. Missing that target, however, brings rapidly escalating and potentially irreversible impacts, especially in vulnerable regions like this one (IPCC, 2023).




**1.16 Global greenhouse gas emissions and temperature increase since 1850**


Global mean surface temperature, compared to 1850-1900, °C
1,5
1,0
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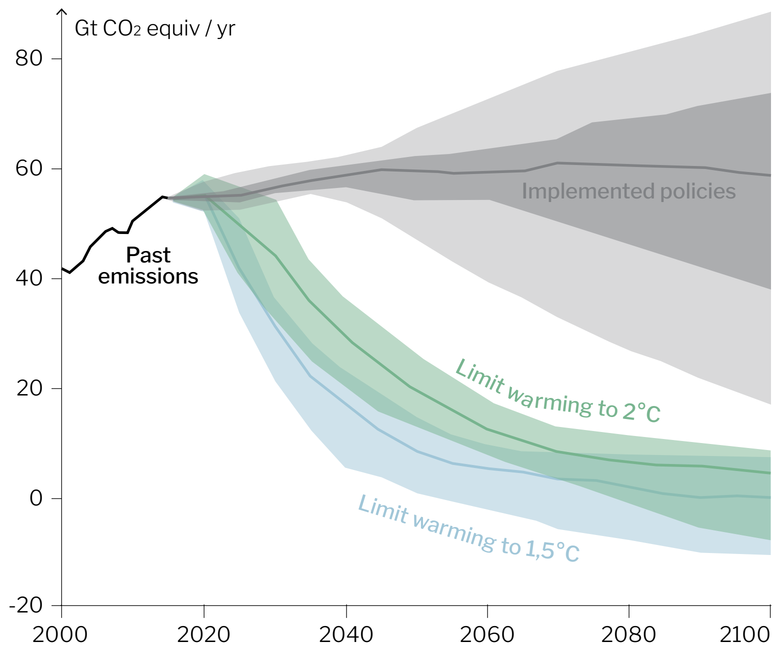
1950
2000
2019




**1.17 Emission pathways to limit warming and current policies**

Fig. 1.17 outlines what is needed to stay within those thresholds: deep and immediate cuts in emissions, particularly in the energy and industrial sectors. But current policy trajectories are still far above those pathways. Policy is trying to catch up. The EU plans to cut carbon emissions by 90% by 2040 (European Commission, 2024), which is a major shift. But implementation lags and climate targets remain aspirational (New Climate Institute, 2024). In the meantime, regions like the Wadden Sea are stuck in the middle, because they are on the frontline to rising waters, but still hosting carbon-heavy industries.

# Pressure

The Wadden Sea region is a place of contrasts: shaped by water and reclaimed by people, appreciated for its ecology yet burdened by industry, exposed to climate risk while tied into carbon-heavy systems. These overlapping spatial, ecological and systemic pressures define the context of this thesis. They raise an urgent question: how did this region, with such sensitive landscapes, become so deeply entangled in systems that now threaten its resilience?
The next chapter traces the underlying structures behind this paradox, revealing how industrial and infrastructural dynamics have locked the region into its current role.

# Points

2

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# Problematisation

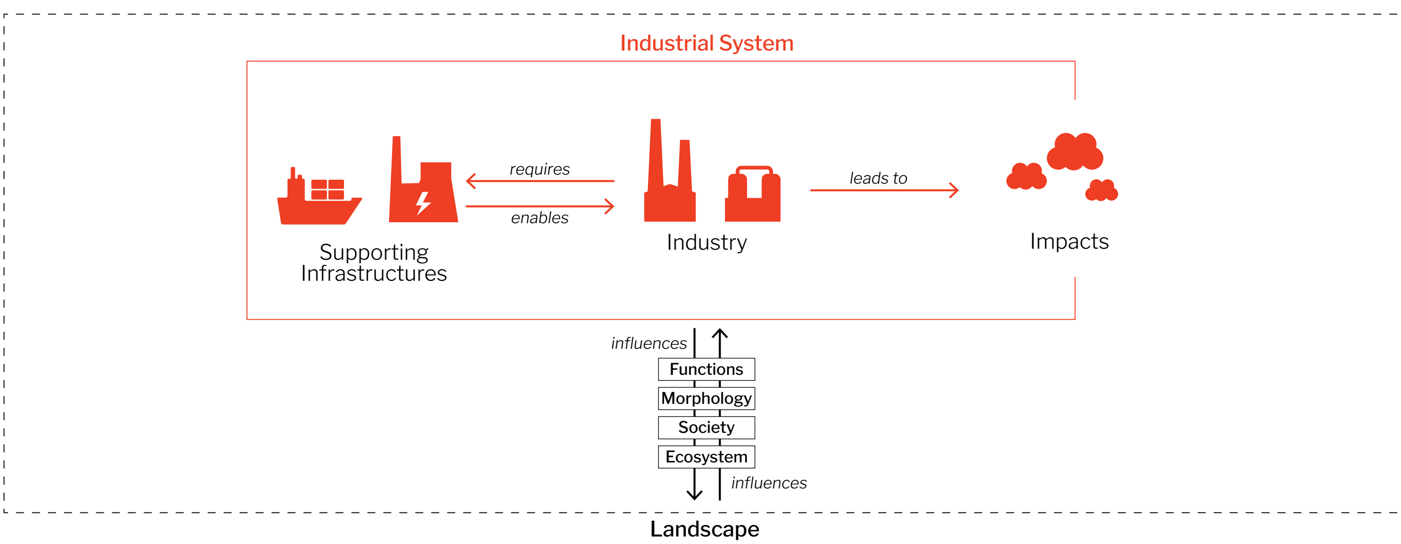
# The Wadden Sea as an Operational Hinterland

## Defining the Problem Field

The Wadden Sea region can be described as an Operational Hinterland, as defined by Brenner and Katsikis (2020). This concept frames the diverse non-urban territories, ranging from rural settlements to industrial fringes, that supply essential resources such as labour, food and materials to urban centres. These zones are systematically reshaped to meet the uncompromising demands of globalised capitalism. This often degrades the environment and has a social cost. These regions are transformed into peripheral production zones where economic pressures lead to land degradation, resource depletion and increased precarity for local communities. Thus, the concept of operational hinterlands critically highlights a problematic development pattern in which urban growth is built on unstable and ecologically unsound foundations. This model, strained by ecological limits and global shifts, is on the verge of collapse, demanding a new vision for the region.

Following the previous depiction of the dual regional identity, consisting of landscape and industry, Chapter 2 problematises this existence as an operational hinterland. A combination of the systemic legacies of industrial processes and escalating pressures of today leads to the current situation of the Wadden Sea as a region at a breaking point.

To map out pathways towards transforming industrial practices in the Wadden Sea region, first the workings of the industrial system and its interplay with the surrounding landscape must be understood. Transformation cannot be achieved without first defining the problem, and defining the problem requires understanding how to read the system itself. Fig. 2.1 illustrates an approach for this: the core of the industrial system – its industries – depends on supporting infrastructures such as energy and transport networks, which, in turn, enable these industries to operate. However, this combination generates impacts beyond the system itself. Together, these three components (industry, infrastructure and impact) constitute the industrial system that not only influences but is also shaped by the landscape in terms of functions, morphology, society and ecosystems. This forms the analytical lens through which this study examines the Wadden Sea region.

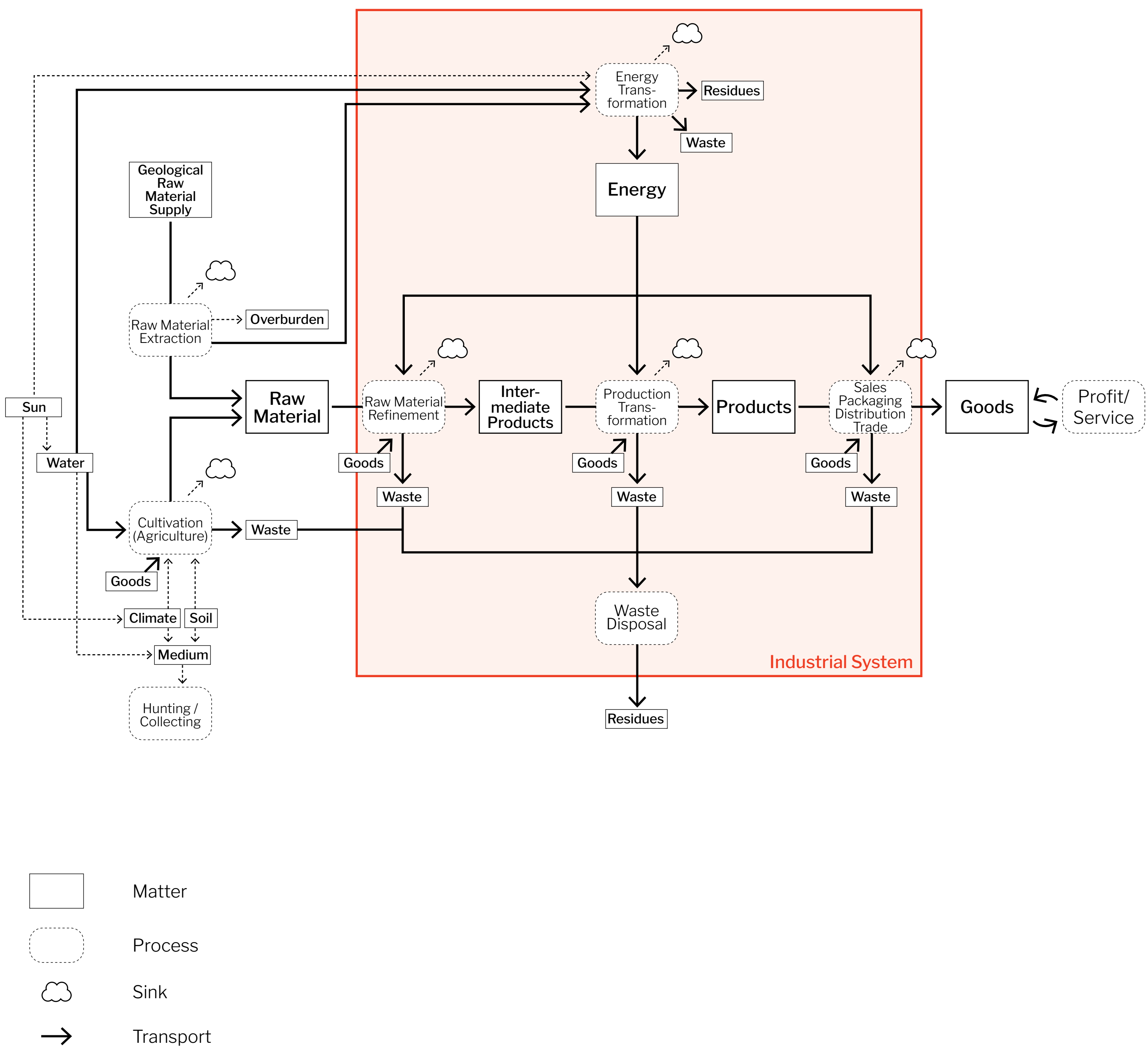



▲ 2.1 Definition of an Industrial System and its connection to the landscape

► 2.2 The Port of Delfzijl as an Operational Hinterland

# Take, Make, Dispose

## Systemic Legacy: Functioning of the Industrial System



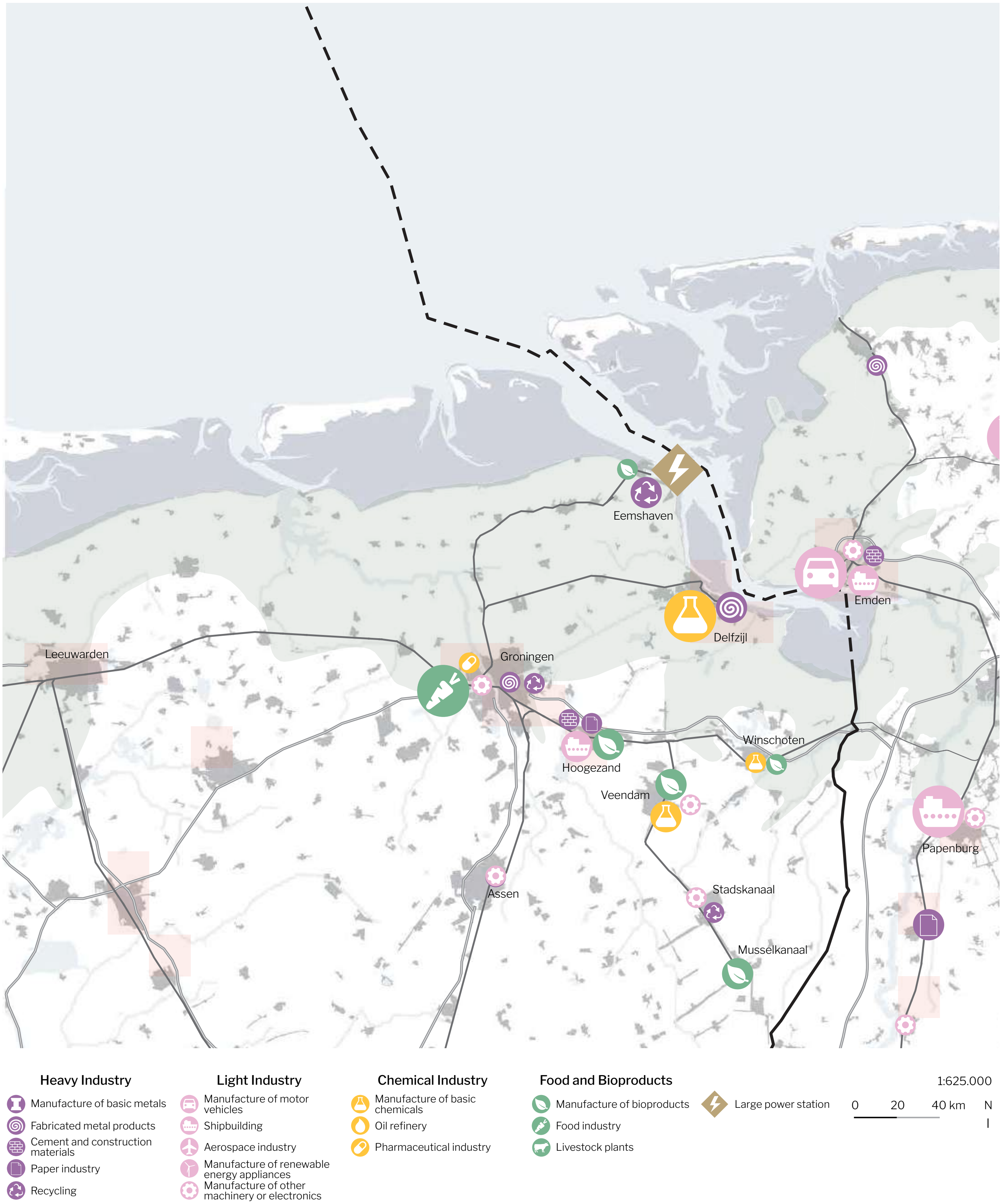

2.3 Functioning of the current industrial system in the Wadden Sea region (adapted from Ayres & Simonis, 1994 and Lehmann & Schmidt-Bleek, 1993)

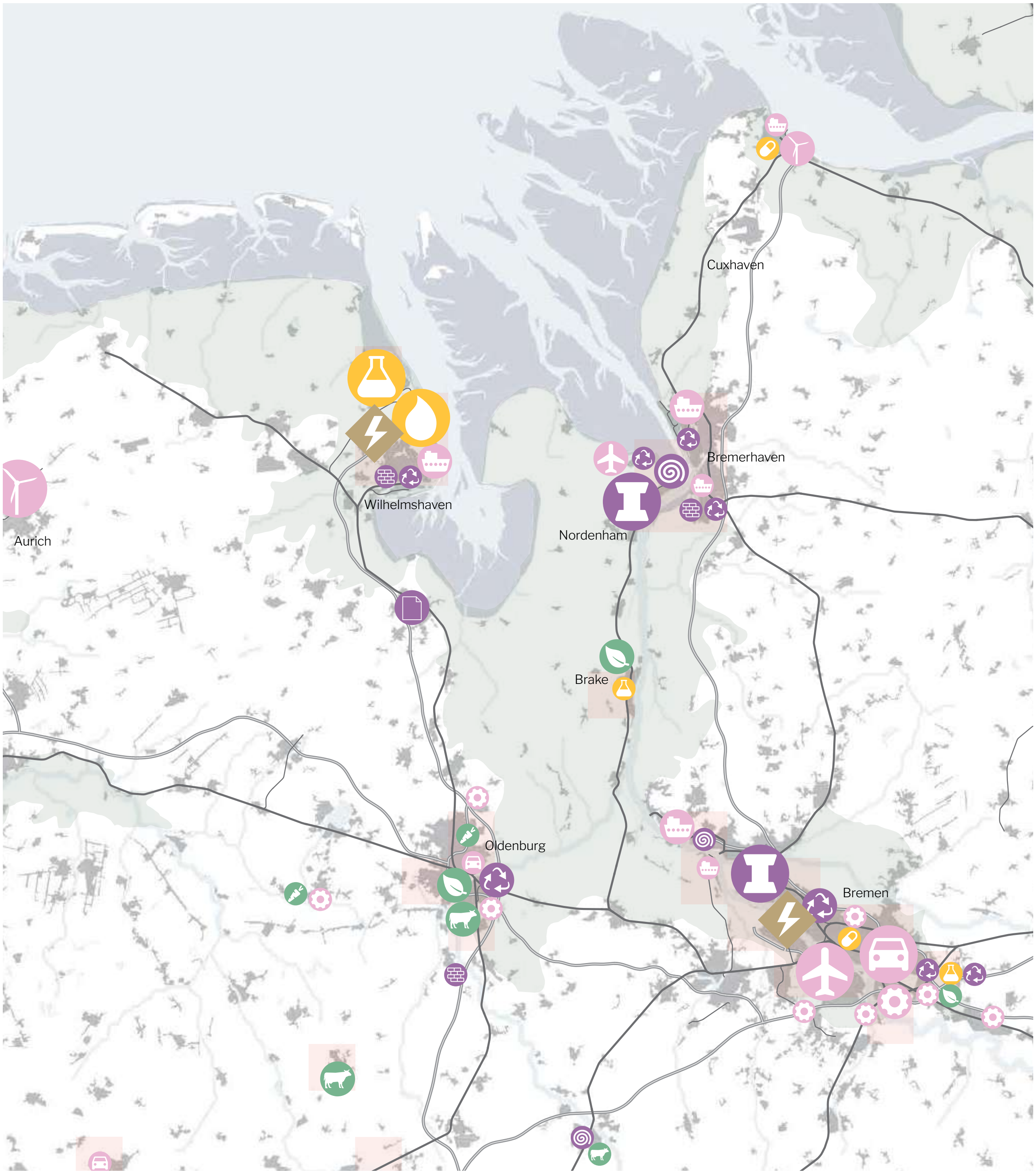

2.4 Materialisation of the current 'take-make-dispose' approach of the industrial system

Fig. 2.3, drawing on the field of industrial ecology (Ayres & Simonis, 1994; Lehmann & Schmidt-Bleek, 1993), presents a simplified scheme of industrial production. It deconstructs the system into four key elements: matter, process, transport, and sink. In its linear flow, raw materials, extracted from natural resources or agriculture, move through stages of refinement, production, transformation and distribution. Each step consumes energy and generates waste, culminating in goods that deliver profit and/or services. Along this trajectory, sinks – waste disposal sites or environmental residues – emerge at multiple points.

Although abstract and theoretical, this model can be utilised to explain the industrial dynamics in the study region. Here, the system's middle section dominates, focused on production and transformation, thus creating an energy-intensive network. Resource extraction, aside from gas and smaller activities, largely takes place elsewhere. Fig. 2.4 illustrates the realities of this linear model: the steel factory in Bremen in the middle image exemplifies a local part of the chain functioning according to the "take, make, dispose" logic central to the system.

# Regional Distribution of Activities






2.5 Distribution of the different sectors across the region

# Industrial Sectors

### Heavy industry

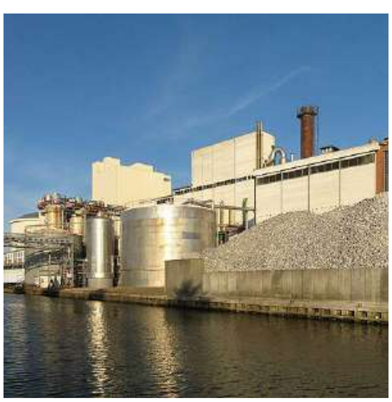
- Manufacture of basic metals
- Fabricated metal products
- Cement and construction materials
- Paper industry
- Recycling

### Light industry

- Manufacture of motor vehicles
- Shipbuilding
- Aerospace industry
- Manufacture of renewable energy appliances
- Manufacture of other machinery or electronics

### Chemicals

- Manufacture of basic chemicals
- Oil refinery
- Pharmaceutical industry



### Bioproducts

- Manufacture of bioproducts
- Food industry
- Livestock plants

To better understand the industrial system, it is useful to categorize its diverse activities into four main sectors that are pictured in Fig. 2.6: heavy industry, light industry, chemicals, and bioproducts. This division reflects distinct production processes, resource demands and environmental impacts and provides a structured lens for the analysis.

- Heavy industry encompasses subsectors such as the manufacture of basic metals, fabricated metal products, cement and construction materials, the paper industry, and recycling. These are resource-intensive and often tied to foundational production processes, such as steel mills or cement plants. For example, Bremen's steel works exemplifies this sector's presence in the region.
- Light industry focuses on higher-value, often precision-driven outputs. It includes the manufacture of motor vehicles, shipbuilding, aerospace, renewable energy appliances, and other machinery or electronics. These industries require less raw material volume but significant technical expertise and innovation. The car plant in Emden is a regional example.
- The chemical sector comprises the manufacture of basic chemicals, oil refining, and the pharmaceutical industry. Characterized by significant energy demands and complex outputs, this sector often clusters near ports for efficient import/export logistics, with Delfzijl being a regional example.
- Bioproducts, including the manufacture of starch-based goods, food processing, and livestock plants, are often tied to local agricultural outputs, evident for instance in the local dairy processing plants.

On the previous spread, Fig. 2.5 maps the regional distribution of these sectors, which results in a mosaic of activities. The map highlights the coexistence of the sectors without a single one dominating. This raises questions about the origins of this pattern, which contrast with major industrial zones elsewhere in the Netherlands and Germany (see Fig. 2.14). The approach to creating Fig. 2.5 was multidimensional, combining EPRTR data with an analysis of CORINE industrial sites, aerial imagery and supplementary web research.

**◀ 2.6 Materialisation of the different industrial sectors in the region in Bremen, Emden, Delfzijl, Groningen (top to bottom)**

## Required Types of Supporting Infrastructure

At the beginning of this chapter, the framework emphasised the critical role of supporting infrastructure (pictured in Fig. 2.7) for industrial systems.

- Energy infrastructure, such as power plants, energy grids, and pipelines, is crucial to fueling industrial activities. Transport networks (railways, ports and roads) enable the movement of raw materials, goods, and people.
- Water infrastructure, including supply networks and treatment plants, supports both production processes and environmental management.
- Waste systems handle by-products and residues, from recycling facilities to landfills.
- IT and communication infrastructure (fiber optics, data centers, and logistics software) enhance operational efficiency and global connectivity.
- Finally, social facilities, such as housing, education and healthcare, sustain the workforce and ensure regional development.

**Energy**

**Transport**

**Water**

**Waste**

**IT and Communications**

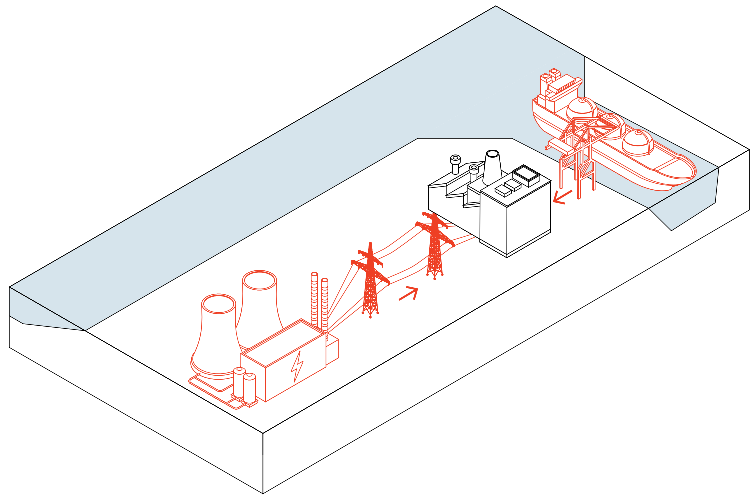

**Social Facilities**

▶ 2.7 Materialisation of the different supporting infrastructures in the Eemshaven, Wilhelmshaven, Bremen, Delfzijl, the Eemshaven and Groningen (top to bottom)

Identified Problematic Legacy

## Industry's Infrastructural Footprint

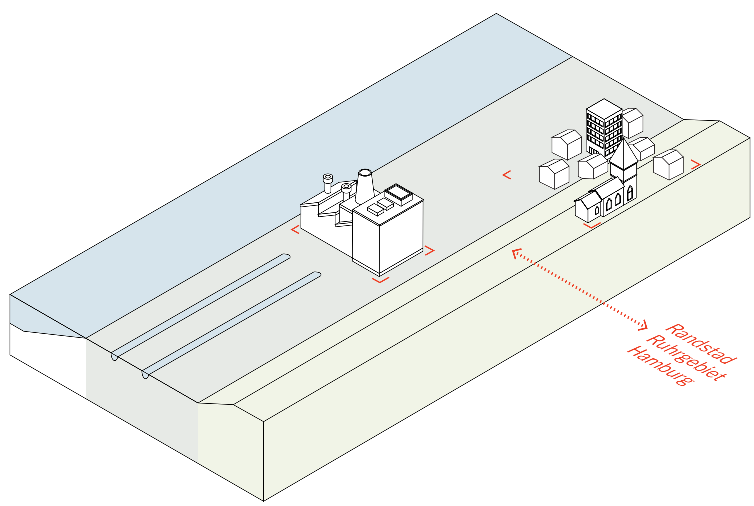
The region's industrial operations rely on an expansive network of infrastructure. Power plants, including coal-based facilities, dominate the energy landscape, while canals support shipping and connect shipbuilding sites to global supply chains. These systems, layered over decades, enable production but also impose a visible footprint on the environment.



⟶ **Identified Problematic Legacy**

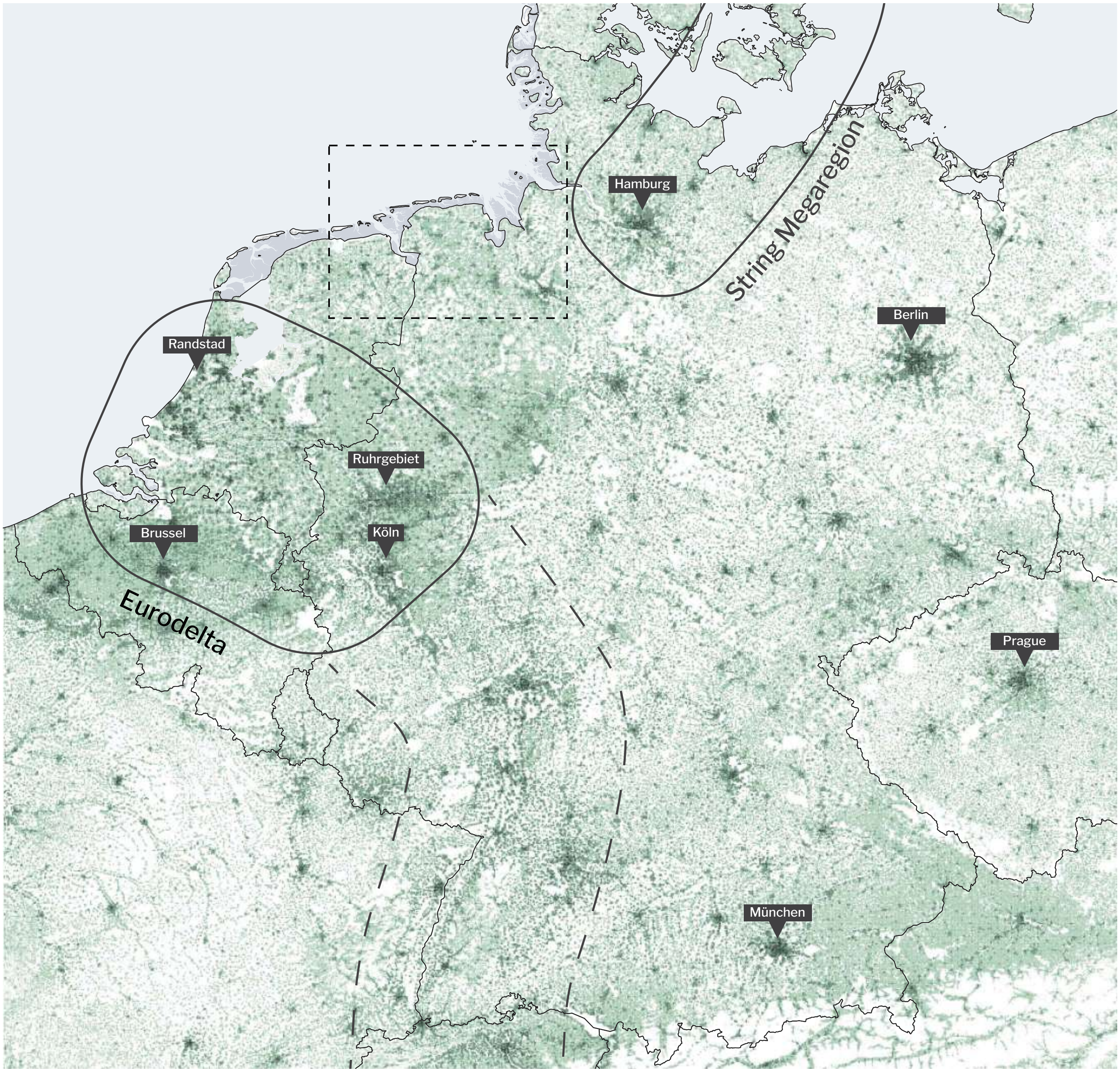
## Man-Made Peripheral Landscapes

The Wadden Sea region is defined by its landscape types. Cities historically settled at the edge of sand uplands and marshlands, while industries were mostly established later in the poldered marshes and along the coast. This landscape itself is engineered and kept dry through ditch systems, which reflects centuries of human intervention. Simultaneously, the region remains semi-peripheral and distanced from European economic cores, which positions it on the fringe of industrial and infrastructural networks.



# Between Core and Periphery

## Systemic Legacy: Semi-Peripheral Location



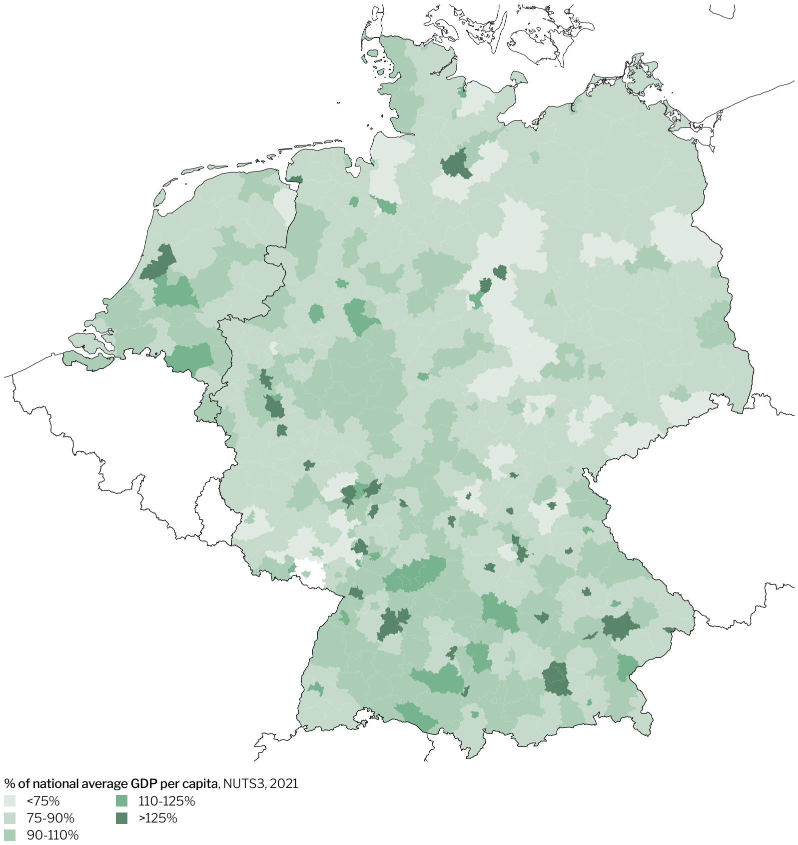

Inhabitants per 1 km$^2$ grid cell
- 0
- 1-9
- 10-19
- 20-199
- 200-499
- 500-4999
- more than 5000

1:5.000.000
0 40 80 km N

2.8 Population density and largest cities of the Netherlands and Germany *“this traditionally prosperous early modern area, more or less overtaken by time, ended up in the lee of commercial and industrial concentration”*

– Common Wadden Sea Secretariat, Wadden Sea Quality Status Report

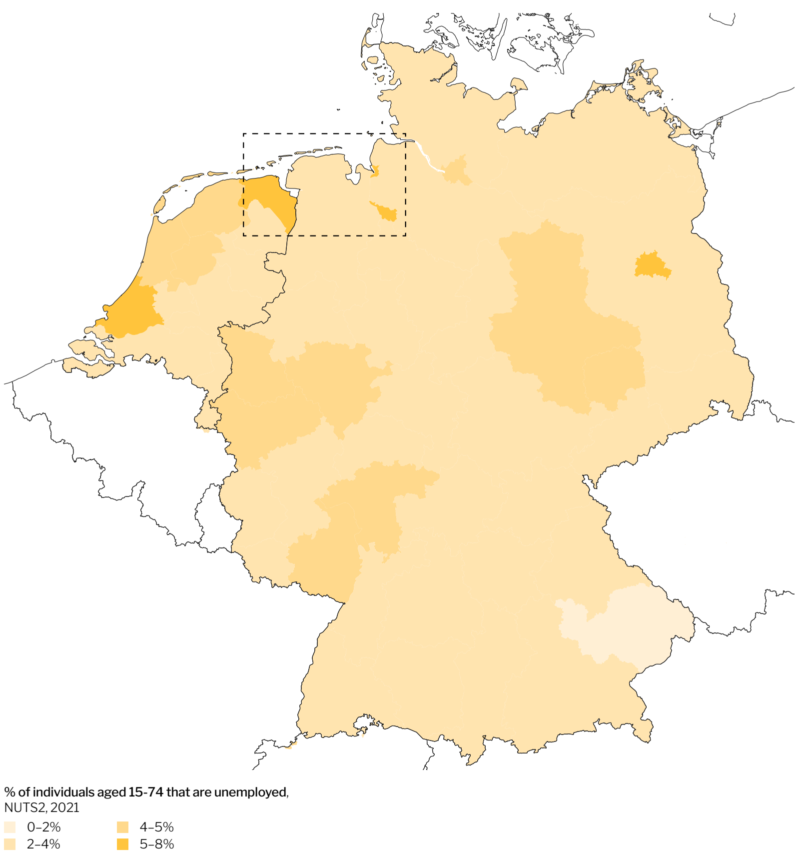
The Wadden Sea region lies geographically between two major Northern European metropolitan areas, positioned between the Randstad and Hamburg. Yet, as highlighted in the introduction, it has a semi-peripheral position, reflecting its participation in value chains with relatively little steering of industrial or economic innovation. Grasland & van Hamme’s economic typology (c.f. Fig. 1.9) categorises it as such, which poses a contrast with core metropolitan areas excelling in high-value tertiary sectors. Fig. 2.8 visualises population density in the Netherlands and Germany, showing the region’s distance from densely populated centres like the Randstad, Ruhrgebiet and the Rhine corridor. However, its evenly distributed population also contrasts with sparsely populated areas in central, eastern, and southern Germany. This underscores its semi-peripheral (instead of peripheral) nature. Historically, this prosperous early modern area fell behind industrial centres, leading to demographic and economic decline. Here, issues like population decline and related effects challenge economic prosperity. While there is nowadays not one single identity of the Wadden Sea region, the decline is compounded by conflicts between environmental goals and local economic needs (CWSS, 2023). The following pages explore the semi-peripheral nature of the region further by compiling different statistics.




## Gross domestic product

This map compares regional GDP per capita to the national average on a NUTS-3 level. In Germany, prosperous cities like Hamburg, Wolfsburg and towns in Bavaria, Baden-Württemberg and the Rhein-Main area stand out. The Netherlands shows similar trends, with Amsterdam and Utrecht performing well above the national average. In contrast, the Wadden Sea region scores mostly average to slightly below, except for Emden, which boasts one of the highest GDP per capita levels nationwide, while parts of Groningen and Bremerhaven's hinterlands underperform.

◀ 2.9 Proportional GDP in the Netherlands and Germany



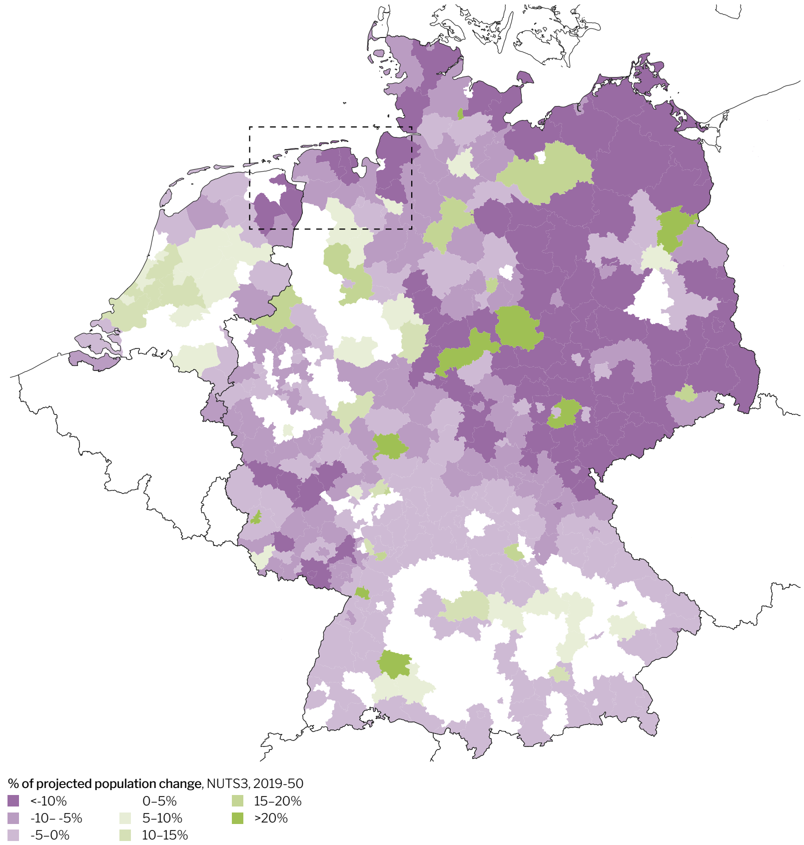

## Unemployment

Unemployment rates are displayed on a NUTS-2 level and highlight regional disparities. While most of the Wadden Sea region aligns with national averages, Groningen (province) and Bremen stand out as areas with the highest unemployment rates in their respective countries. These figures underscore challenges faced by parts of the region in sustaining strong economic activity.

◀ 2.10 Unemployment in the Netherlands and Germany

## Projected population change

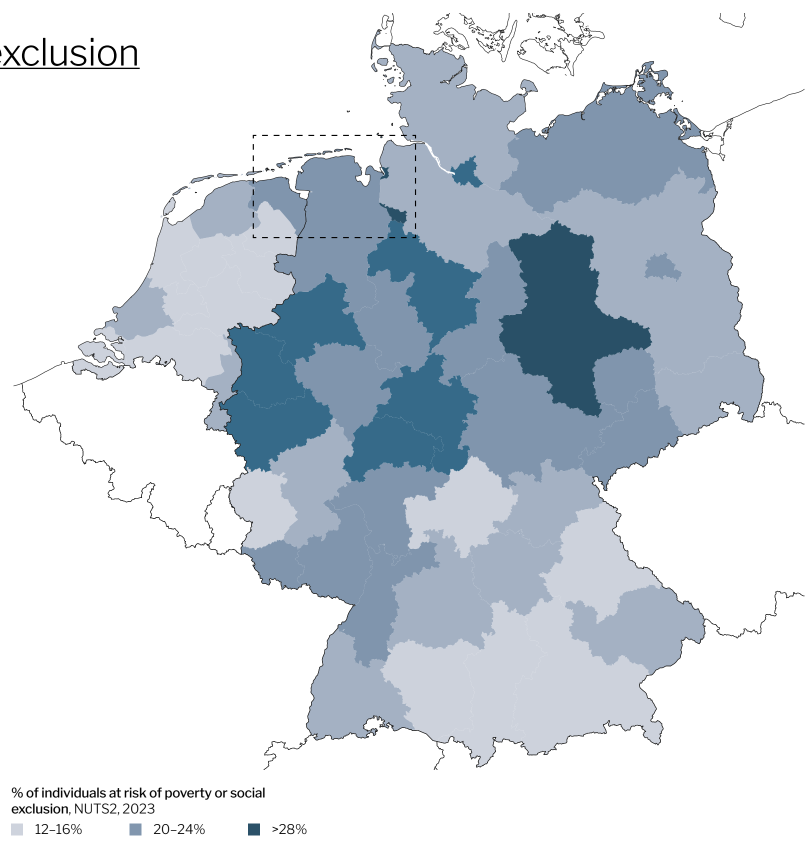
Population trends until 2050 show different patterns in the Netherlands and Germany on a NUTS-3 level. In the Netherlands, the Randstad and Noord-Brabant are projected to grow, while rural areas, particularly eastern Groningen and Drenthe, will shrink. German cities, both in the west and east, are expected to grow, but rural areas, especially in eastern Germany, will face significant decline. Among shrinking areas in western Germany, the Wadden Sea region will see one of the steepest population decreases.




▶ **2.11 Population trend in the Netherlands and Germany**

## Persons at risk of poverty or social exclusion

The percentage of people at risk of poverty or social exclusion, shown on a NUTS-2 level, highlights clear differences: Germany generally has higher percentages than the Netherlands, where Groningen scores the worst. In Germany, Bavaria has the lowest percentages, while central regions show higher risks. Bremen, part of the Wadden Sea region, has the highest risk level nationwide, alongside Sachsen-Anhalt.




▶ **2.12 Poverty/exclusion in the Netherlands and Germany**

## Nationwide Distribution in Germany and the Netherlands

**1** Emden Car Factory

**2** Bremen Steel Works

**3** Rotterdam Chemical Industry

**4** Stuttgart Car Factory

**◄ 2.13 Examples of industrial manifestation in the zones depicted in fig. 2.14**

Mapping the regional distribution of this industrial activity is no simple task due to the sector's complexity. Fig. 2.14 represents an effort to address this, visualising industrial hotspots not just within the Wadden Sea region but also across the Netherlands, Germany and surrounding areas. This broader focus contextualizes the regional industrial practices within nationwide patterns. Key rail lines and ports are included for reference.

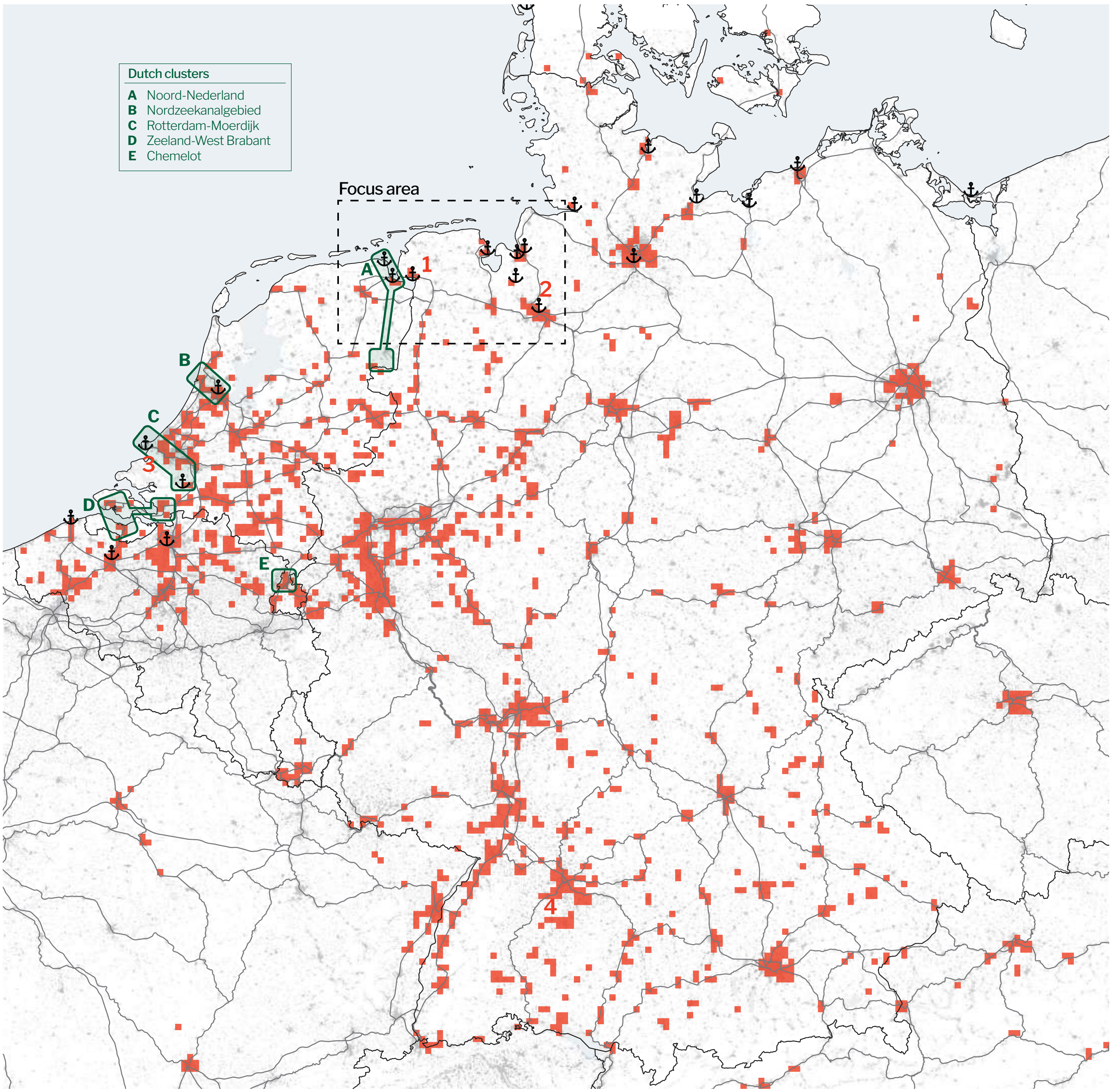
The industrial concentration zones were derived using a structured geoprocessing method:

1. A 5x5 km grid was established across the study area.
2. Cells containing large industrial areas (CORINE class 121, >100 ha) were selected.
3. Only those grid cells with more than 50% of their area within a NUTS 3 region with a GDP per capita above €35,000 were included.
4. Finally, cells were overlaid with a 1x1 km grid of industrial electricity demand (EIGL, 2023). Cells with a demand exceeding 1,000 toe/year were identified as part of the industrial system.

The results reveal clear regional patterns. In the Netherlands and Belgium, industrial hotspots cluster densely in the southern provinces and extend into the Ruhrgebiet, although northern parts of this traditional industrial area are less represented due to their decline. In Germany, clusters emerge in Frankfurt/Rhein-Main, along the upper Rhine, around Stuttgart and Munich, and in metropolitan areas like Berlin, Hamburg, and Leipzig/Halle. A looser distribution of industrial zones spans Baden-Württemberg, Bavaria, and northern North Rhine-Westphalia, as well as southern Lower Saxony, reflecting these region's "Mittelstand" and "hidden champions".It is also notable that the Dutch government has defined five spatially delineated clusters of energy intensive industrial locations (also depicted in fig 2.14; (MinBZK, 2020, 2024)), while no such spatial policy exists on national level in Germany, even though a spatial distribution is clearly visible.

Where does the Wadden Sea region fit into this distribution? While it does not form part of the primary industrial hotspot zones, it hosts several concentration grid cells, primarily near ports. These illustrate the region's role in connecting industrial practices to maritime infrastructure.

Fig. 2.13 adds depth to this analysis, showcasing aerial views of industrial cluster cells. In the Wadden Sea region, the landscape remains visible, which contrasts with the "petrolscapes" of Rotterdam or the car manufacturing hubs of southern Germany.

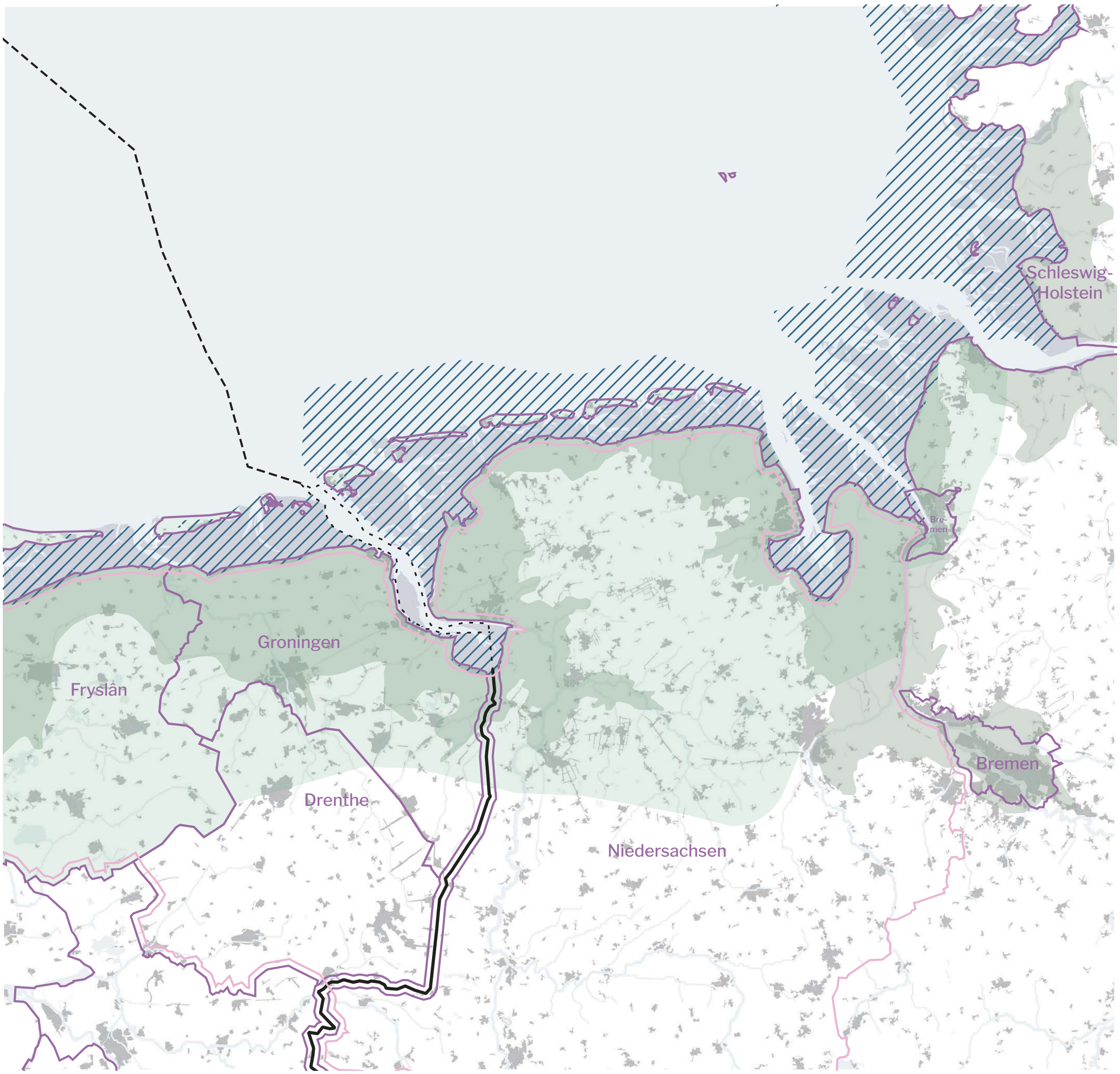



Built-up area
Zone with Industrial Concentration
Main International Seaport
Key Rail Line (TEN-T)
NL: Industry and Energy Intensive Clusters in NOVI/Nota Ruimte (MinBZK, 2024)

1:5.000.000
0 40 80 km
N

**2.14 Zones with industrial concentration in the Netherlands, Germany and neighbouring countries**

# Borders as part of the semi-peripheral position



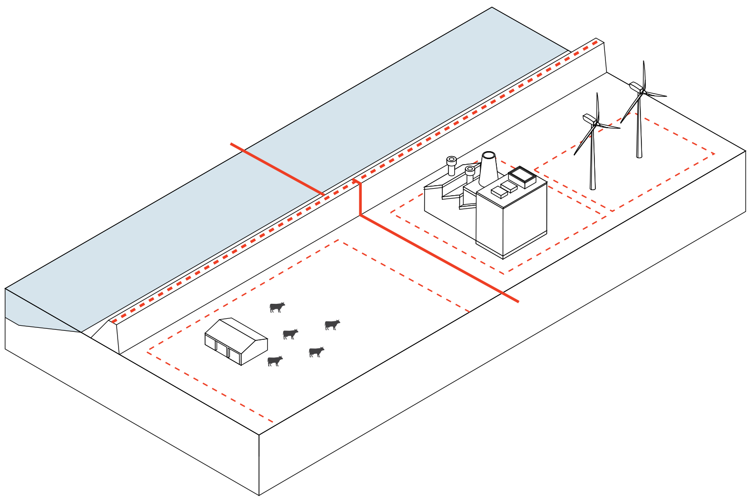



2.15 Current and historic borders in the Wadden Sea Region


2.16 Historic map of the Frisian territories by Abraham Ortelius, 1574

The Wadden Sea region is fragmented by multiple borders, most prominently the Dutch-German national border, but also provincial and state boundaries, as shown in Fig. 2.15. Historically, this area was more unified as the heartland of Frisian settlement. An old map by Abraham Ortelius from 1574 (Fig. 2.16) illustrates the extent of the Frisian territories stretching across what are now multiple administrative divisions. Today, the region is shaped by differences in governance structures: the German Bundesländer, such as Niedersachsen – which is as large as the entire Netherlands – hold significant autonomous powers, while the Dutch provinces are smaller and more interconnected.

Border cooperation exists, notably through the Ems Dollart Region, a cross-border Euroregion aimed at collaboration, although it extends well beyond the actual Wadden Sea region. Unresolved disputes exist, however, as in the Dollart estuary, the precise trajectory of the German-Dutch border remains undefined. Germany bases its claims on a 1558 imperial decree, arguing the Ems entirely belongs to Ostfriesland, while the Netherlands supports a midline boundary (FGE Ems, n.d.). A 2014 agreement adopted a pragmatic approach, enabling joint management of shipping, resource extraction, and wind energy while avoiding the border's formal resolution (Auswärtiges Amt, 2014). This pragmatic coexistence shows how the region has a legacy of overlapping identities and cooperation despite divisions.



Identified Problematic Legacy

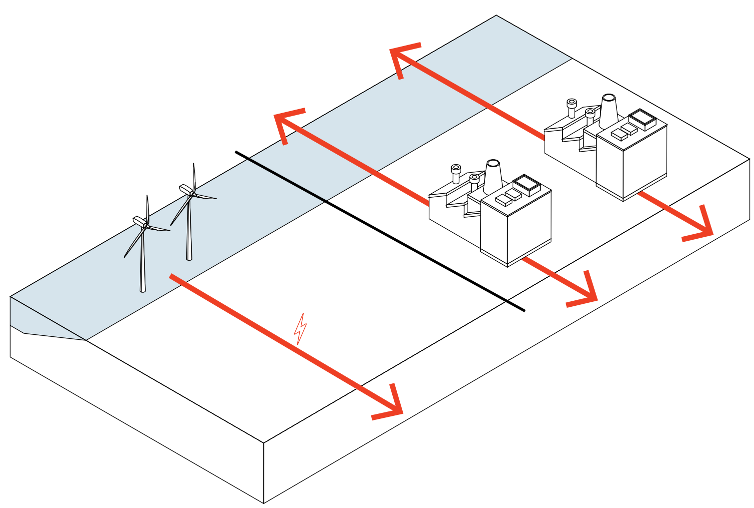
## A Region Shaped by Borders

This region is crisscrossed by many visible and invisible borders. Most obviously, the German-Dutch national boundary divides governance and collaboration, but private ownership – and sometimes fences and surveillance – isolate industrial sites and agricultural land from public access. Even the dykes can be read as borders, separating the natural ebb and flow of the Wadden Sea from the marshes. These boundaries define the area not only physically but also socially and economically and can be interpreted as a tension between separation and connectedness in the industrial and environmental systems.

⟶ **Identified Problematic Legacy**

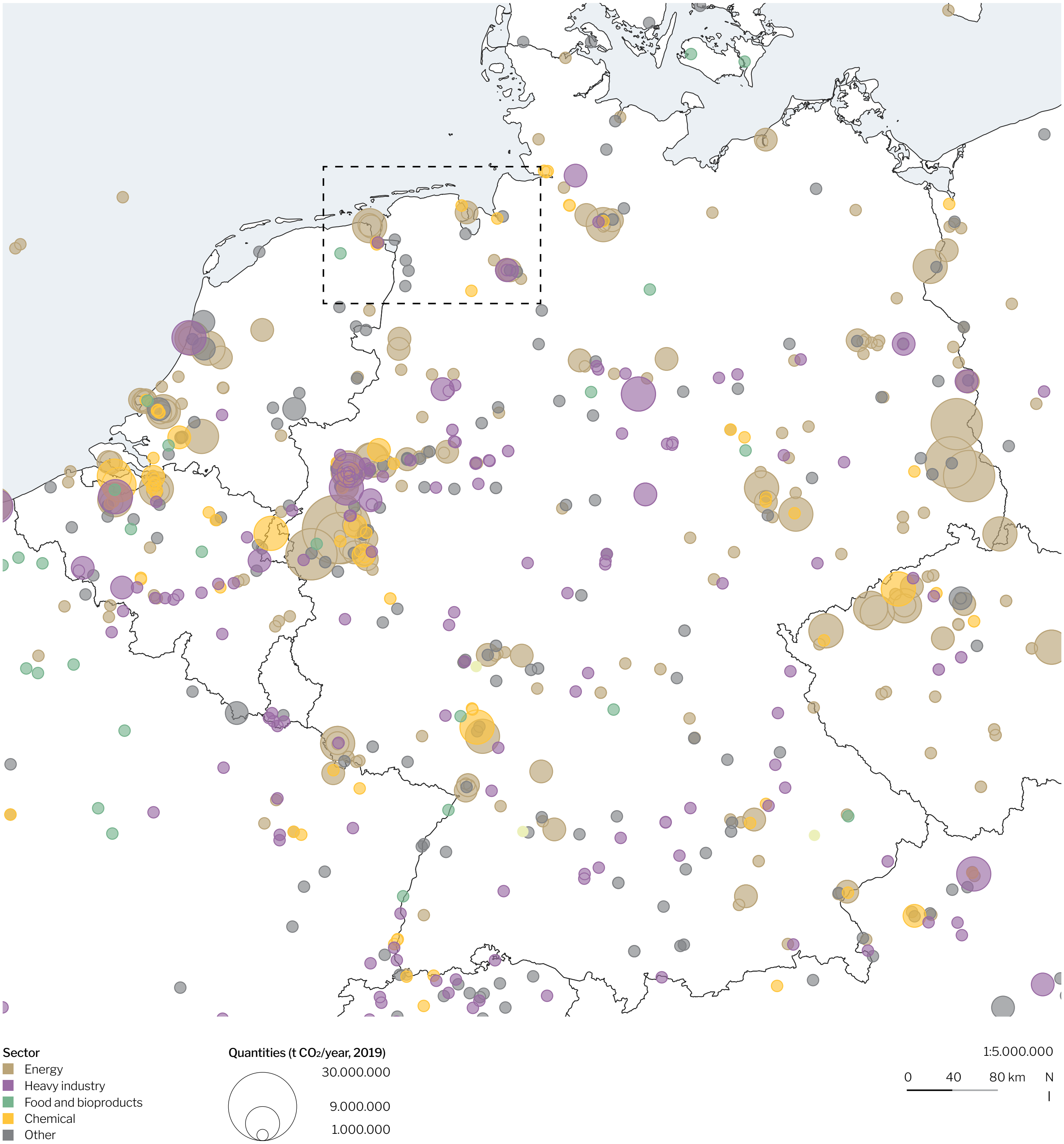
## The Throughput Nature of Flows

While the Wadden Sea region is not among the primary industrial core of Europe, it contains several industrial zones that link into broader European networks. The TEN-T corridors and dispersed sectoral presence suggest a transit-oriented structure, where activity is shaped more by infrastructural throughput than regional embeddedness. This raises the hypothesis that the regional industrial metabolism may function in a largely linear and throughput-driven manner.

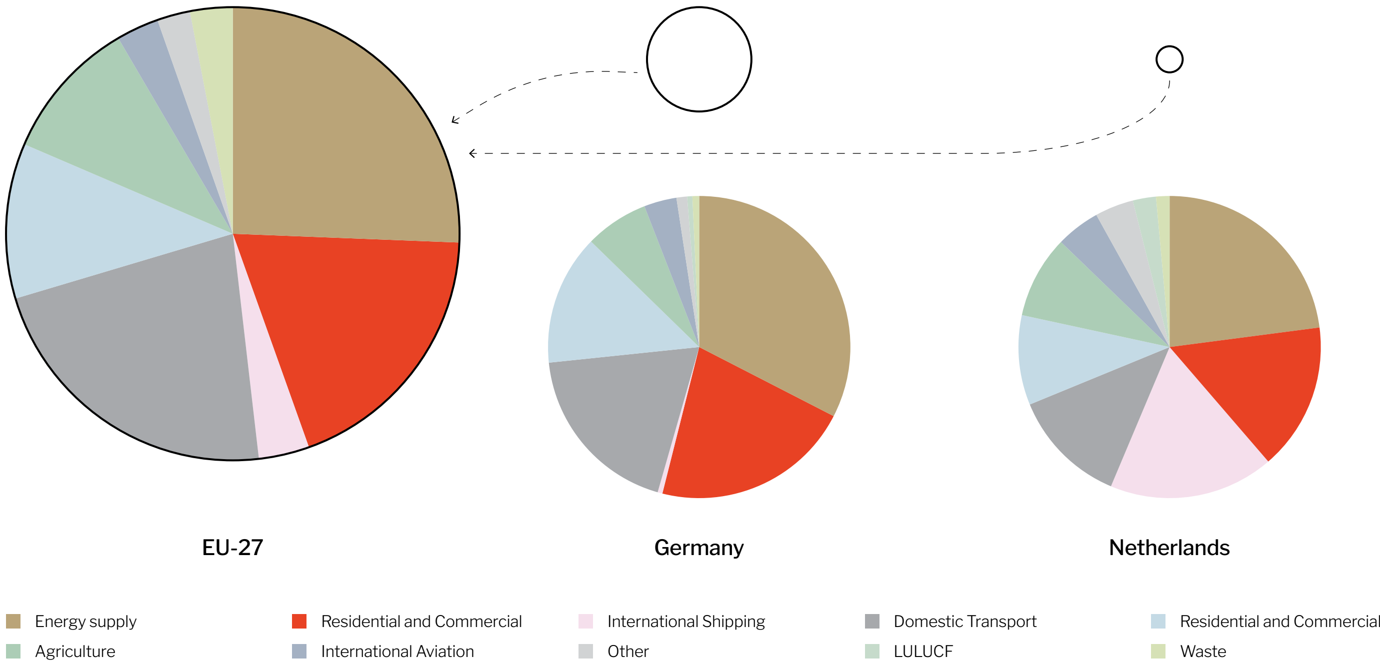


# Carbon Footprints of the Industrial System

## Systemic Legacy: Pollution




2.17 Largest pollutants of $CO_2$ according to the EPRTR

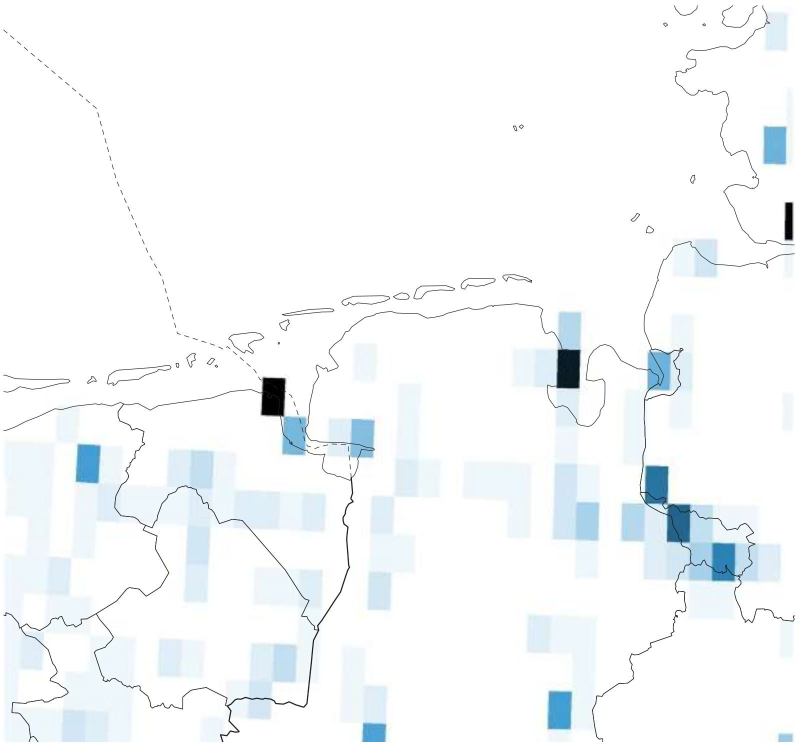



**2.18 Composition and Proportions of Greenhouse Gas Emissions, 2022**

Fig. 2.17 illustrates how pollution forms part of industrial systems. The map displays the largest CO2-emitting installations across Germany and the Netherlands in 2019, based on EPRTR data. While the industrial distribution pattern seen in Fig. 2.13 is partly repeated, the Wadden Sea region takes on a more prominent role. Though not hosting the largest clusters nationally, the region stands out with significant emitters, particularly power plants in Eemshaven, Bremen, and Wilhelmshaven. The steelworks in Bremen also leave a notable mark, while chemical plants are more dispersed across the area.

Fig. 2.18 compares the greenhouse gas emission composition across the EU-27, Germany and the Netherlands. While the energy and industrial sectors play a smaller role in Dutch emissions relative to the EU average, they account for a disproportionately large share in Germany.

The following spread shows regional pollution patterns.

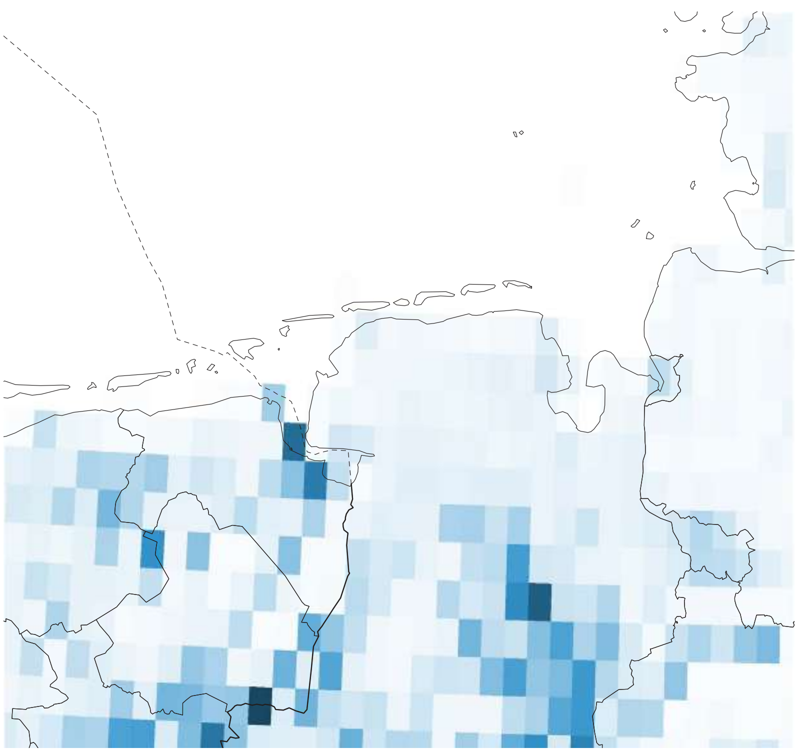


$CO_2$, ton / 0,1degree x 0,1degree, 2022
18.000.000
0

## CO2

CO2 is the primary greenhouse gas emitted by burning fossil fuels and industrial processes. The darkest concentrations appear in Eemshaven and Wilhelmshaven, with Bremen also prominent; smaller hotspots include Delfzijl, Emden, and Bremerhaven, while Oldenburg and rural areas in Groningen, Drenthe, and Emsland are less significant. This pattern likely reflects the presence of large energy and industrial facilities, as highlighted in Fig 2.5.

◀ **2.19 CO2 pollution in the region**



$CH_4$, ton / 0,1degree x 0,1degree, 2022
10.000
0

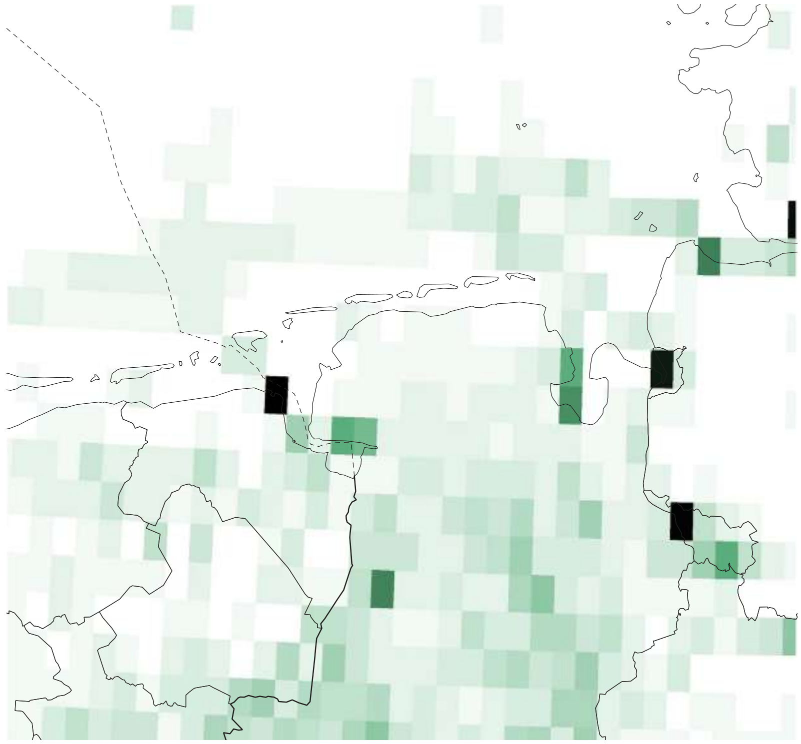
## CH4

CH4 (methane) is a potent greenhouse gas, often linked to agriculture and certain industrial processes. Pollution clusters appear in Delfzijl, south of Oldenburg, and in southern Groningen, Friesland, and Drenthe. These areas likely reflect a mix of chemical industry emissions and agricultural activities, particularly livestock and dairy farming.

◀ **2.20 CH4 pollution in the region**

## PM10

PM10 refers to coarse particulate matter, harmful to human health and linked to combustion, industry, and dust. The highest concentrations are in Eemshaven, Wilhelmshaven, Bremerhaven, Bremen, and Cuxhaven, with notable offshore clusters along shipping lanes and rural areas south of a Bremen-Emden line. This distribution suggests contributions from industrial facilities, urban traffic and possibly large-scale livestock farming.



**PM10**, ton / 0,1degree x 0,1degree, 2022
4.000
0

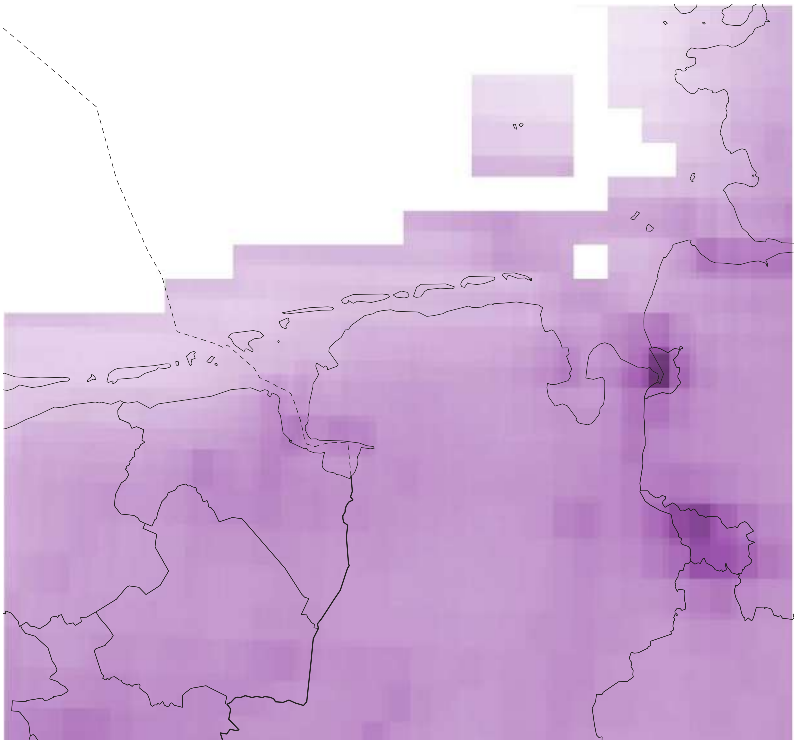
▶ **2.21 PM10 pollution in the region**

## PM2.5

PM2.5, finer particulate matter, poses significant health risks due to its deep penetration into the respiratory system. Concentrations follow a similar pattern to PM10, with major hotspots in large industrial and urban centers, fewer rural emissions, and visible clusters offshore along shipping routes. This indicates a stronger association with industrial and maritime activities compared to agriculture.

**PM2.5**, ton / 0,1degree x 0,1degree, 2022
18.000
0

▶ **2.22 PM2.5 pollution in the region**

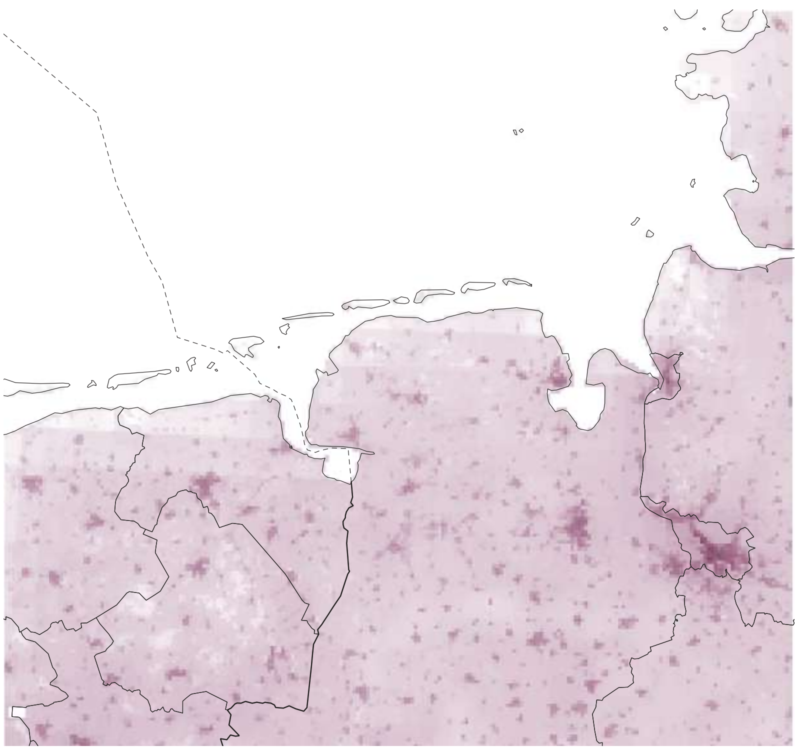


NO₂, annual average human exposure, 2022
high
low

## NOx

NOx (nitrogen oxides) is a group of pollutants primarily emitted from combustion in vehicles and industrial processes. The highest concentrations are in Bremerhaven, Bremen, and the Ems Delta. This likely reflects emissions from maritime traffic, industrial activities and urban transport.

◀ **2.23 NOx pollution in the region**

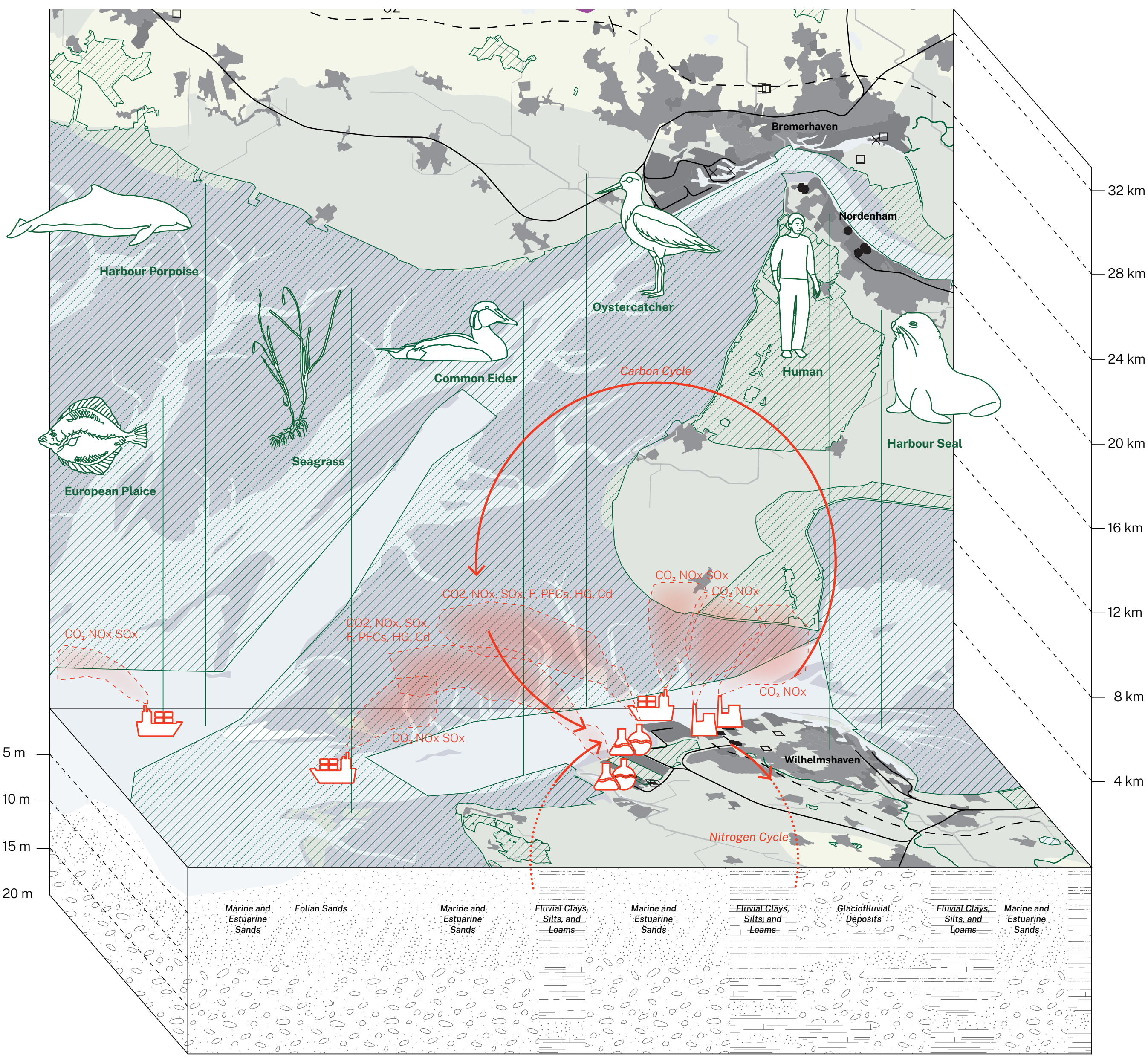


**NOx**, annual average concentration, 2022
high
low

## NO2

NO2, a specific nitrogen oxide, contributes to respiratory issues and is primarily associated with traffic and combustion. It appears dispersed across cities, with Bremen and Bremerhaven most prominent, alongside smaller hotspots in rural areas. The absence of the Eemshaven on this map suggests this pollutant is more tied to urban traffic than industrial sources.

◀ **2.24 NO2 pollution in the region**



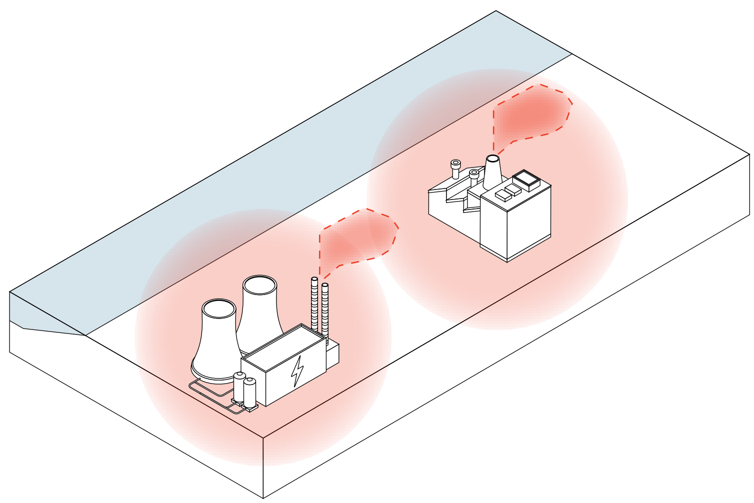

**2.25 Examplified effects of industrial pollution in the case of Wilhelmshaven**

Regarding the Wadden Sea, these systemic legacies, rooted in industry and its infrastructure footprint, have direct negative impacts on the fragile tidal flat ecosystems, globally recognized for their biodiversity (Kabat et al., 2012; Lotze et al., 2005). Fig. 2.25 illustrates pollution types and their effects in and around Wilhelmshaven using a flipped map/axonometric format. It highlights soil and landscape types, protected areas adjacent to industrial system elements (chemical plants, power stations, ports), and impacted species such as seals, seagrass and porpoises, and disrupted carbon and nitrogen cycles.

→ **Identified Problematic Legacy**

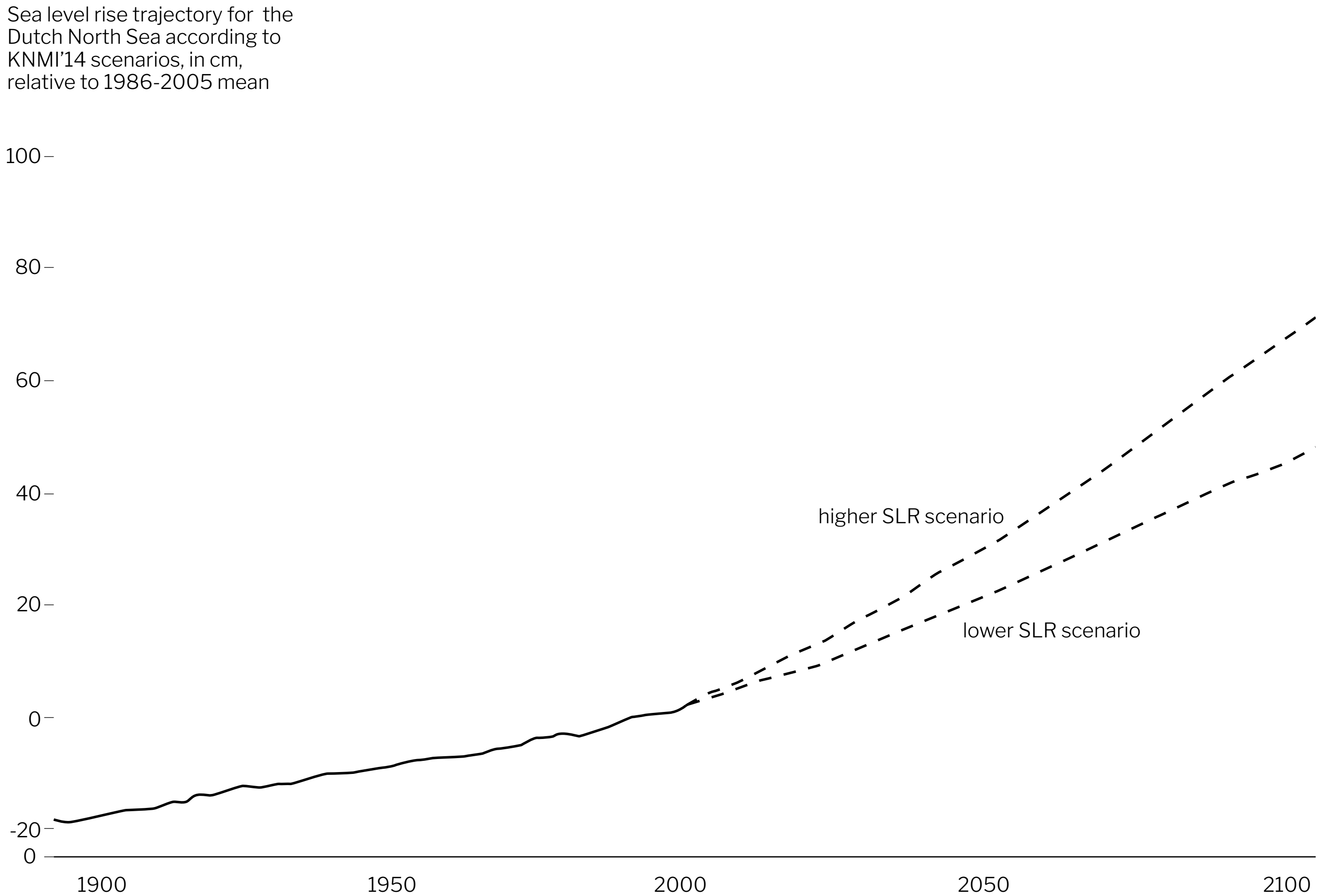
## Pollution in a Fragile Landscape

The industrial and infrastructural systems of the Wadden Sea region are deeply intertwined with pollution. Airborne pollutants, including $CO_2$ and $NO_x$, intersect with sensory disturbances such as light, noise, and odors, creating challenges for this fragile environment. The proximity of industrial activity to ecologically sensitive areas intensifies these impacts,

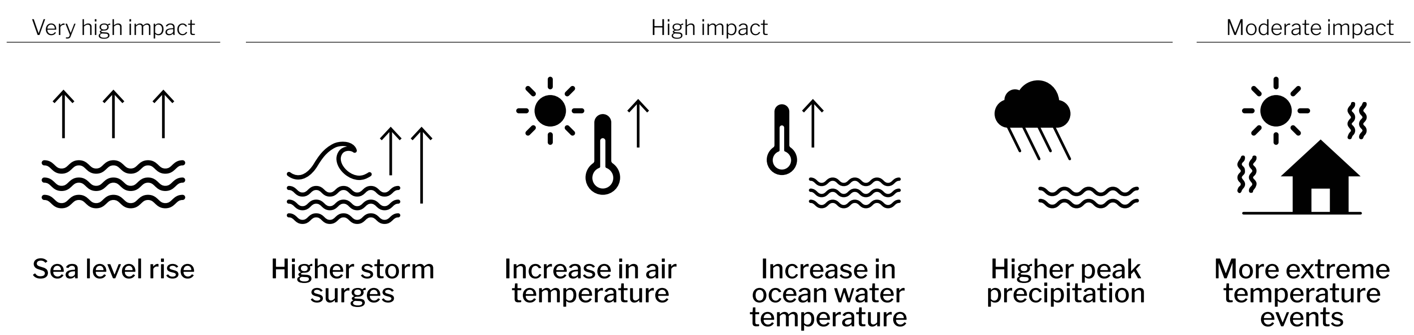


# A Fragile Future

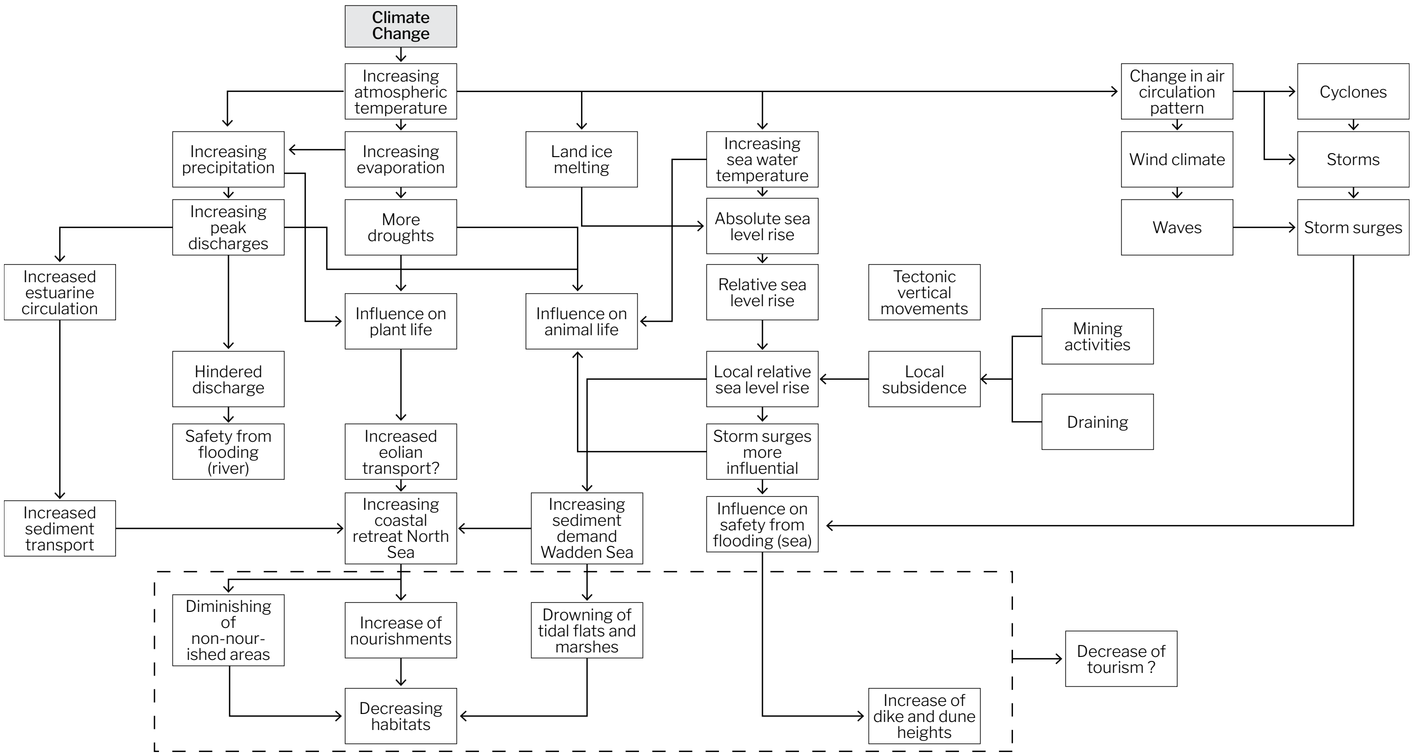
## Contemporary Development: Climate Change




2.28 Projected trajectories of sea level rise in the North Sea



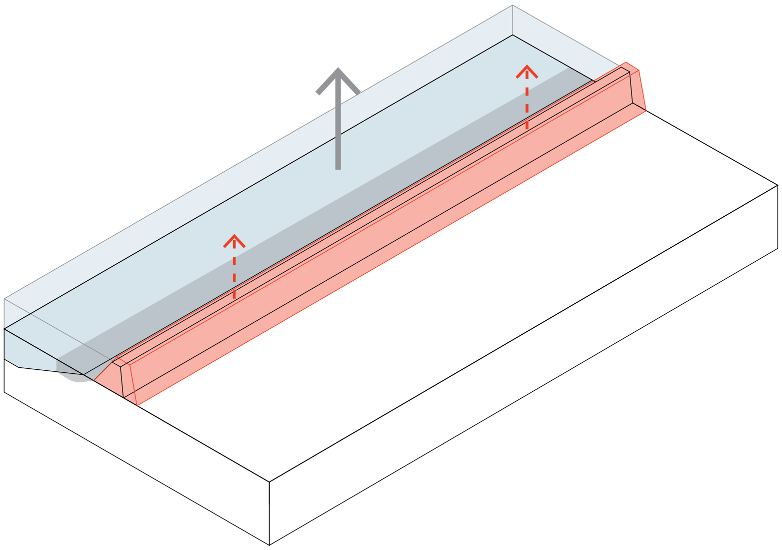

2.26 Main effects of climate change in the Wadden Sea Region




**2.27 Potential effects and interactions of climate change in the Wadden Sea, adapted from Oost et al., 2017**

In the Wadden Sea region, climate change – which regional effects are shown in Fig. 2.27 – poses a far-reaching challenge that intersects with the unique ecological and morphological features. Projections for sea-level rise in the North Sea (up to 80 cm by the end of the century, see Fig. 2.26) threaten the balance of tidal flats, marshes and islands, which all have only a limited ability to adapt to rapid change. The tidal Wadden area, an almost closed system for sediment, struggles to replenish sand as sea levels rise, leading to faster coastal retreat and increased pressure on dykes. Storm surges will become more damaging if tidal flats and marshlands fail to keep pace and necessitate expensive reinforcements of hard infrastructure.

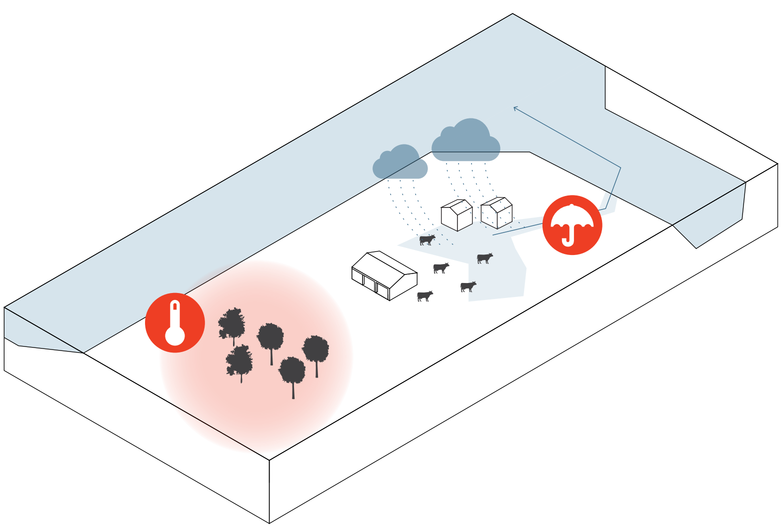
Higher air and ocean temperatures, combined with more extreme weather events, will bring ecological changes, including vegetation shifts, dune erosion, and stressed ecosystems. These changes amplify the region's vulnerability. This is particularly exacerbated beyond the effects shown here if West Antarctica's glacier collapse accelerates after 2050, although exact effects remain uncertain (CWSS, 2017).



Identified Problematic Urgency

## Effects of Rising Sea Levels

The Wadden Sea region is defined by its landscape types. Cities historically settled at the edge of sand uplands and marshlands, while industries were mostly established later in the poldered marshes and along the coast. This landscape itself is engineered and kept dry through ditch systems, which reflects centuries of human intervention. Simultaneously, the region remains semi-peripheral and distanced from European economic cores, which positions it on the fringe of industrial and infrastructural networks.



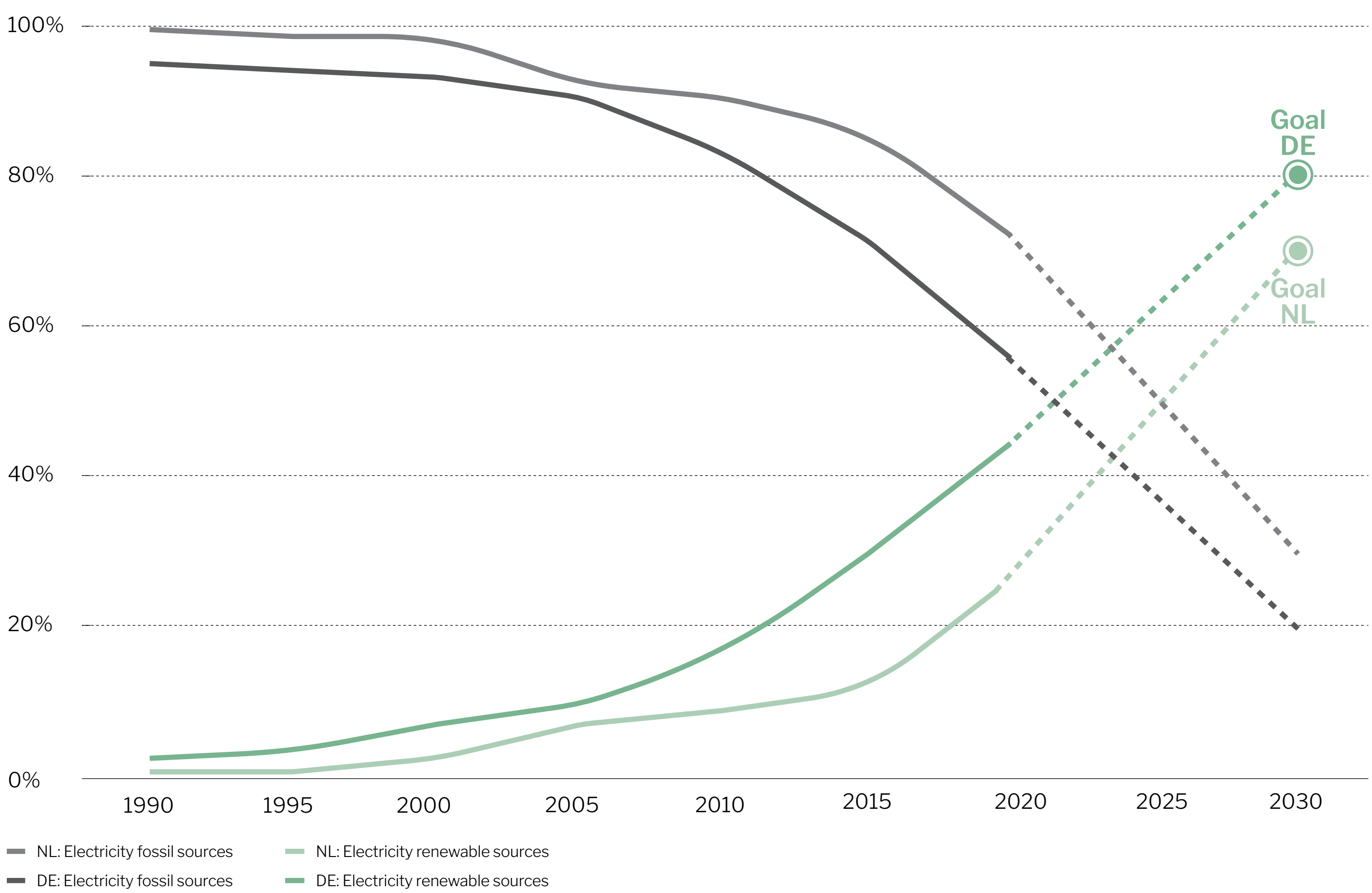
Identified Problematic Urgency

## Climate Change in the Hinterland

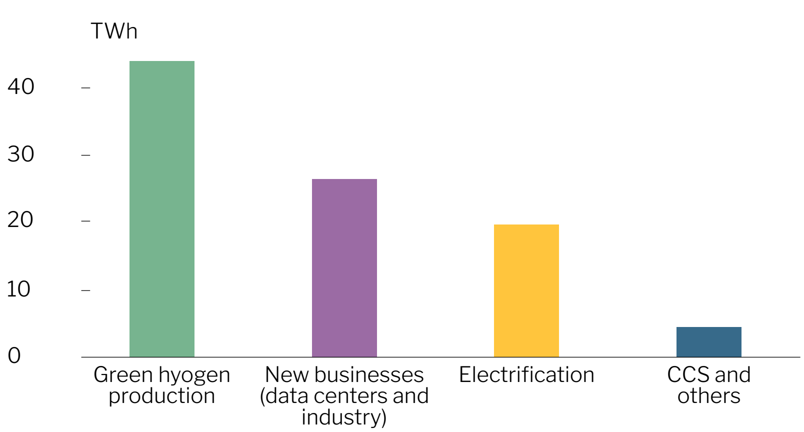
This region is crisscrossed by many visible and invisible borders. Most obviously, the German-Dutch national boundary divides governance and collaboration, but private ownership – and sometimes fences and surveillance – isolate industrial sites and agricultural land from public access. Even the dykes can be read as borders, separating the natural ebb and flow of the Wadden Sea from the marshes. These boundaries define the area not only physically but also socially and economically and can be interpreted as a tension between separation and connectedness in the industrial and environmental systems.

# Power Shifts

## Contemporary Development: Energy Transition




**2.28 Past developments and governmental goals for the energy transition in the Netherlands and Germany**




**2.29 Additional electricity demand in Dutch industrial clusters until 2030**

The energy transition is reshaping the Wadden Sea region, as the share of renewable energy in electricity generation has risen sharply in both Germany and the Netherlands since 1990. Germany leads this shift, with both countries targeting over 70% renewable energy by 2030 (Fig. 2.28). This transformation is part of the broader push for carbon neutrality (see Chapter 1), which extends beyond electricity to decarbonising hard-to-abate industries like steel, chemicals, and heavy transport. Consequently, electricity demand will rise significantly, with Dutch industrial clusters alone requiring an additional 94 TWh annually by 2050, more than double their current consumption (PBL, 2022; Fig. 2.29). This shift will lead to additional

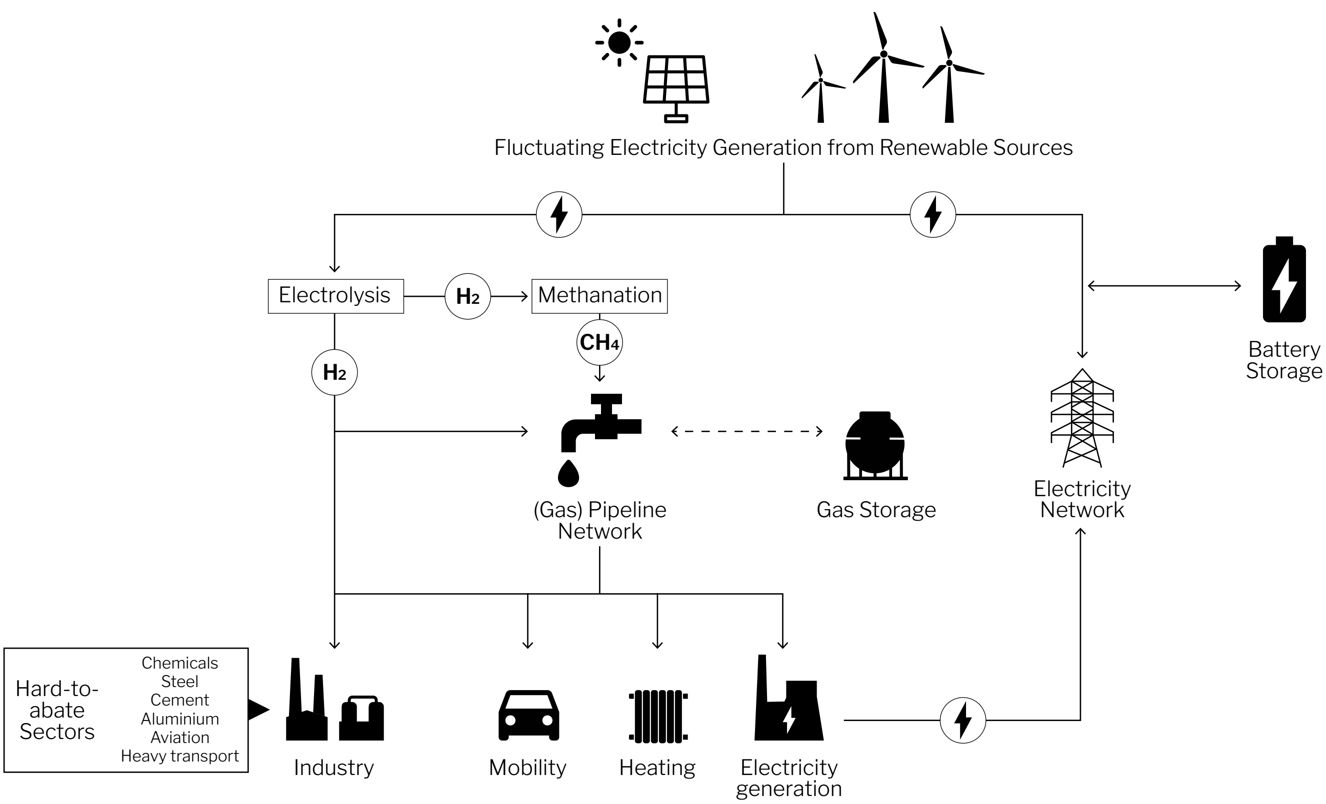
2.30 Gas field in Groningen

2.31 Gas storage in Huntorf that will be used for hydrogen from 2027

network capacity and also space claims and impact on the landscape in various forms.

Hydrogen emerges as a cornerstone in this transition that enables renewable energy storage and the decarbonisation of industrial processes (Fig. 2.32).

The Wadden Sea region, formerly a hub in fossil energy, is also transitioning. The gas production in Groningen, which caused earthquakes and regional insecurity, ceased in 2024, closing a chapter of the fossil age (MinAZ, 2024).

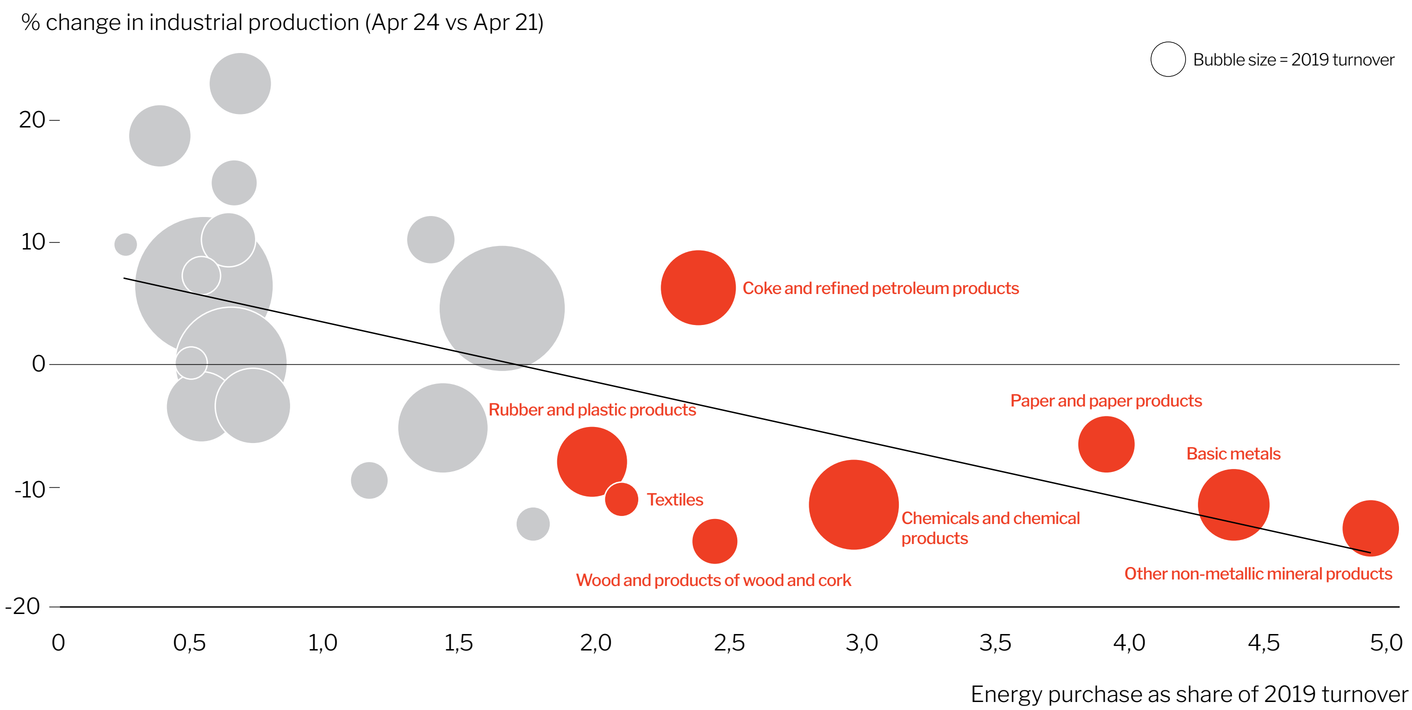



2.32 Overview of hydrogen and other elements of a renewable energy network

# Local Issues Reflect Broader Trends

## Contemporary Development: Crisis of Manufacturing


2.33 Recent developments with industrial facilites closing or threatened by closure




**2.34 Development of energy-intensive manufacturing in the EU since 2021**

The Wadden Sea region is facing struggles in manufacturing that mirror a broader European crisis. Long-standing industries are under pressure from structural economic shifts and financial issues, as shown in Fig. 2.33. These struggles exemplify the challenges of adapting to changing energy systems and market dynamics.

These challenges reflect a European decline in productivity across energy-intensive industries like metals, chemicals, and plastics (Fig. 2.34). Underlying factors include high energy prices, insufficient innovation, and reduced global competitiveness. Key statements from the Draghi Report (Fig. 2.35), published by the European Commission in 2024, highlight the need for decarbonisation, innovation, and reduced dependencies to address these systemic issues. As industrial closures might occur, the Wadden Sea region faces an uncertain future, with significant societal impacts such as widespread job losses.

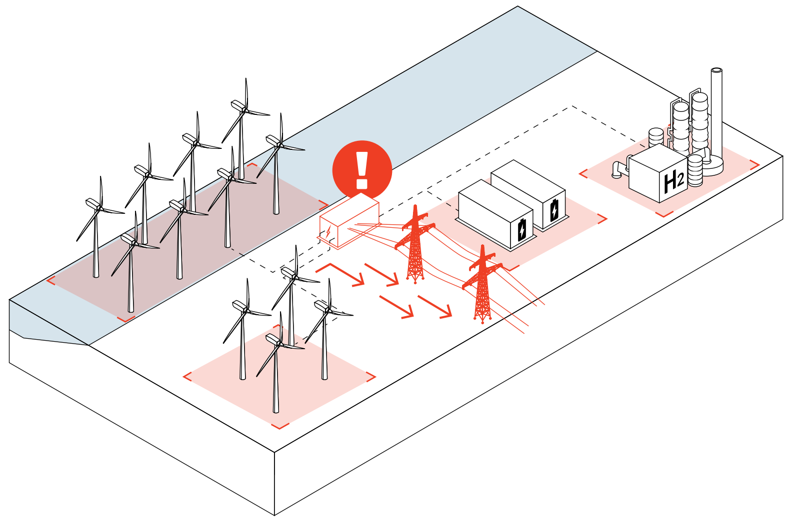
| Issues | Proposed Solutions |
|---|---|
| • Uncertainty about Europe's economic future: End of the era of EU reliance on cheap Russian fossil fuels, open markets and exports to China and provision of security by the US<br>• Lack of dynamism and productivity if compared to the US and China, but also of coordinated industrial strategy<br>• Undermining of European economic growth by insufficient investment and austerity following the financial crisis in 2008<br>• Relatively high energy prices<br>• Lack of innovation and R&D in the age of tech industries, also reflected in localisation of global player companies | • Closure of the innovation gap with the US and China to increase, making use of the AI revolution that is about to start<br>• Joint plan for decarbonisation and competitiveness, aiming at both producing affordable clean energy and supporting industries that enable decarbonisation (i.e. clean tech)<br>• Increasing (military) security and reducing dependencies, for example in terms of the supply of critical raw materials, but also regarding trade and export dependencies, in light of growing instabilities |

**2.35 Key statements of the Draghi Report**

Identified Problematic Urgency

## New Dependencies of Renewables

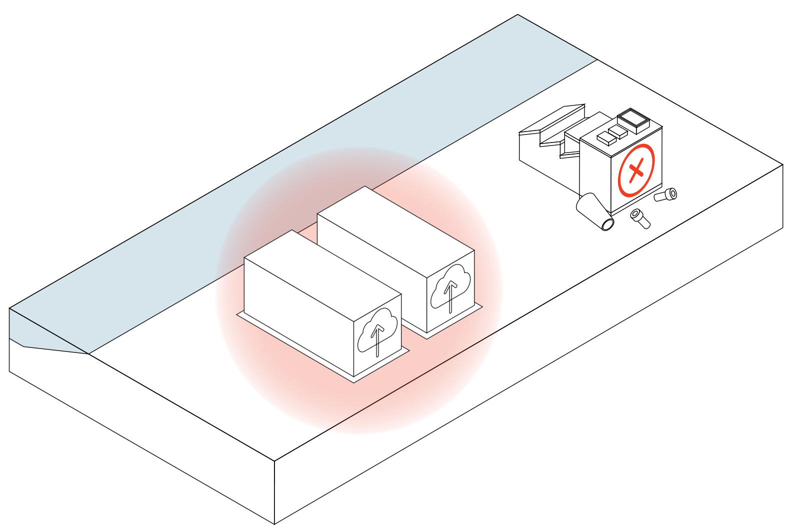
The region's industrial operations rely on an expansive network of infrastructure. Power plants, including coal-based facilities, dominate the energy landscape, while canals support shipping and connect shipbuilding sites to global supply chains. These systems, layered over decades, enable production but also impose a visible footprint on the environment.




Identified Problematic Urgency

## Changed Pattern of Manufacturing

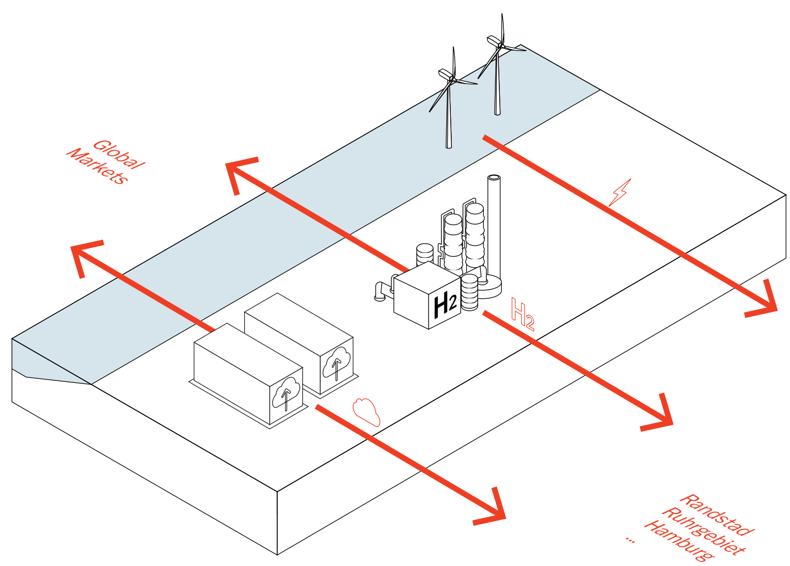
The industrial and infrastructural systems of the Wadden Sea region are deeply intertwined with pollution. Airborne pollutants, including $CO_2$ and $NO_x$, intersect with sensory disturbances such as light, noise, and odors, creating challenges for this fragile environment. The proximity of industrial activity to ecologically sensitive areas intensifies these impacts,



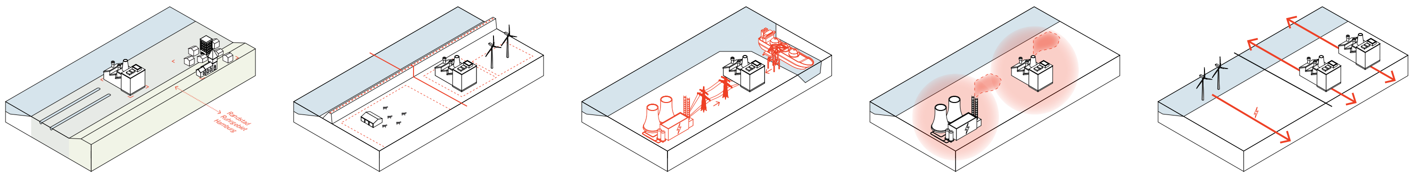
Identified Problematic Urgency

## Semi-Periphery, but Rethought

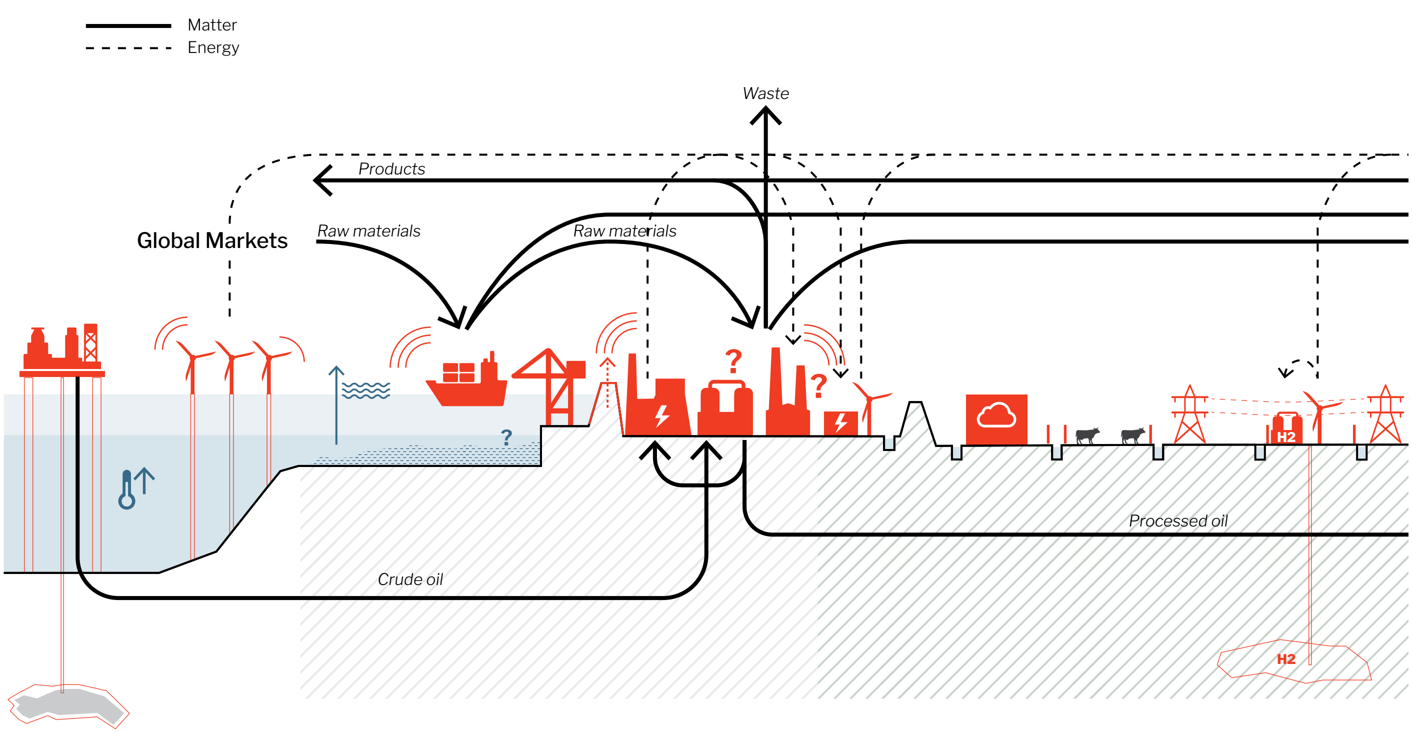
The Wadden Sea region functions as a transit zone, with flows of goods and energy moving predominantly north-south on both sides of the border, to and from the global markets via the North Sea to Europe's economic cores like the Randstad and the Ruhrgebiet. This underscores both its dependency on and contribution to larger European economic systems.

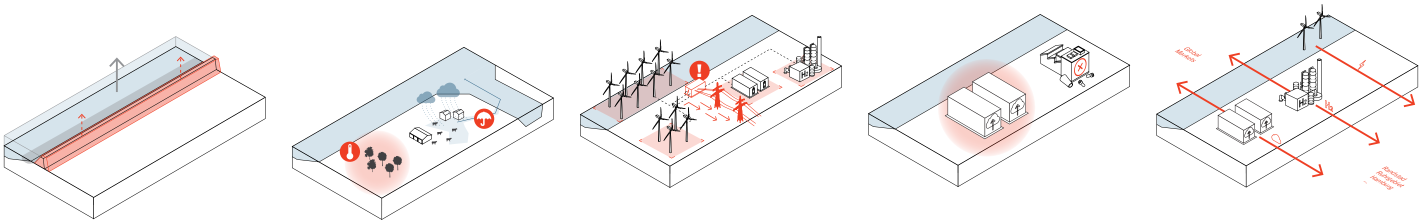


# Problem Statement



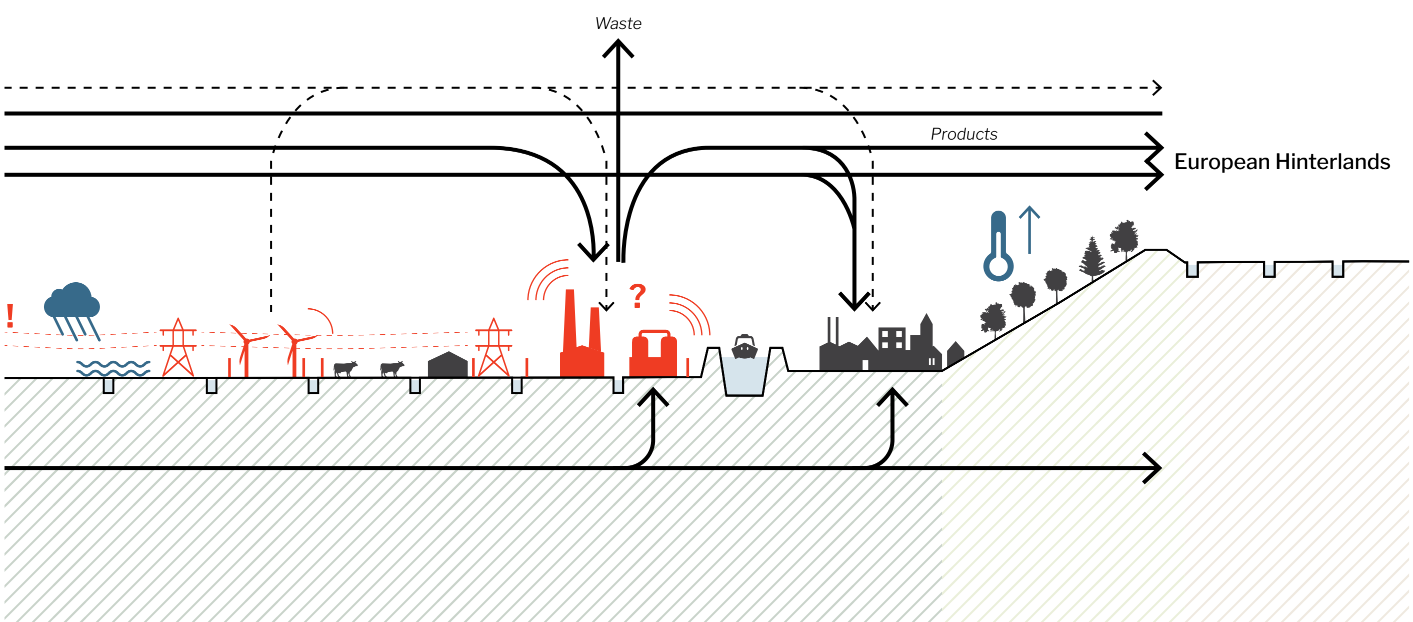
Throughout this Chapter, it became apparent how the throughput economy has an imprint on the landscape, how the region was structured to serve and how this has effects on the landscape. On top of these Systemic Legacies, there are Pressures unfolding that pose a challenge to the future of the region: Changing climate and sea level rise mean a greater vulnerability. Deep-ranging shifts in economy and energy lead to spatial impacts and potentially an intensified manifestation of the role of an Operational Hinterland.
Combining all these issues lead to the formulation of the Problem Statement, which is then spatial-ised in the section at the bottom in Fig. 2.36.





Synthesised Problem Statement

Situated in a unique and ecologically vulnerable zone, the Wadden Sea region functions as an operational hinterland defined by infrastructural throughput and industrial extraction. As climate breakdown intensifies and supply chains shift, its spatial logic is reaching its limits, demanding a new imagination of regional development.

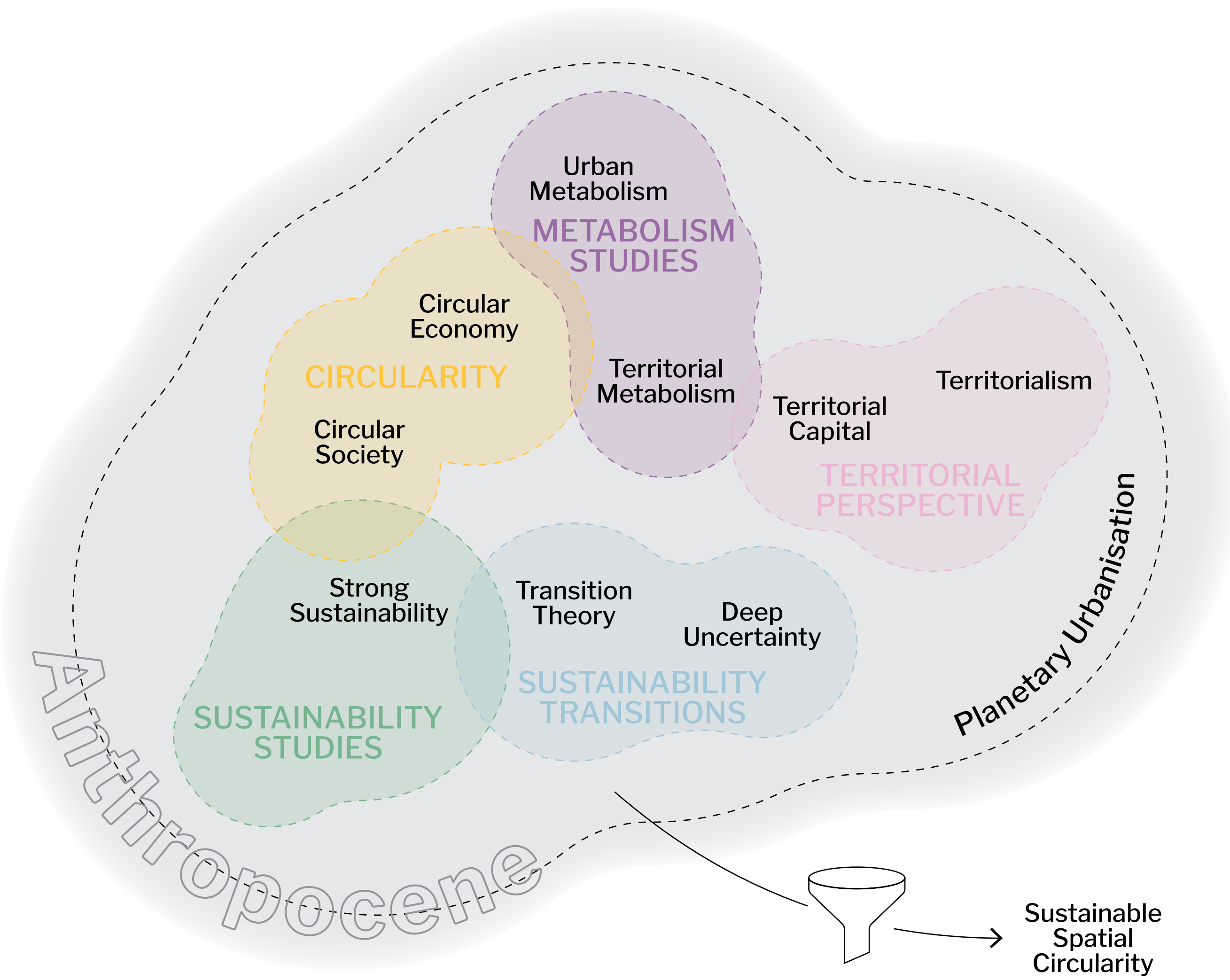



2.36 Systemic section summarising the problematisation

3

# Theoretical Underpinnings

# Theoretical Framework



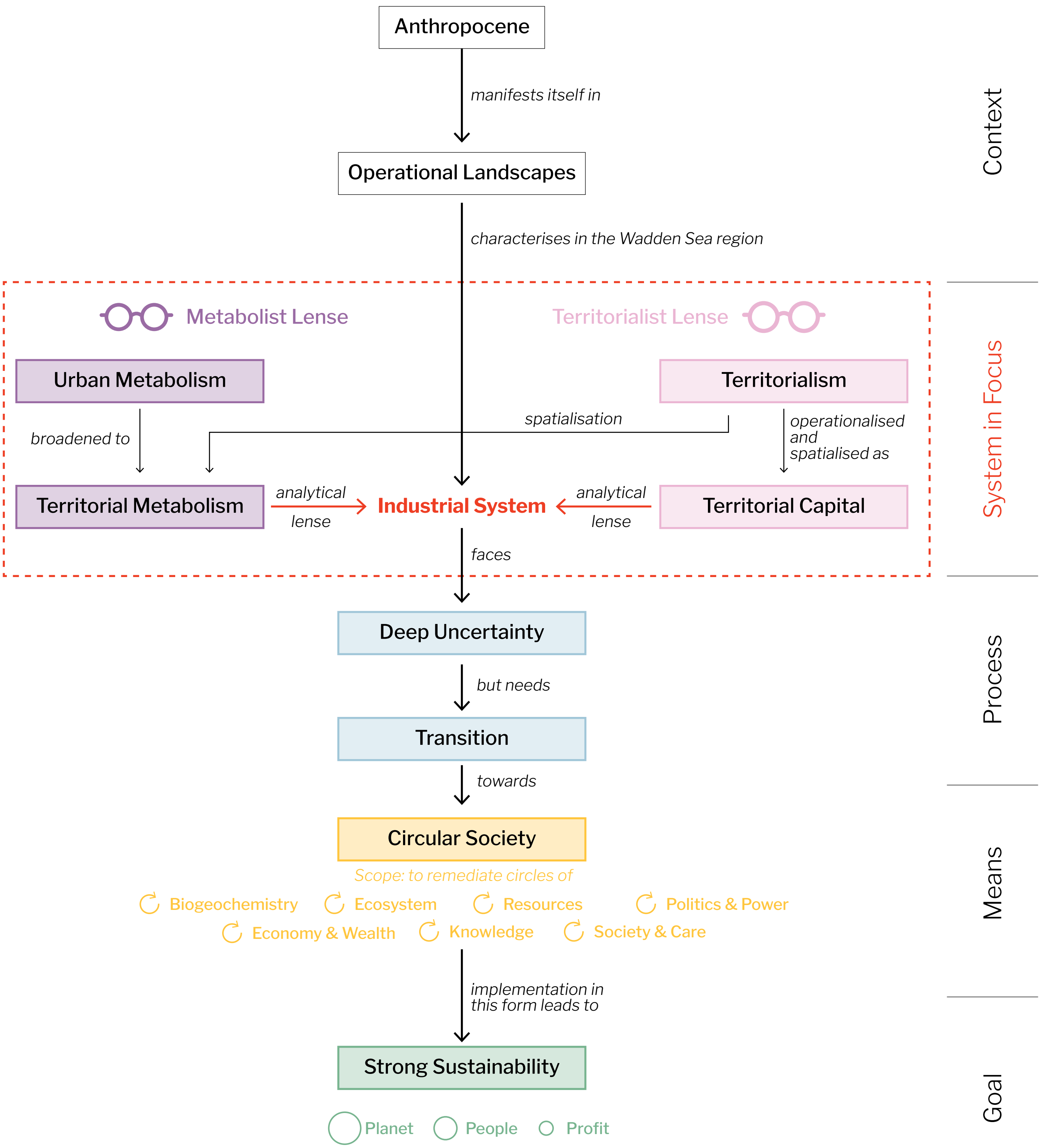

3.1 Theoretical Framework

This chapter introduces the theoretical foundations that support the analysis of the Operational Hinterland and design of a sustainable circular industrial system in the Wadden Sea region. Two linked frameworks guide this approach.

The first (Fig. 3.1) positions this thesis within relevant scientific fields and brings them into a connection with each other and within the broader contexts of the Anthropocene.

The second (Fig. 3.2) operationalises this positions through a line of inquiry: beginning with a system inventarisation, it explores metabolic and territorial logics as stepping stones toward circularity and sustainability. Together, these frameworks provide the conceptual backbone of the thesis and structure the chapters that follow.

# Conceptual Framework




3.2 Conceptual Framework

# The Planetary Context

The Anthropocene marks a condition where human activity reshapes planetary systems. To situate the Wadden Sea region within this global context, this section examines the Anthropocene as a framework for understanding environmental transformation. It then connects this to Planetary Urbanisation, which reveals how these global processes manifest spatially and turn landscapes like the Wadden Sea into active zones of extraction, logistics and ecological tension.

## Anthropocene

The term 'Anthropocene' describes a planetary condition in which human activity has become the dominant driver of system change on Earth. It was coined by chemist Paul Crutzen, who argued that since the late 18th century, human-driven emissions, population growth and the extraction of resources have irreversibly pushed the planet out of the relatively stable conditions of the Holocene (Crutzen, 2002). This framing gained traction particularly in relation to the so-called "Great Acceleration" after World War II, when global economic growth became tightly linked with rapid environmental degradation (Zalasiewicz et al., 2015).

However, the term remains contested. In 2024, the proposal to declare the Anthropocene an official geological epoch was rejected (Carrington, 2024) and critics argue that it obscures responsibility by flattening differences across time, space and class. Here, alternative framings such as the "Capitalocene" (Moore, 2016, p. 4) highlight the central role of capitalism in driving ecological degradation. These critiques are valid, but they do not negate the analytical value of the concept.

For the Wadden Sea region, the Anthropocene provides a lens to interpret how ecological vulnerability and economic development collide. It anchors the regional challenges within broader planetary dynamics.

## Planetary Urbanisation

While the Anthropocene frames human influence at a planetary scale, Planetary Urbanisation explains how that influence materialises spatially. Brenner and Schmid (2015) argue that capitalism and neoliberalism drive a condition in which urbanisation is no longer confined to cities but extends through the operational landscapes that sustain urban life, such as production zones, logistical corridors and areas of resource extraction. These areas, often dismissed as peripheral, , having been restructured to serve global urban economies. The Wadden Sea region, with its ports, industries and infrastructures, exemplifies such a landscape.

Furthermore, Brenner and Katsikis (2020) describe some of these territories as "hinterlands of hinterlands" that are disconnected from any single urban core, but integrated into global flows of materials and waste. Despite covering most of the planet's surface, these zones remain underexamined and treated as a "black box" (Brenner & Katsikis, 2020, p. 26) rather than active spatial agents. Reading the Wadden Sea through this lens shifts the perspective. As an operational hinterland, it is no longer just a natural reserve or industrial zone, but fundamentally tied to planetary systems. The following sections explore how this region operates metabolically and territorially and how those logics might be redirected towards circularity.

Reading the Wadden Sea through this lens shifts the perspective. As an operational hinterland, it is no longer just a natural reserve or industrial zone, but fundamentally tied to planetary systems. The following sections explore how this region operates metabolically and territorially and how those logics might be redirected towards circularity.

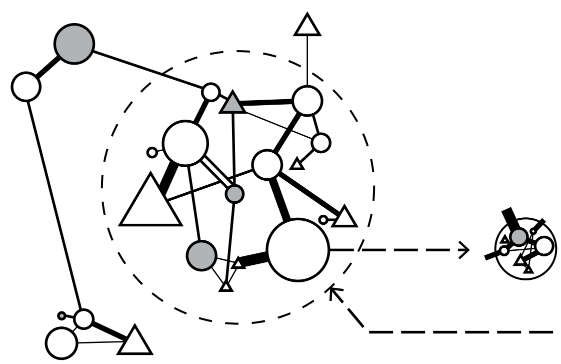
# Understanding the Industrial System

This section zooms in on the Wadden Sea region. Building on the idea of the operational hinterland in the Anthropocene, it analyses the working as industrial system not as neutral infrastructure, but as a manifestation of planetary urbanisation. Taking the role of an operational hinterland as starting point, it opens the region's 'black box' by asking: how do flows and space interact? Two lenses guide this reading: metabolism to trace material dynamics and territory to understand spatial structure and potential.

## Complex Systems

For the analytical steps, this thesis adopts systems thinking as its framing. This is necessary due to the complexity of urban landscapes in the Anthropocene, which, shaped by planetary processes and embedded within multi-scalar interactions, often surpasses the understanding or influence of the individual (Nijhuis & Jauslin, 2015, p. 15).

One of the foundational models of system analysis comes from McLoughlin (1969), who describes regions as nested systems composed of interdependent parts and subsystems, each evolving at its own pace and interacting across various spatial and temporal scales (see Fig. 3.3). This approach allows complexity to be traced without reducing it to a single logic. To make this complexity tangible, the next step is to uncover how the lenses of metabolism and territory reveal the flows and structures shaping the industrial landscape in the Wadden Sea region.




**3.3 A City as a System, adapted from McLoughlin, 1969**

## Urban Metabolism

Urban Metabolism offers a way to quantify the resource flows (energy, water, materials and waste) that move through urban systems. They form a dynamic network of inputs, transformations, storage and outputs (Barles, 2010; Zhang, 2013). Originally modelled after biological organisms, it allows researchers to trace how resources circulate through urban systems and where inefficiencies or leakages occur. With sufficient data, these quantifications provide a balance sheet of the metabolism of a city.

Kennedy et al. (2011) highlight the role of urban metabolism in urban design and policy. Beyond reporting and modelling, it can inform how to redesign infrastructure systems towards more sustainable configurations. In the context of the Wadden Sea, this means understanding how port operations, energy production and industrial activities are embedded in resource-intensive flows and how those flows might be redirected.

However, the framework has critical limitations. Firstly, data availability generally remains a major hurdle (Williams, 2021). Secondly, metabolism studies often use administrative or statistical boundaries rather than functional territorial units, which misaligns the scale of analysis with the actual spatial dynamics (Barles, 2010). Thirdly, the social dimension is frequently underexplored (Kennedy et al., 2011). Human practices, governance arrangements, and institutional systems are often treated as external conditions rather than integral parts of metabolism. Yet, as Russo and van Timmeren (2022) argue, human settlements are unique in their ability to adapt consciously and systemically, meaning that metabolic analysis must account for socio-political agency and decision-making.

Finally, a key blind spot for this thesis lies in the missing link to territory (Barles, 2010; Williams, 2021). While urban metabolism explains the what and how much of resource flows, it says little about where these flows are anchored. To address this gap, the next section turns to Territorial Metabolism, which is a broader approach that combines flows with spatial structure and landscape.

## Territorial Metabolism

While Urban Metabolism tracks what flows through a system, Territorial Metabolism asks where those flows occur, who shapes them and how they interact with the spatial structure of a region. It also extends metabolic thinking beyond the city to include wider metropolitan landscapes (Grulois et al., 2018).

This shift is especially relevant for the Wadden Sea region, because it offers a more integrated, spatialised view of systemic functioning. As an operational hinterland, the region is not simply a passive supplier of resources but a highly active and configured space shaped by industries and supporting infrastructure. While traditional metabolic studies would typically treat such areas as the "black box", Territorial metabolism responds to this shortcoming by linking flows with land use, morphology and governance. Kampelmann (2018) stresses that circularity cannot be realised within city boundaries alone, as resource cycles must be traced across urban–rural gradients, infrastructure systems and ecological zones. In this view, material flows are inseparable from spatial politics.

Responding to that, this thesis adopts the Design of a Territorial Metabolism (Ranzato & Grulois, 2018) as both a conceptual and operational lens, as it positions metabolism not just as a diagnostic tool but as a design challenge: how can we spatially reconfigure territories to support circular transitions? This requires understanding where flows concentrate or disperse, how infrastructures channel or constrain them and which spatial layers might be involved.

For the Wadden Sea, this means connecting the physical presence of both industrial and ecological structures to the metabolic processes they host. Territorial metabolism allows these hidden dynamics to become legible by revealing tensions, potentials and points of intervention. Unlike traditional sustainability metrics, this approach insists on spatial specificity.

As a bridge between flows and form, territorial metabolism sets the stage for the next step: reading the Wadden Sea not only as a metabolic system, but as a layered and historically shaped territory with its own spatial logic and capital.

## Territorialism and Territorial Capital

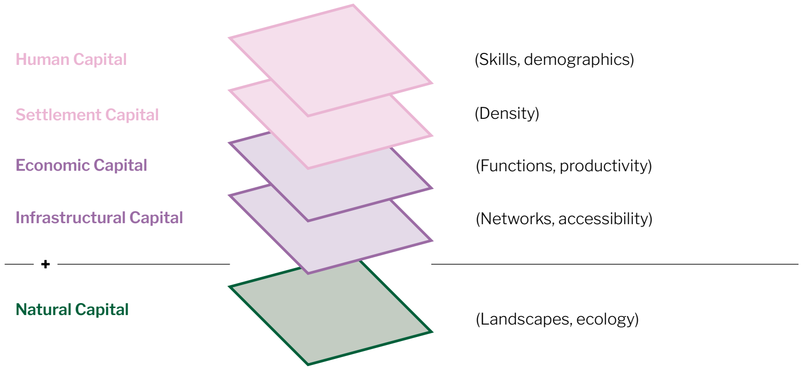
If metabolism reveals how resources move, then territory reveals where and through what structures those flows are anchored. It is not simply land, but a dynamic condition composed of material, social and political dimensions (Furlan et al., 2022). In this thesis, two conceptual tools are used to read and work with territory: Territorialism and Territorial Capital.

Territorialism, as developed by Paola Viganò (2014), proposes that territory is both a physical environment and a social construct which is shaped by ecological processes, cultural practices and historical transformations. Rather than seeing it as a static backdrop for human activity, she frames it as a palimpsest: a layered and evolving spatial condition. This reading moves beyond the urban-rural duality, understanding all territory as active and interdependent.

To support this reading, Viganò (1999) introduces the concept of the Elementary City, which breaks down territory into fragments, such as built forms, infrastructures, boundaries, networks, and examines their synchronic (current) and diachronic (historical) relationships. Through this stratigraphic lens, the fragmented and often-overlooked components of the Wadden Sea landscape, for instance dikes, ditches, roads or wetlands, can be reassembled into a readable structure. This perspective makes the embedded potential of territory visible by looking not only at what it contains, but how it has evolved and might be redirected.

Building on this spatial reading, the concept of Territorial Capital offers a way to assess the assets and qualities embedded in a region. Originally proposed by the OECD (2001) and developed further by Camagni and Capello (2009), refers to the mix of tangible and intangible resources that shape a region's development potential, such as infrastructure, land use, institutions and social networks. What matters is not just the presence of these assets, but how they interact within a specific territorial configuration. In the Wadden Sea, territorial capital becomes a lens to understand what makes the region function and how it might be able to transition. From its physical structures (ports, wind farms, dikes) to its social and ecological systems (labour networks, salt marshes, tidal zones), the region is shaped by a mingle of various forms of capital. Recognising this diversity is essential for conceiving circular transitions: it is impossible to design for meaningful change without knowing what is being built on.

Yet, existing models of territorial capital have limitations. As Orsi et al. (2024) argue, many policy tools reduce territorial capital to economic indicators or demographic trends, again neglecting spatial structure and morphology. To counter this, they propose a spatially grounded approach based on four mapped dimensions (Fig. 3.4): human, settlement, economic and infrastructural-relational capital. While this approach improves granularity, it still underrepresents key layers such as landscape




**3.4 Dimension of spatialised teritorial capital by Orsi et al., 2024**

and ecology. These omitted dimensions are not just aesthetic or symbolic, because they are structuring forces, as Russo and van Timmeren (2022) argue. Landscapes, especially in a region like the Wadden Sea, carry spatial memory, ecological logic and socio-cultural meaning. If ignored, spatial strategies risk being technically correct but contextually blind. This thesis therefore proposes a combination: Viganò's stratigraphic perspective allows for a situated and layered reading of the Wadden Sea region's territory, while a refined concept of territorial capital provides a tool for assessing and activating its assets. By valuing not just infrastructure and institutions, but also ecological systems, spatial morphology and cultural narratives, the region becomes readable as a dynamic system with embedded potential.

In summary, this territorial lens anchors abstract metabolic flows in the grounded realities of space, form and structure. It moves the thesis from diagnosis to opportunity: revealing not just what is broken, but what might already exist as material for building a circular, place-based transition.

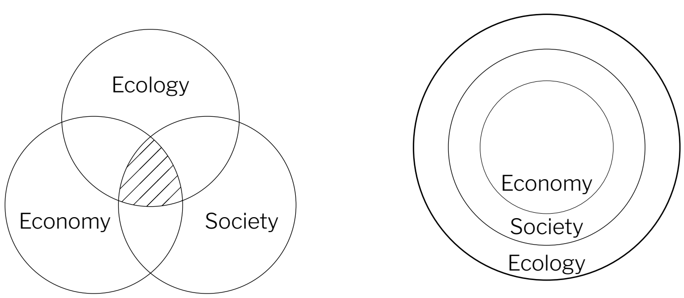
# Towards Sustainable Spatial Circularity

As an operational hinterland in the Anthropocene, the Wadden Sea region faces urgent challenges of industrial pressure and ecological degradation. This chapter explains the response in the Conceptual Framework: a threefold structure for sustainable circularity. It combines strong sustainability as a normative goal, circular economy as an operational approach and transition theory as a guide for navigating change under uncertainty.

## Sustainability

Strong sustainability forms the normative foundation of this thesis. It rests on the understanding that environmental systems are the irreplaceable basis for all human activity in the social and economic realm. This contrasts with the more widely adopted, conventional (Purvis et al., 2019) "weak" sustainability model, which (often implicitly) assumes that natural capital (such as forests, wetlands or clean air) can be substituted by human-made capital (like technology or infrastructure). While it is convenient for policy, this view underestimates planetary limits and risks irreversible loss (Dietz & Neumayer, 2007). Strong sustainability rejects that trade-off. It argues that certain ecological systems, especially those that regulate climate, purify water or support biodiversity, are non-substitutable and must be preserved as preconditions for life. The nested logic, coined by Scott Cato (2009, p. 37), is clearly visualised in Fig. 3.5. Rather than treating environment, society, and economy as equal pillars, it emphasises dependence: no economy without society, no society without ecology.

This perspective is especially relevant for the Wadden Sea. As a region of high ecological value and vulnerability to climate change, it exposes the tensions between extractive industry and environmental limits. Applying strong sustainability to this region means not simply balancing interests, but redesigning systems around what the biosphere can support and regenerate.




Prevailing economic framing of how Economy, Society and Environment relate

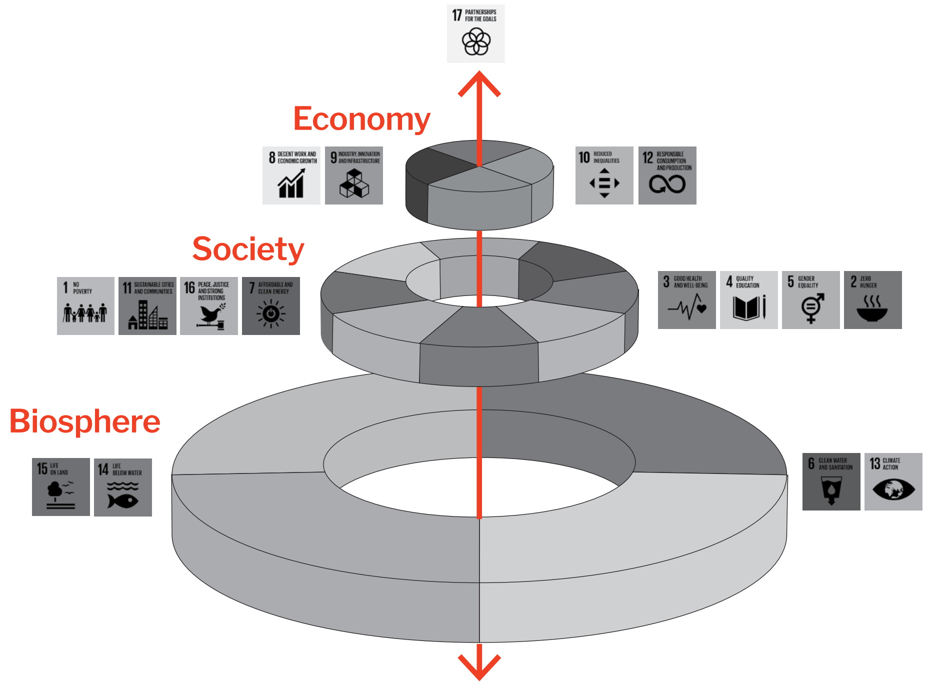
Economy depends on Society, which in turn relies on the Environment

**3.5 Weak and Strong Sustainability, adapted from Cato, 2009**

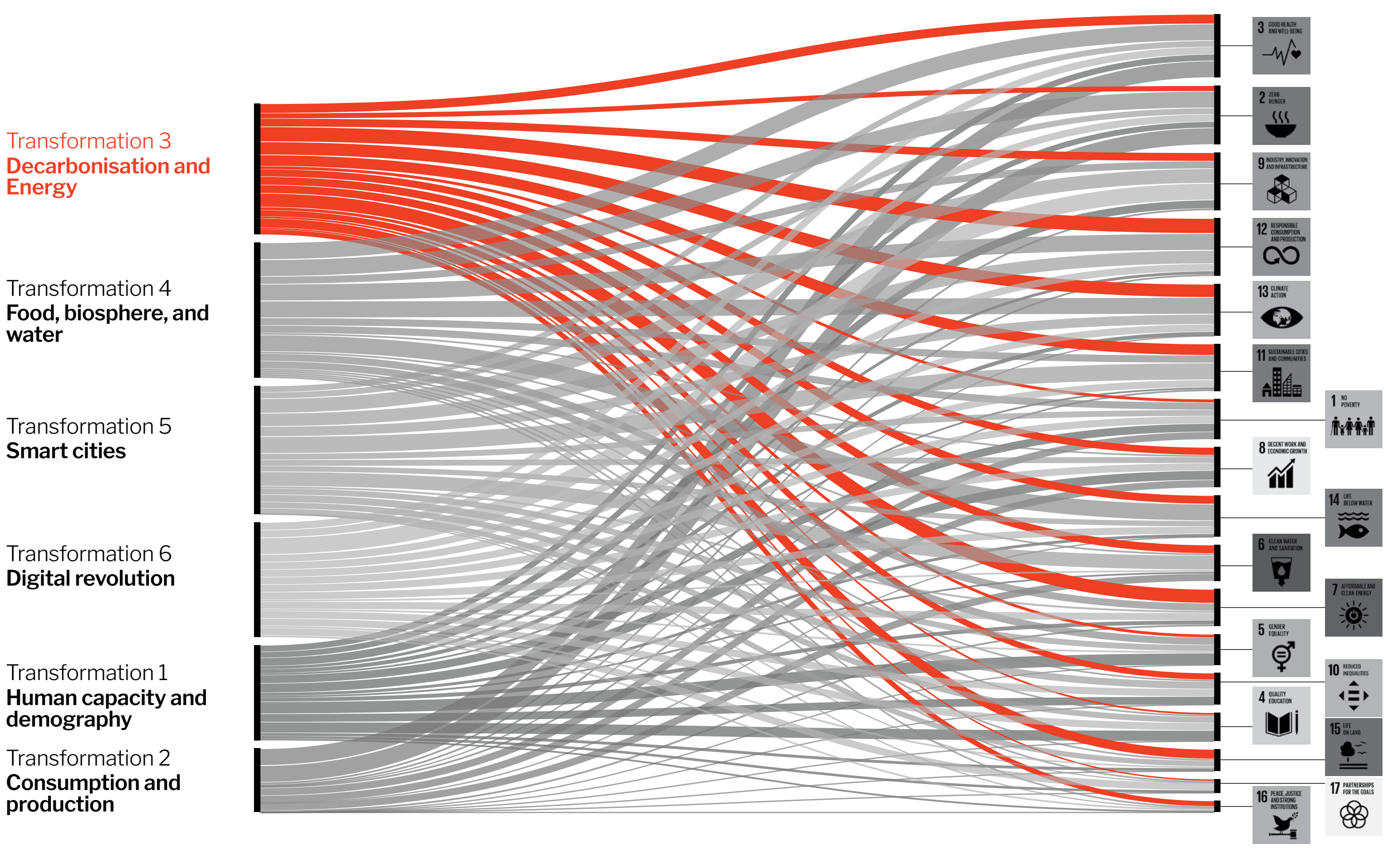
The Sustainable Development Goals (SDGs), adopted by the UN in 2015, provide a broad global framework for translating this into policy. They are structured across 17 goals, with interconnected targets for ecological, social and economic development. The approach of strong sustainability can be applied when they are grouped into a "wedding cake", introduced by Rockström & Sukhdev (2016): Goals relating to climate action, life below water and life on land form the base and are essential for achieving the others. To make these SDGs actionable, Sachs et al. (2019) propose six transformations that can guide systemic change, as displayed in Fig. 3.7. Among them, Transformation 3, which focuses on sustainable energy and industry, directly aligns with this thesis. It aims to decarbonise industrial systems, increase energy efficiency and reduce pollution. Key measures include electrification, renewable energy integration and circular strategies that reduce material dependency.

However, Sachs et al. also emphasise the risks: trade-offs between decarbonisation and affordability, resource scarcity and potential rebound effects. To manage these, they argue that circularity is not optional, but essential. It shifts focus from linear extraction and disposal toward closed-loop systems that regenerate, reuse and retain value.

This sets the direction for the next section, which explains circularity is both a design logic and a spatial strategy for landing strong sustainability in place.




3.6 “Wedding cake” of the Sustainable Goals by the Stockholm Resilience Center

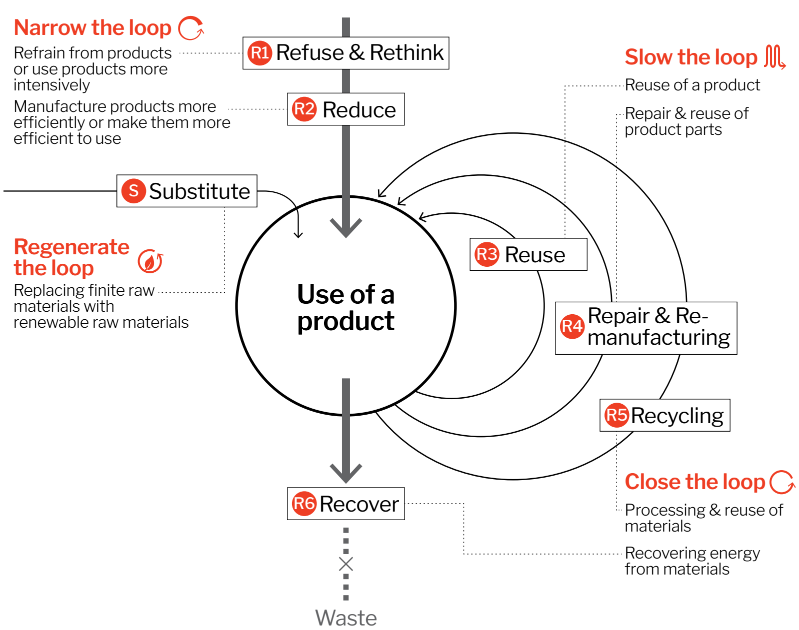



3.7 Contribution of each transformation to each SDG, adapted from Sachs et al., 2019

## Circularity

In recent years, circularity has emerged as a central strategy for addressing the environmental impact of industrial production. At its core, it proposes a shift away from the dominant "take-make-dispose" model toward regenerative, closed-loop systems. The Ellen MacArthur Foundation defines the circular economy (CE) as "an industrial system that is restorative or regenerative by intention and design" (2013, p. 7). It aims to intentionally design out waste, keep materials in use and regenerate natural systems. The model distinguishes between biological cycles, where consumable materials safely return to the biosphere, and technical cycles, where durable materials are reused, repaired, or remanufactured (Ellen MacArthur Foundation, 2013). This foundational definition remains influential, but its implementation requires clearer operational strategies.

One of those is the R-Ladder, a hierarchy of circular actions ranging from avoidance to recovery (R0 Refuse, R1 Rethink, R2 Reduce, R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, R7 Repurpose, R8 Recycle, R9 Recover, plus Substitute). Based on Kishna & Prins (2024), it includes ten strategies, which are depicted in Fig. 3.8. These strategies help to structure interventions along the material stream, from upstream design choices to downstream waste management, and provide a practical toolkit for analysing circularity in industrial systems.




3.8 Circular Actions from the R-Ladder in relation to each other

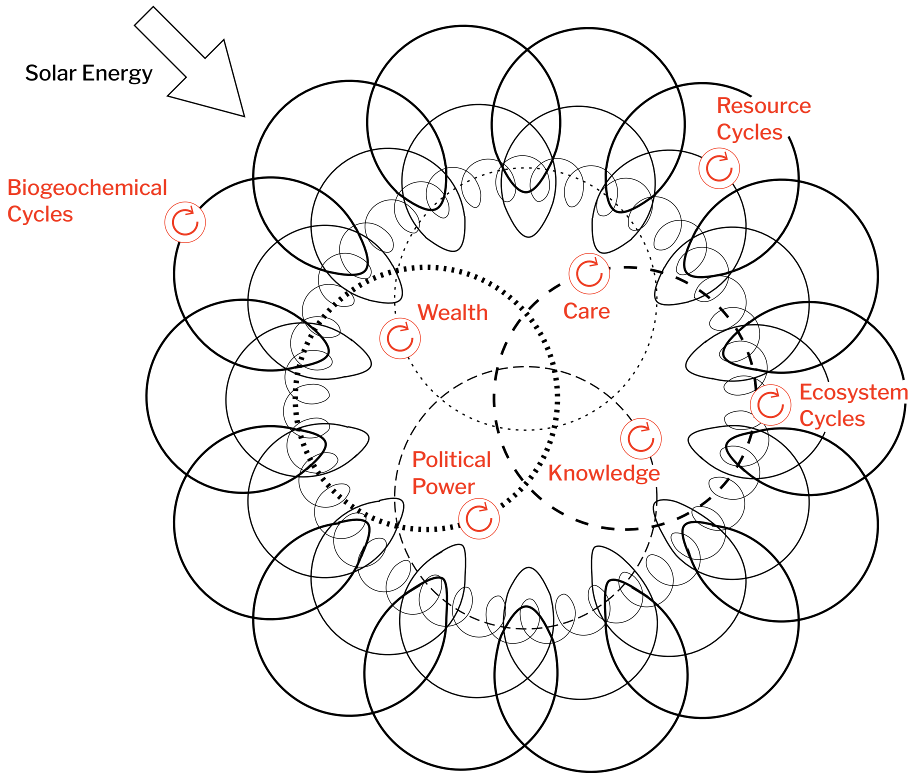
Yet despite its growing popularity, CE does face limitations. As Geissdoerfer et al. (2017) point out, the concept often suffers from a vague definition and overlaps with sustainability, which leads to confusion about how to apply it in practice. Moreover, CE tends to focus on material flows and technological solutions. This often neglects the social, political and spatial dimensions that decide its success or failure.

This narrow framing has led to a technocratic and sometimes depoliticised discourse. As Calisto Friant et al. (2024) argue, many mainstream CE models avoid engaging with deeper systemic issues such as power relations, distributional justice or democratic control. Questions like "who benefits from circularity?" or "whose labour enables it?" are often sidelined. Moreover, despite the promises of transformation, the implementation of CE often centres on efficiency upgrades rather than fundamental restructuring.

In response, Friant et al. (2024) propose a broader framework: the Seven Socio-Ecological Circles. These interdependent cycles expand the concept of circularity to include ecological, political, economic and cultural systems:

1. Biogeochemical Cycles – preserving natural cycles like carbon and water.
2. Ecosystem Cycles – safeguarding ecosystem functions and biodiversity.
3. Resource Cycles – managing materials and energy through reuse, repair, recycling.
4. Political Cycles – ensuring democratic control and equitable governance.
5. Economic Cycles – redistributing wealth and resisting extractive accumulation.
6. Knowledge Cycles – promoting open access to education and technology.
7. Social Cycles of Care – recognising care work and social cohesion as foundations of society.

Mainstream CE approaches focus mostly on the third circle, resource cycles, and partially on the first two. The remaining cycles are often ignored, yet they are essential for creating a just and resilient circular society. This expanded view offers a



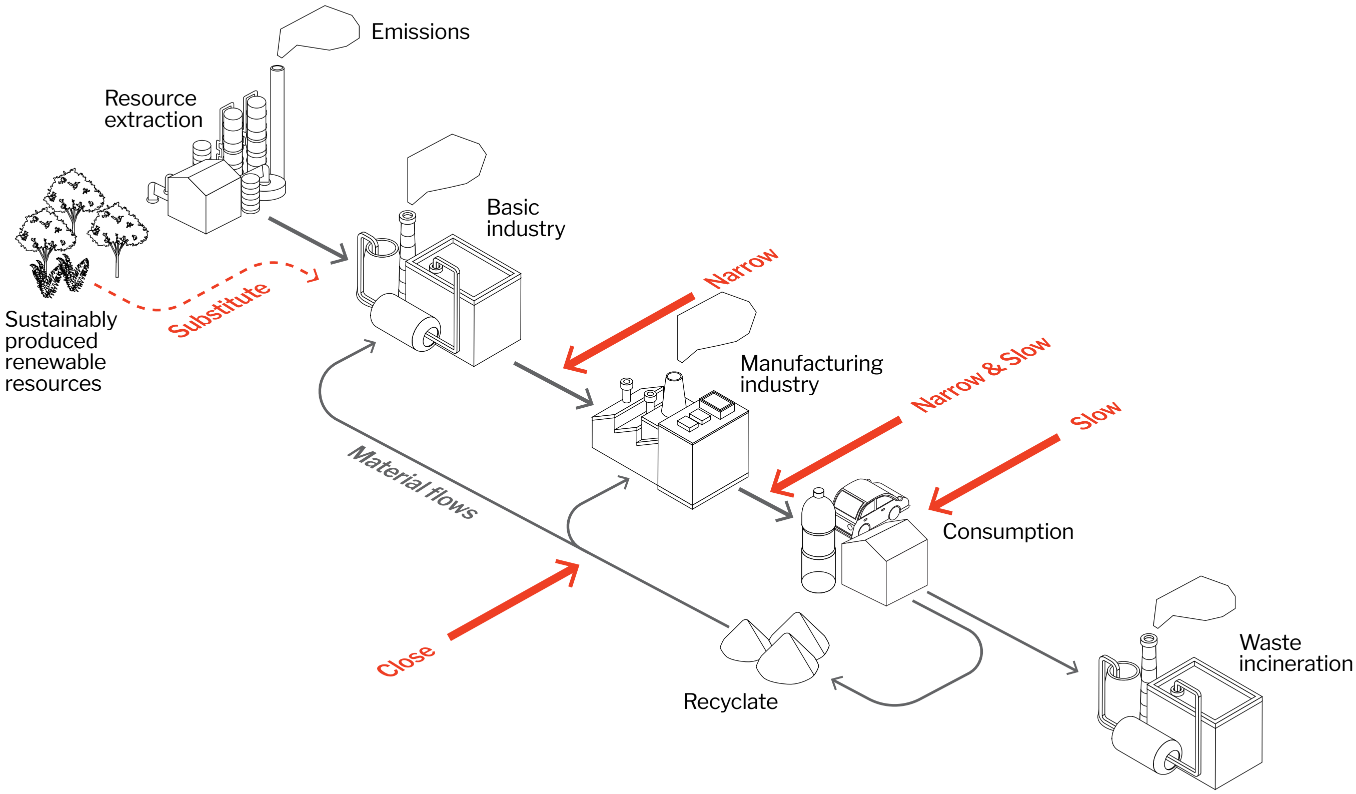

3.9 Seven Circles of a Circular Society, adapted from Calisto Friant et al., 2024

stronger alignment with the principles of strong sustainability, recognising that environmental repair must be accompanied by social transformation.
The concept of the Circular Society results from incorporating all seven circles (Calisto Friant et al., 2024). Rather than a purely economic or technical fix, it envisions a systemic and just socio-ecological balance. For industrial regions like the Wadden Sea, this means looking beyond logistics and waste flows to consider how circular practices might affect labour, territory and power.

Despite its ambition, circularity is still poorly integrated into spatial and urban thinking. As Furlan et al. (2022) observe, most CE models were developed for industrial or business contexts and are often applied to cities without considering morphology, infrastructure or land use. Even in pioneering cities like Amsterdam or Paris, CE strategies often rely on abstract principles rather than spatialised design.
In this thesis, the territorialisation of circularity is key. Rather than treating CE as a generic model to be implemented abywhere, it is seen as a spatial practice that must respond to site-specific conditions, flows and structures. The R-strategies, for example, apply differently at various points in the material stream (See Fig. 3.10):

- Upstream strategies (Refuse, Rethink, Reduce) require changes in product design and supply chains.
- Midstream strategies (Reuse, Repair, Refurbish) depend on local infrastructure, skills and markets.
- Downstream strategies (Recycle, Recover) involve waste systems, energy facilities and regulatory frameworks.

Each of these strategies has spatial implications and demands space, governance and social coordination. Yet, the CE discourse rarely reflects this. As Williams (2019) argues, current circular city strategies often neglect the role of land, infrastructure and territorial logic. This is a missed opportunity, especially in area where land use is contested, as in the Wadden Sea region. Turcu & Gillie (2020) further criticise CE's limited engagement with scale and governance. Circular strategies are often promoted at the city level, but industrial flows and infrastructures extend far beyond municipal borders. Similarly, in the Wadden Sea, circularity cannot be planned at the level of single ports or towns,




**3.10 Focal Points of Circular Actions from the R-Ladder along the Value Chain**

because it requires coordinated strategies across jurisdictions and sectors.

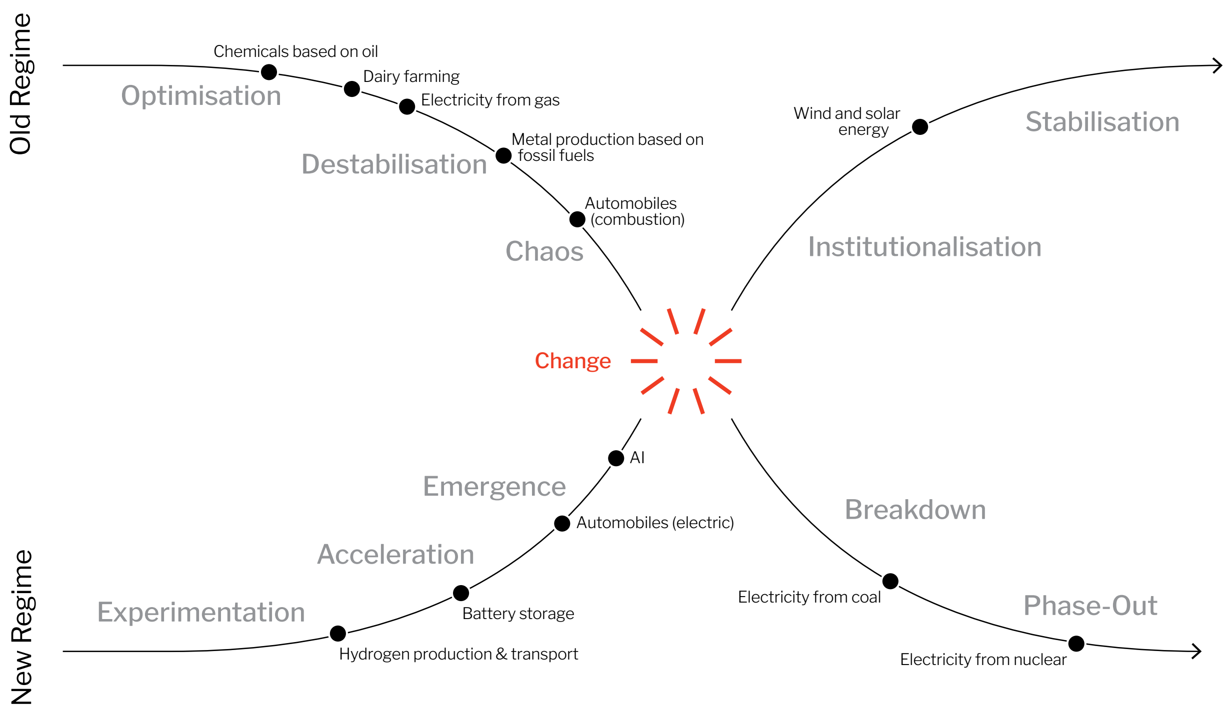
Responding to these shortcomings, Furlan et al. (2022) argue for a greater translation of CE into spatial practice. This involves recognising that circularity is not just about technological processes, but about reconfiguring the relationships between space, flows and institutions. Territorialised CE needs planning approaches that address both flows and spatial structures, making room, literally and politically, for alternative futures. As Russo & van Timmeren (2022) conclude, circularity must not be treated as a method, but as a paradigm. It calls for new ways of designing territories, reading landscapes and imagining futures. In the Wadden Sea region, this means embedding circular strategies into the physical, ecological and institutional fabric of the region, not as afterthoughts, but as central elements in shaping sustainable industrial system.

## Sustainability Transitions

As circularity becomes a paradigm shift instead of a quick fix, transitions become the lens through which such change unfolds. These are not linear processes, but involve breakdowns of existing systems and the build-up of new ones. This often unfolds in unpredictable and overlapping ways. In sustainability research, transitions refer to long-term, structural shifts in how societies produce, consume and organise themselves (Loorbach et al., 2017).

This thesis uses the X-curve as a model to conceptualise this dynamic. It visualises transition as two intermingled trajectories: one of destabilisation and phase-out and another of experimentation and build-up. As an established systems loses prominence, alternatives begin to emerge, often in messy, non-linear forms. Over time, these new systems can stabilise and replace their predecessors. This model reflects the situation in the Wadden Sea: existing fossil practices are under pressure, while renewables began to surface and are now expanding. However, these transitions do not unfold automatically. They require intentional direction, especially in complex, spatially fragmented regions. One of the key mechanisms for steering transitions is visioning: the collective imagination of preferable futures. Visioning allows actors to articulate shared values, challenge dominant assumptions and explore possibilities beyond business-as-usual. Closely tied to this is scenario-building as a method for navigating uncertainty and complexity (Mannucci et al., 2023). It enables strategic thinking across multiple futures. In design-led planning, scenarios help to translate abstract goals, like sustainability or circularity, into spatial strategies grounded in real contexts.

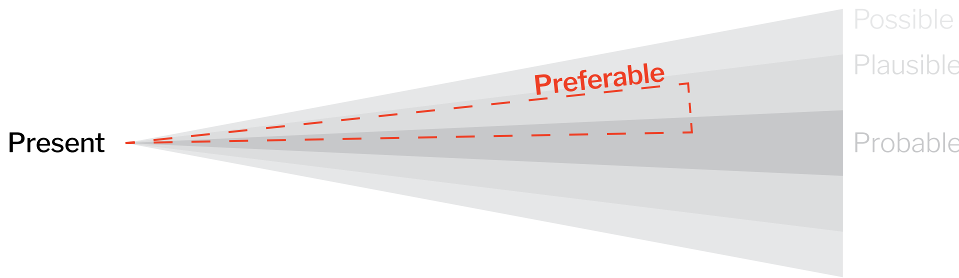
Together, the X-curve, visioning and scenario-building provide a framework for thinking about transformation in the Wadden Sea region. They emphasise that systemic change is both disruptive and creative and that it requires space for alternatives, flexibility in planning and the courage to break with outdated logics.
As the thesis now moves into the dimension of uncertainty, these transition tools form the basis for developing adaptive spatial strategies: not as fixed blueprints, but as pathways that evolve with unfolding conditions.




**3.11 X-Curve of Sustainability Transitions and Socio-Technical Regime Change, adapted from Loorbach et al. (2017)**

## Uncertainty

Planning for sustainable transitions in regions like the Wadden Sea means working under the condition of deep uncertainty. Climate change, ecological vulnerability, industrial transition and spatial marginality collide here, which makes linear forecasting not realistic and insufficient. Walker et al. (2003) define uncertainty as any departure from complete determinism. At its most complex level, deep uncertainty, alternatives may be known but cannot be ranked, either due to disagreement among actors or a fundamental lack of knowledge. This is where traditional planning approaches assuming predictability and stability fail. As Mannucci et al. (2023) argue, these assumptions break down when facing volatile economic trends, demographic shifts and non-linear climate dynamics. In these contexts, uncertainty will not be a temporary obstacle. It rather is a structural condition that must be embraced.




3.12 PPPP or cones of potential futures by Dunne & Raby (2013)

For this, Dunne & Raby's (2013) PPPP model comes in handy, a framework for engaging with Probable, Plausible, Possible and Preferable futures. This approach challenges linear thinking about the future by expanding the space of imagination. It encourages design to speculate about multiple futures that do not only represent what is likely, but also what is desirable. Accordingly, speculative design opens up space for imagining change. Instead of predicting the future, it helps to test ideas, challenge assumptions and rethink can be a catalyst for change (Theye, 2023). In the Wadden Sea, uncertainty must therefore not be treated as a barrier to action, but as the basic condition for designing circular, adaptive transitions.

In conclusion, this chapter took theory as the basis for a design toolbox, because it aims not only to explain the present, but to think about spatial futures under the conditions of uncertainty and systemic transitions.


5

4

# Research Approach

# A Circular and Sustainable Industrial System

## Research Aim

Taking the critique from Chapter 2 as a starting point, the need for a critical rethinking of the systemic and spatial dynamics in the Wadden Sea region becomes clear. This must be realised through circular principles that go beyond just resource efficiency, as outlined in Chapter 3. Only by addressing these challenges can the region move toward a sustainable future that balances its industrial roles with the preservation of its unique landscape and ecosystems.

This overall aim of transforming the linear and unsustainable industrial system of the Wadden Sea region into a circular and sustainable one guides the definition of the overall research question. The methodology for the Foundation phase is built to interrogate the logic, structure and impacts of the role as an operational hinterland. As a second step, this thesis investigates in the Projection how this spatial organisational logic can be reprogrammed for circularity.

Fig. 4.1 shows how this approach is reflected in the four sub-questions: By exploring the historical development of industries and their spatial patterns, the study establishes a foundation for understanding current dynamics. This contextual knowledge, combined with cross-scale analysis examining territory and flows, provides a comprehensive basis for developing pathways towards the overall thesis aim. Given the uncertainties posed by climate breakdown, policy shifts and socio-economic volatility, the methodology then includes scenario building,  and local testing to accommodate flexibility while remaining grounded in the systemic analysis.

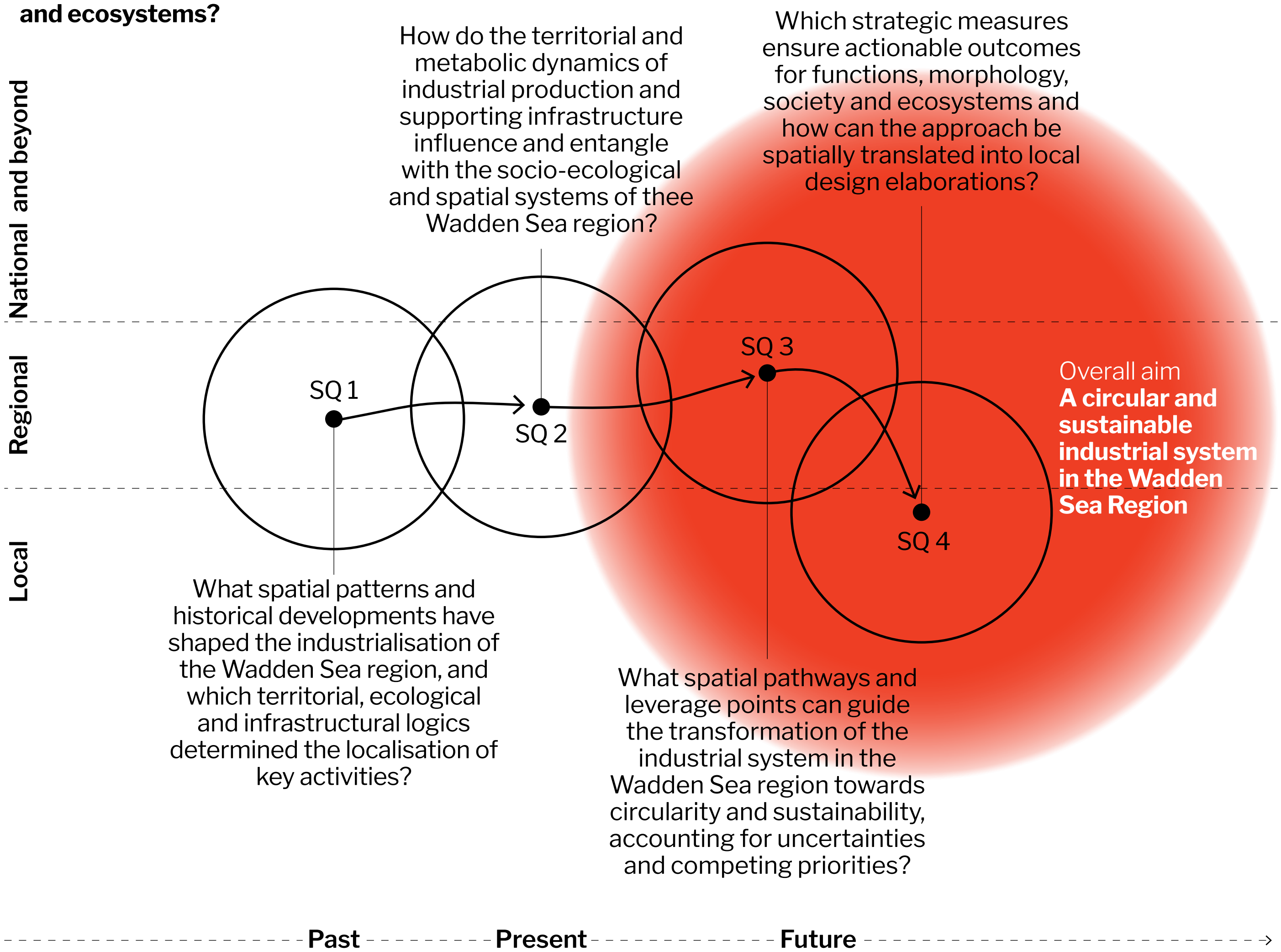
## Societal relevance

Societally, this project addresses the profound socio-economic changes needed in the Wadden Sea Region. Here, raising awareness and creating positive visions for sustainable development are crucial. Transformative proposals often face political resistance, a challenge this project seeks to overcome by providing and illustrating optimistic, but also actionable pathways for change. It also responds to broader European industrial challenges that have social implications, as highlighted in the Draghi report and addresses the disparities faced by a semi-peripheral area, which is exemplified by the struggles of the Province of Groningen with the aftermath of gas extraction. By naming these pressing issues and proposing integrated spatial solutions, the project promotes equitable societal development that can gain public and political support.

## Scientific relevance

The scientific relevance of this project lies in its application of the concepts of circularity and territorial metabolism to the Wadden Sea Region, which bridges the gap between theoretical concepts and practical implementation, especially concerning the spatialisation. By addressing this semi-peripheral geography, the project tackles a notable research gap, as these principles remain relatively underexplored in such a context. The cross-border focus enhances the significance because it enables comparative analyses of regional dynamics and interdependencies between Germany and the Netherlands. Furthermore, linking historical development patterns with future scenarios offers valuable insights for both policymakers and academics.

Research Question
**How can the industrial production system in the Wadden Sea region be spatially transformed into a circular and sustainable model, considering its role as an operational hinterland and its impact on functions, morphology, society and ecosystems?**



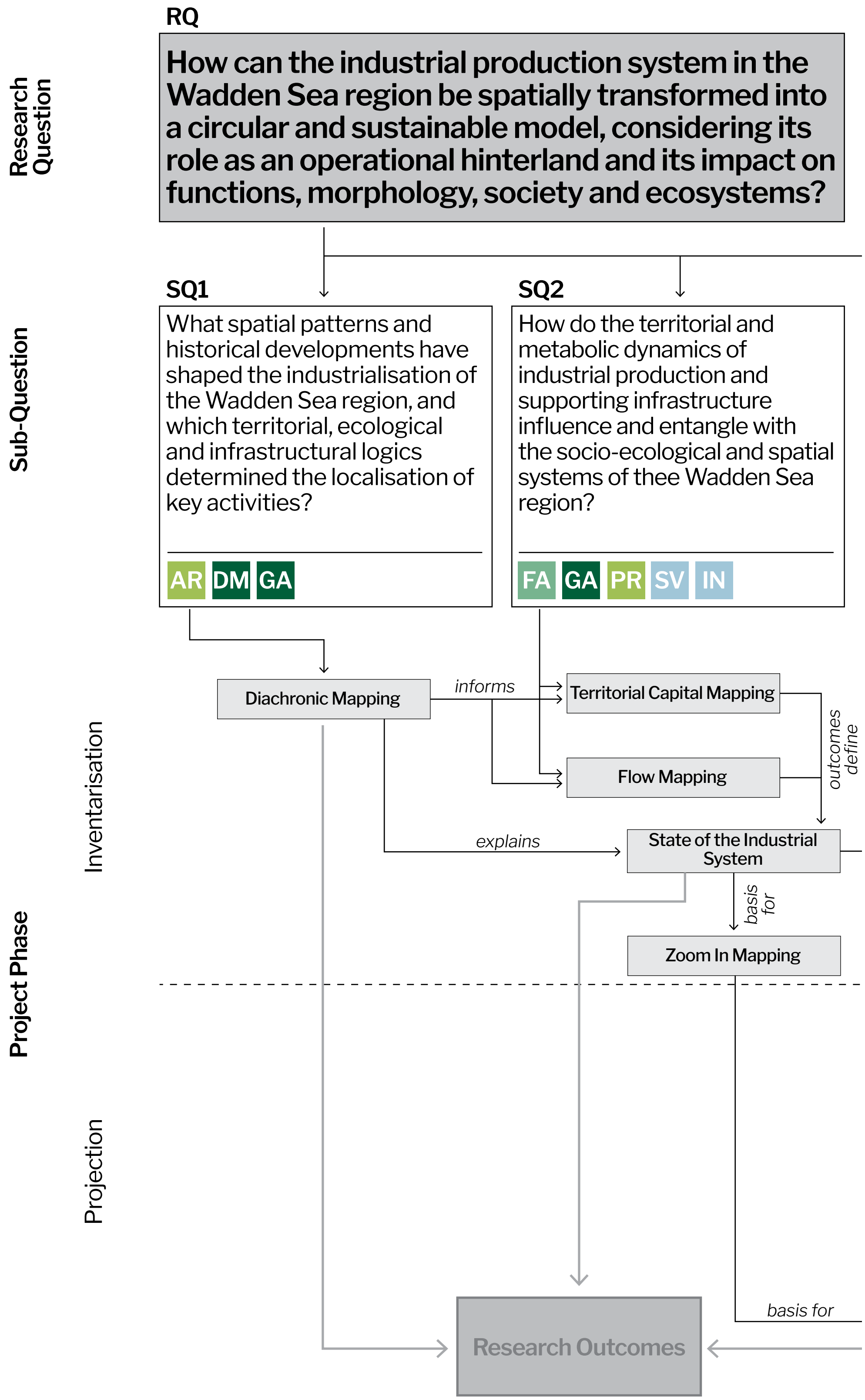

4.1 Temporal and spatial dimensions of the research questions and relation with the overall aim

# The Toolbox of this Thesis

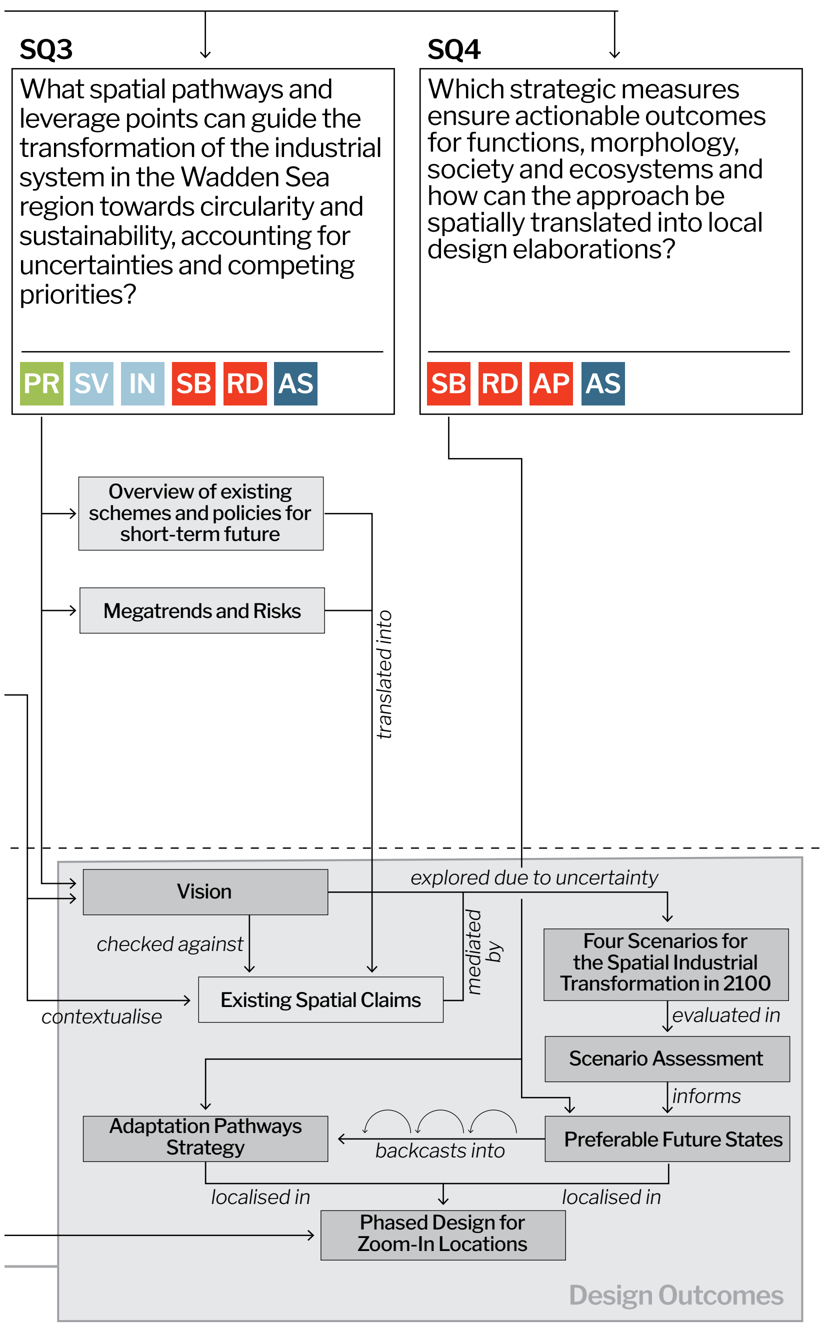
## Methodology

Different methods are used across this project to address the central research question and the four sub-questions that reflect different stages in the investigation, from past through present towards the future-oriented projection. These methods are further framed through the dual reading of the region via Territory and Metabolism, acknowledging both the spatial form and material flows that define the Wadden Sea region. The methodological framework (Fig. 4.2) combines analytical and design methods to create products regarding to the region's past, present and potential futures.

In the following, each method that is applied according to the Methodological Framework is described in greater detail.




▶ 4.2 Methodological Framework




**Mapping**

DM Diachronic Mapping

GA GIS-Based Analysis

**Qualitative Research**

AR Archival Research

PR Policy Review

**Quantitative Research**

FA Flow Analysis

**Methods on Site**

SV Site visit

IN Stakeholder interview

**Design Methods**

RD Research by Design

SB Scenario Building

AP Adaptation Pathways

**Evaluation Methods**

AS Multi- Criteria Assessment

In the following, each method that is applied according to the Methodological Framework is described in greater detail.

## Mapping

Mapping plays a central role in this research as both an analytical and projective method. According to Friendly and Palsky (2007) cartographies can serve three functions: exploration, analysis, and presentation. Within this thesis, maps are consequently used to reveal spatial patterns, to interpret relationships across layers of data, and to communicate systemic findings and proposals to answer SQ1 and 2. In the context of a circular transformation, mapping is not limited to description but becomes a generative planning tool (Russo & van Timmeren, 2022). Therefore, Mapping is used here to both read the region and to reveal potentials. Following Marin and De Meulder (2018), systemic sections and resource cartographies are deployed to bridge abstract models of urban metabolism with spatial practices. Moreover, maps form the spatial basis of the design projections that follow in the projection phase of this thesis, which contributes to the work on SQ3 and 4.

### DM Diachronic Mapping

Diachronic mapping is employed to reconstruct the historical trajectory of industrialisation and infrastructure development in the Wadden Sea region. Through temporal layering within the same map frame (Cialdea & Maccarone, 2012), this method uncovers spatial dynamics and territorial rhythms that shaped the present operational hinterland. The approach builds on stratigraphic thinking (Viganò, 1999), where layering urban materialities across time reveals both synchronic and diachronic developments.
In doing so, it delivers insight into how infrastructure, resource flows, settlement typologies and ecological pressures have co-evolved and offers a grounded base for understanding contemporary challenges.

### GA GIS-based Analysis

Geographic Information Systems (GIS) are used to integrate, process and analyse diverse spatial datasets, ranging from land use and infrastructure to demographic patterns. GIS enables a multi-scalar, data-rich reading of the region and supports comparative and synthetic analyses across the border. One key application in my project is the mapping of territorial capital, a concept that inventorises both tangible (infrastructure, resources) and intangible (identity, institutions) qualities of a region (Camagni & Capello, 2009). Yet, as Orsi et al. (2024) critique, spatial thinking is often missing from its application. Therefore, this thesis develops a spatialised and visual application of a territorial capital analysis through layered mapping and synthesis.

## Qualitative Research

To deepen the spatial and metabolic insights from mapping, qualitative methods are applied to uncover the socio-political, historical and institutional forces behind the regional development and future pathways. This contributes to answering SQ1, 2 and 3.

## AR Archive Research

Archival research focuses primarily on historical maps and development records, complementing the diachronic mapping. It follows the interpretive and constructive logic described by Rutte and Hein (2020): archival work is not merely about retrieving facts but about composing a storyline from heterogeneous fragments such as documents, images and plans that represent the evolution of space and infrastructure. The researcher's role is active and interpretive: asking questions, reflecting and documenting findings in a way that reveals the spatial logic and cultural narratives that are embedded in industrialisation and transformation processes.

## PR Policy Review

The policy review method surveys key policy frameworks, strategies and planning documents across EU, national (NL/DE) and regional levels. The goal is to identify how institutions understand and intervene in territorial capital and material flows and how they envision circular futures. Interpretive policy analysis is used to uncover underlying assumptions and strategic tensions (Yanow, 2007). Special attention is given to the alignment, or misalignment, between policy goals and spatial impacts, as well as to how equity, ecological restoration and industrial transformation are framed in relation to one another. All relevant documents were systematically catalogued, scanned for spatial relevance and summarised in a structured overview. The complete policy scan, including document list and key findings, is provided in the appendix.

# Quantitative Research

To analyse the quantitative side of territorial and metabolic dynamics in SQ2, a combination of flow-based and spatial analysis methods is applied.

## FA Flow Analysis

Given the anticipated limitations in regional flow data, this method relies on available infrastructure datasets and estimates to approximate key flows. The analysis thus adopts a systemic and spatial perspective on flows to focus on interdependencies between industrial metabolism and regional infrastructures.

Two major approaches guide this method: Material Flow Analysis (MFA), which categorises and balances inputs, transformations, and outputs of materials across the urban system (Zhang, 2013), and Energy Flow Analysis (EFA), which maps energy balances and their environmental implications (Barles, 2010). A common shortcoming in both approaches, however, is the lack of territorial specificity (Williams, 2021). Many studies operate only on a regional scale without spatial granularity, which limits the ability to connect flows to concrete places, actors or socio-ecological systems. Therefore, this thesis puts an emphasis on spatialising flow-based insights to understand how metabolism is embedded in the local fabric.

## Methods on Site

In-situ methods are applied to complement systemic insights with localised, situated knowledge and experience to enable a more grounded understanding of spatial dynamics and stakeholder perspectives. This helps to answer SQ1 to 4.

### SV Site Visit

Field visits to strategically selected locations across the Wadden Sea region serve to validate data, observe territorial logics and register multi-sensory impressions. The approach draws on multi-perspective urban reading methods that combine spatial, sensory, systemic and socio-cultural dimensions (Floet et al., 2020). Validating the findings on site ensures the accuracy of the analysis and provides inspiration for the design phase.

### IN Stakeholder Interviews

Semi-structured interviews with regional stakeholders are conducted to access situated knowledge and assess the feasibility of future pathways. This qualitative method is crucial for mapping perceptions and sectoral knowledge that are not available through secondary sources (Kleinhans et al., 2020). The interviews follow a flexible guideline, which allows for both structure and open exploration. Respondents are treated as experts and interviews function as informative conversations that bridge analysis and design (Lamnek & Krell, 2010; Koolwijk & Wieken-Mayser, 1974). A full list of the nine interviewees (anonymised) and individual interview syntheses are provided in the appendix. The appendix also contains the Data Management Plan, which outlines procedures for secure data collection, storage and accessibility throughout the project and beyond. In-text citations of interview material employ codes (I-1, I-2, etc.) corresponding to the list in the appendix. Additionally, significant quotations are highlighted as speech bubbles within relevant chapters to highlight key stakeholder perspectives.

## Design Methods

To explore spatial transformations in the future, design-based methods are employed as both analytical and generative tools. They are employed to answer SQ3 and 4, but are also linked to SQ1 and 2. Considering the deep uncertainties discussed in Chapter 3, it is necessary to explore a wider range of potential futures (Pelzer & Versteeg, 2019). Thus, the concept of "speculative design" (Candy & Dunagan, 2017, p. 137) has been introduced to operate within the framework of "preferable futures" depicted in Fig. 3.13.

### RD Research by Design

This iterative and multi-scalar method integrates analytical findings and spatial synthesis to explore transformative solutions for circular industrial systems. Drawing from the tradition of tackling "wicked problems" (Rittel & Webber, 1973, p. 160) through design, it uses drawing and representation to produce and test spatial imaginaries. In an iterative manner, it also informs and sharpens the research activities. Moreover, design is not an end in itself, but a knowledge-generating process that helps define and solve complex challenges by making alternatives tangible (Nijhuis & Lousberg, 2020). In this thesis, design becomes a tool to translate systemic insights into testable futures to build transferable spatial principles.

### SB Scenario Building

To navigate deep uncertainty and explore different transformation trajectories, qualitative scenarios are developed (instead of quantitative ones). These scenarios synthesize research findings into spatially explicit narratives using maps, diagrams and visualisations (Dammers et al., 2019). Emphasis is placed on normative backcasting, which aligns with the project goal of proposing a circular industrial future. Working with scenarios allows for testing different leverage points and understanding the implications of strategic choices under uncertainty (Mannucci et al., 2023).

### AP Adaptation Pathways

This method supports the design of flexible transformation strategies over time. Rather than defining a single linear route, adaptation pathways allow for sequential and contingent planning based on evolving contexts and can be employed in different structural ways (Werners et al., 2021). In this thesis, pathways are used not to achieve one defined goal (as they are in the Dutch Delta Programme, for instance), but to accommodate shifting conditions and competing priorities in the Wadden Sea region. This utilisation aligns well with the transformation-oriented nature of the project and adds a strategic component to the scenario building.

## Evaluation Methods

To assess and compare the proposed design as part of SQ3 and 4, an evaluation is carried out to ensure that selected interventions support the overarching aim of this project.

### AS Multi-Criteria Assessment

This method facilitates the evaluation and comparison of spatial scenarios and design proposals based on a set of ecological, economic, social, and morphological criteria. MCA supports transparent and evidence-based prioritisation. It also accounts for trade-offs and synergies between competing objectives (Zijlstra & Rooij, 2020).

## Note on the Use of AI

This thesis made responsible use of Artificial Intelligence tools, primarily ChatGPT, to support specific stages of analytical process and writing. AI was used to refine language and wordings, test the argumentative structure in clearly demarcated sections and simulate expert feedback through user-defined personas. It also helped to accelerate the initial structuring of policy reviews and already anonymised interview transcripts. These results were then verified, synthesised and critically interpreted by the author. All outputs were used with caution: The limitations and potential biases of AI were recognised and taken into account and no content was included without full authorial review and contextual understanding.


Inventa

# risation

5

# Diachronic Analysis

# Anchored in Time

## Diachronic Mapping of the Territorial Transformations

This chapter reconstructs the long-term spatial evolution of the Wadden Sea region through a diachronic analysis. In line with Cialdea & Maccarone (2012), six key historical moments (800, 1500, 1850, 1910, 1980 and 2025) are layered within a consistent cartographic frame. Each of these timeframes was selected for its marking of a systemic shift in how the region was inhabited, used and connected: from early subsistence strategies on elevated grounds, through pre-industrial trade and peat extraction, to fossil-fuel industrialisation and contemporary logistical intensification. Taken together, they reveal not only what has changed, but what has persisted quietly beneath transformation.

Using a fixed scale and consistent visual elements allows a comparative reading across centuries. The analysis traces changes in water/land relations, industrial and fuel regimes, transport infrastructures and settlement footprints. In each era, a zoom-in on a characteristic subregion offers a comparative lens on how the human presence became increasingly space-consuming and infrastructurally embedded. Additional drawings give insight into the metabolisms of each period: how people moved, traded and lived at the edge between sea and land. A schematic section shows how these patterns translated into space horizontally. The legend for this series of sections can be found on the right.

Methodologically, this chapter therefore treats the landscape as a layered archive of ecological, infrastructural, and territorial co-evolution. Here, the notion by Russo & van Timmeren (2022) is crucial: Using mapping can not only be employed to uncover the past, but to inform how we might project forward with greater spatial awareness.

In doing so, this step of the Inventarisation sharpens our understanding of the current role of the Wadden Sea region as an operational hinterland. But besides understanding it as a space of extractive connection, shaped by centuries of infrastructural embedding, it also offers something gentler: a grounding from which to imagine futures that are more attuned to the landscape's memory, its capacities and its constraints.


5.1 Overview of the Timeframes of the Diachronic Analysis

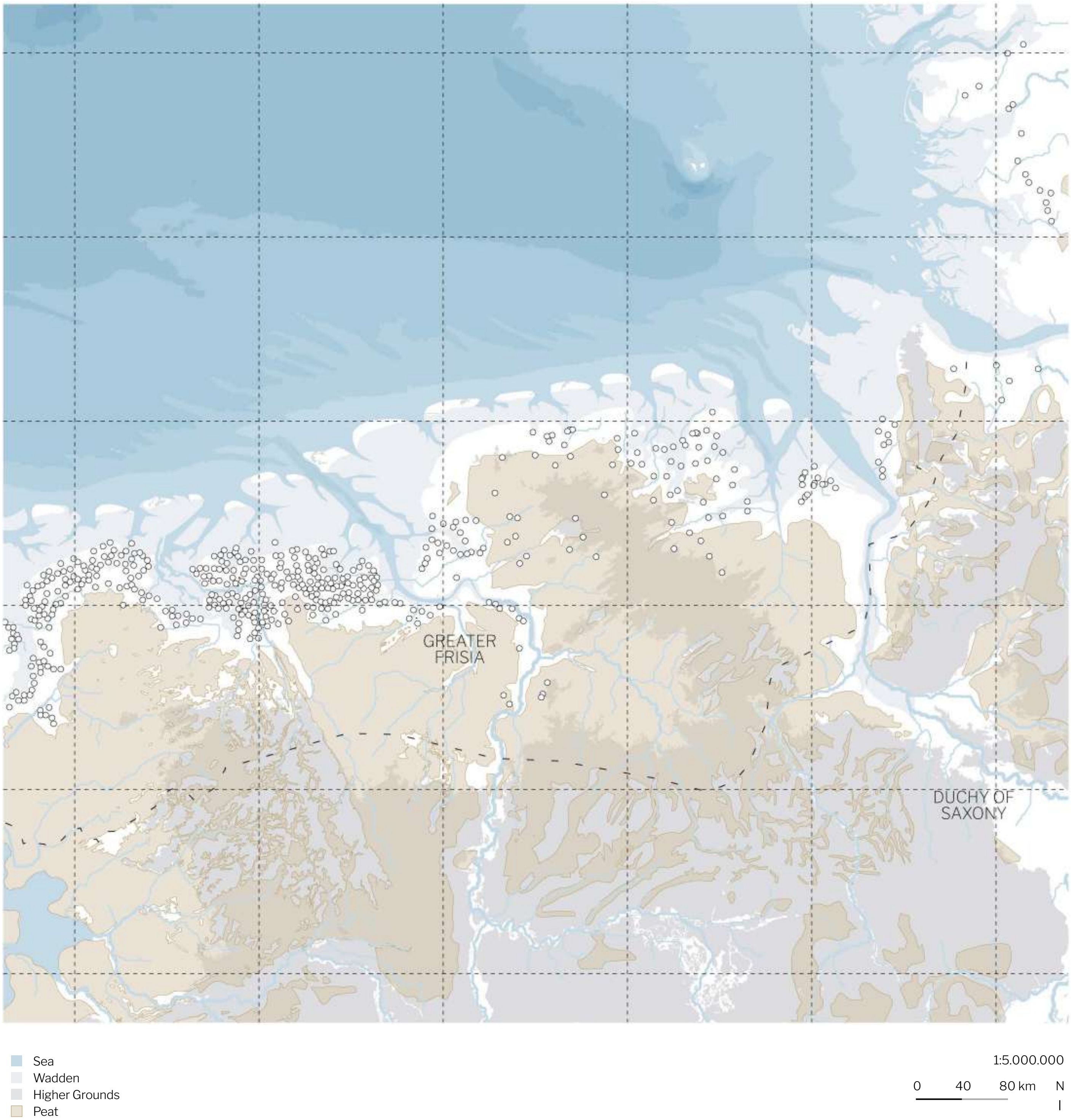
**Legend for Fig. 5.7,10,13,16,19 (on the following spreads)**

- Water
- Intertidal area
- Soil: Sand
- Soil: Peat
- Soil: Clay
- Hydraulic engineering intervention
- Settlement
- Industrial system element



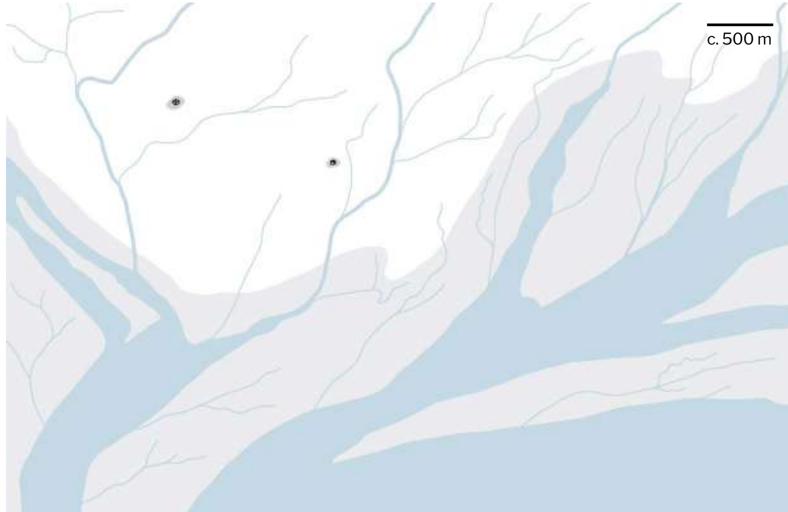
# Frisian Freedom on the Terps

800

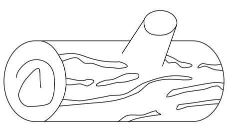



**5.2 The Wadden Sea Region in 800**

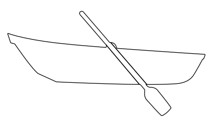
The first settlers from German estuary margins and Drenthe colonised the salt marshes c. 600 BC by constructing dwelling mounds, called terpen, wierden or wurten, to reside on and escape storm surges. The productive silted marsh soils allowed agriculture, even though those pioneer zones remained precarious.
The drainage of the coastal peat lands since the Roman era accelerated subsidence and channel enlargement and reshaped hydrology (Vos & Knol, 2015). Way before nation states existed, early medieval commerce wove local communities into proto-regional trade networks in this then-united Frisian area (CWSS, 2017).



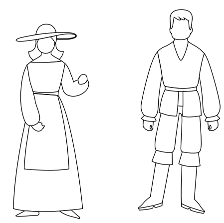

**5.3 Characteristic sub-area: Exemplified view of a terp**



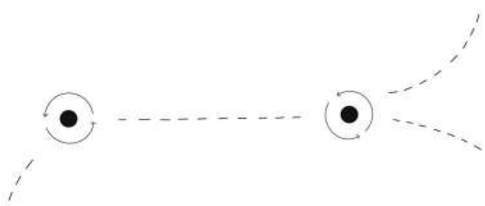
Dominant Fuel



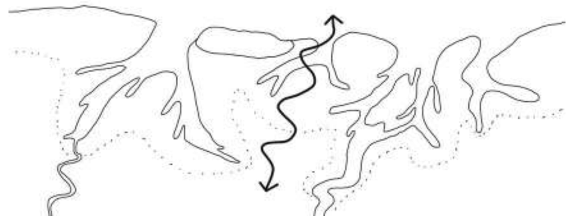
Water Transport



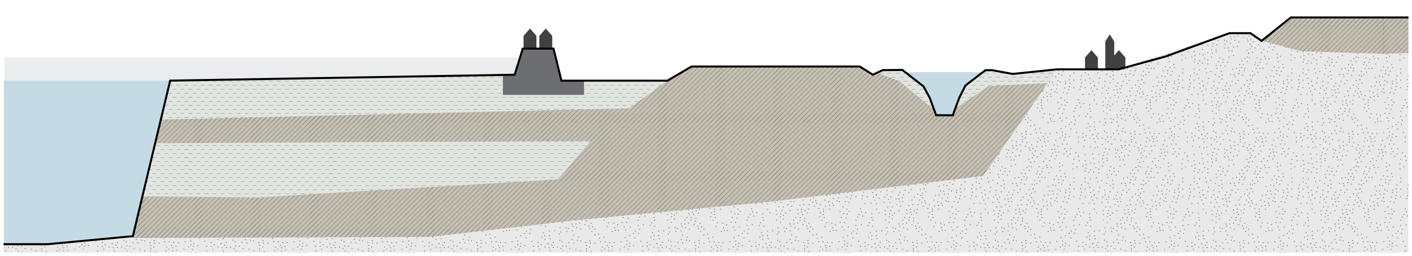
Land Transport



Trade and Movement Patterns



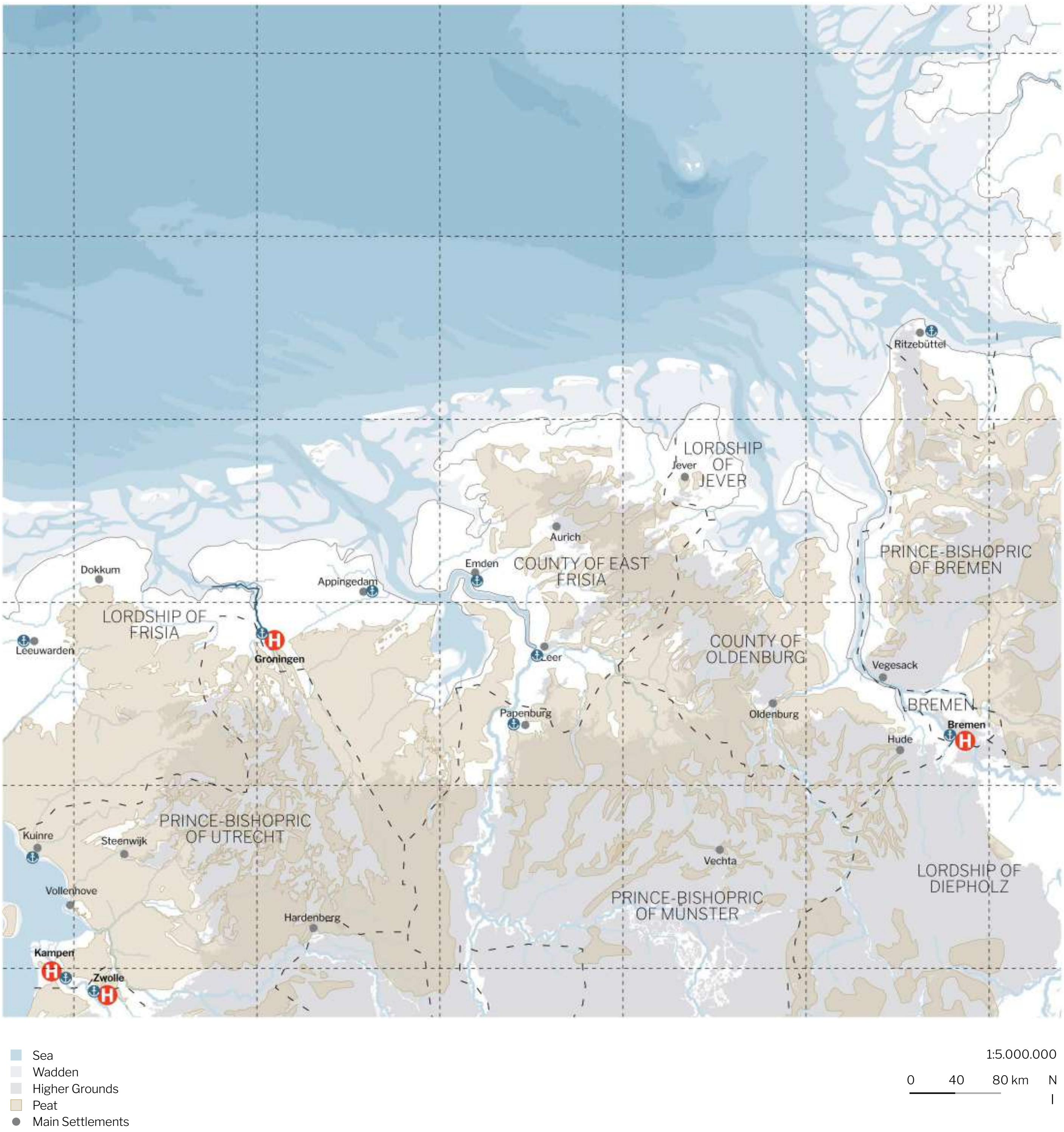
Relation between Water and Land



**5.4 Abstracted section through the Wadden Sea Region in 800**

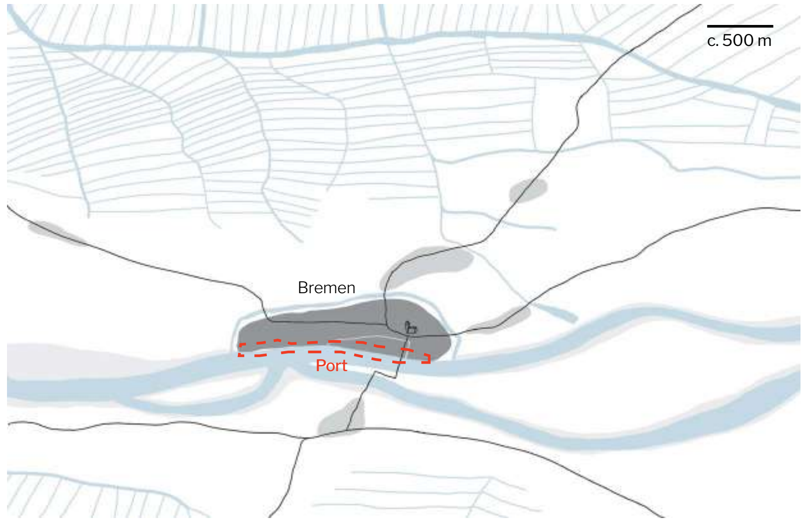
# Hanseatic Trade and Creation of Large Estuaries

1500

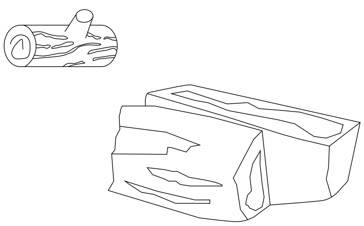



5.5 The Wadden Sea Region in 1500

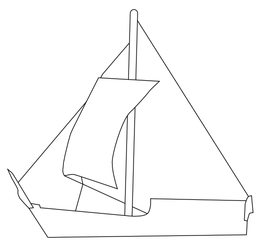
In the late Middle Ages, extensive embanking between 1200 and 1300 transformed marshes into polders drained by dikes and sluices, disrupting natural tidal exchange and increasing subsidence (Vos & Knol, 2015). The Frisians pioneered moor reclamation techniques later exported to Holland and the Weser region. Dikes fixed water–land relations but remained fragile under extreme floods. Storm-driven breaches at the Jade and Dollard estuaries reshaped the coastline, while peat-compaction reduced land heights and enlarged tidal channels. The Hanseatic League emerged in coastal cities such as Hamburg, Bremen, Groningen, Stavoren and overlayed local trade with trans-regional networks (CWSS, 2017)



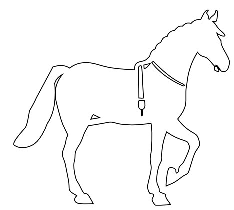

**5.6 Characteristic sub-area: Bremen as a trading centre of the Hanze**



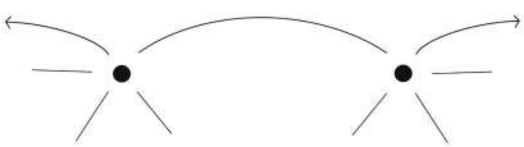
Dominant Fuel



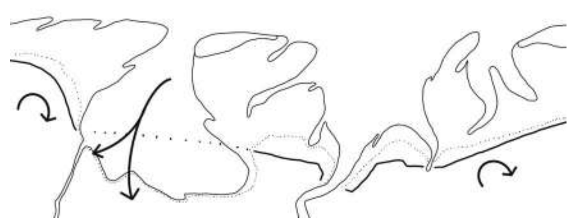
Water Transport



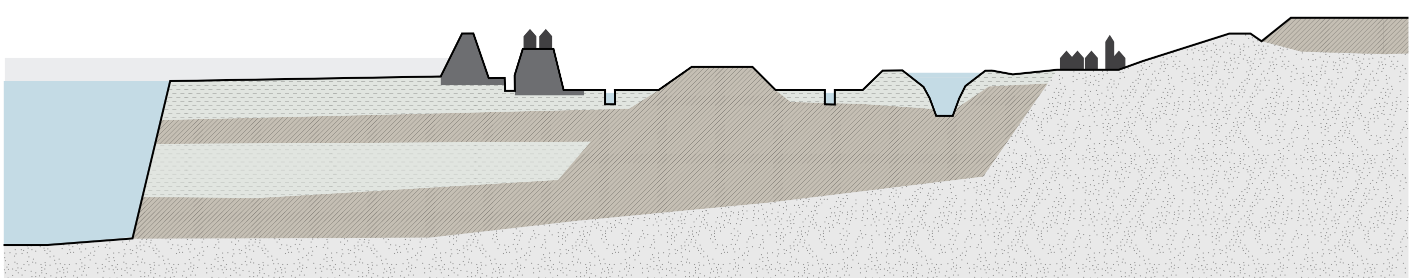
Land Transport



Trade and Movement Patterns



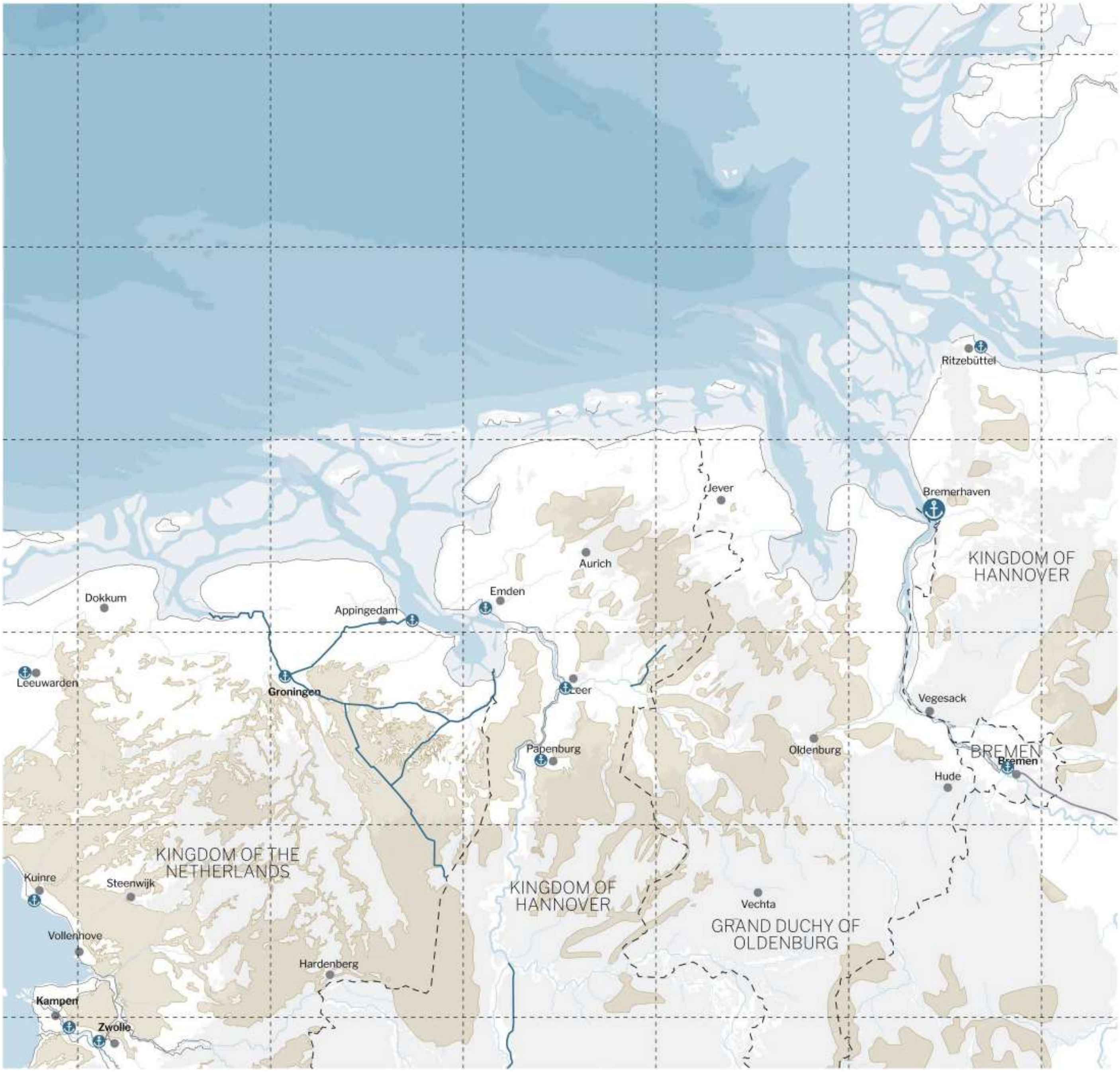
Relation between Water and Land



**5.7 Abstracted section through the Wadden Sea Region in 1500**

# Peat Extraction, Early Globalisation

1850



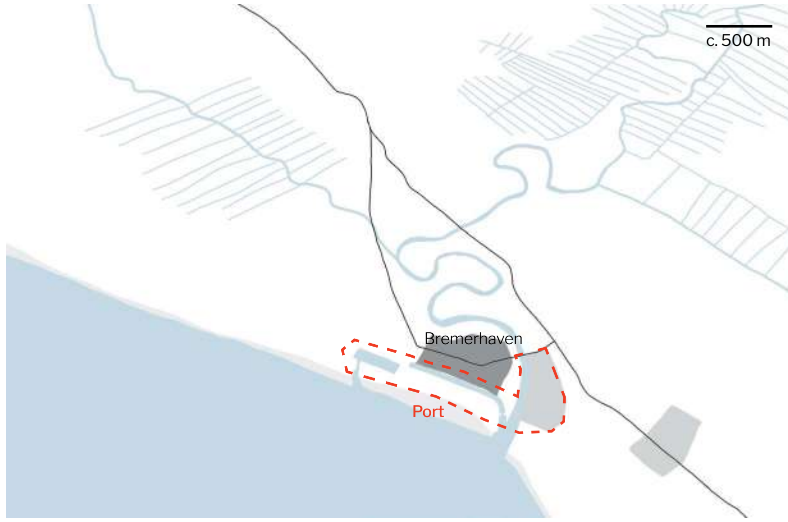

- Sea
- Wadden
- Higher Grounds
- Peat
- Main Settlements
- Minor Port
- Major Port
- Canal
- Railway Line

1:5.000.000

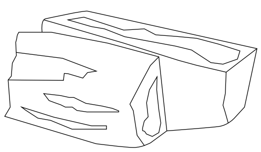
0 40 80 km N

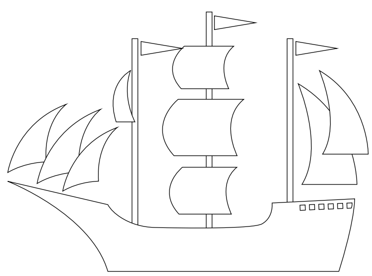
5.8 The Wadden Sea Region in 1850

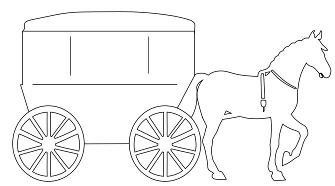
Silt deposition expanded salt marshes, which were diked in stages to create new polder areas. Meanwhile in the hinterland, large-scale peat cutting and oxidation from the 17th century onward dramatically reduced peat areas (Vos & Knol, 2015). In these Veen/fehn colonies with their canal structures, cross-border parallels are visible (LBEG Niedersachsen, 2023). The region exported dairy, grain, bricks and luxury goods via tonnage vessels to metropolises (Amsterdam, Bremen, Hamburg) while drawing seasonal labour (CWSS, 2017). In 1827 Bremerhaven was founded to bypass silting of the Weser; its rapid growth was fuelled by emigration trade (Bickelmann, 2013).

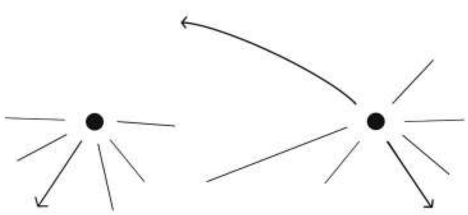


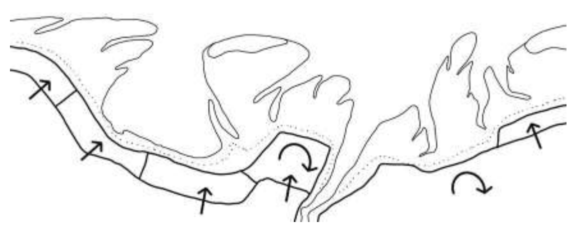
**5.9 Characteristic sub-area: Emigration facilities in Bremerhaven**

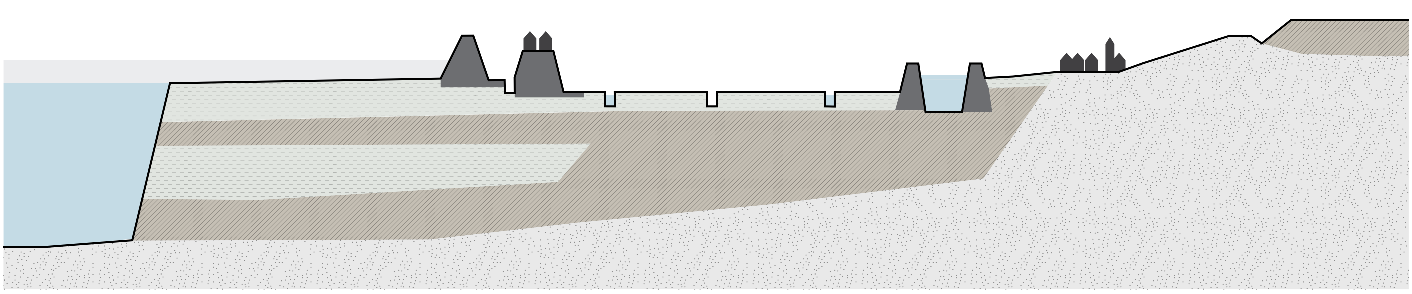

Dominant Fuel


Water Transport


Land Transport


Trade and Movement Patterns


Relation between Water and Land


**5.10 Abstracted section through the Wadden Sea Region in 1850**

# Two Paces of Industrialisation

1910


Sea
Wadden
Higher Grounds
Peat
Main Settlements
Minor Port
Major Port
Canal

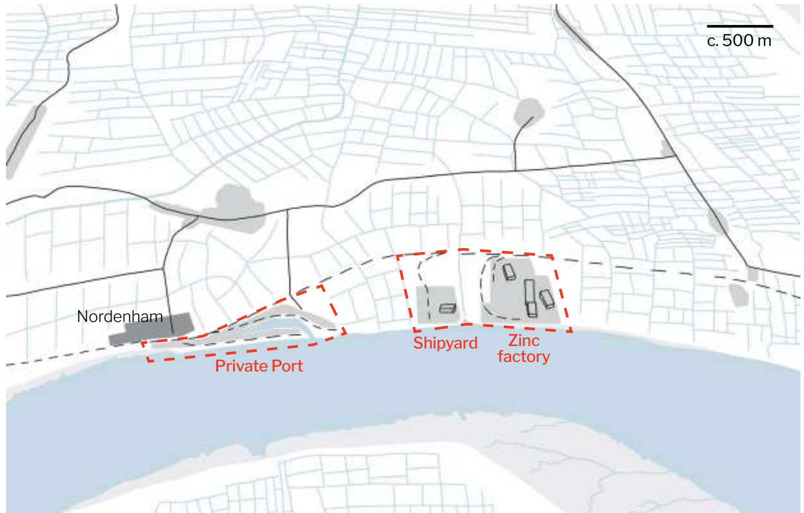
Railway Line
Shipbuilding Industry
Heavy Industry (Metals)

1:5.000.000

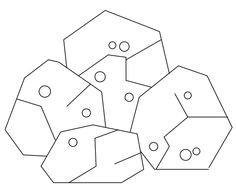
0 40 80 km N

5.11 The Wadden Sea Region in 1910

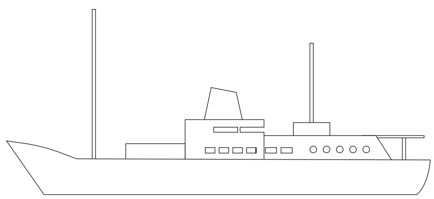
By the late 19th century, reclaimed intertidal zones were expanded by silt-trapping structures and then diked (Vos & Knol, 2015). Germany industrialised running on coal: Wilhelmshaven was founded due to naval reases, while Emden's harbour was redeveloped by Prussia to bypass Rotterdam and Antwerp (Stadt Emden, n.d.). On a smaller scale, dozens of brickworks, sawmills and shipyards lined rivers and canals, peaking in the 19th century as fen-colony shipbuilding hotspot (CWSS, 2017). Inland canals, locks and towpaths facilitated waterborne transport until the 1930s, reinforcing fixed water-land infrastructure patterns.



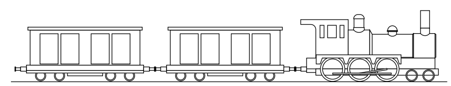

**5.12 Characteristic sub-area: Metal processing in Nordenham**



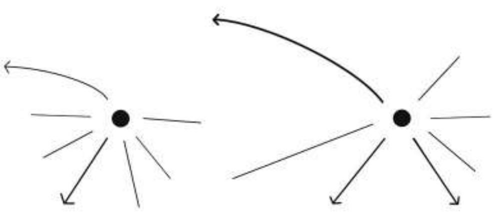
Dominant Fuel



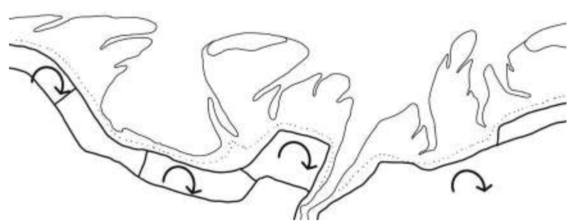
Water Transport



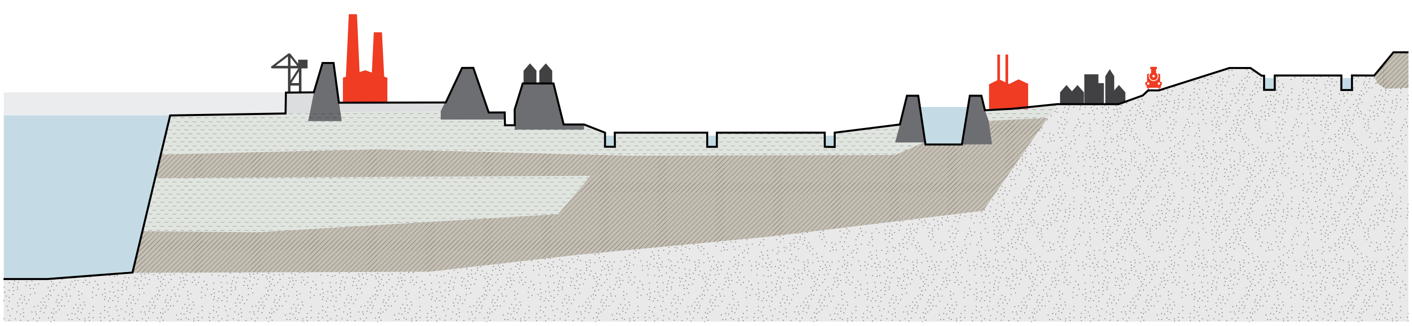
Land Transport



Trade and Movement Patterns



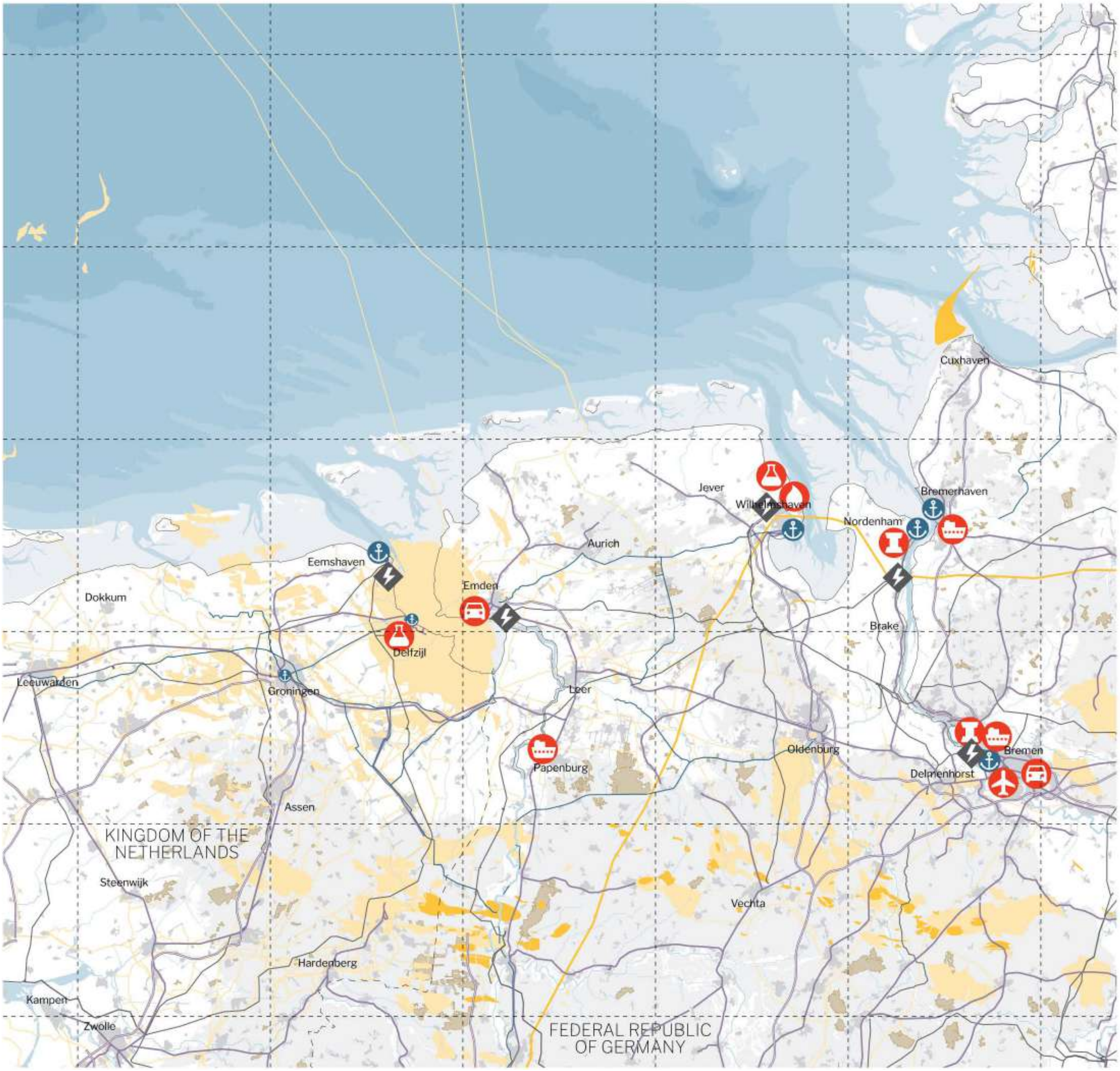
Relation between Water and Land



**5.13 Abstracted section through the Wadden Sea Region in 1910**

# Age of the Fossils

1980



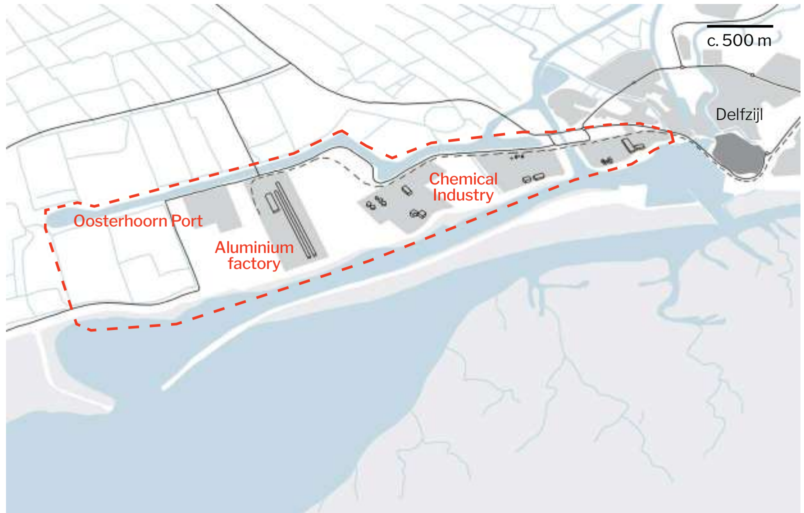

- Sea
- Wadden
- Higher Grounds
- Peat
- Main Settlements
- Minor Port
- Major Port
- Canal
- Railway Line
- Motorway
- Shipbuilding Industry
- Heavy Industry (Metals)
- Chemical Industry
- Refinery
- Car Industry
- Aerospace Industry
- Oil field
- Gas field
- Large power station (Oil / Gas)

1:5.000.000

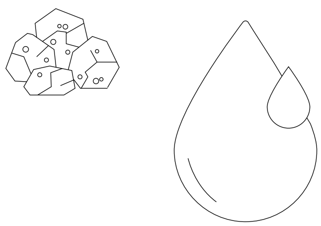
0 40 80 km N

**5.14 The Wadden Sea Region in 1980**

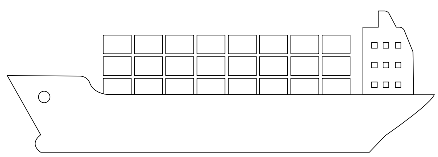
Fossil Energy became key after WW2: Wilhelmshaven added oil and gas to its naval focus. The container arrived and in the 1960s–70s, the Dutch industry was dispersed northward: Delfzijl hosted chemical plants drawn by discharge rights and salt supply, while the Eemshaven was built on the shore. The 1973 oil crisis exposed regional over-reliance on petrochemicals as planned expansions stalled (Knol, 2005). From 1959, the Groningen gas field reshaped energy supply, generating vast state revenue but later triggered earthquakes (NOS Nieuws, 2024). Traditional shipyards succumbed to global competition, reflecting early de-industrialisation trends (Böse et al., 2018).



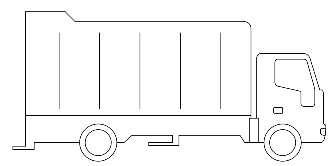

5.15 Characteristic sub-area: Post-war industrial development scheme in Delfzijl



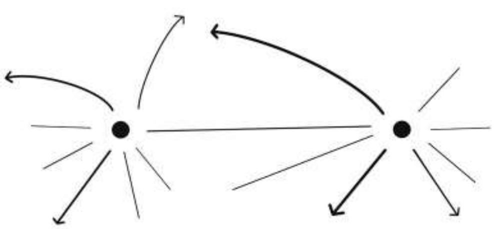
Dominant Fuel



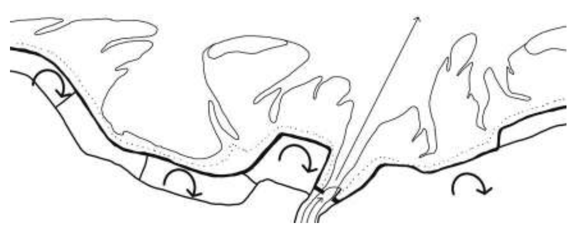
Water Transport



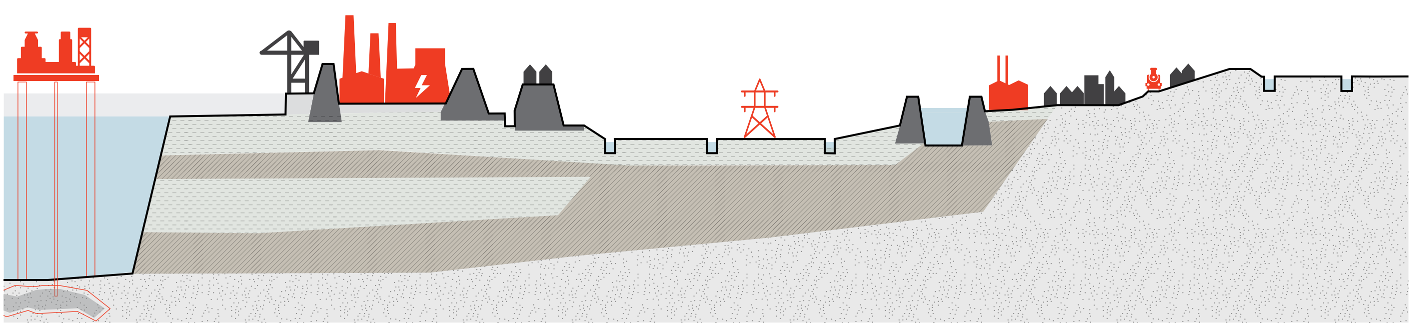
Land Transport



Trade and Movement Patterns



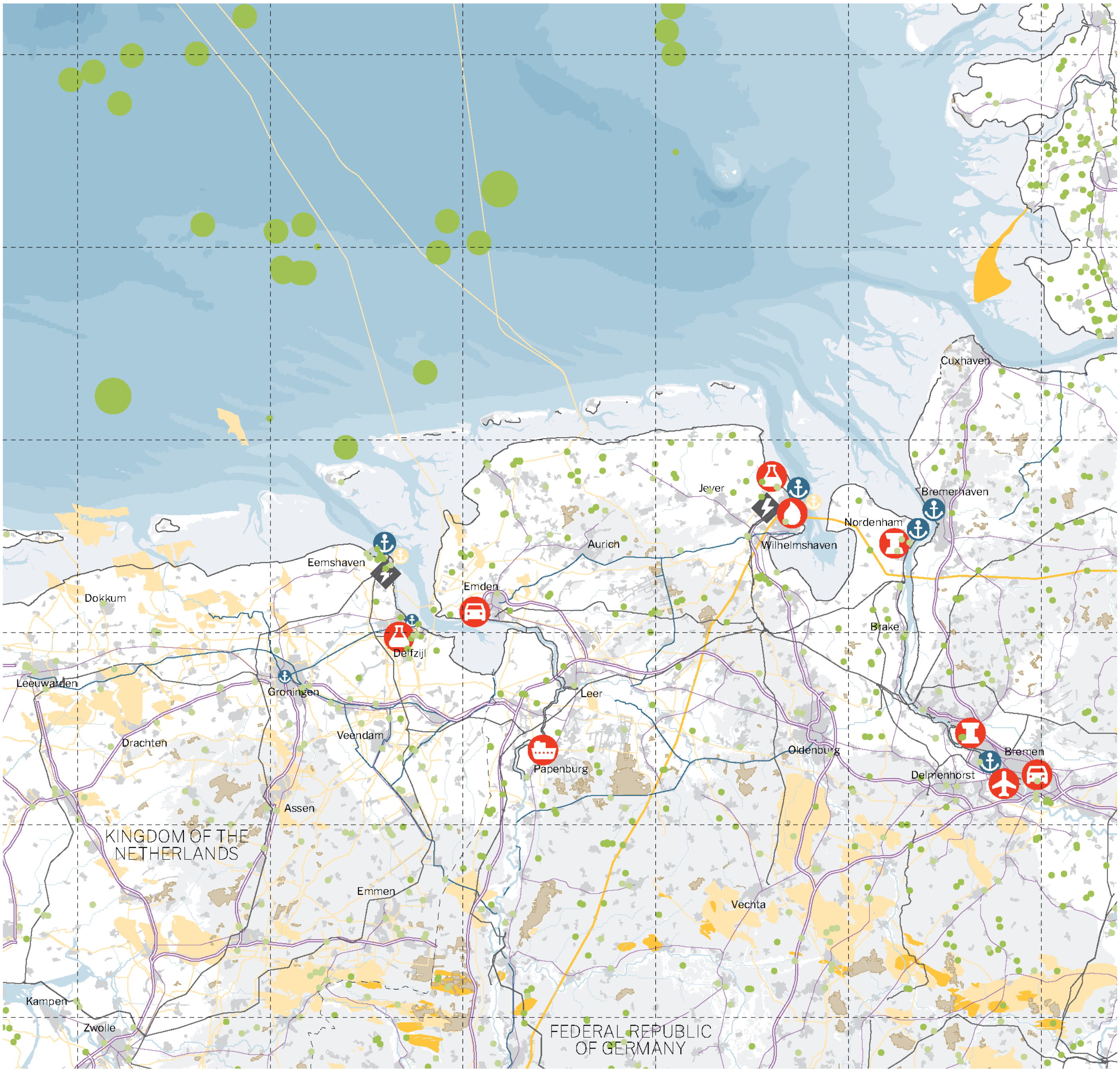
Relation between Water and Land



5.16 Abstracted section through the Wadden Sea Region in 1980

# Renewable Futures?

2025




Sea
Wadden
Higher Grounds
Peat
Main Settlements
Minor Port
Major Port
Canal

Railway Line
Motorway
Shipbuilding Industry
Heavy Industry (Metals)
Chemical Industry
Refinery
Car Industry
Aerospace Industry

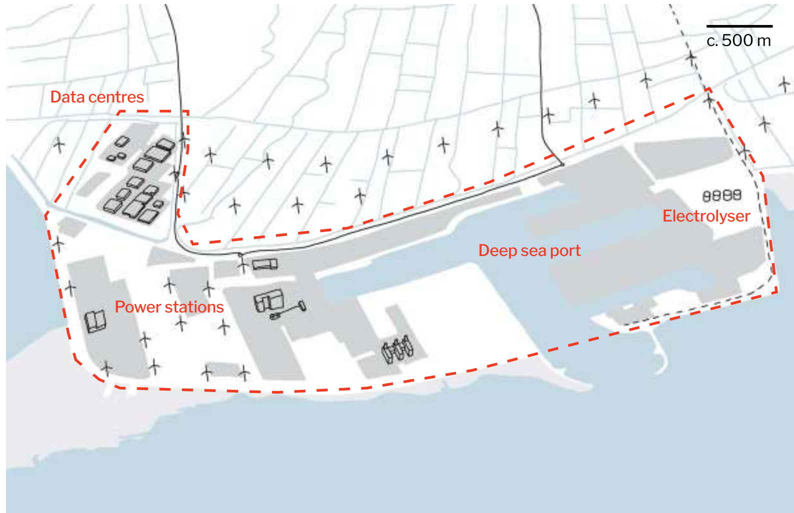
Wind energy generation (size = capacity)
Solar energy generation
Oil field
Gas field
Large power station (Oil / Gas)

1:5.000.000

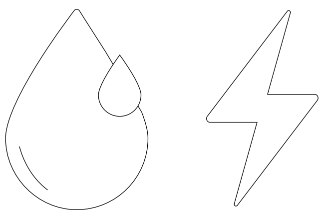
0 40 80 km N

5.17 The Wadden Sea Region in 2030+

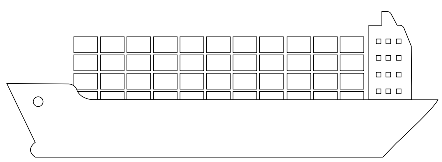
Decades of channel deepening have alternated erosion and deposition in the estuaries, raising turbidity and stressing ecosystems (Vos & Knol, 2015). For instance the yard in Papenburg has repeatedly deepened the Ems to build cruise ships, secured by the 1998–2002 Emssperrwerk (Böse et al., 2018). A 2019 inquiry found Groningen's gas extraction priorities overrode local safety (NOS Nieuws, 2024). The region faces a transition whose end is unclear: Ports pivot to hydrogen production but encounter technical, safety and social hurdles amid offshore wind delays and local resistance (Der Spiegel, 2025; Middel, 2023)



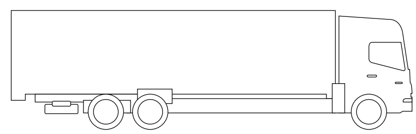

5.18 Characteristic sub-area: Renewable energy schemes in Eemshaven



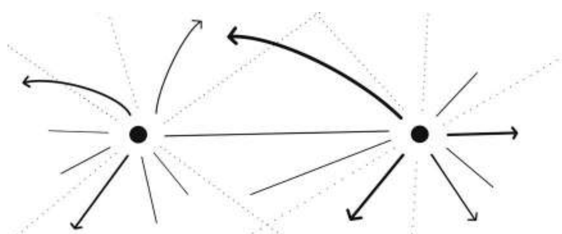
Dominant Fuel



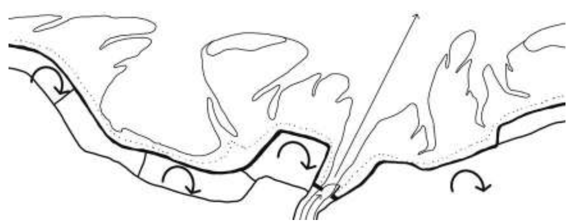
Water Transport



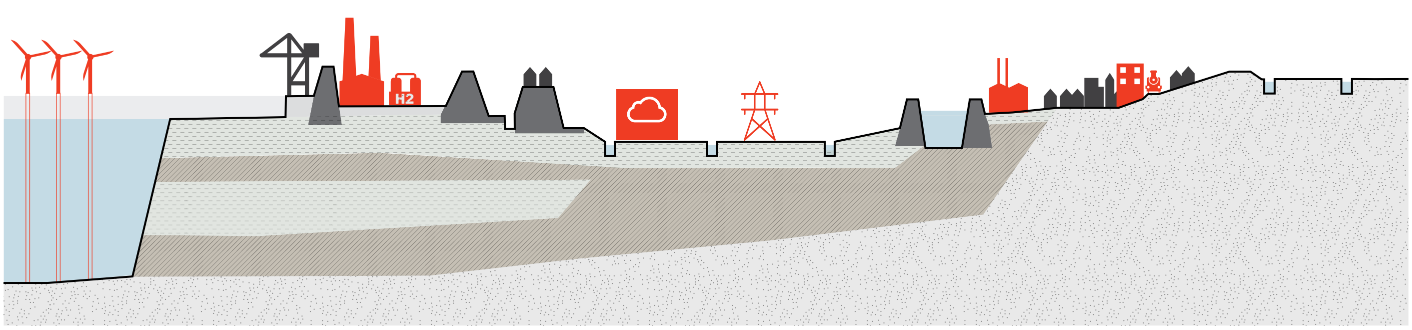
Land Transport



Trade and Movement Patterns



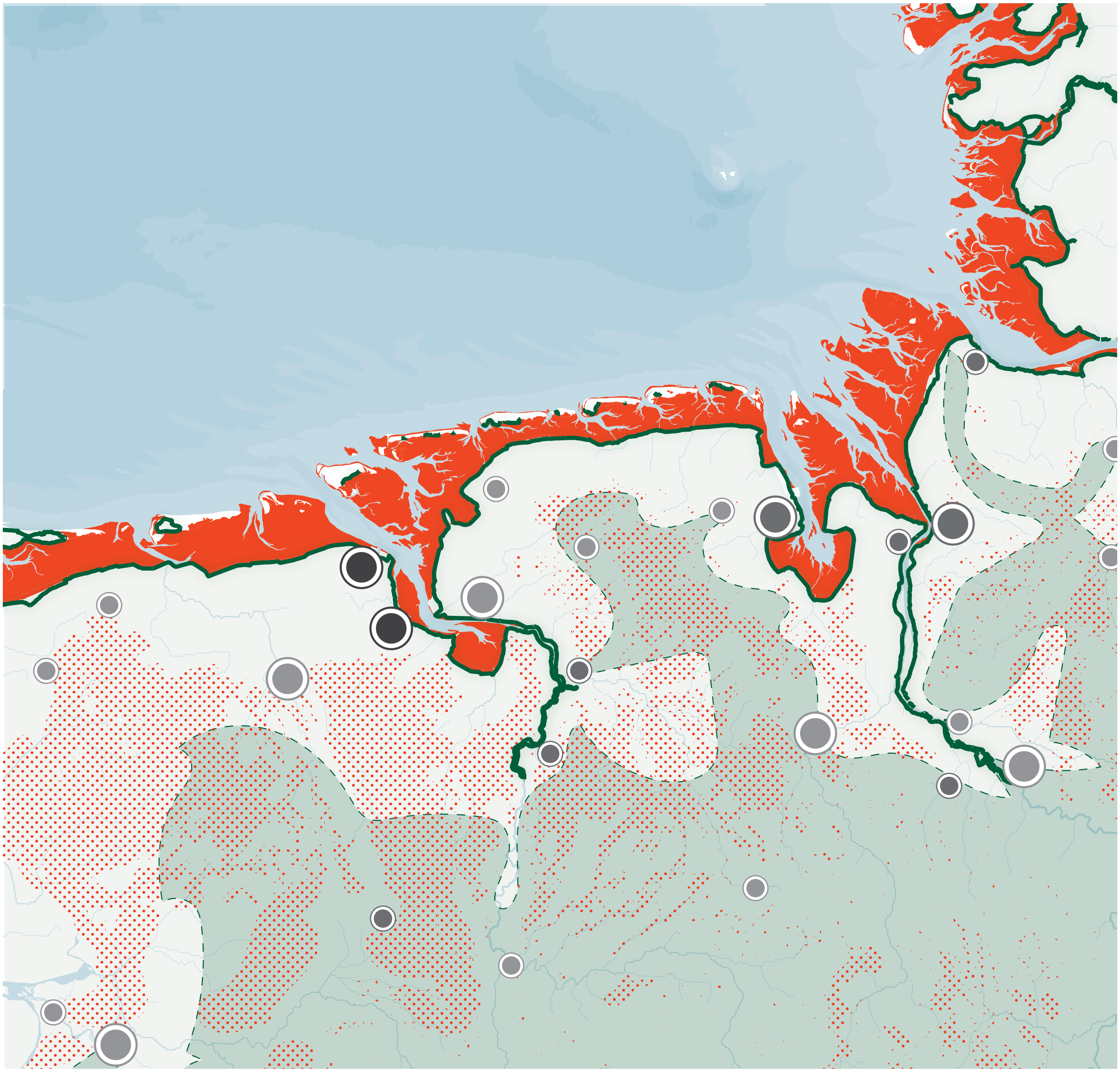
Relation between Water and Land




5.19 Abstracted section through the Wadden Sea Region in 2030+

# Conclusions

## Diachronic Analysis




5.20 Summarised Findings from the Diachronic Analysis

Mapping was employed not only to visualise transformation, but as a method to trace how spatial form and territorial function co-evolved. By layering six key historical eras from 800 to 2025 within a consistent cartographic frame, diachronic mapping revealed patterns invisible in textual analysis alone. It shows how the region gradually shifted from adaptive occupation to systemic over-determination. This historical grounding clarifies today's vulnerabilities and highlights inherited constraints and capacities. Based on these findings, eight conclusions were drawn that are presented below.

### ⟶ 1. Landscape Transformation

From terps embedded in tidal rhythms to engineered port-industrial systems, the Wadden Sea region transitioned from adaptive occupation to structural control. Diachronic mapping shows how dikes, polders and drainage systems replaced fluid landscape dynamics. This shift has underpinned ecological degradation, such as subsidence and sediment disruption, while also reducing the adaptive capacity.

### ⟶ 2. Changed Spatial Localisation Patterns

Early urban centres like Bremen and Groningen emerged on stable sandy ridges at the marsh edge to balance trade access and water safety. Later, the development dikes allowed expansion into marshlands. Only in the 20th century did heavy industry anchor directly on the coastline, enabled by modern engineering. Mapping shows this spatial logic evolving toward greater exposure and increasing dependence on technological stability. See Fig. 5.20 for a visual summary of settlement persistence and dynamism.

### ⟶ 3. Resource Exploitation Cycles

Each fuel era (from wood and peat to fossil fuels and renewables) left spatial imprints that restructured landscapes and economies. Canals for peat, railways for coal, port retrofits for oil and gas all exemplify how material logics shape territory. Diachronic layering reveals these as sequential waves of extraction and adaptation with technical legacies and infrastructures often locked in after their peak utility.

### ⟶ 4. Infrastructure as Economic Driver

Infrastructures have consistently driven economic shifts, shaped flows and territorial rhythms. Early systems like peat canals responded closely to local use and geography. Modern nodes such as JadeWeserPort and Eemshaven reflect ambitious planning but struggle with underuse and peripheral integration. Mapping shows how large-scale infrastructures increasingly override local geographies.

### ⟶ 5. Ecological Trade-Offs

Land-making strategies prioritised economic output over ecosystem function: peatland drainage, river canalisation, estuary dredging. These interventions expanded farmland and logistics, but at the cost of biodiversity loss, water retention and geomorphological stability. The energy transition risks reinforcing these logics by implanting new infrastructures—solar fields, substations, pipelines—into landscapes already burdened by ecological strain. Spatial mapping reveals the contraction of transition zones and the loss of morphological diversity.

### ⟶ 6. Vulnerability versus Innovation

Historical disruptions (floods, fuel shortages, industrial collapse) have repeatedly triggered infrastructural responses. Yet these often land in geographies already exposed to risk. Ports expand into erosion zones, dikes thicken over time, energy hubs settle at storm-prone shores. Fig. 5.20 shows this pattern: the most dynamic zones absorb the heaviest infrastructures.

### ⟶ 7. Cross-Border Continuity

Despite a national border, the region reveals consistent land-use logics, infrastructure strategies and territorial ambitions. Terp landscapes, reclamation systems and port-industrial zones evolved in parallel. While Germany industrialised earlier (c. 1900) and the Netherlands followed decades later, both coasts were shaped to serve larger metropolitan cores. Diachronic mapping visualises this mirrored evolution.

### ⟶ 8. Shifting Agency

Agency over the region's development shifted from local communities, who once built terps in mixed-use landscapes, to external industrial, institutional and infrastructural actors. This is spatially visible in homogenised land-use, the erosion of traditional field patterns, and the imprint of top-down projects. As noted in the Wadden Sea Quality Status Report (CWSS, 2017), weakening cultural identification undermines adaptive capacity: shrinking towns like Delfzijl and Wilhelmshaven exemplify the gap between spatial control and local anchoring.

6

# Territorial Capital Analysis

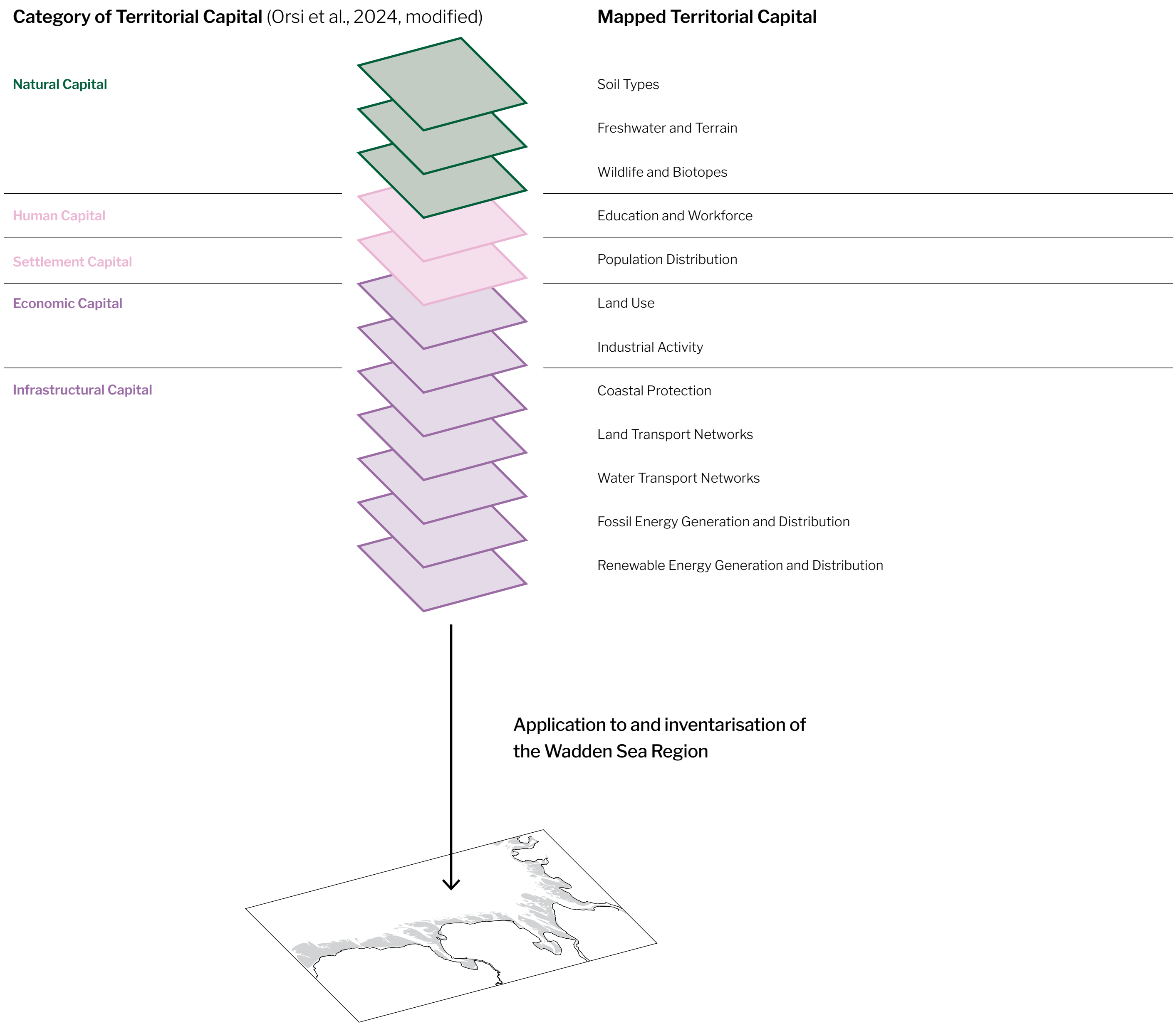
# Territorial Capital Analysis

## Introduction to the Method

This chapter applies the concept of territorial capital as a way of spatial reading to frame and analyse the Wadden Sea region. Following Camagni and Capello (2009), territorial capital is understood as the collection of localised, non-replicable assets that shape the competitiveness of regions, including both material and immaterial characteristics that influence how a region functions and develops. While the original concept is primarily used to enhance growth-oriented regional strategies, this thesis adopts a more critical stance. It acknowledges the need to move beyond a narrow focus on economic competitiveness and instead integrates ecological and social dimensions into the interpretation of regional assets. As stated in Chapter 3, this thesis builds on the categorisation of five capitals by Orsi et al. (2024): natural, human, settlement, economic and infrastructural capital.

These five capital types are spatially mapped using Geographic Information Systems (GIS), drawing on available datasets that capture both physical and socio-economic characteristics. Each capital is represented in one or more separate maps and described through a short summary. The synthesised territorial capital is displayed in a smaller map. This process enables a comparative analysis of territorial capital across the border and thus prepares the ground for a more integrated territorial reading. For a synthesis, the mapped layers of territorial capital are visually overlaid to identify spatial constellations, concentrations and frictions across the Wadden Sea region.

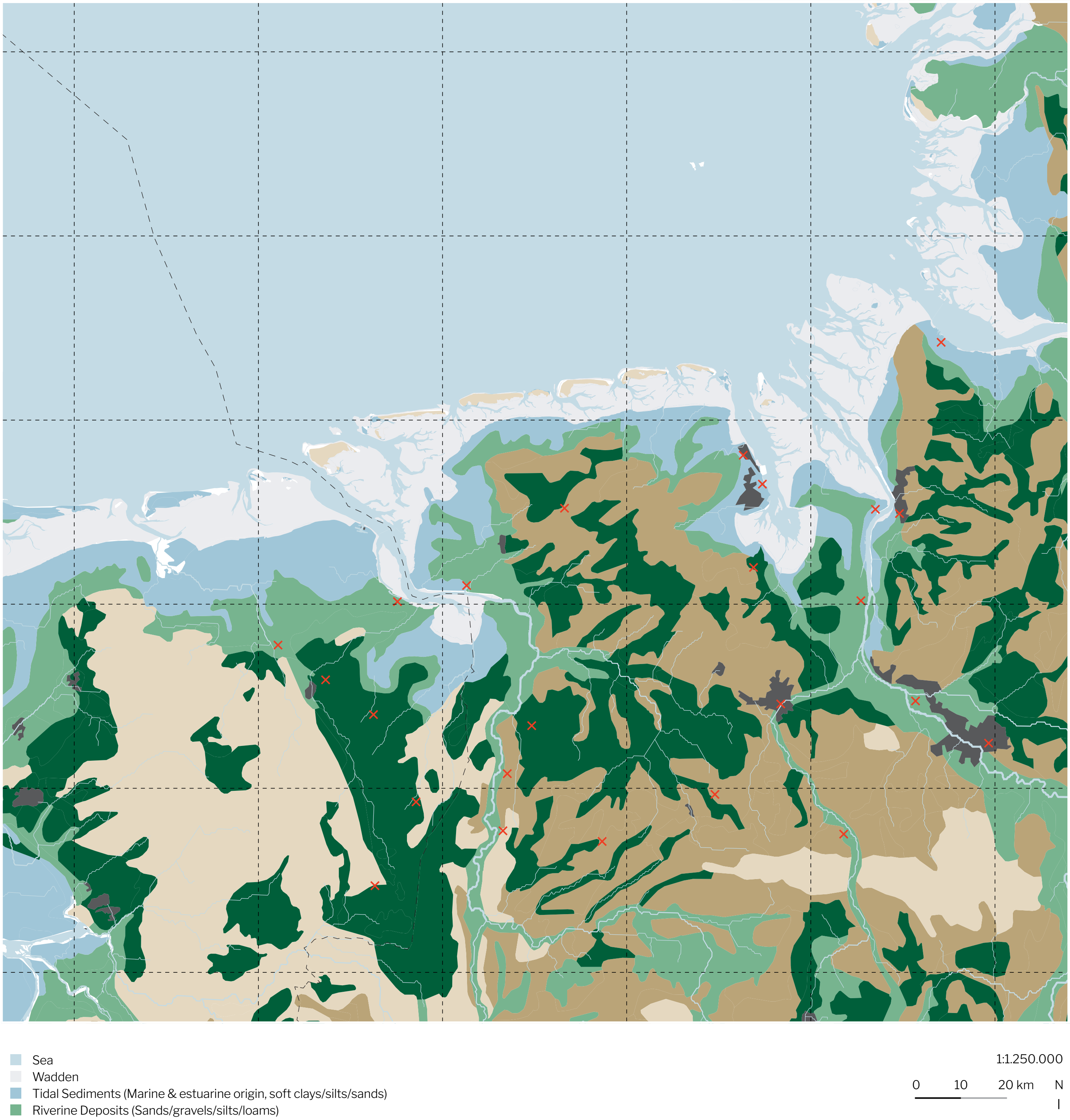
The purpose of this analytical step is twofold. First, it allows a more granular understanding of how distinct territorial qualities work to configure the operational logic of the region. Second, it supports the research objective of tracing how the industrial production system entangles with spatial, ecological and infrastructural systems.




6.1 Approach of the Territorial Capital Mapping

# Soil

## Natural Capital



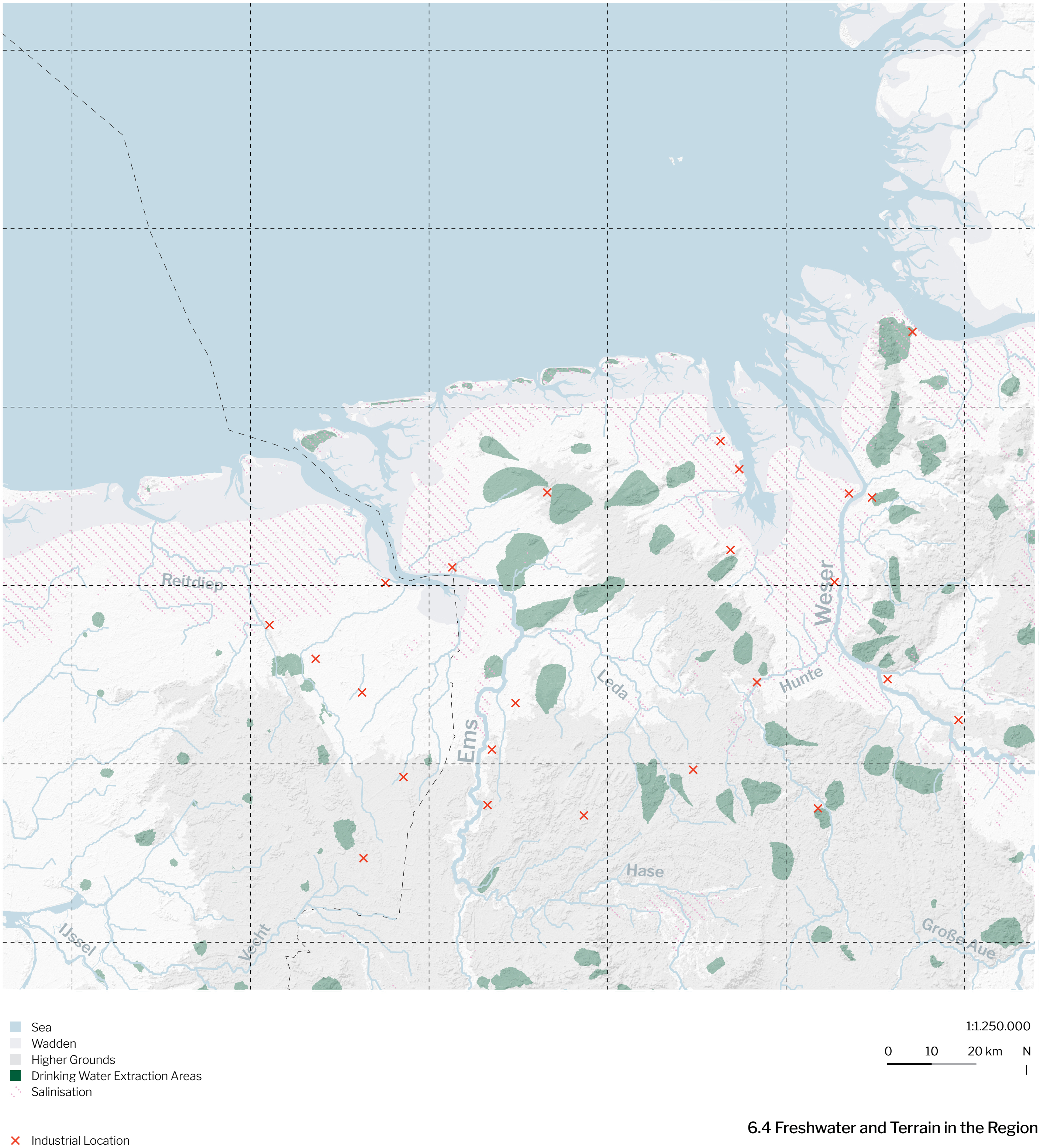

6.2 Soil Types in the Region

6.3 Abstracted Distribution of the Territorial Capital

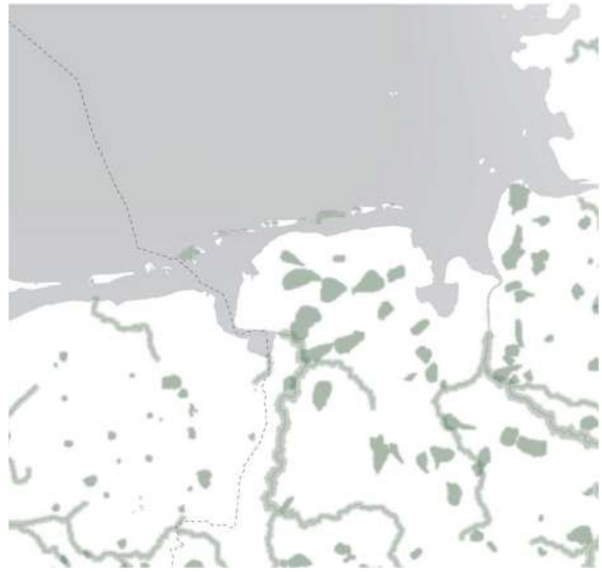
The territorial capital visible in this first mapping is defined by the underlying landscapes of the Wadden Sea region. The substratum show clear spatial patterns: marine clays dominate the diked coastal strip, with peat in some pockets like the Wesermarsch. Higher zones such as the Geest and Hondsrug are marked by glacial and aeolian deposits which offer more stability and used to be the backbone for the development of settlements and infrastructure. Peat bogs on higher ground (e.g. Bourtanger Moor) are the soil of fragile ecosystems. While from a view focused on restoration, peat and marine soils are key, stable sandy/gravel soils inland offer better ground for spatial interventions and infrastructure for an industrial system.

# Freshwater and Terrain

## Natural Capital




6.4 Freshwater and Terrain in the Region

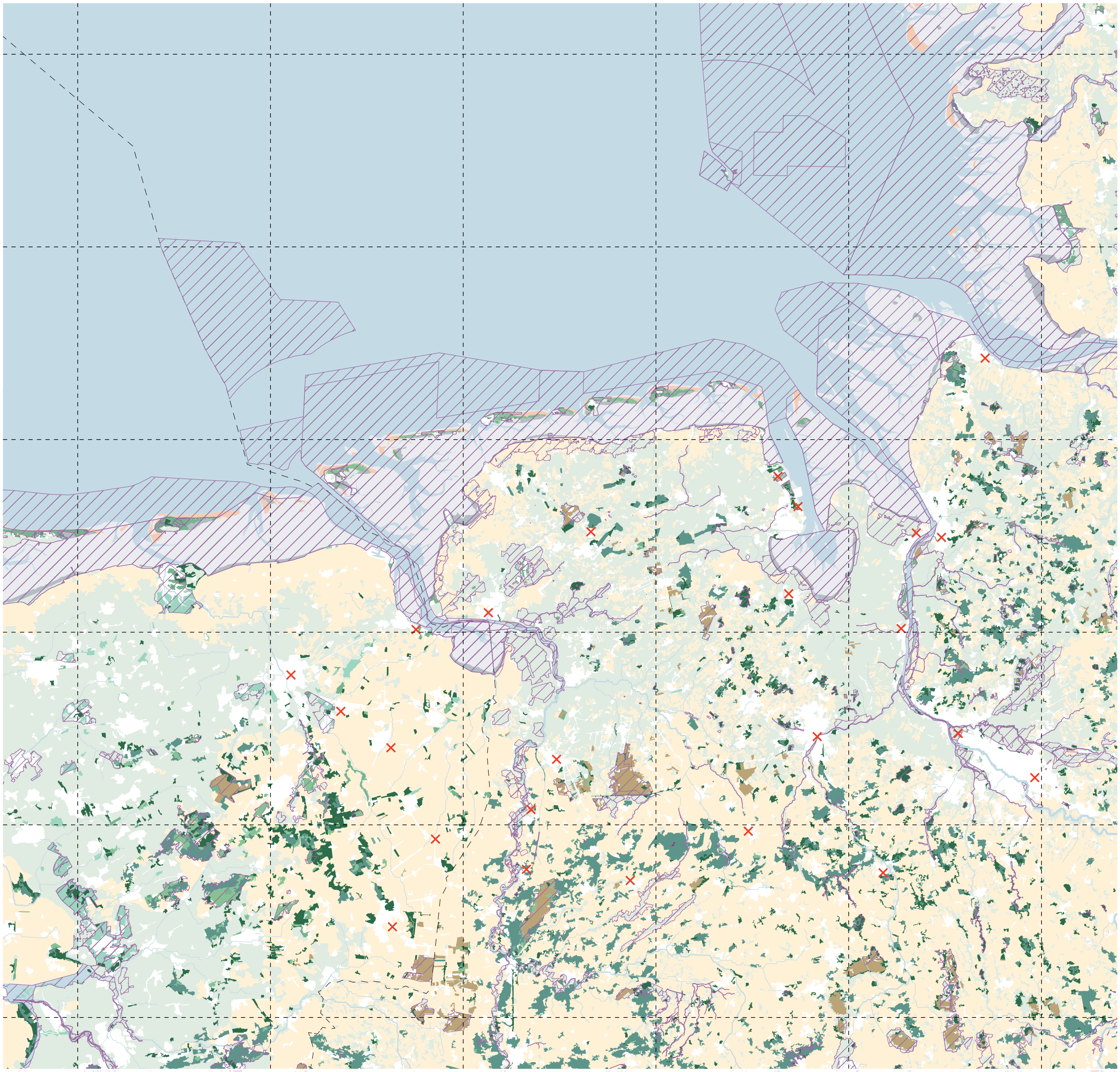


6.5 Abstracted Distribution of the Territorial Capital

Larger rivers like the Ems and Weser shape the territory, while higher grounds (e.g. Hümmling, Hondsrug) provide aquifer recharge zones and sources of drinking water. Coastal areas increasingly suffer from salinisation. Freshwater-rich zones have a potential for water-dependent circular industries (e.g. green chemistry), while saline-prone areas need to be buffered or transformed towards nature-based solutions.

# Wildlife and Biotopes

## Natural Capital



Sea
Wadden
Mixed / Broad-leaved forests
Coniferous forests
Natural Grasslands
Heathlands and shrub
Dunes and Sand plains
Inland marshes
Peat Bogs
Salt marshes
Agriculture: Grassland
Agriculture: Crops / arable land
Natura 2000

Industrial Location

1:1.250.000
0 10 20 km N

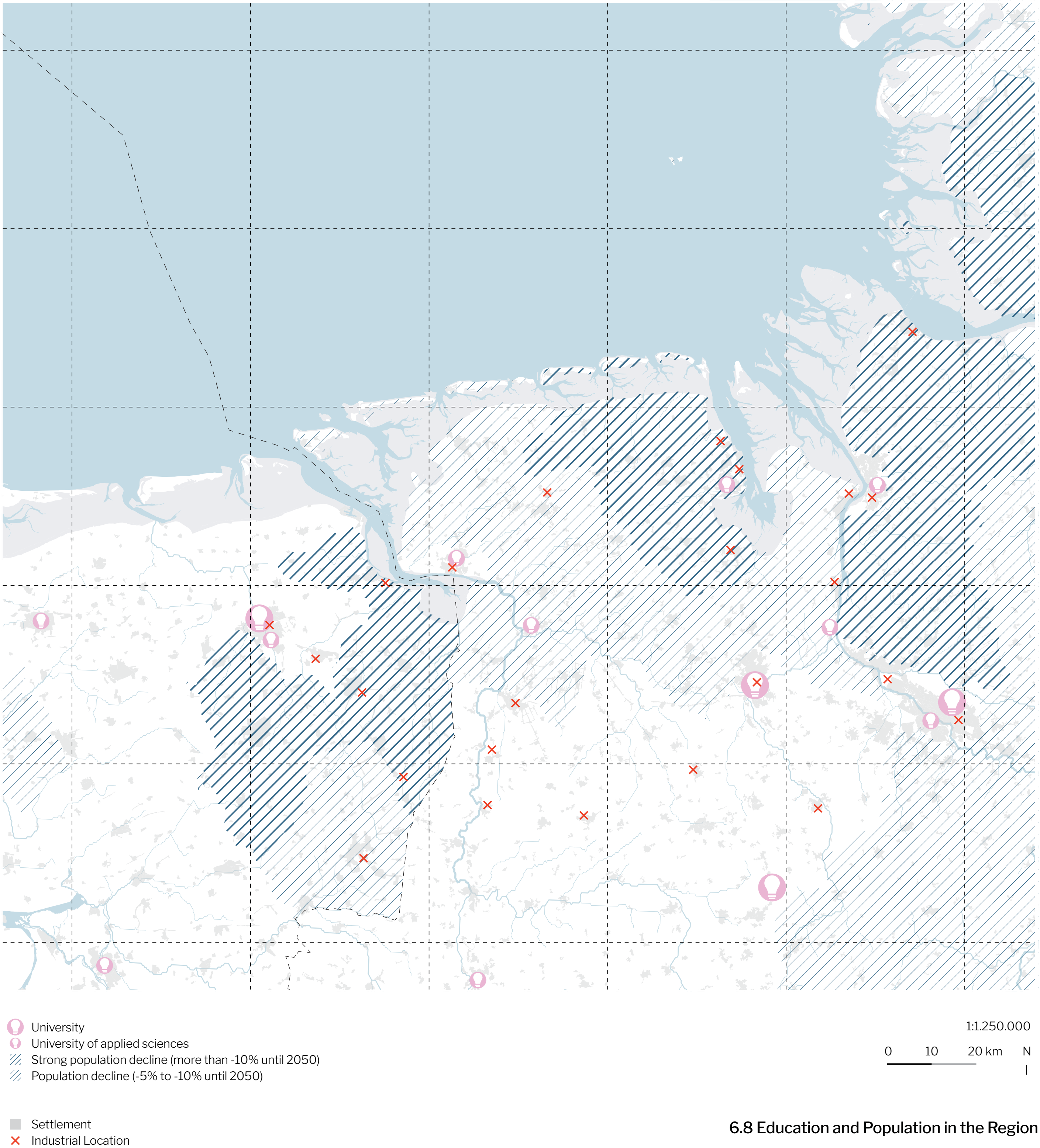
6.6 Wildlife and Biotopes in the Region

6.7 Abstracted Distribution of the Territorial Capital

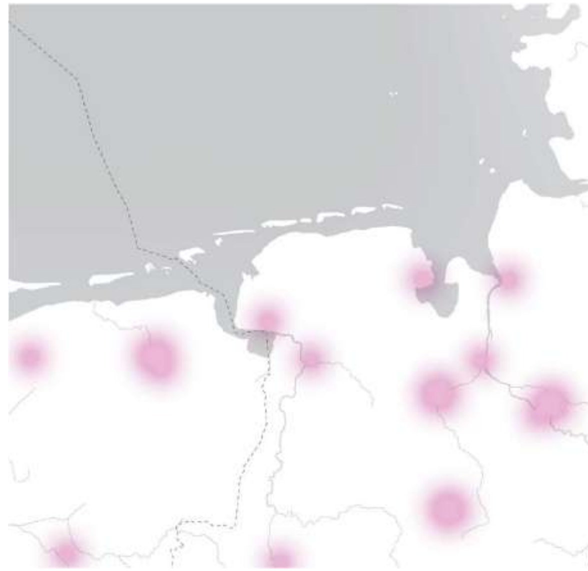
The Wadden Sea, a UNESCO World Heritage site, is a key biotope with unique intertidal habitats and migratory functions. It is of international significance and needs to reflect a logic of preservation rather than production. Further inland, fragmented forests and remaining peatlands (like Esterweger Dose, Bargerveen) form isolated ecological zones. This natural capital is territorially uneven: it is concentrated along the coast and in specific inland pockets, often fragmented and under pressure from surrounding productive land uses. Its territorial capital lies in its ecosystem services and regulatory functions (e.g. flood buffering, carbon storage), but also in its symbolic and touristic significance.

# Education

## Human Capital




6.8 Education and Population in the Region

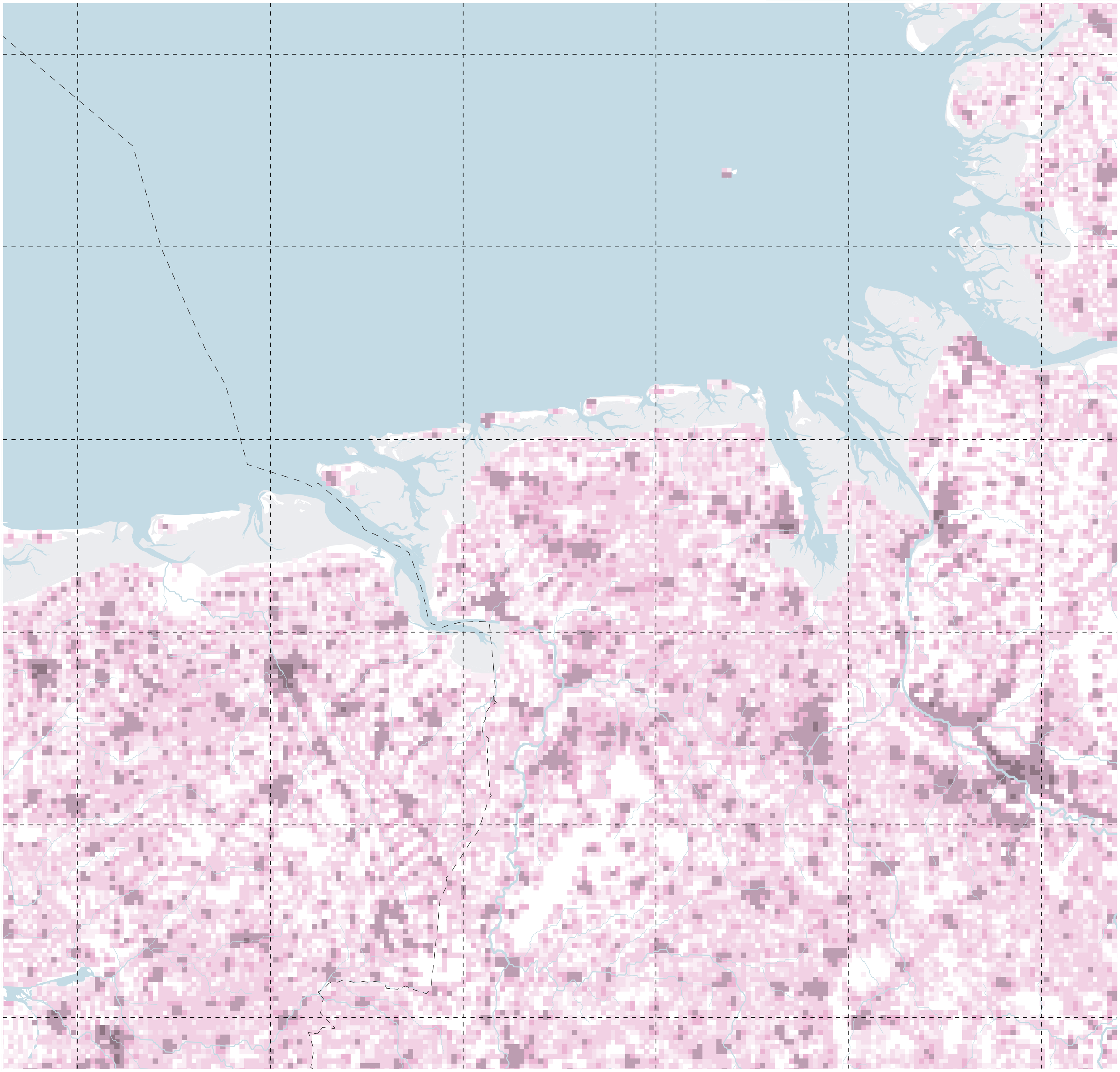


6.9 Abstracted Distribution of the Territorial Capital

The universities in Bremen, Oldenburg and Groningen form a line of innovation that is complemented by applied science institutions across the Wadden Sea region. Parallel to this strength, demographic projections show population decline in peripheral rural areas.
Education clusters are a human capital core. However, the challenge lies in bridging a spatial mismatch by linking academic innovation with industrial transformation in depopulating areas.

# Population Distribution

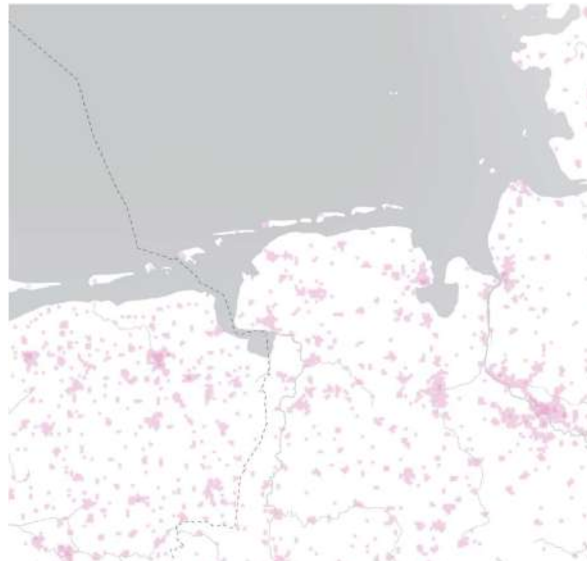
## Settlement Capital



Sea
Wadden
< 10 inhabitants in 1x1 km grid cell
10-20 inhabitants in 1x1 km grid cell
20-200 inhabitants in 1x1 km grid cell
200-500 inhabitants in 1x1 km grid cell
500-5000 inhabitants in 1x1 km grid cell
>5000 inhabitants in 1x1 km grid cell
× Industrial Location

1:1.250.000
0 10 20 km N

6.10 Population Distribution in the Region

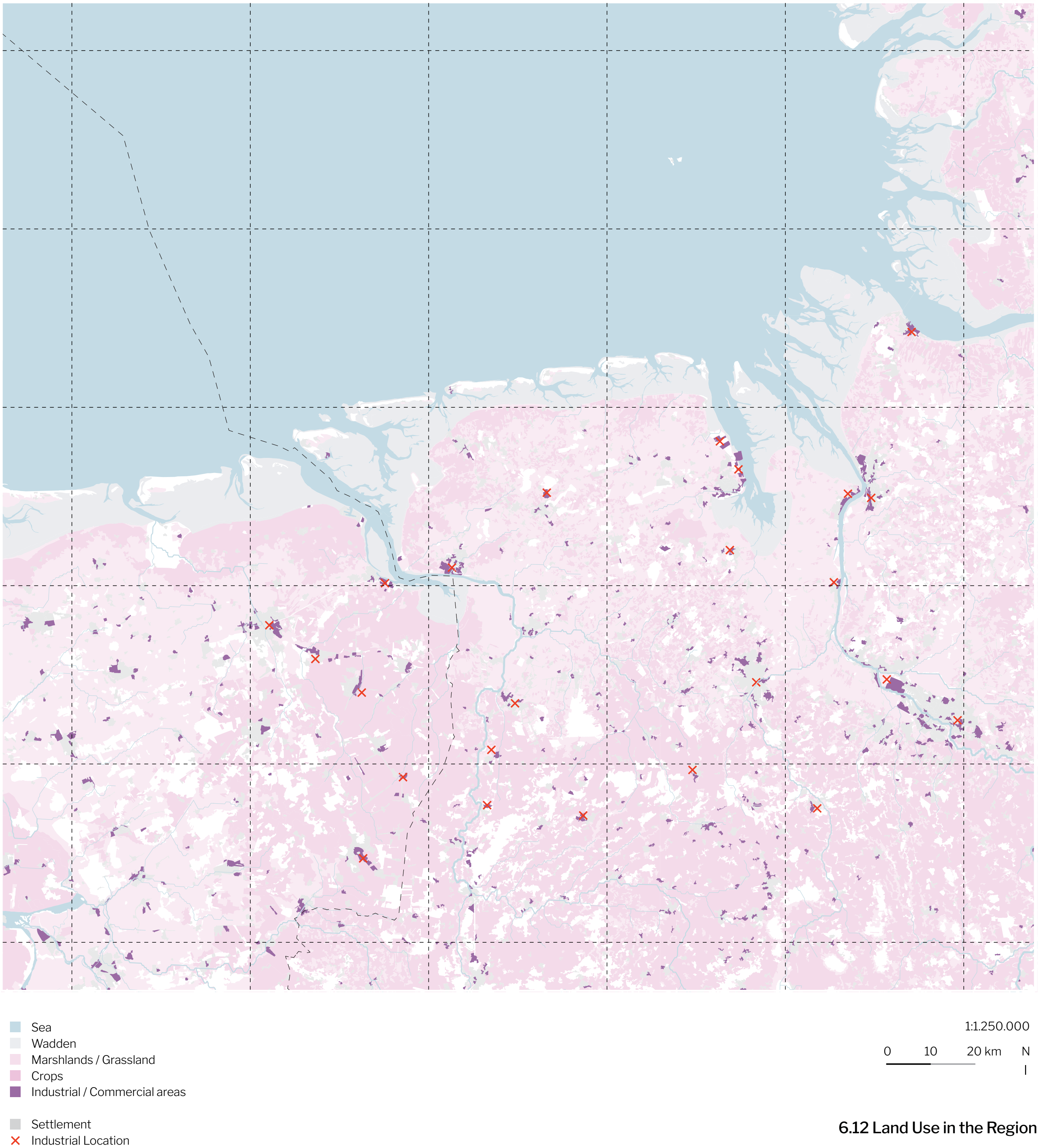


6.11 Abstracted Distribution of the Territorial Capital

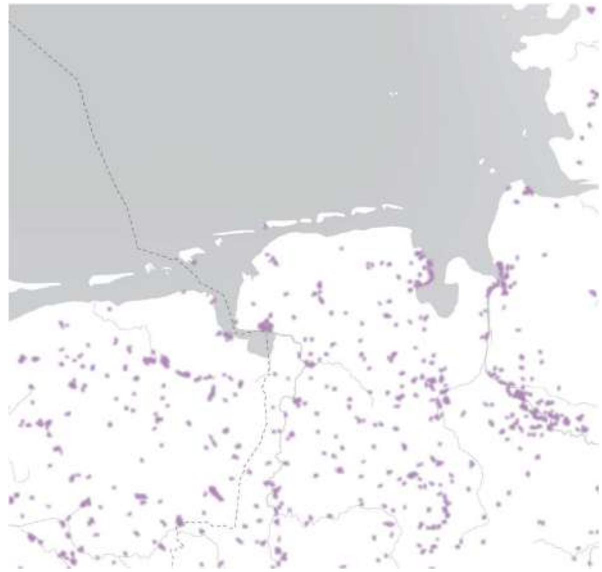
Population clusters are found in Bremen, Groningen and Oldenburg, with smaller concentrations in mid-sized places like Bremerhaven and Wilhelmshaven. Coastal and rural zones show lower density, especially in Emsland and parts of Drenthe. The towns themselves are relatively compact.
Urban nodes with dense settlement and connectivity accumulate settlement capital as they are anchors for transformation, while simultaneously low-density zones could host land-intensive circular systems (e.g. biomass, rewilding, wind farms).

# Land Use

## Economic Capital




6.12 Land Use in the Region

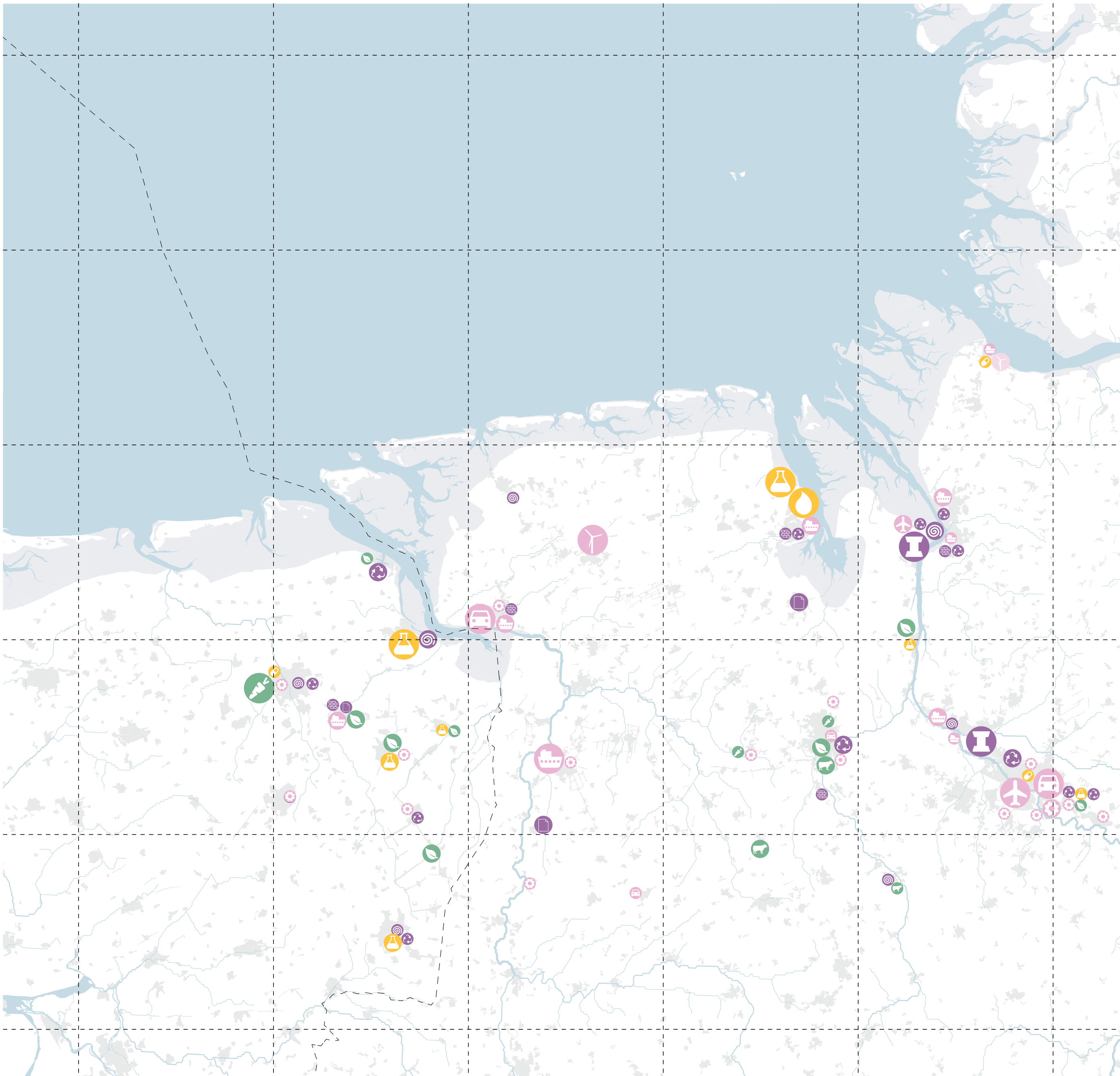


6.13 Abstracted Distribution of the Territorial Capital

The land use mapping displays a highly productive agricultural landscape that is shaped by centuries of reclamation and technical maintenance and that dominates the surface area of the region. Agriculture consists of crop farming mainly inland and grasslands in marshes. The industrial and commercial land is spatially concentrated in coastal zones and at urban fringes. The uses of this land type range from production and logistics to research, energy and waste. These coastal-industrial corridors are often hubs of productivity. Their spatial clustering could allow for systemic retrofit approaches (e.g. symbiosis) while rural/agricultural zones offer biobased potential.

# Industrial Sectors

## Economic Capital



Sea
Wadden
**Heavy Industry**
Manufacture of basic metals
Fabricated metal products
Cement and construction materials
Paper industry
Recycling

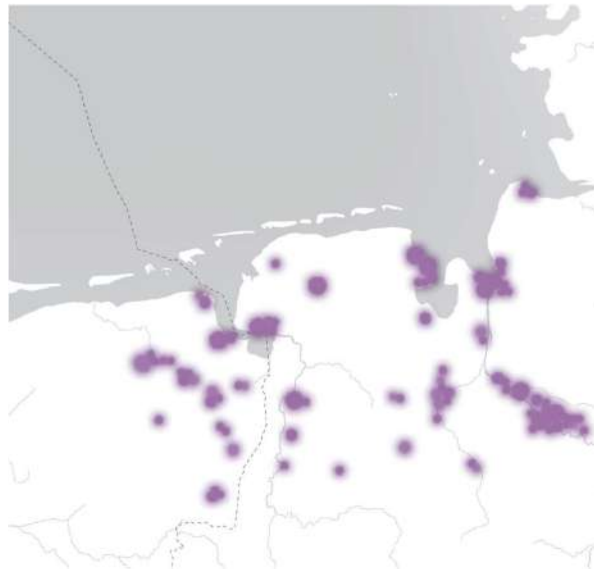
Settlement
Industrial Location
**Light Industry**
Manufacture of motor vehicles
Shipbuilding
Aerospace industry
Manufacture ren. energy appliances
Manufacture machinery/ electronics

**Chemical Industry**
Manufacture of basic chemicals
Oil refinery
Pharmaceutical industry

Manufacture of bioproducts
Food industry
Livestock plants

1:1.250.000
0 10 20 km N

6.14 Industrial Types in the Region

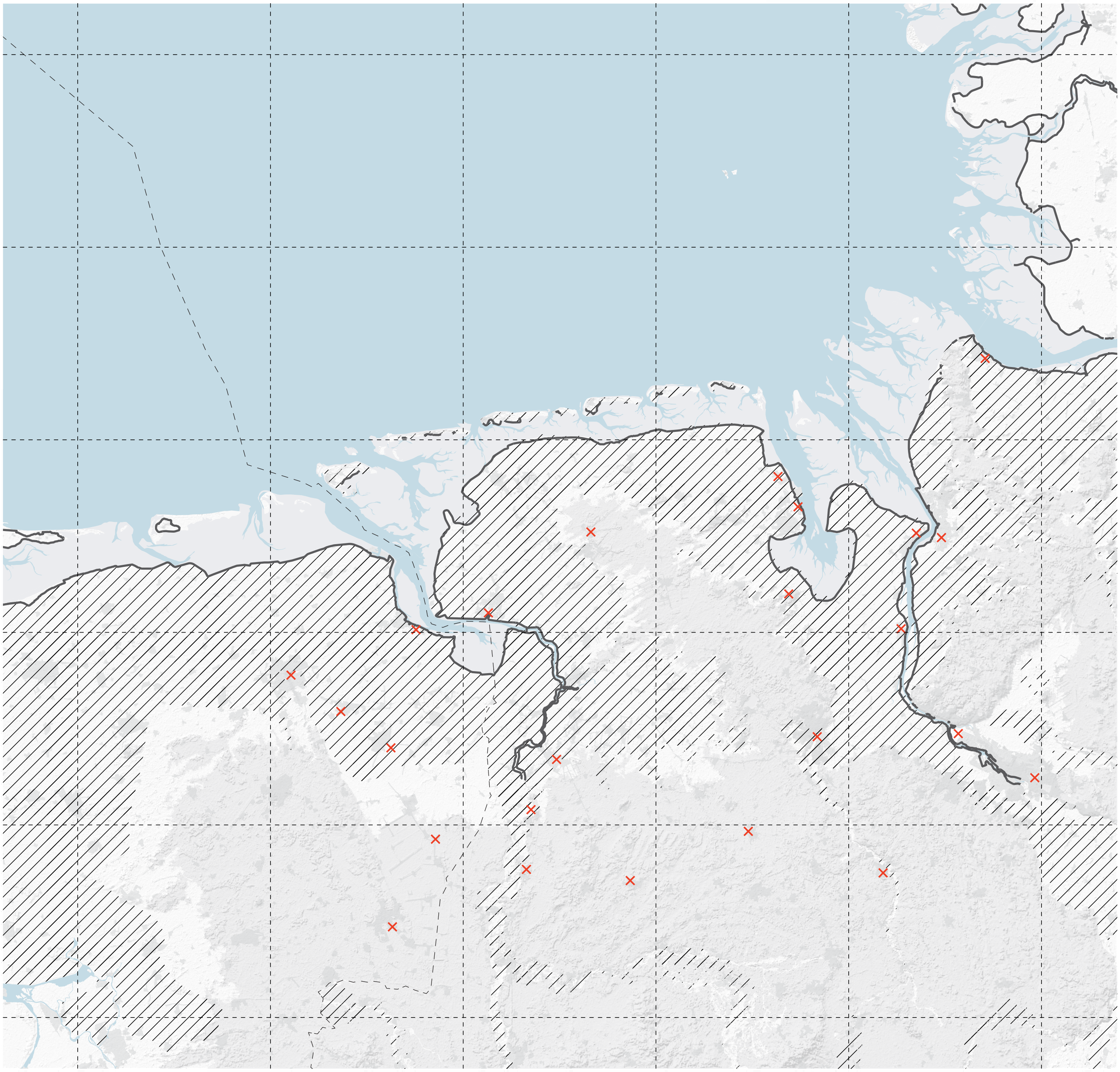


6.15 Abstracted Distribution of the Territorial Capital

The economic capital regarding industrial uses can be divided into the four key sectors: Heavy industry (e.g. the Bremen steelworks) relies on raw materials and large-volume logistic networks. Light industry (e.g. the Emden car plant) focuses on high-tech and precision outputs. The Chemical sector (e.g. in Delfzijl) is energy-intensive and clustered near ports. Bioproducts depend on agricultural and are spatially more dispersed. The map reveals a mosaic of different, apparently siloed sectors with coastal nodes (such as Delfzijl, Emden or Wilhelmshaven) playing a central role. These clustered ecosystems, with their spatial density and sectoral diversity, could provide a high leverage for piloting circular transition models (e.g. shared energy/waste systems).

# Coastal Protection

## Infrastructural Capital



Sea
Wadden
Higher Grounds
Flood-prone Area
Dike

Settlement
Industrial Location

1:1.250.000
0 10 20 km N

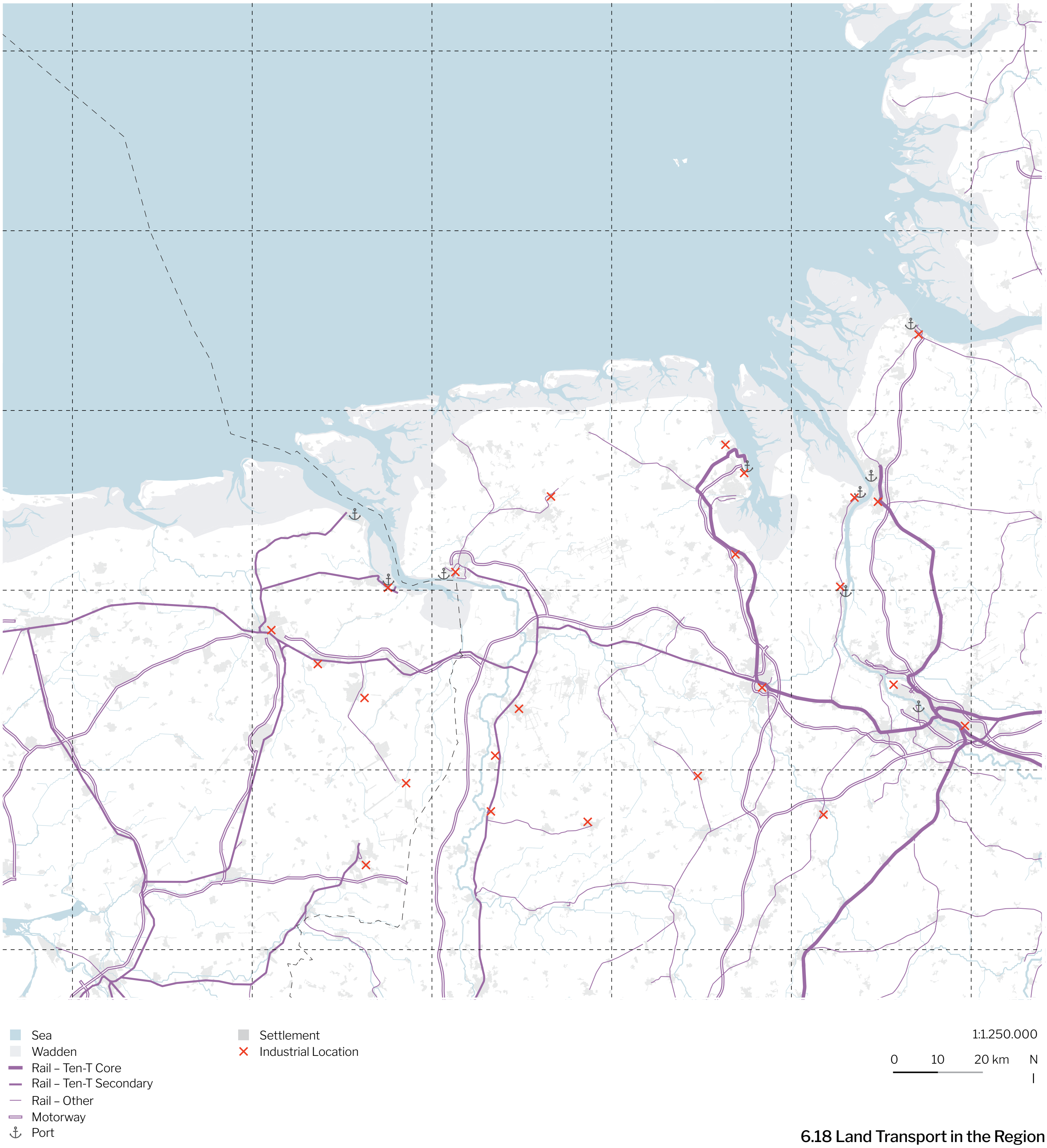
6.16 Dikes in the Region

6.17 Abstracted Distribution of the Territorial Capital

A continuous dike system defines the human settlement and productive land use boundaries in the low-lying, coastal zones. The terrain representation shows the critical transitions between marsh and geest zones regarding water safety. As an infrastructural capital, dikes are both a constraint and an opportunity: they demarcate boundaries of development and at the same time provide crucial safety from flooding that is the very basis of almost every human activity.

# Land Transport

## Infrastructural Capital



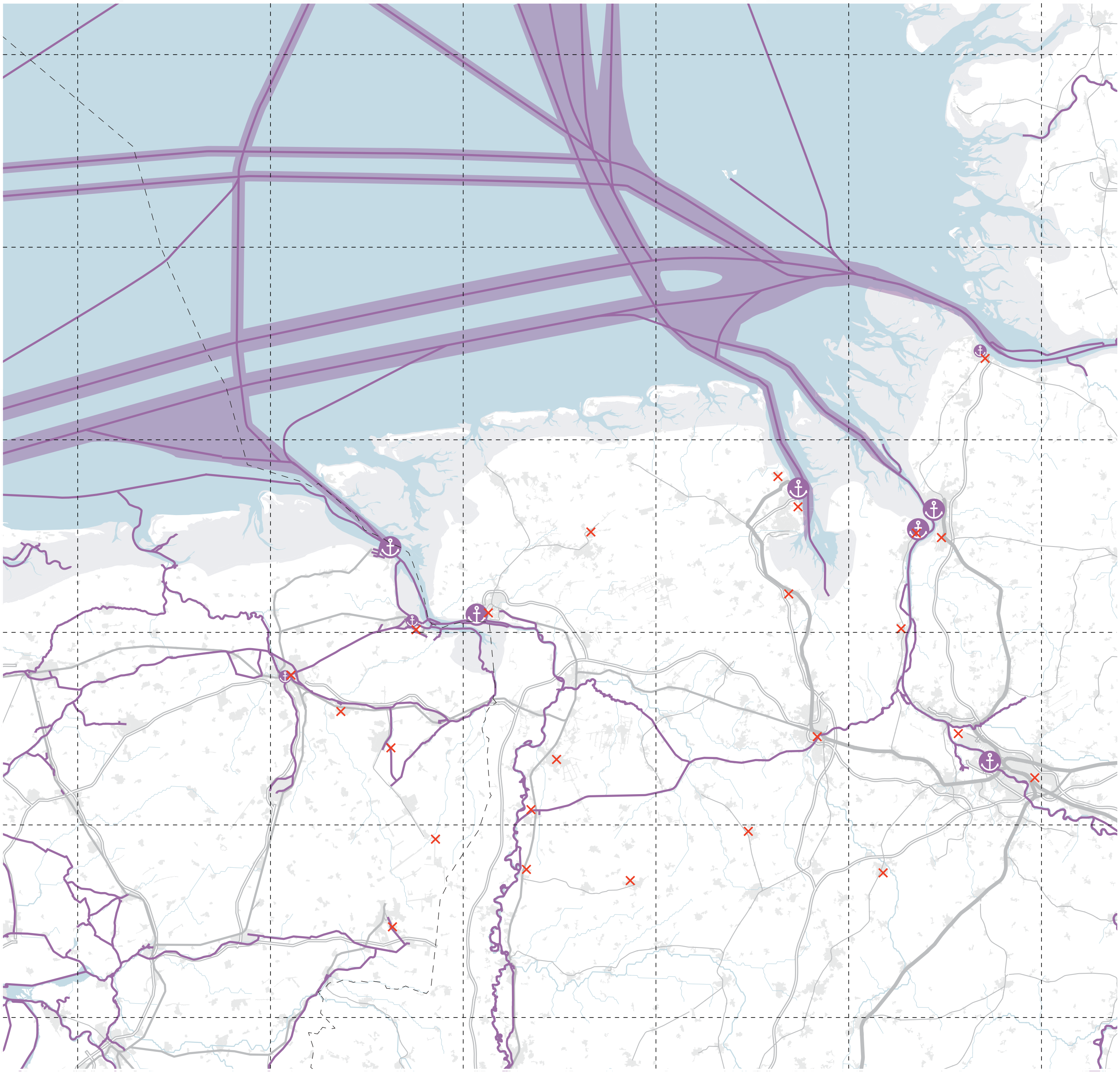

6.18 Land Transport in the Region

6.19 Abstracted Distribution of the Territorial Capital

Rail and road networks cover the whole region, even though the systems are thinner than in other parts of the Netherlands or western Germany. The highest category of pan-European TEN-T rail lines link the German hinterland via Bremen to the ports, but does not stretch across the whole Wadden Sea region. Also, the cross-border rail links (e.g. Groningen-Leer) is broken. Transport nodes act as crucial facilitators, which is why they are key for building up territorial capital.

# Water Transport

## Infrastructural Capital

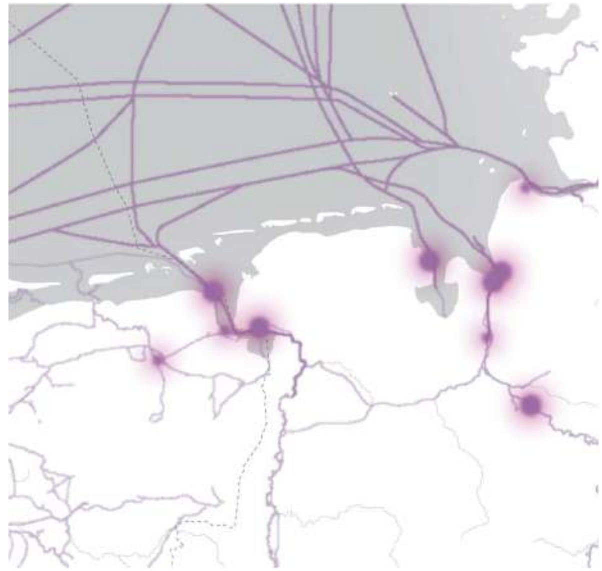


Sea
Wadden
Shipping Lane, Canal
Main Port

Settlement
Industrial Location
Rail – Ten-T Core
Rail – Ten-T Secondary
Rail – Other
Motorway

1:1.250.000
0 10 20 km N

6.20 Water Transport in the Region

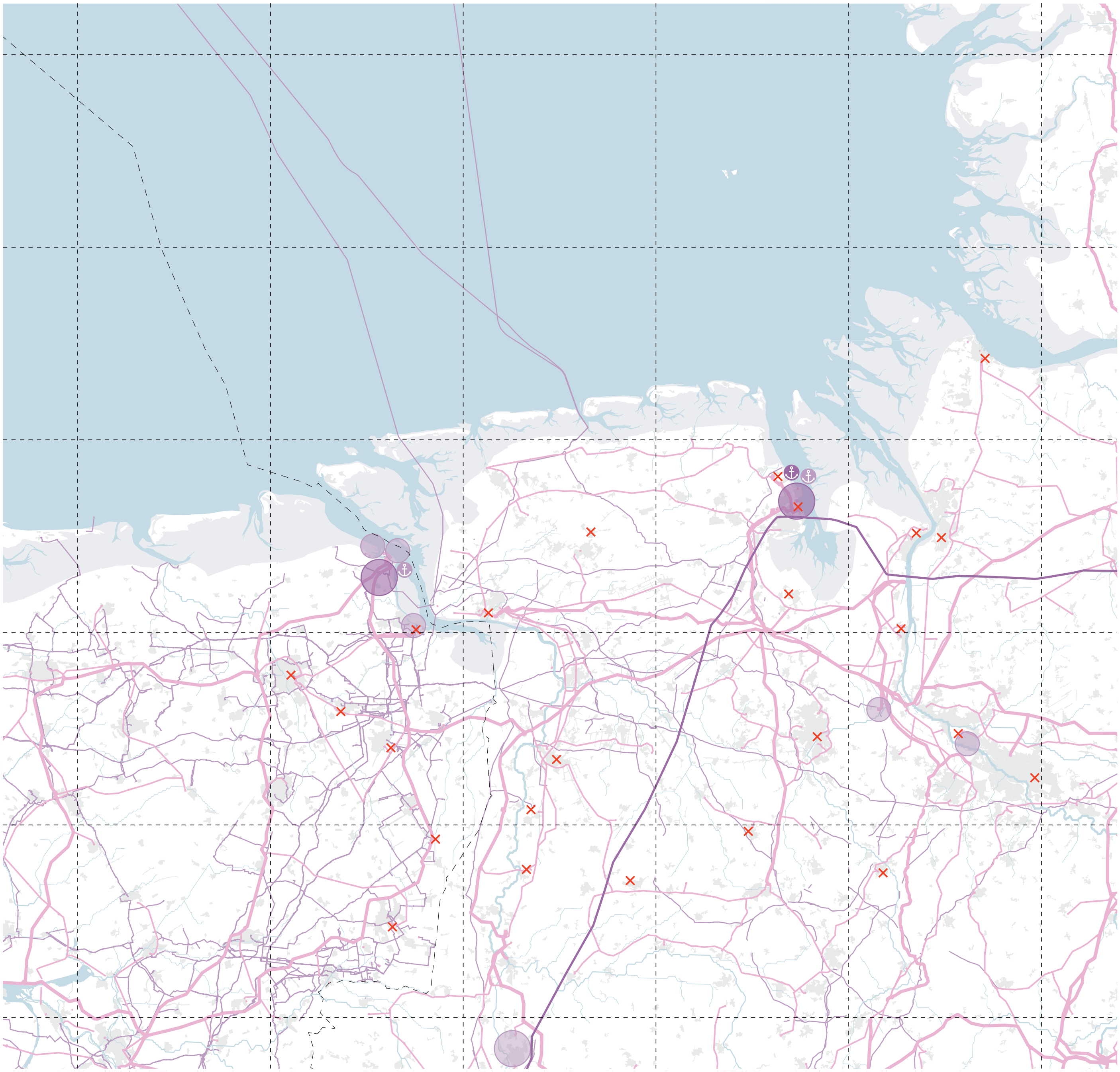


6.21 Abstracted Distribution of the Territorial Capital

The major ports (Bremerhaven, Emden, Wilhelmshaven, Eemshaven) connect to global flows, while the inland canals have become fragmented. Ports are high-leverage nodes regarding territorial capital as they facilitate logistics and therefore both linear and circular trade chains.

# Fossil Energy

## Infrastructural Capital



Sea
Wadden
Coal Power Plant
Gas Power Plant
Oil Pipeline
Gas Pipeline
High-voltage Grid
Local distribution Grid

Settlement
Industrial Location
Oil Terminal
Gas Terminal

1:1.250.000

0 10 20 km N

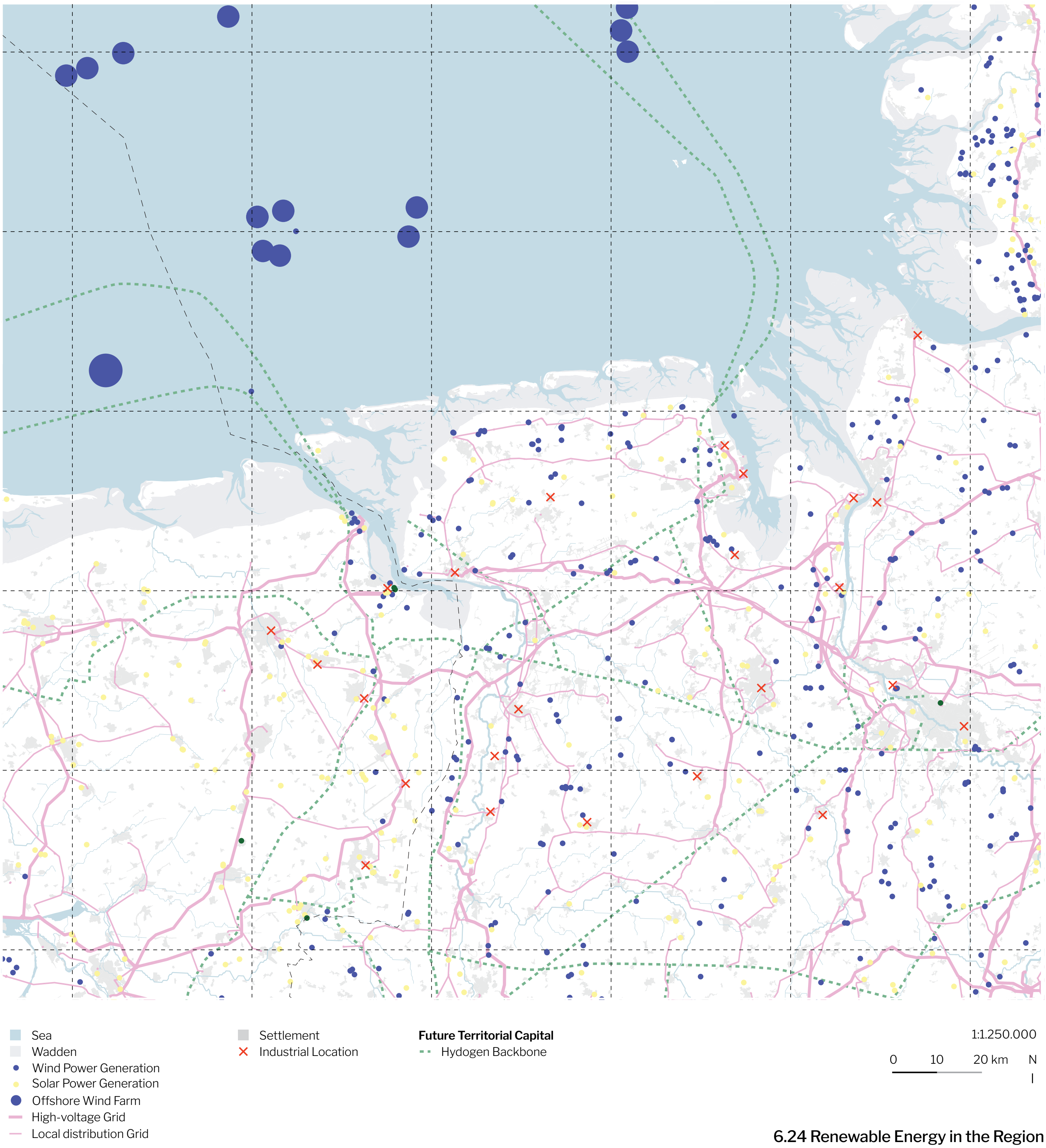
6.22 Fossil Energy in the Region

6.23 Abstracted Distribution of the Territorial Capital

Fossil energy clusters remain dominant in Eemshaven, Wilhelmshaven. The transition to renewables is underway (see next page), but infrastructure (e.g. LNG terminals, pipelines) is fixed in legacy systems. Still, they form a key territorial capital: These hubs can serve as anchor points for infrastructure that is needed for a transition, like hydrogen conversion, CCS or offshore grid connections.

# Renewable Energy

## Infrastructural Capital



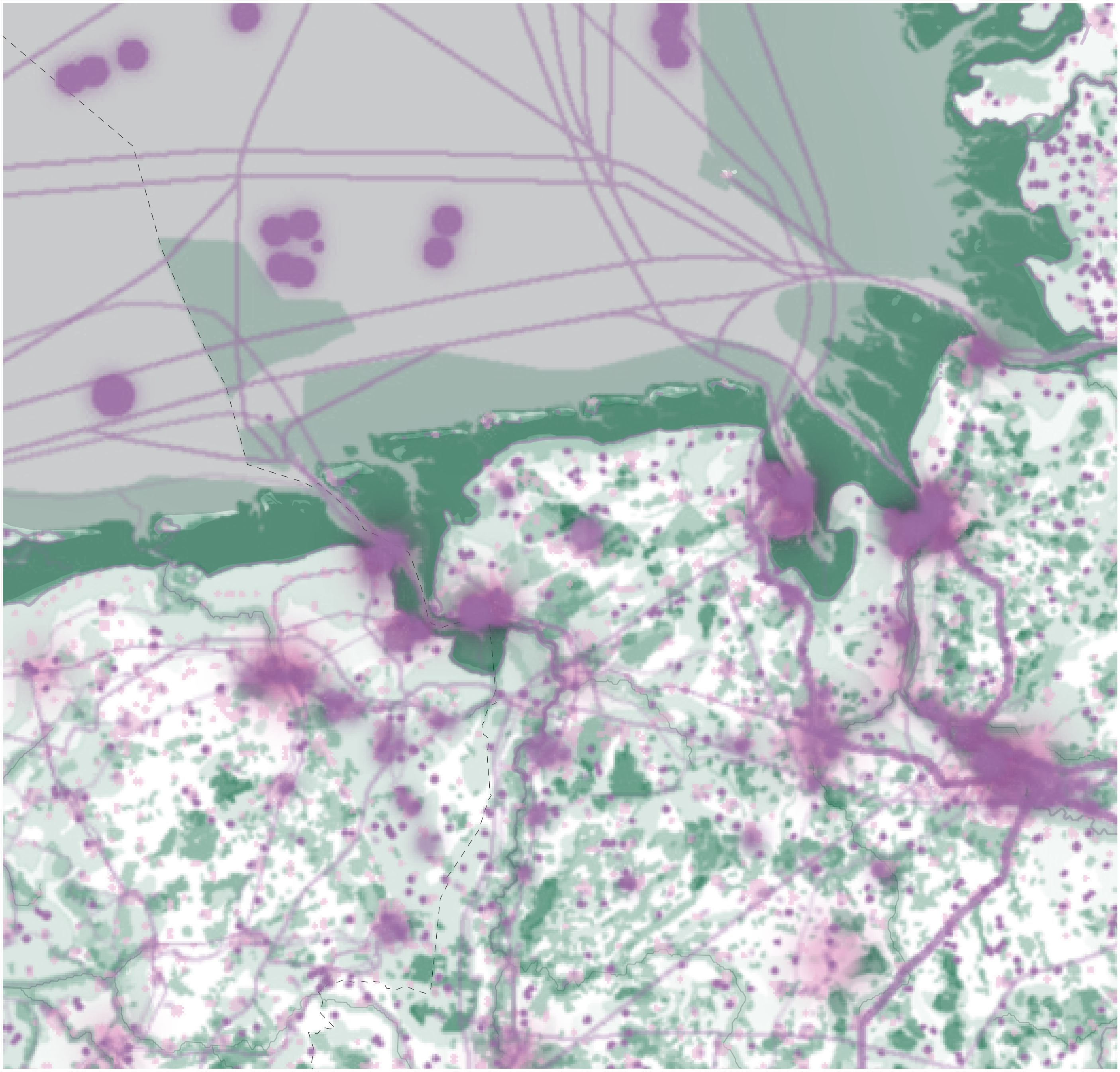

6.24 Renewable Energy in the Region

6.25 Abstracted Distribution of the Territorial Capital

Onshore wind turbines dominate the German coastal landscape, especially in Lower Saxony, where their spatial density far exceeds that of the Dutch side. Offshore wind farms in the North Sea form a backbone of energy production for both countries. Although hydrogen infrastructure is largely in planning, its emerging presence signals a future shift in regional energy flows and storage capacities.

# Overlay

## Summary of all Capitals



1:1.250.000

0 10 20 km N

6.26 Overlay of Territorial Capital

The territorial capital of the Wadden Sea region, as mapped through natural, human, settlement, economic and infrastructural lenses, unveils a complex landscape that is ready for a sustainability transformation. This synthesis distils five core insights from the overlaid capitals in Fig. 6.26, that do not only further explain the current state, but can also be a departure point towards a more circular industrial system.

First, foundational spatial dynamics rooted in substratum and hydrology shaped the regional historical trajectory and current vulnerabilities. Stable Geest ridges are the base for settlements, while marsh zones, though agriculturally productive, face flood risks and salinisation. This can frame a spatial logic for intervention.

Second, productive nodes, notably ports and industrial clusters, emerge as pivotal assets. Despite their peripheral location, these hubs have national or even European significance through their connectivity and sectoral diversity. They can also offer sites for circular economy experiments where resource loops can be closed.

Third, ecological imperatives underscore the natural capital. The Wadden Sea's global ecological value contrasts with fragmented inland biotopes, which necessitates finding a new balance between preservation and production to safeguard ecosystem services amid productive pressures and climate change.

Fourth, systemic relationships between capitals reveal synergy potential. Infrastructure and ecology, often at odds, can potentially be reconciled more through relational strategies that aim at greater diversity and resilience and enable integrated industrial/nature systems.

Finally, the region's semi-peripheral status and cross-border flows highlight its dual identity as an extraction zone and innovation frontier. Greater transnational cooperation is essential to leverage these dynamics to create sustainability.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1,0

7

# Flow Analysis

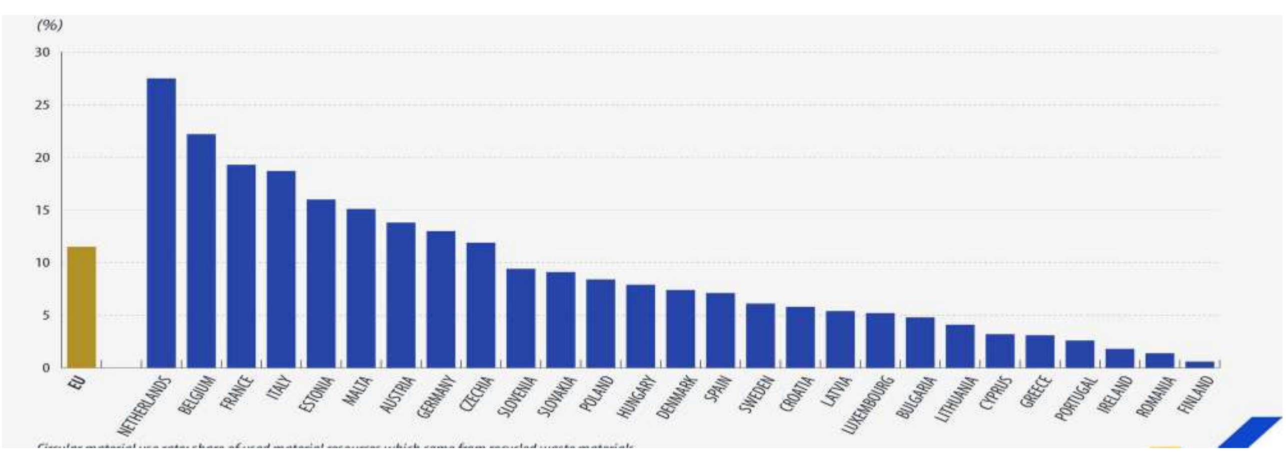
# Flow Analysis

Understanding how materials and energy move through space is central to this thesis. Yet, the available data on metabolic flows is rarely regionalised, let alone spatialised to a complex system like the Wadden Sea region.

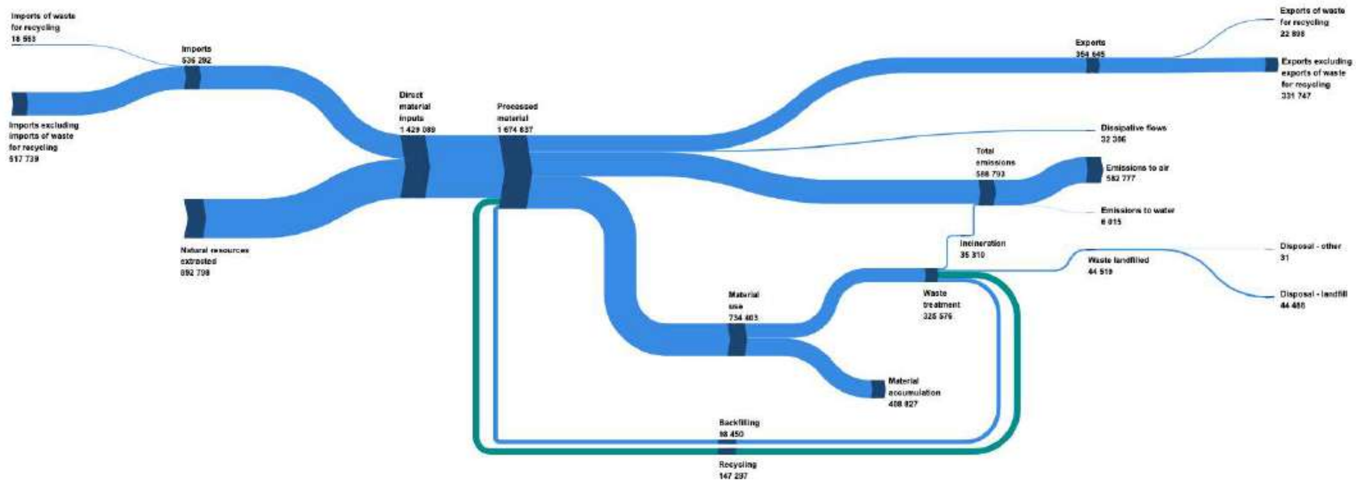
To address this, the following chapter works in three steps. First, I sketch a national overview of material and energy flows in Germany and the Netherlands. This helps to establish a baseline. Then, I turn to the landscape itself: What activities take place where (drawing on territorial findings from chapter 6) and how do they relate to flows? The final map offers a deliberately rough sketch: not a quantified diagram, but a spatial hypothesis. It suggests where major movements likely occur, which infrastructures they follow and where frictions or opportunities may arise. With the aim of orientation instead of precision, this should help to reveal blind spots and suggest questions about the future.

## Material Flows

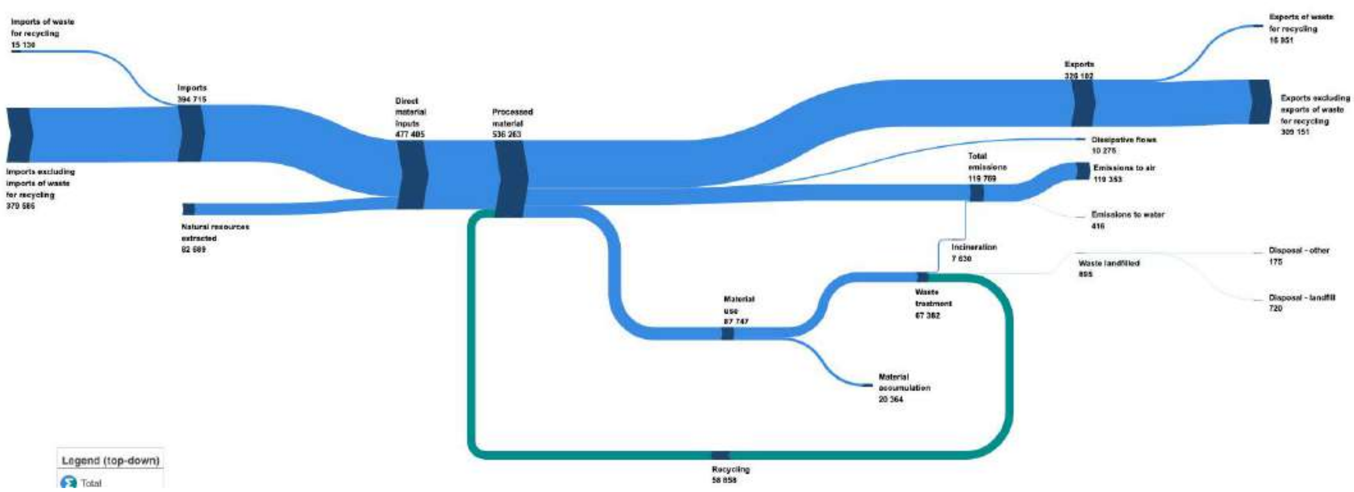
Fig. 7.2 and 7.3 reveal different national material metabolisms: Germany has a relatively autonomous, consumption-based economy with 62% of its domestic material input coming from local extraction. Its high overall material use (734 Mt) and substantial accumulation (409 Mt) indicate a system built on local sourcing and persistent internal demand. In contrast, the Netherlands relies heavily on imports (83% of its domestic material input) and acts as a trade-dependent, flow-through system with almost all processed material (326 Mt of 536 Mt) re-exported, while accumulating only 20 Mt. However, these national overviews cannot capture the precise regional situation. Although figures represent overarching logics (extraction versus transit), main spatial hubs of material throughput (e.g. Rotterdam, Ruhrgebiet, Rhein-Main) lie outside the Wadden Sea region. Here, the limitations of national metrics become evident. On the Dutch side, the region nevertheless hosts a critical energy port (Eemshaven), while on the German side, regional nodes like Emden or Bremen also feature manufacturing. Complementing this, a diagram of the EU circular material use rate (fig. 7.1) shows the Netherlands with 27.5% at the top the EU, with Germany roughly average. However, Germany's circular economy performance remains unassessed under the EU CE Monitoring framework (EEA, 2024a). The EEA notes that the Netherlands recycles 80% of its waste (albeit largely low-grade) and uses 22% less raw material than the EU average, partly because of the service-oriented economy and a high population density promoting efficient infrastructure use (EEA, 2024b).



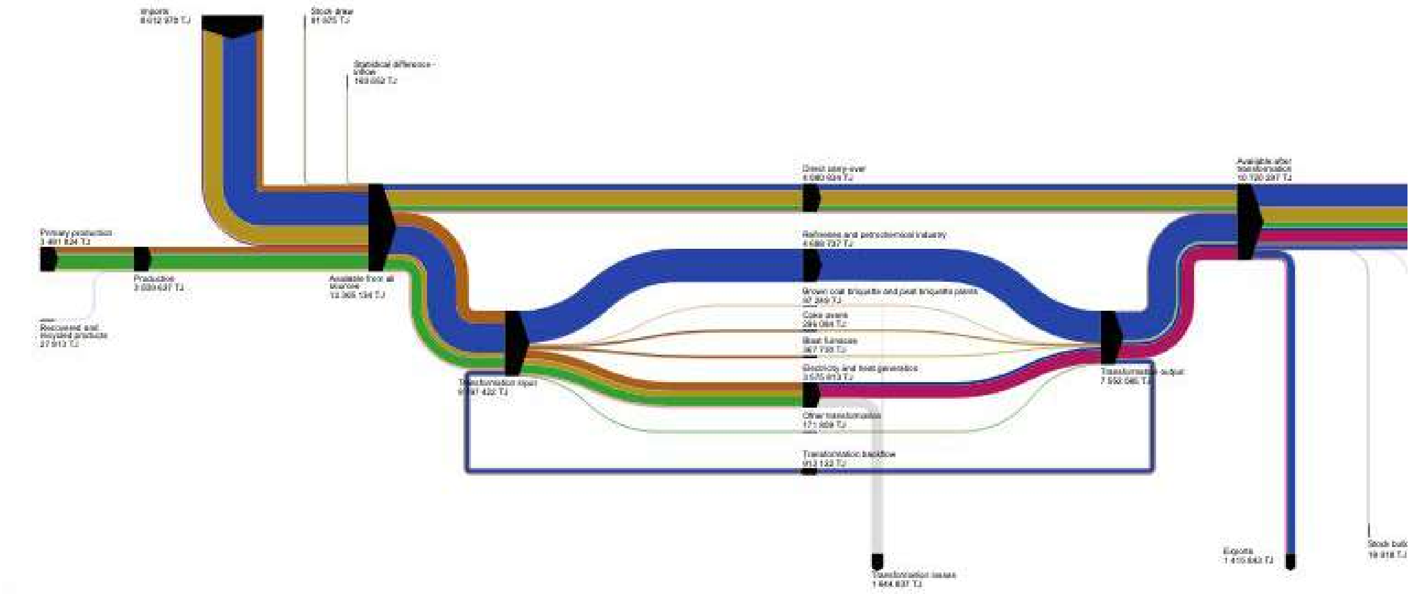

7.1 Circular material use rate in the EU, 2022



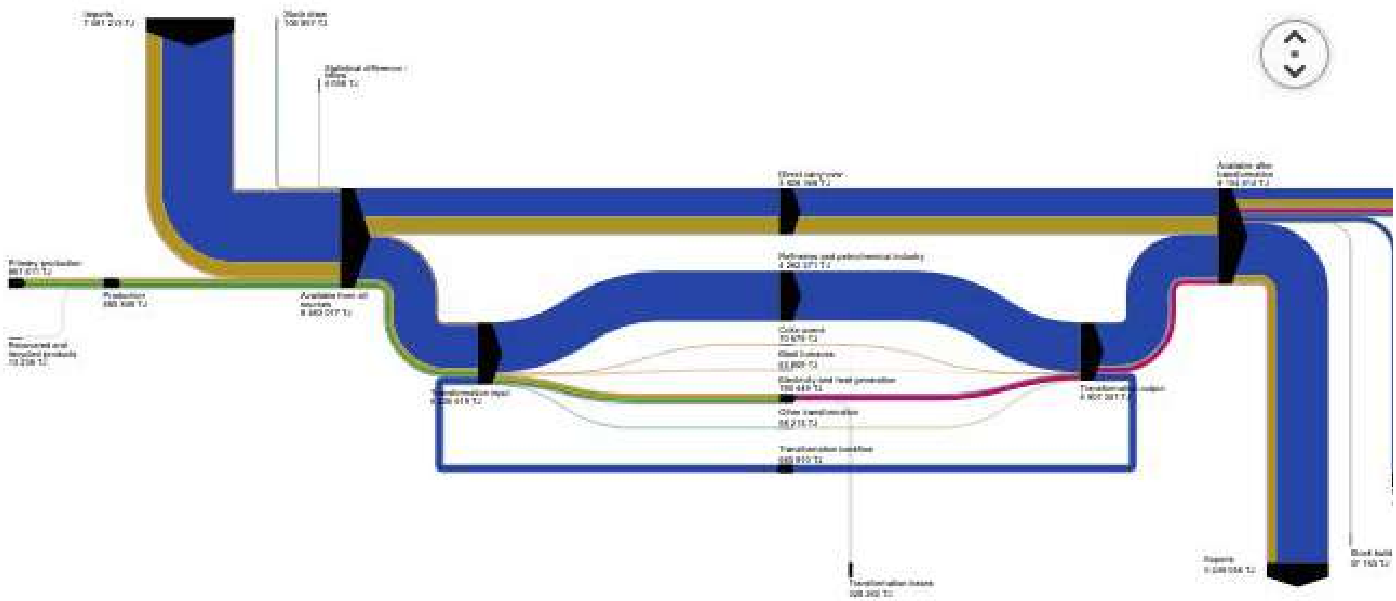

7.2 Sankey diagram of material flows in Germany, 2023, in thousand tonnes




7.3 Sankey diagram of material flows in the Netherlands, 2023, in thousand tonnes



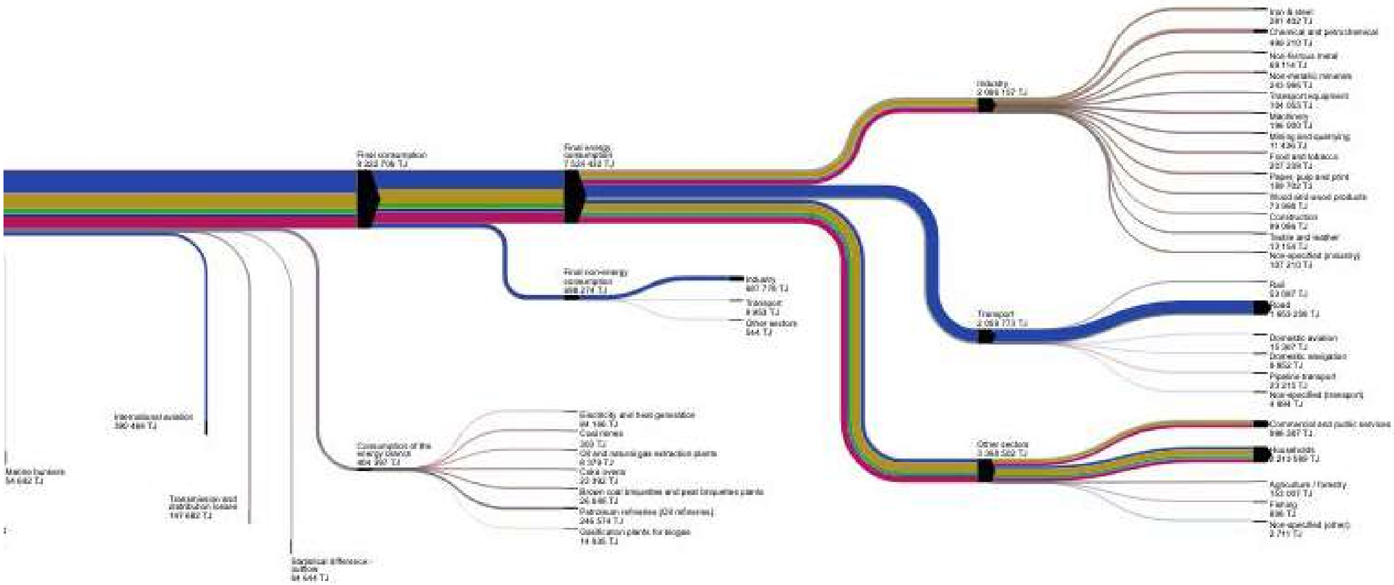
7.4 Sankey diagram of energy flows in Germany, 2023, in Terrajoules

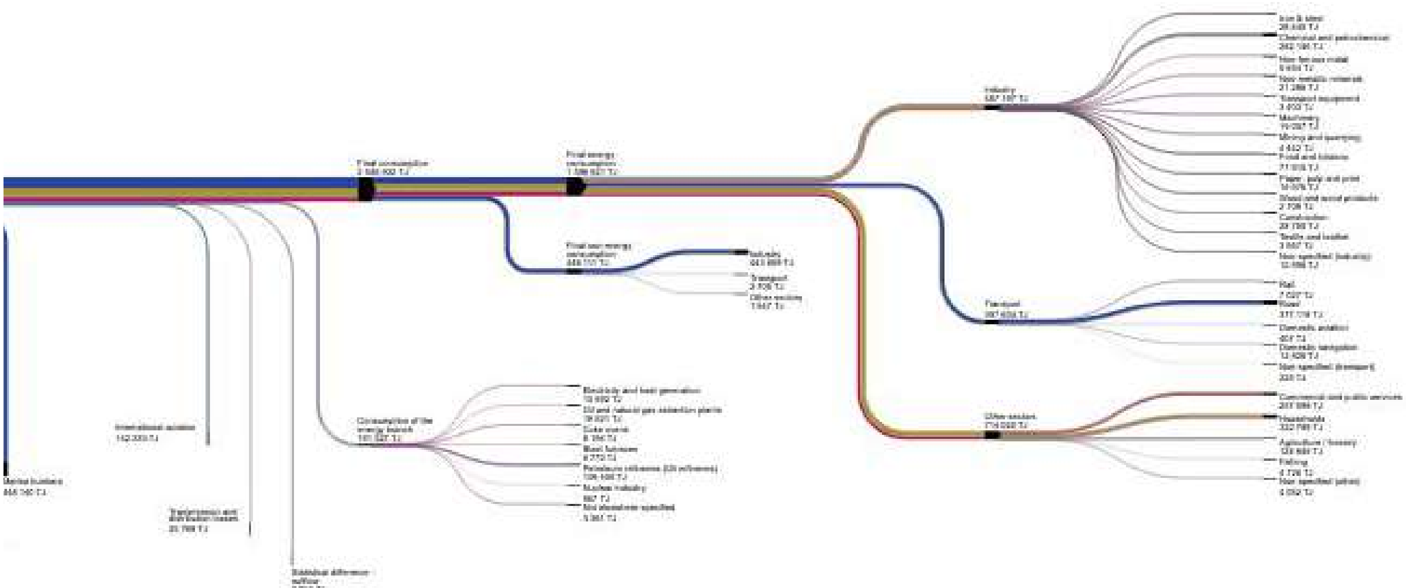


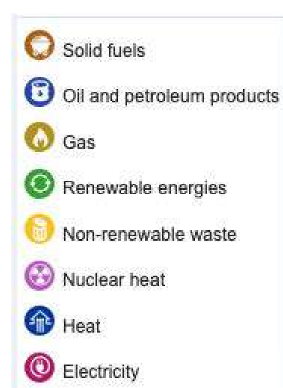
7.5 Sankey diagram of energy flows in the Netherlands, 2023, in Terrajoules

## Energy Flows

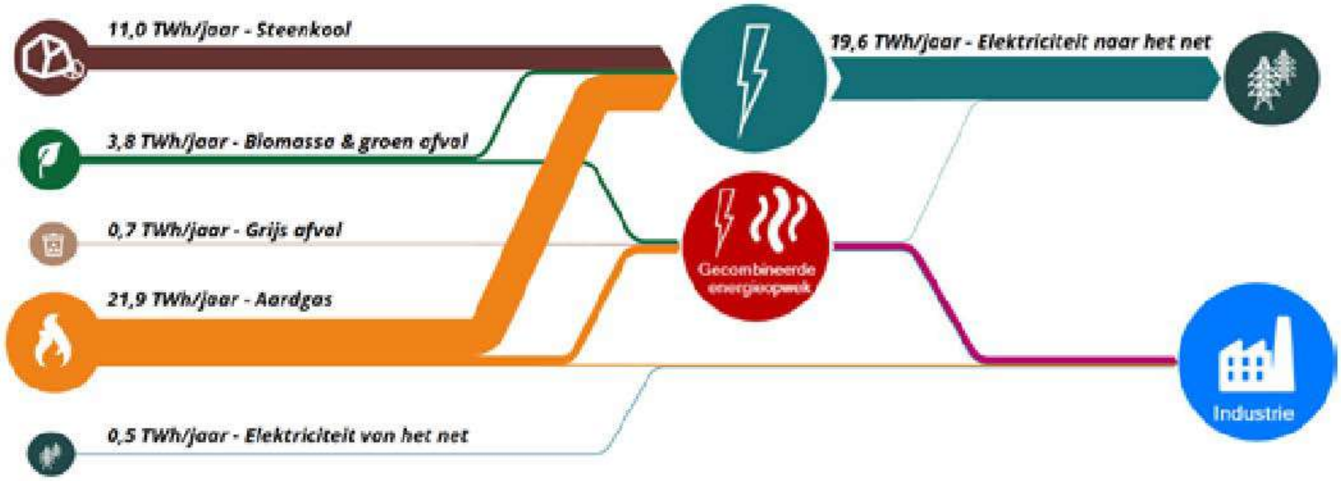
A comparison of fig. 7.4 and 7.5 shows that though smaller in population, the Netherlands handles over three times the energy per capita as Germany: less as consumer, more as transmitter. Massive oil imports (almost six times more per capita) feed refineries like that in Rotterdam and turn the country into an energy logistics machine. The chemical sector accounts for over 50% of all industrial energy consumption, which hints specialisation and concentration. The German system is broader: more renewables, more consumption, more domestic production. What emerges is a clear contrast: Germany as a demand-heavy, diversified industrial economy; the Netherlands as a streamlined energy transformation and export node. This cannot be directly translated to the Wadden Sea



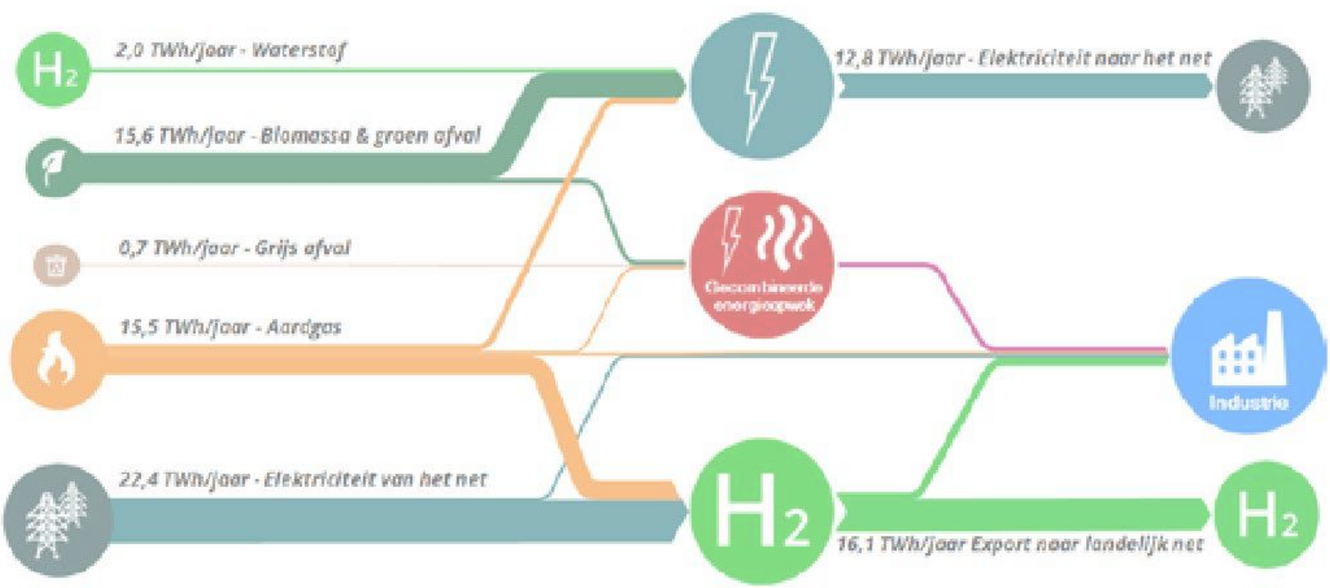





Region however. The main demand clusters lie outside, but from the Territorial Capital analysis we learned that key throughput infrastructures (refineries, pipelines, LNG) are present. The region therefore already has a high strategic value as an energy region, a factor which might become even greater with the transitions ahead, which, however, are hardly reflected in the current energy balance.




7.6 Energy flows cluster North Netherlands (participating companies, including electricity production), 2021

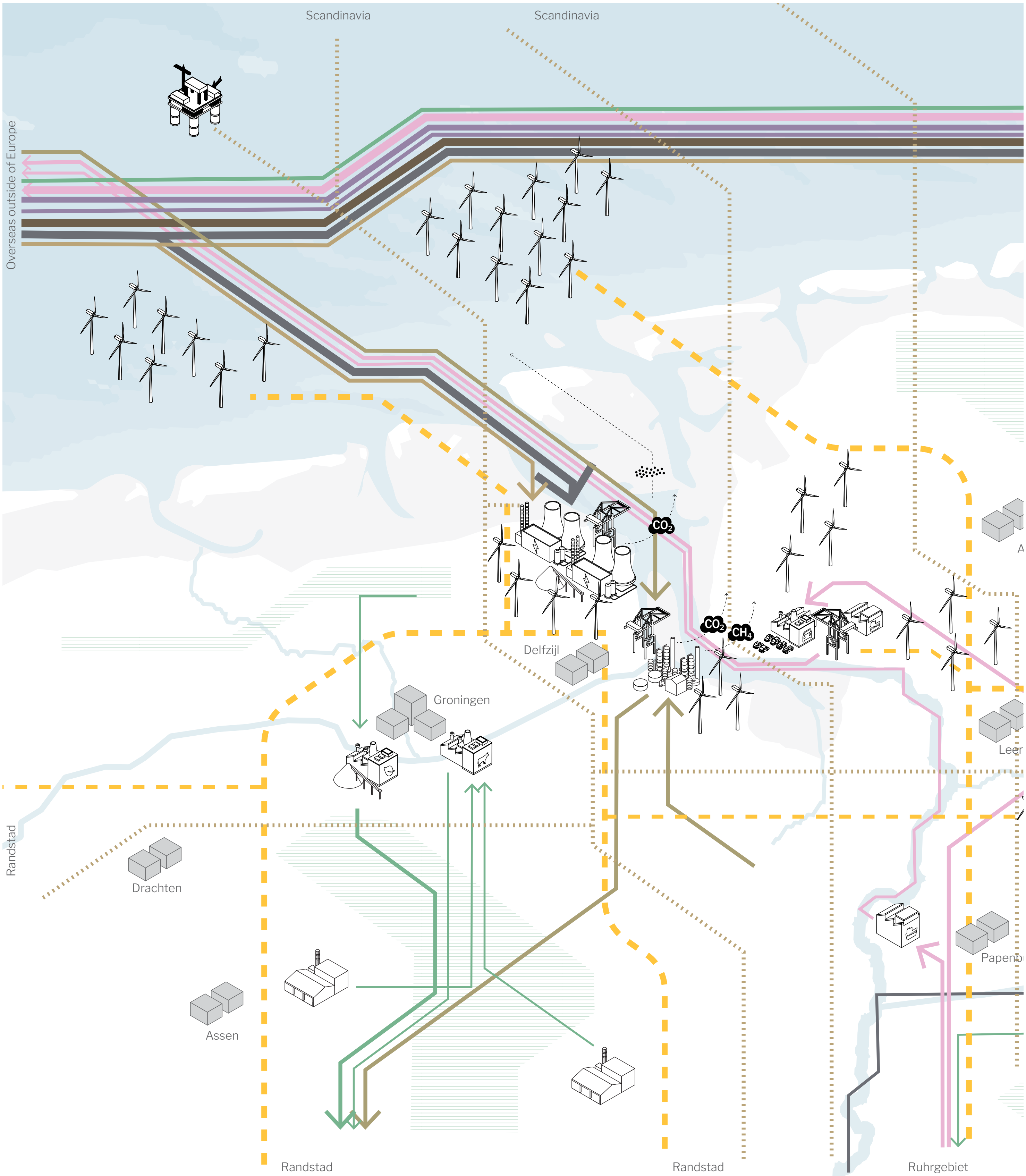



7.7 Potential energy flows cluster North Netherlands (participating companies, including electricity and hydrogen production), 2035

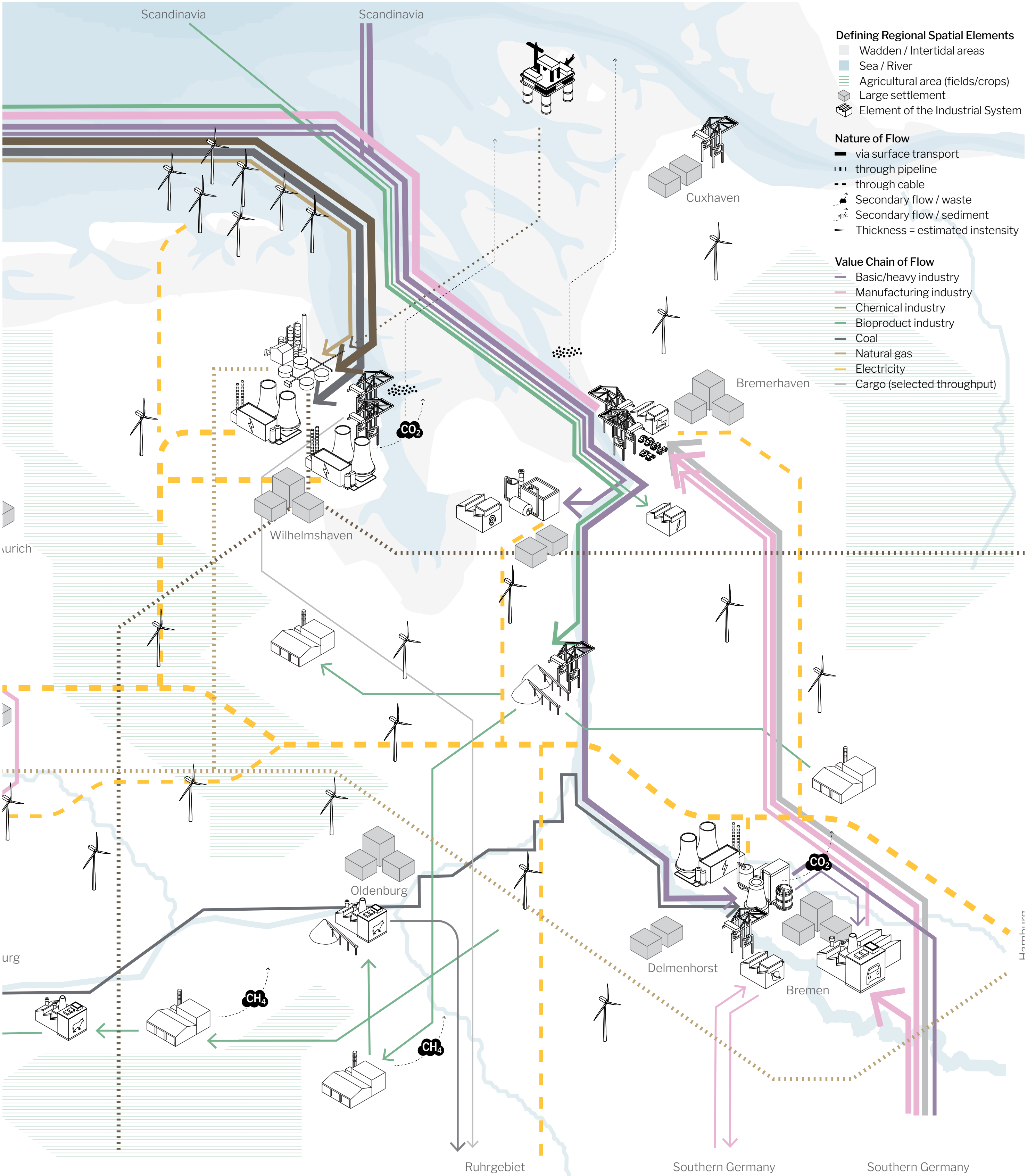
Subnational flow data is extremely scarce, making this Fig. 7.6 and 7.7 from the Cluster Energiestrategie unique and valuable. The current energy metabolism of the Cluster Noord-Nederland shows a dual role: high industrial consumption and substantial electricity production, making it a net energy exporter. Despite efficiency gains, fossil fuels dominate and CO2 emissions remain high. On-site steam generation and local CHP underline a decentralised setup. Also, this cluster plays a key role in the national system, as an energy supplier with demand elsewhere. Hidden flows like steam and waste emerge at the cluster scale. First signs of current plans point to a future marked by hydrogen and industrial electrification.

## Towards a Territorialised Hypothesis

The final map in this chapter presents a spatial hypothesis of the industrial metabolism Wadden Sea region. It combines the findings from the preceding national and subnational flow analyses with earlier results from Chapter 6. Rendered as an axonometric drawing with stylised tiles and industrial elements, it employs a constructed geography to prioritise systemic relationships over precise cartography. The map highlights six principal industrial nodes: Eemshaven, Delfzijl, Emden, Wilhelmshaven, Nordenham/Bremerhaven, and Bremen. Each node is colour-coded to denote its dominant sector. Stylised flows interconnect these sites as an hypothesis of movements of matter and energy. Distant hinterlands, notably southern Germany and the ABC region, appear as controlling entities, underscoring the semi-peripheral position within broader industrial networks.
Notable here is that research by design, can turn the limitation of data scarcity, which might stall conventional research methods relying on quantitative inputs, into an opportunity. Uses existing national, combined with insights about the territorial capital can be a starting point to hypothesise how flows might work to build a plausible starting point. The graphical result can be a tool to think with to understand the system, which is more important than pinning down precise numbers.




7.8 Hypothetical Spatial Flow Map

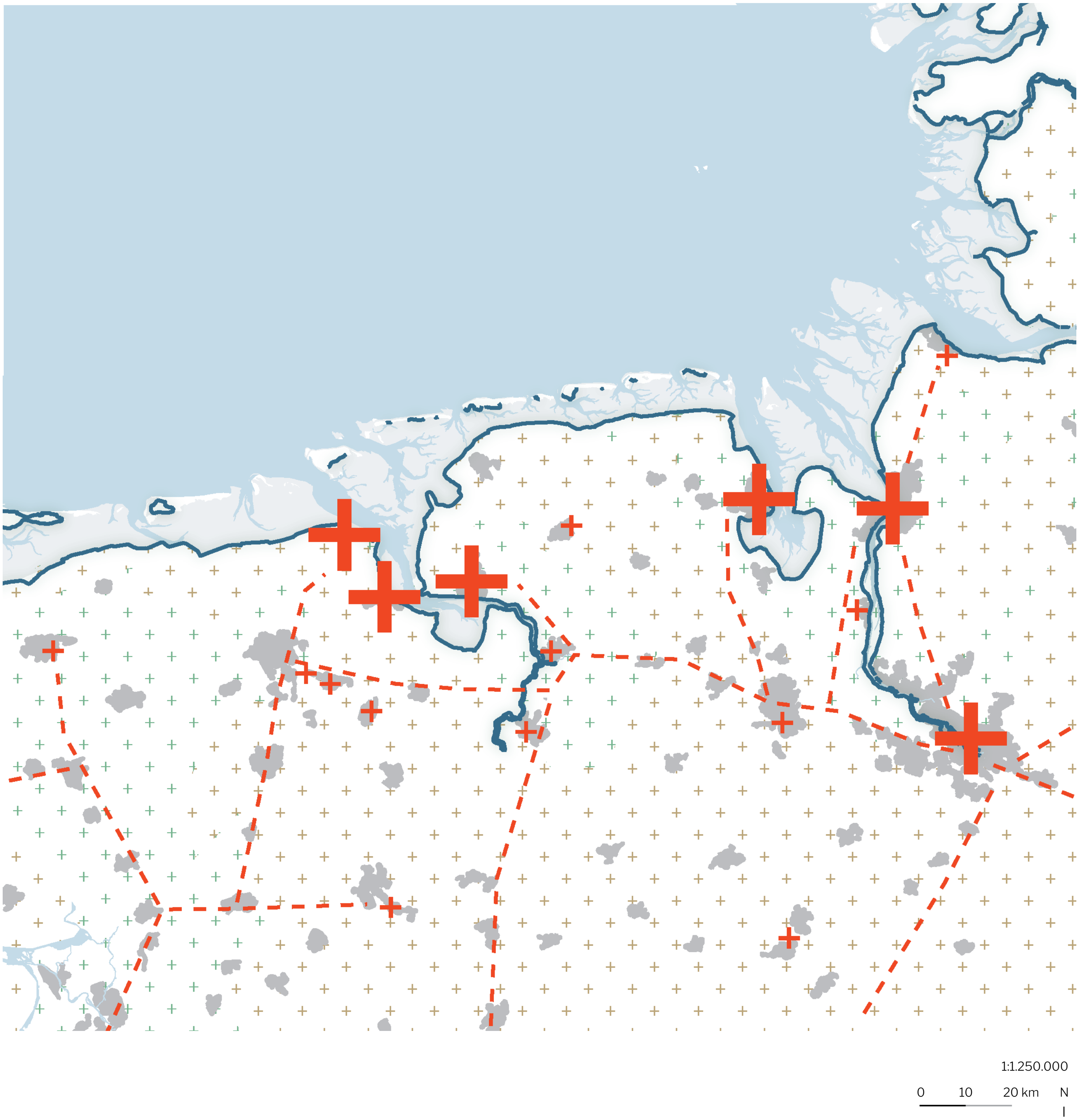

Scandinavia
Scandinavia
Defining Regional Spatial Elements
Wadden / Intertidal areas
Sea / River
Agricultural area (fields/crops)
Large settlement
Element of the Industrial System
Nature of Flow
via surface transport
through pipeline
through cable
Secondary flow / waste
Secondary flow / sediment
Thickness = estimated instensity
Value Chain of Flow
Basic/heavy industry
Manufacturing industry
Chemical industry
Bioproduct industry
Coal
Natural gas
Electricity
Cargo (selected throughput)
Cuxhaven
Bremerhaven
Wilhelmshaven
$CO_2$
$CO_2$
$CH_4$
$CH_4$
Oldenburg
Delmenhorst
Bremen
Ruhrgebiet
Southern Germany
Southern Germany

8

# Systemic Synthesis

# How the Region Works

## Synthesis: Typologies and Their Territorial Roles




8.1 Spatial Synthesis Map

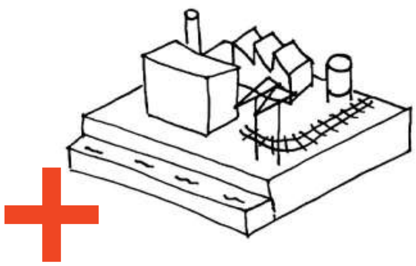
This overview builds on the preceding analyses of history, territorial capital and metabolism. It distills eight spatial types that can be seen as the region's 'grammar', each with its own individual logics. Their distribution is shown on the map and their material form is illustrated through axonometries below. Together, these elements reveal the forces that shape the Wadden Sea region. As a result, three metaphorical territorial 'motors' can be deducted: production, protection and ecology. They serve as a tool to tackle the complexity of the systems and understand how this landscape works and evolves, which successively forms the basis for proposing change.

## The Three Motors of the Region

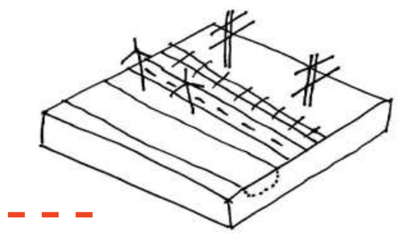
**Productive Motor**
Extraction, fabrication, logistics, large-scale industry

**Protective Motor**
Dykes, defenses, safety systems, risk adaptation

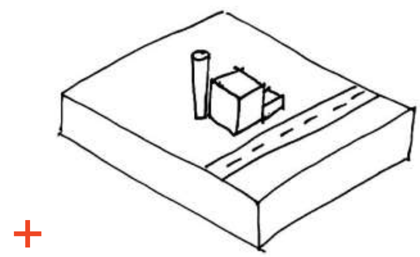
**Ecological Motor**
Flora, fauna, biotopes, soils, ecosystem services



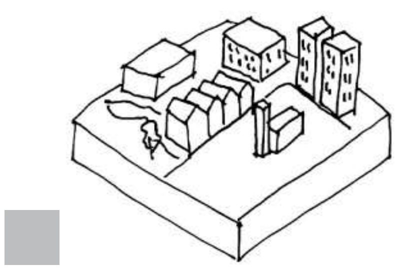
Large Industrial Cluster



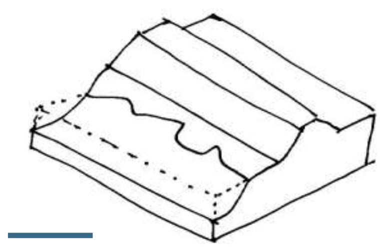
Infrastructural Line



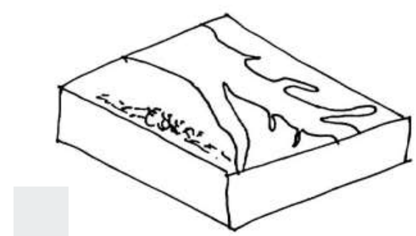
Smaller Industrial Location



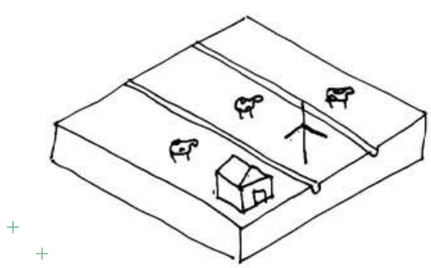
Urbanised Area



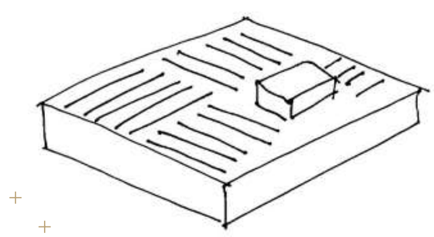
Dike



Wadden



Marsh / Grassland



Agriculture/Crops

8.2 Spatial Typology

Large Industrial Cluster

Infrastructural Line

Smaller Industrial Location

Urbanised Area

Dike

Wadden

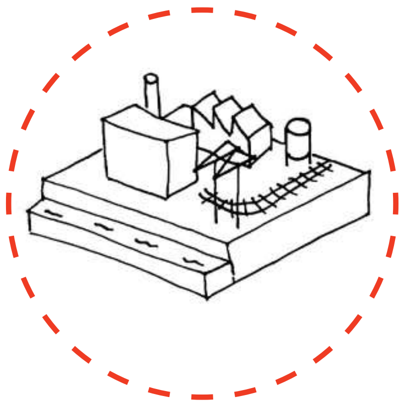
Marsh / Grassland

Agriculture/Crops

8.3 Manifestation of the Typology in space

# Zooming into the Engines

## Atlas of the Large Industrial Clusters



The following series of maps zooms into six areas I have defined as 'Large Industrial Clusters' in the synthesis on the previous page. They all lie along the Wadden coast: Eemshaven, Delfzijl, Emden, Wilhelmshaven, Nordenham & Bremerhaven, and Bremen. These sites are not only current engines of production but also potential levers for future transformation. Due to their way of working as nodes, changing their layout, function or connections could shift the metabolism of the wider region.

Each map is drawn at the same scale (1:90,000), allowing spatial comparison between clusters. What happens when you look at these places as a family, not as exceptions, but as variations of a shared theme?

The maps combine figure-ground diagrams (revealing the urban grain) with overlays of industrial buildings, wind turbines, port basins, energy and transport infrastructures and key hydrological elements like dikes and tidal zones. Industrial buildings are colour-coded by sector: heavy (purple), light (pink), chemical (yellow) and food/bioproducts (green).

The goal of this series of maps is to uncover hidden patterns of co-location, separation, tension or synergy. These clusters are at once embedded in landscape and driving its transformation. The legend below applies to all maps.

**Legend for the Maps on the following pages ►**

- Sea
- Wadden
- Marshland/Meadow
- Agricultural Area (Crop)
- Forest
- Urban Green (Park, Cemetery)
- Peatland
- Building
- Building in Urban Centre
- Building: Light Industry
- Building: Heavy Industry
- Building: Chemical Industry
- Building: Biobased Industry
- Building: Energy Generation
- Harbour Basin
- Rail Line
- Road
- Power Grid
- Wind Turbine

# Cluster: Eemshaven

8.4 Map of the Large Industrial Cluster in Eemshaven

1:90.000

0 1 2 km N


8.5 Large Industrial Cluster in Eemshaven


8.6 Large Industrial Cluster in Eemshaven

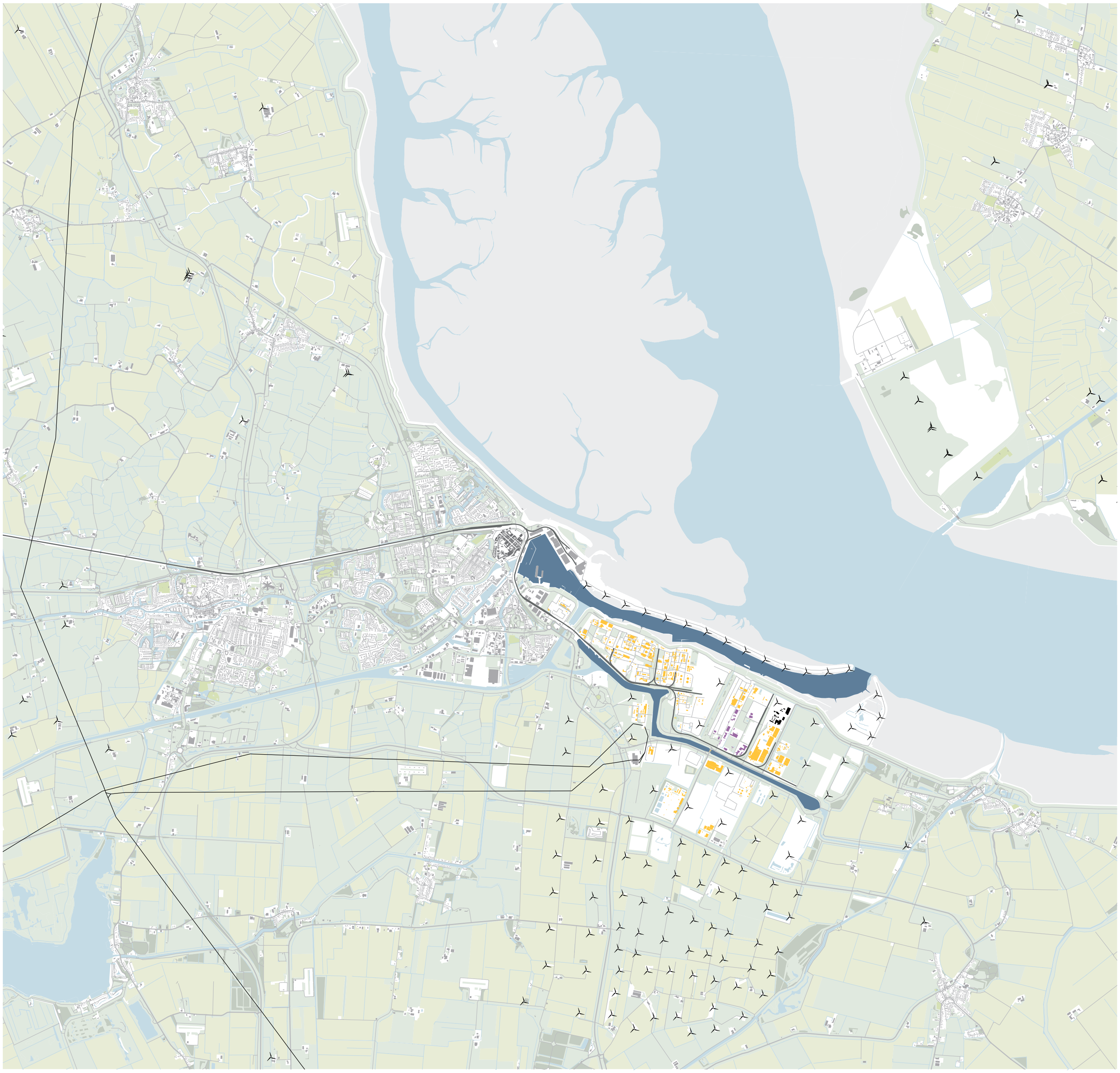

8.7 Large Industrial Cluster in Eemshaven


8.8 Large Industrial Cluster in Eemshaven


8.9 Large Industrial Cluster in Eemshaven


8.10 Large Industrial Cluster in Eemshaven

# Cluster: Delfzijl



8.11 Map of the Large Industrial Cluster in Delfzijl

1:90.000

0 1 2 km N

8.12 Large Industrial Cluster in Delfzijl

8.13 Large Industrial Cluster in Delfzijl

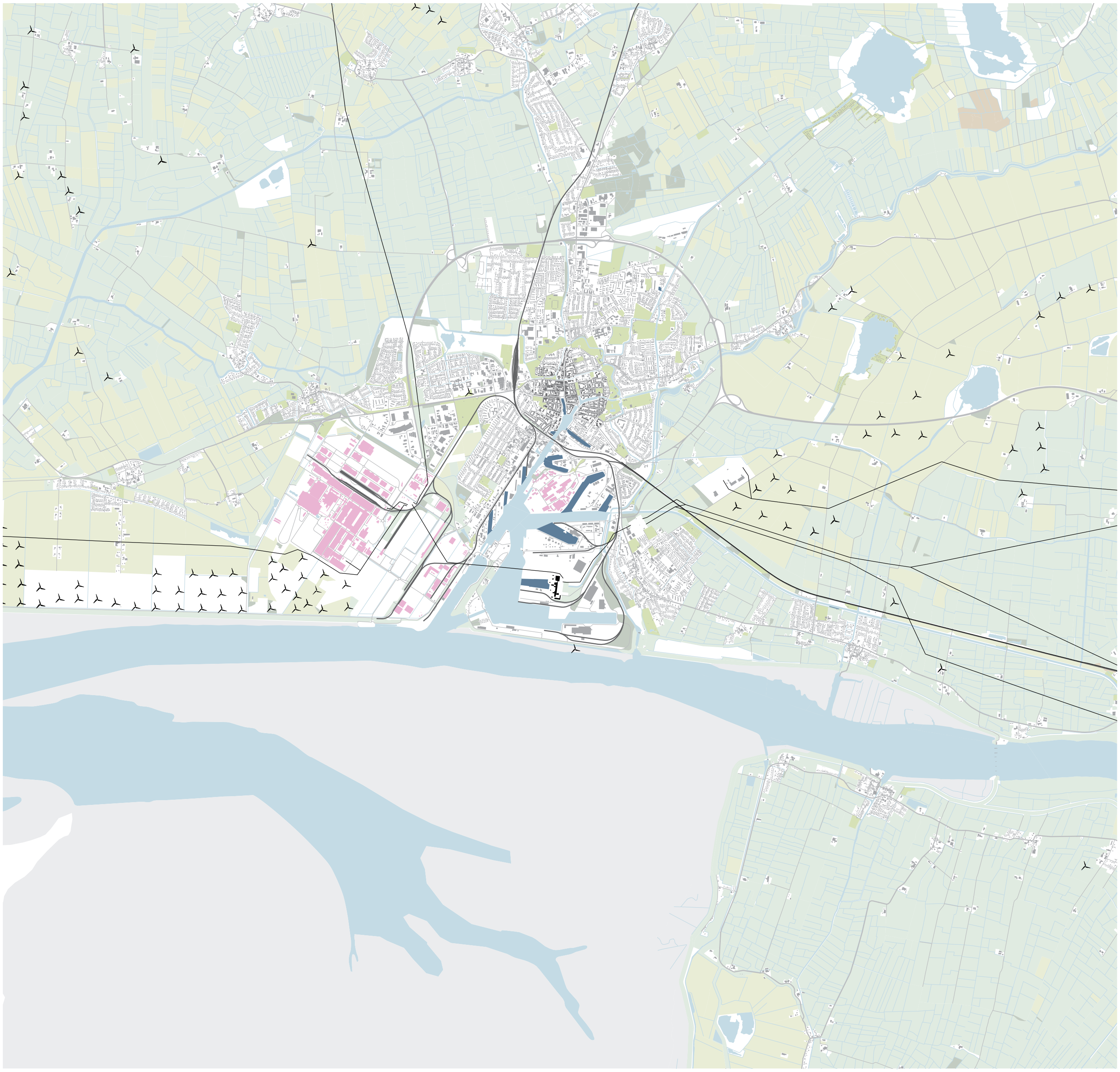
8.14 Large Industrial Cluster in Delfzijl

8.15 Large Industrial Cluster in Delfzijl

8.16 Large Industrial Cluster in Delfzijl

8.17 Large Industrial Cluster in Delfzijl

# Cluster: Emden

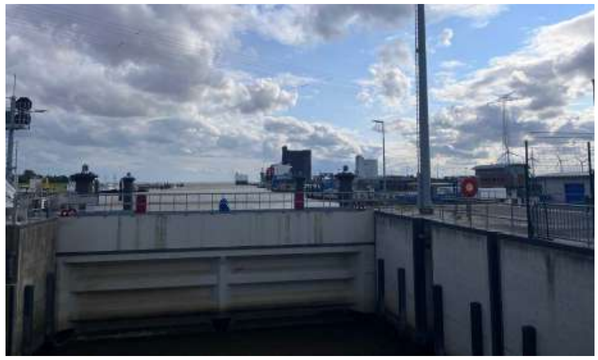


8.18 Map of the Large Industrial Cluster in Emden

1:90.000

0 1 2 km N

8.19 Large Industrial Cluster in Emden



8.20 Large Industrial Cluster in Emden

8.21 Large Industrial Cluster in Emden

8.22 Large Industrial Cluster in Emden

8.23 Large Industrial Cluster in Emden

8.24 Large Industrial Cluster in Emden

# Cluster: Wilhelmshaven

8.25t Map of the Large Industrial Cluster in Wilhelmshaven

1:90.000

0 1 2 km N

8.26 Large Industrial Cluster in Wilhelmshaven

8.27 Large Industrial Cluster in Wilhelmshaven

8.28 Large Industrial Cluster in Wilhelmshaven


8.29 Large Industrial Cluster in Wilhelmshaven

8.30 Large Industrial Cluster in Wilhelmshaven

8.31 Large Industrial Cluster in Wilhelmshaven

# Cluster: Nordenham / Bremerhaven


8.32 Map of the Large Industrial Cluster in Bremerhaven/Nordenham

8.33 Large Industrial Cluster in Bremerhaven/Nordenham

8.34 Large Industrial Cluster in Bremerhaven/Nordenham

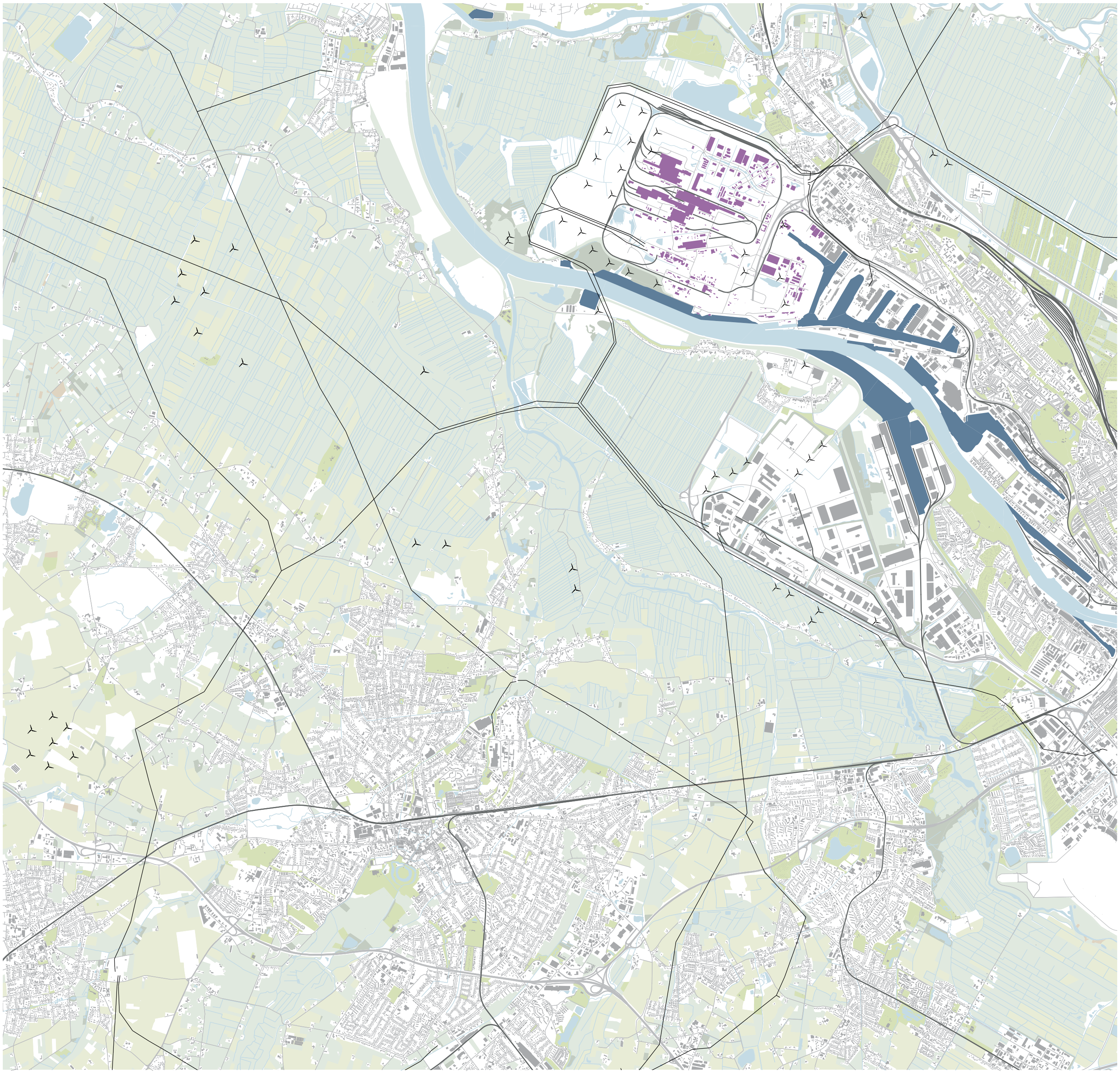
8.35 Large Industrial Cluster in Bremerhaven/Nordenham

8.36 Large Industrial Cluster in Bremerhaven/Nordenham

8.37 Large Industrial Cluster in Bremerhaven/Nordenham


8.38 Large Industrial Cluster in Bremerhaven/Nordenham

# Cluster: Bremen



1:90.000

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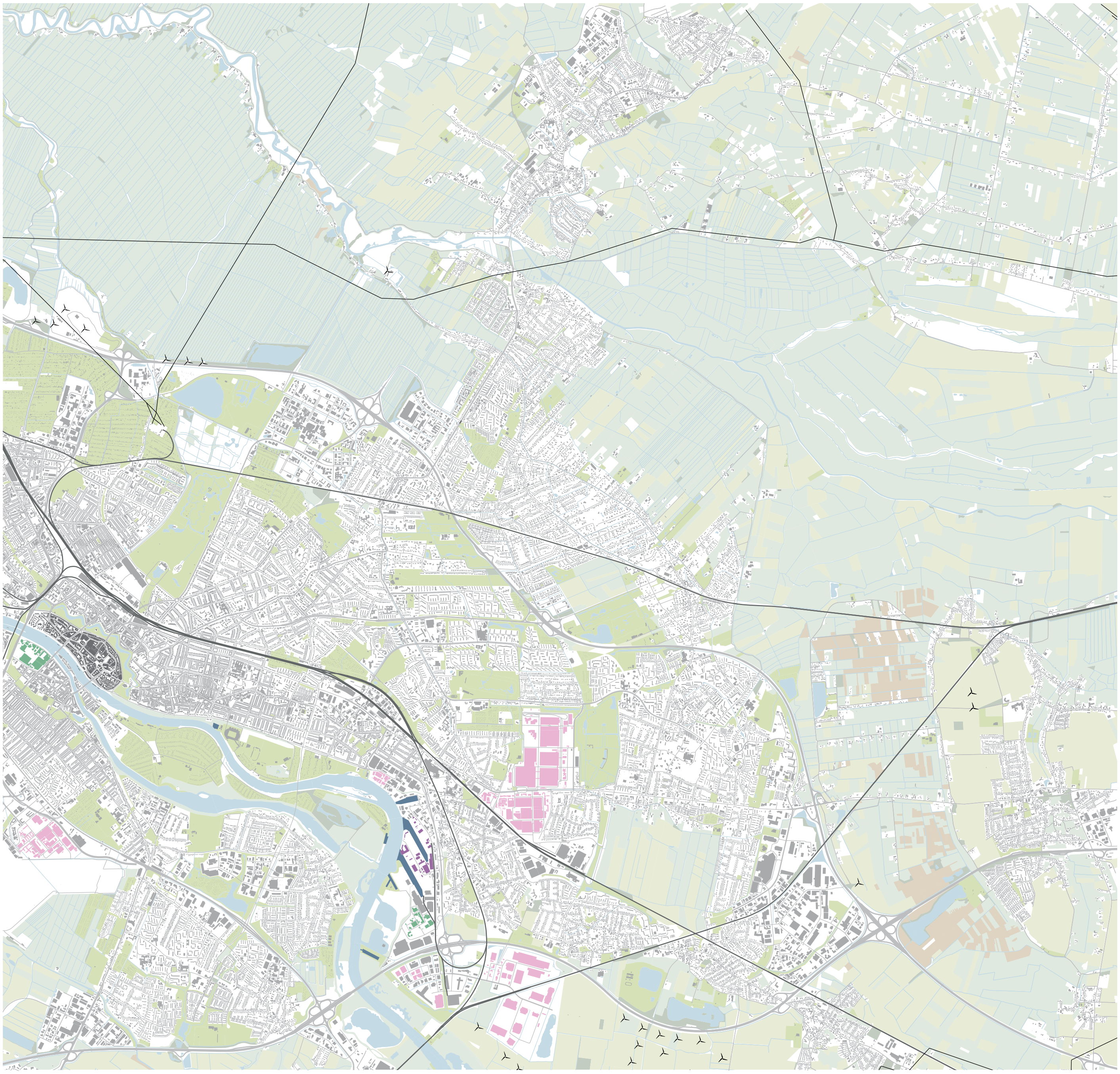


8.39 Map of the Large Industrial Cluster in Bre men


8.40 Large Industrial Cluster in Bremen


8.41 Large Industrial Cluster in Bremen


8.42 Large Industrial Cluster in Bremen


8.43 Large Industrial Cluster in Bremen


8.44 Large Industrial Cluster in Bremen


8.45 Large Industrial Cluster in Bremen

# Conclusions

## Atlas of the Large Productive Clusters

Based on the findings from the previous pages, the different Large Industrial Clusters can be compared in their materialisation to then identify specific logics that are typical for this space type. Their identification leads to several conclusions that can be drawn regarding the way of working as production engines.

### Comparison of the Clusters

**Eemshaven**

- Dominated by energy generation (power plants, data centres) with a characteristic, planned harbor layout.
- Lacks any immediate settlement, which makes it a purpose-built industrial zone with clear pockets for different uses.

**Delfzijl**

- A primarily chemical cluster founded around salt and gas resources that drove its planned expansion.
- Mechanical separation from settlements via dike structures. Also a historically layered development that now shows gaps from past economic hurdles.

**Emden**

- Overwhelming presence of a large VW car plant
- Spatial fragmentation with physical boundaries (rail lines, waterways) delineating the plant from surrounding urban and agricultural areas

**Wilhelmshaven**

- Characterised by a huge chemical/industrial complex with very large, planned installations (e.g., refineries and ports).
- Shows extreme physical separation from urban zones, with the sheer scale emphasising a fragmented industrial area juxtaposed next to sensitive tidal water/mud flat areas.

**Bremerhaven / Nordenham**

- A juxtaposition of differing industrial logics: Nordenham focuses on metals, aerospace and cable production, while Bremerhaven leans toward logistics, container and food/ fish industries.
- Both sites reveal a pattern where industrial areas are demarcated from settlements through natural and infrastructural buffers.

**Bremen**

- Has multi-industrial uses: steel, car manufacturing, aerospace and food production coexist.
- Unlike the other, mostly segregated clusters, the industrial sites in Bremen are frequently embedded within the urban fabric, although they are still characterised by infrastructural separations that fragment certain areas.

8.46 Spatialised Conclusions of the Systemic Synthesis ►


Bremen

→ Infrastructural Logic

## Infrastructure binds and breaks

Infrastructure enables industrial scale and global connectivity, but it comes at a spatial cost. Railways, highways, energy lines and large ports often cut through urban and ecological fabrics, creating hard edges and mono-functional zones. These systems connect the clusters outward, while disconnecting them inward from their local surroundings.


Bremerhaven

→ Ecological Logic

## Overwriting Nature

Industrial development layers itself onto fragile ecological landscapes, often overwriting them. Dikes, polders, tidal zones and drainage logics are reconfigured or erased to meet technical demands. Even wind parks, though symbolising transition, become spatial intrusions when layered without regard for existing ecologies.


Delfzijl

→ Typological Logic

## Planned and Patchworked

The clusters reflect diverging spatial DNA, from purpose-built industrial zones to layered, evolving typologies. Some were planned as single-industry hubs, and are still often dominated by one big 'player'; others grew messily through historical layering. This variation reveals distinct local logics and calls for tailored strategies grounded in morphology and memory.

# Proje

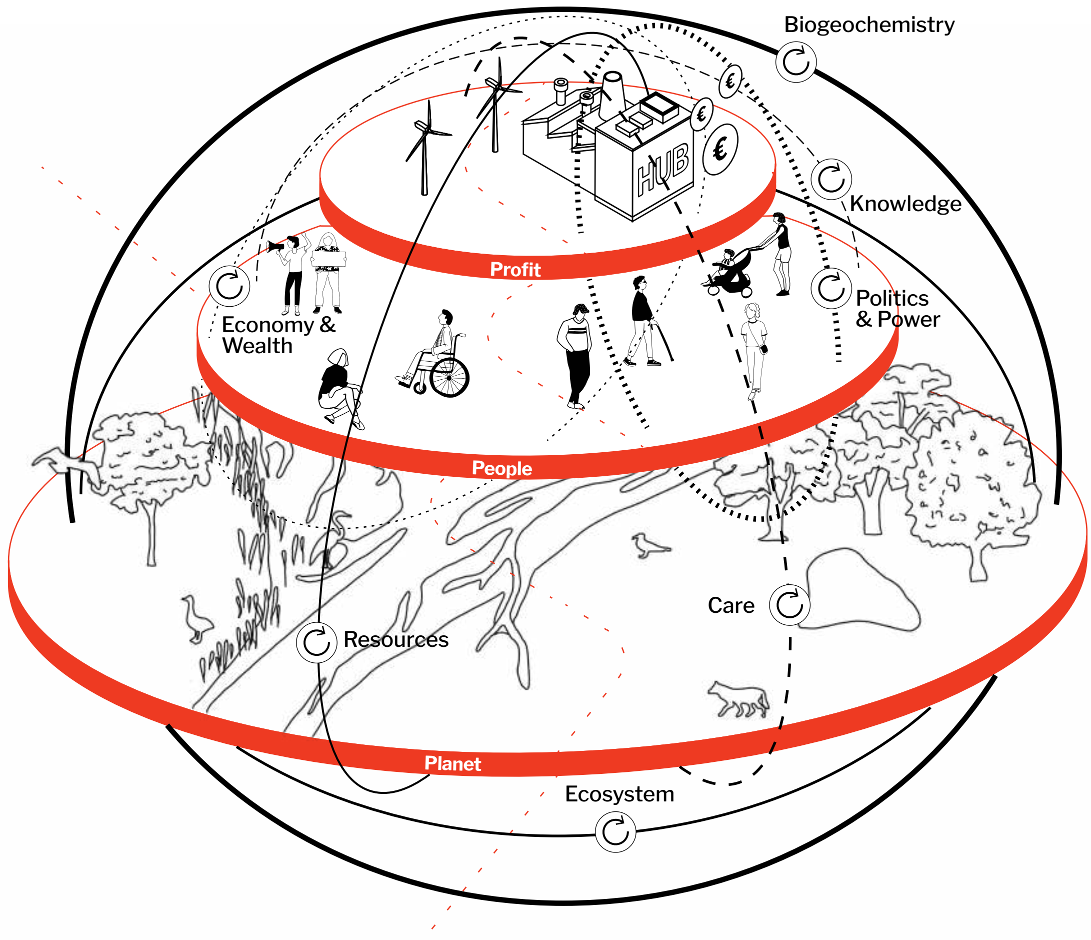
# ction

9

# Vision

# A Circular Cross-Border Metabolism

## Vision for Strong Sustainability and Spatial Circularity in the Wadden Sea Region

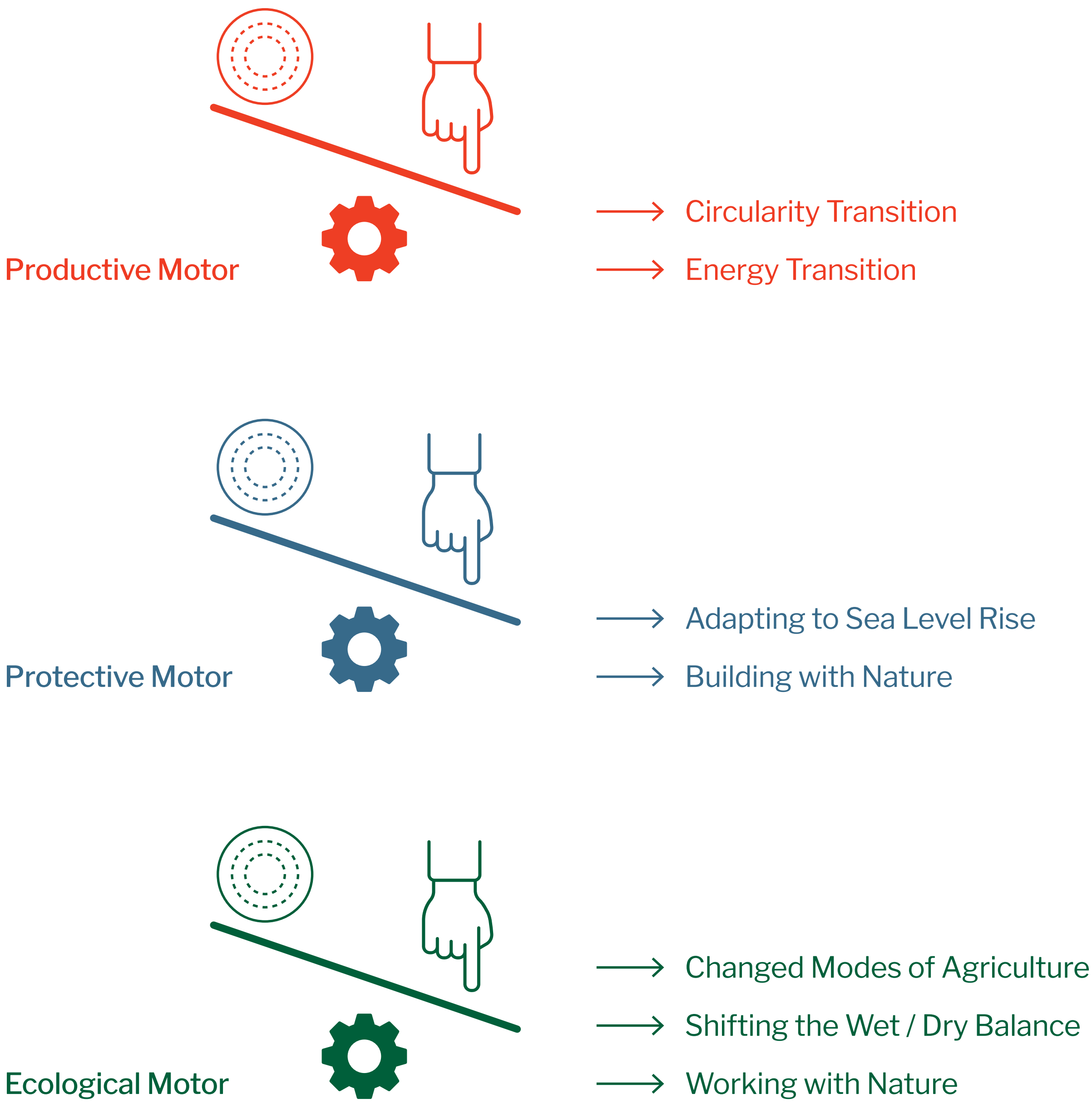



9.1 Representation of the Vision

> *Geographically, we literally face the same challenges on both sides of the border.*
>
> I-1, Sustainability Officer (NL)

To realise the overarching aim of this thesis, a sustainable, circular industrial system spanning both sides of the Wadden Sea region, this vision builds on the principle of strong sustainability, coupled with a broadened understanding of circularity as introduced by Calisto Friant et al. (2024). As can be seen in Fig. 9.1, the biosphere is not a resource but a non-substitutable foundation, and circularity extends beyond materials into care, knowledge, power and ecosystems. Achieving this vision requires entangled and balanced actions: restoring planetary health, empowering people, and rethinking profit as a means rather than an end, all across borders and sectors.

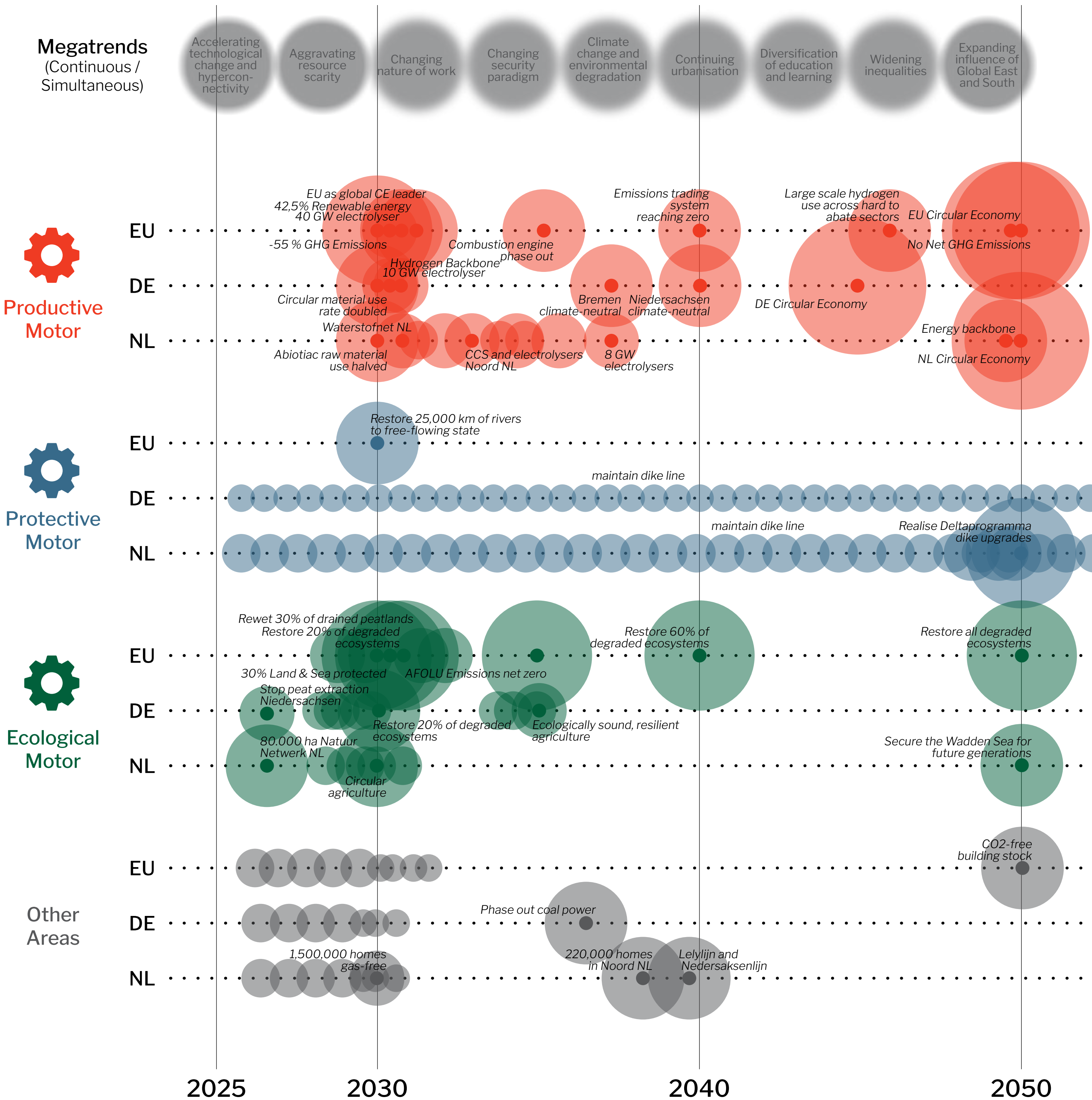
Shifting the Wadden Sea region towards this sustainable circularity requires activating leverage points within the three systemic motors defined in Chapter 8. Each motor (productive, protective, and ecological, Fig. 9.2) offers targeted interventions: from energy and material transitions to adaptive infrastructures and ecological land-use shifts. These levers aim to redirect flows, spatial logics and institutional norms deeply embedded in the current system. When aligned, they unlock a regenerative transformation that strengthens territorial robustness and coherence across this cross-border industrial landscape.



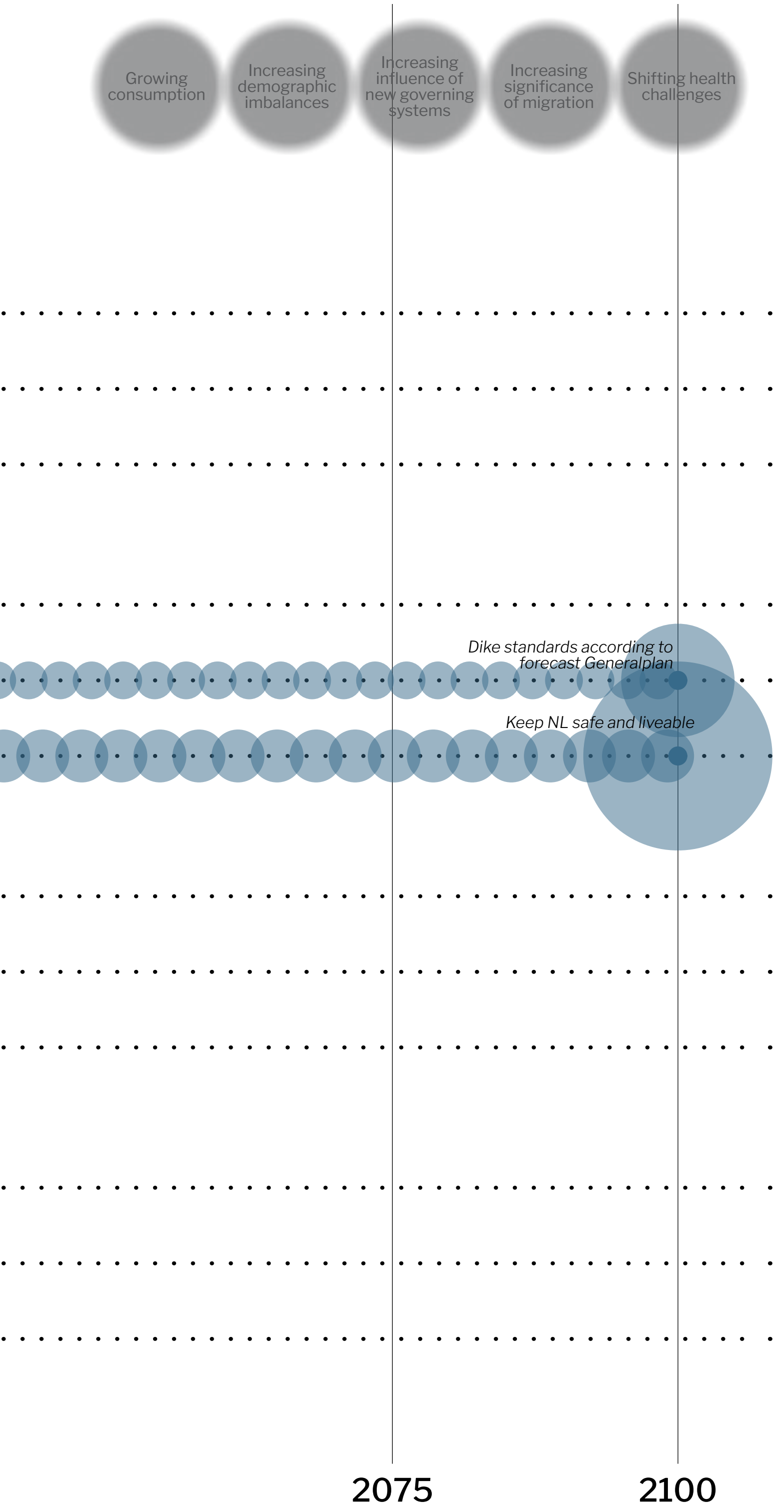

9.2 Leverage Points per Motor

# Where are we Heading Now?

## Existing Policies and Goals




9.3 Overview of Existing Policies and Megatrends




On both sides of the border, the Wadden Sea region sees bold sustainability targets, but so far, little happens in practice. Across scales, policymakers envision radical change (Fig. 9.3): the EU's Green Deal targets a 55% reduction in greenhouse gas emissions by 2030, a fully circular economy by 2050, and the restoration of 20% of degraded ecosystems within this decade. Germany and the Netherlands add national goals like climate neutrality (2045 and 2050), and sectoral strategies targeting for instance a circular agricultural sector.

Yet, most goals remain just that: goals. Only 6% of Dutch companies operate circularly (EEA, 2024b), German resource productivity lags its 1.5% annual growth target (EEA, 2024a), over 80% of EU marine protected areas are deemed ineffective (McVeigh, 2024) and the Netherlands Nature Network expansion is behind schedule (Michels, 2024).

Meanwhile, structural change looms on the horizon: The EU Joint Research Centre outlines 14 megatrends Centre (European Commission, 2024b), from demographic shifts and digitalisation to resource scarcity and intensifying climate risks, that will reshape the region beyond 2050. These trends demand not only urgent action, but a new kind of planning: long-term, cross-scale and spatially grounded.

Yet current policies rarely offer such a spatial foresight. Their fragmented goals lack the territorial strategy to deal with cumulative claims, interdependencies or system shocks. To make future ambitions spatially plausible, the next section translates the ambitions into space claims along the three systemic motors of the region.

***Perhaps the urgency just isn't high enough yet – which is why people avoid tough decisions.***

I-4, Business Representative (NL)

***Circular economy is undoubtedly the path to the future, but realisation is stalling.***

I-9, Environmental Officer (DE)

# Open Landscape vs Scarce Space

## Translation of Ambitions into Space Claims

The following pages explore the spatial demands of future transitions. Each motor – productive, protective, and ecological – comes with its own claims. Together, they form an overlapping landscape of competing needs in the Wadden Sea region.

### Productive Motor

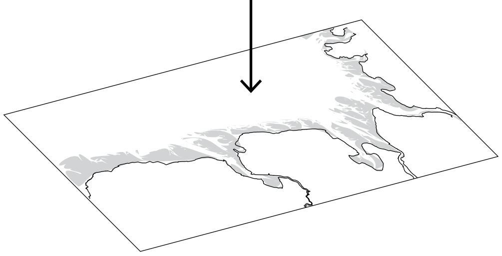
Energy Transition

### Space Claims: Energy Transition

The energy transition brings significant spatial demands: some quantifiable, others uncertain. Electricity and gas transport, renewable generation, storage and import terminals all claim space. The matrix in Fig. 9.4 functions as an option matrix, not as a prediction. For instance, large-scale hydrogen import may relieve pressure on local land, but hinges on uncertain geopolitical and infrastructural developments. What seems to be already clear: Northwest Europe will remain a net energy importer due to limited domestic potential and cheaper production costs in other regions. A hierarchy for a successful energy transition means to save as much energy as possible, then apply efficient electrification, then deploy hydrogen, where necessary, directly as an energy carrier, without first converting for transport/use and then deploy the remaining energy to produce energy-intensive products and hydrogen-based products (Deen & Jongsma, 2023, p. 30).

> ***Hydrogen requires more space than natural gas. We're talking about entirely different voids.***
>
> **I-7, Utility Planner (DE)**

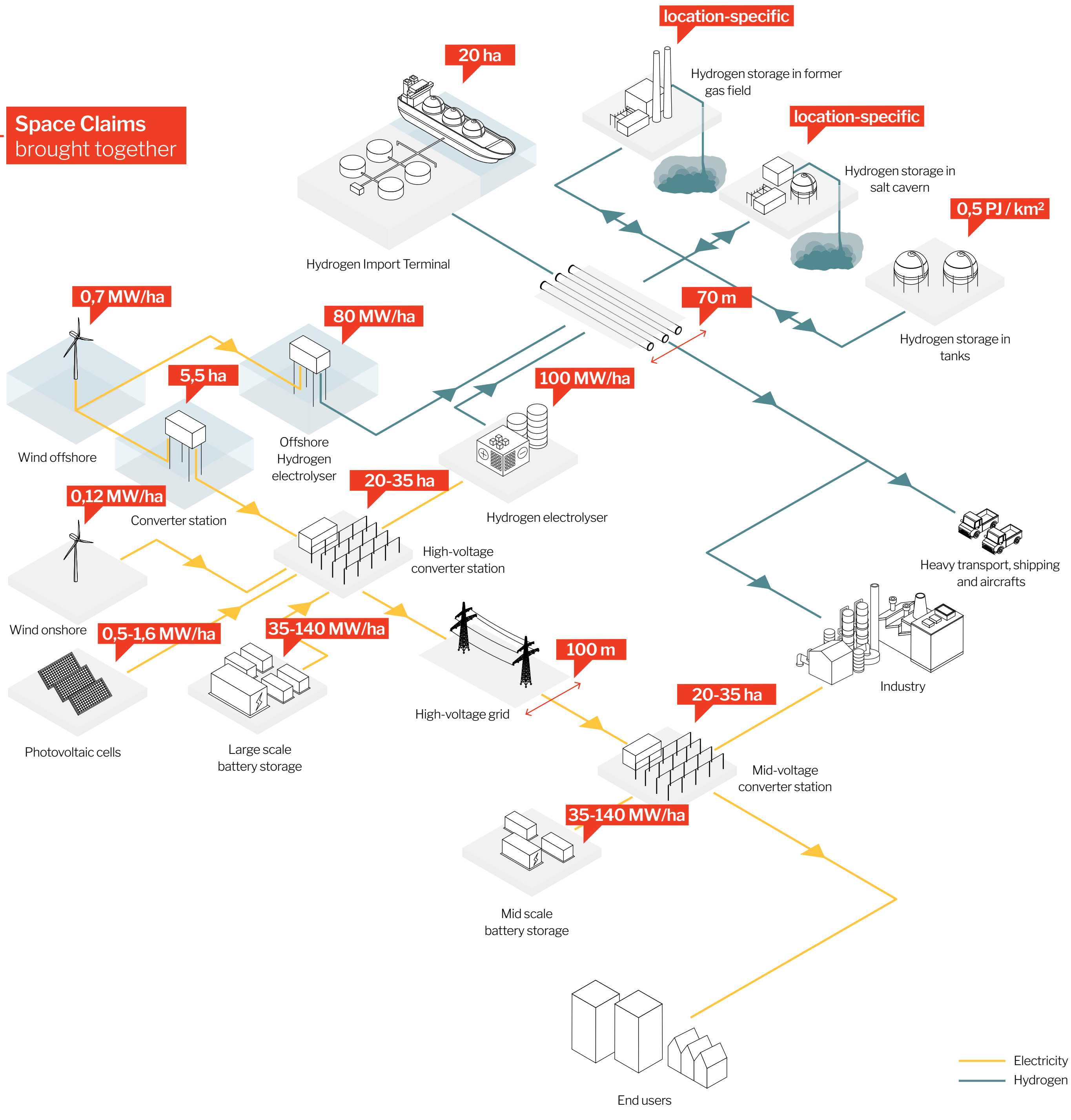
> ***The region must benefit from the energy transition and not just provide the infrastructure.***
>
> **I-5, Regional Planner (DE)**



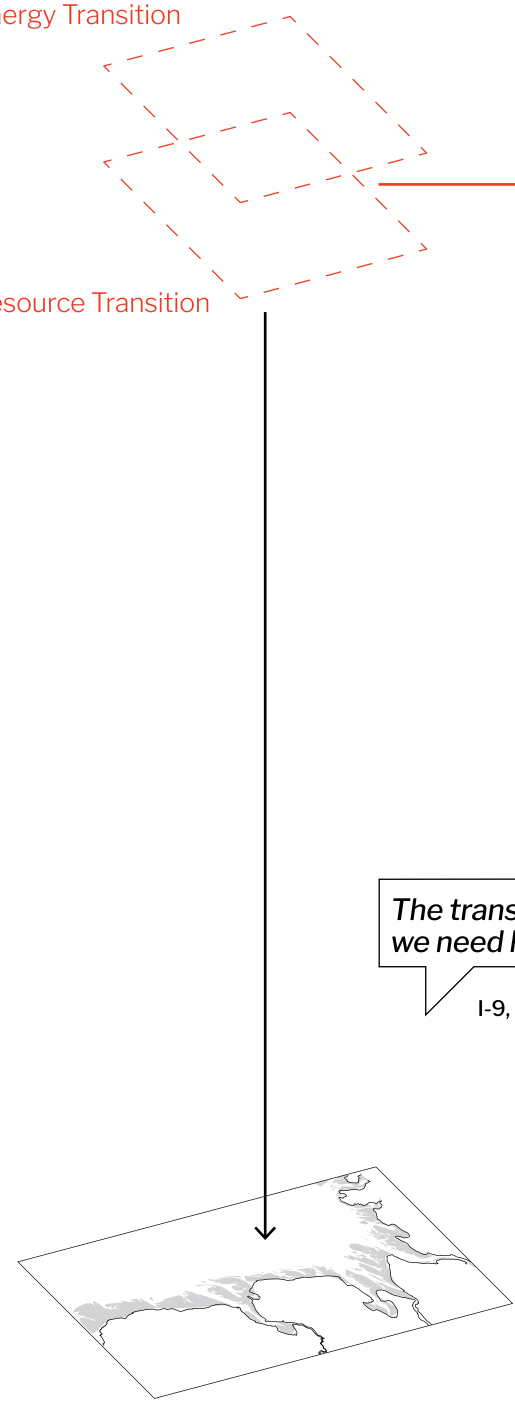
> ***Storage is the missing link.***
>
> **I-7, Utility Planner (DE)**

9.4 Matrix of spatial claims ▶

## **Space Claims** brought together



## Productive Motor




## Space Claims: Circularity Transition

The resource transition that leads to a circular economic model induces spatial demands: activities like repair, refurbishment and modular production require new zones, while declining fossil-based industries free up land (Deen & Jongsma, 2023). Yet, shifts, overlaps and site remediation are likely to cause temporarily increased spatial pressure. Different strategies are possible, ranging from reducing material consumption to reusing, substituting, localising and decarbonising production. This leads to great unsecurity about space demands, but in general, circular activities often need more room than linear predecessors, which leads to a projected demand ranging from current use up to 40% more (Rood & Evenhuis, 2023). Specialised areas for logistics, storage, and shared services will emerge, with buffer space essential for flexibility.

> *The transition unfolds in steps – which means we need lots of 'sliding space' over time*

I-9, Environmental Officer (DE)

> *The circular transition is now slowly translating into space demand as well.*

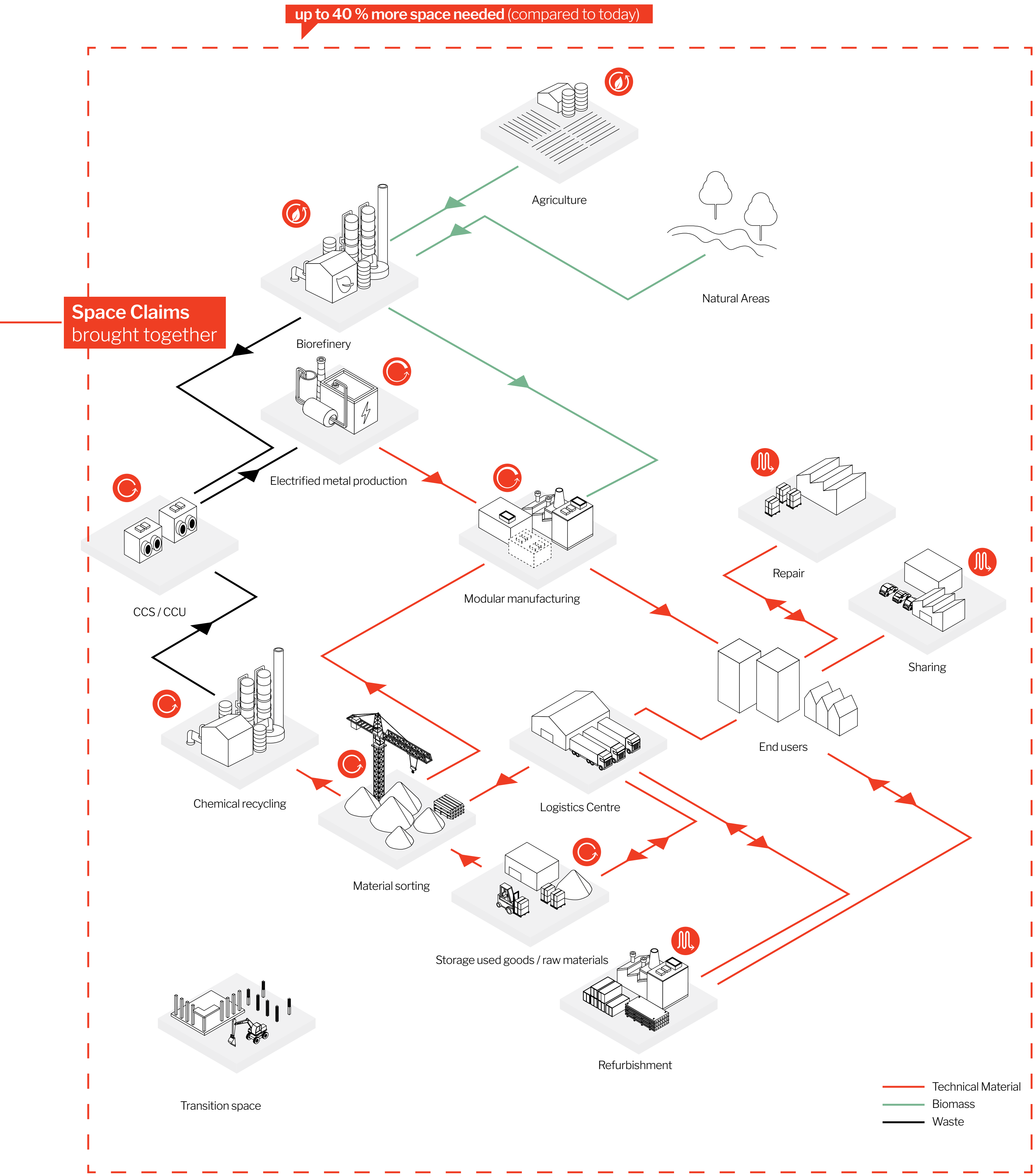
I-1, Sustainability Officer (NL)

> *CE often adds an extra production step – and spatially, that usually doesn't fit.*

I-1, Sustainability Officer (NL)

9.5 Matrix of spatial claims ▶

## Space Claims brought together



*If the area becomes too small, it can no longer deliver its ecosystem services.*

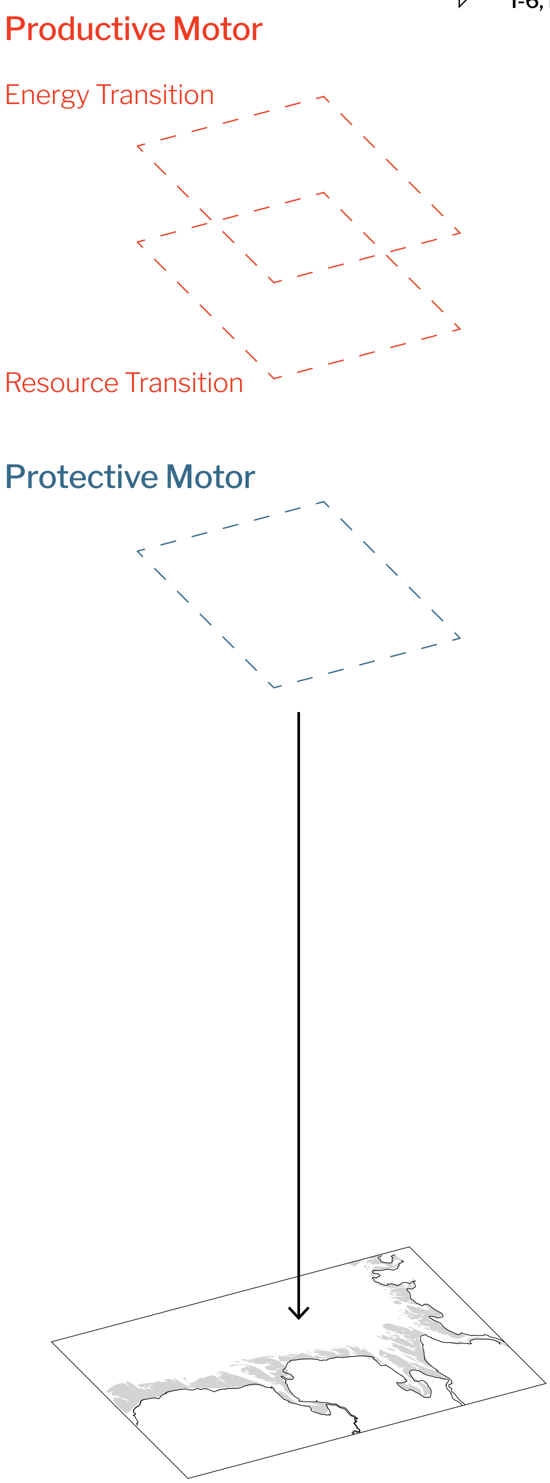
I-6, Environmental Officer (DE)

*Not all dike lines will be maintainable by the end of the century.*

I-6, Environmental Officer (DE)

*Soft summer dikes and retreat-based projects show alternatives.*

I-6, Environmental Officer (DE)

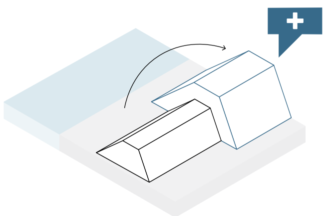



Sea level rise imposes growing spatial demands along the Wadden Sea coast. Projections vary, but recent insights suggest levels could rise beyond the earlier assumed range of 0.3–1 m by 2100, potentially reaching 2 m or more (IPCC, 2023, p. 18). This endangers the balance of tidal flats, marshes and islands, which are increasingly unable to adapt to rapid change. Hence, the sediment system may struggle to keep up, risking erosion and added pressure on dykes. Storm surges are likely to become more destructive. Deltares An option matrix building on the work of Deltares (2022, pp. 38–40) illustrates options to cope: hard protection, soft protection, retreat and accommodation. Each pathway comes with unique and often overlapping spatial claims, meaning keeping multiple adaptation routes open demands significantly more land than following one single course.

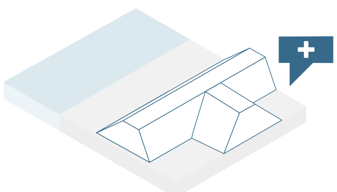
9.6 Matrix of spatial claims ▶

## Space Claims
brought together, by type of solution

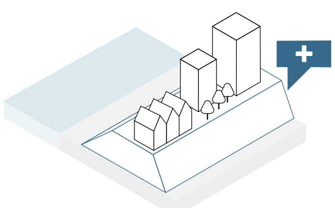
### Hard protection



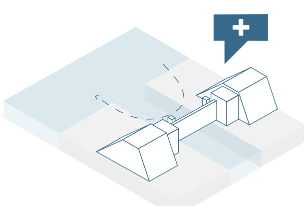
Raise dikes



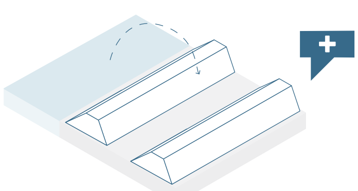
Compartmentalise



Mega Dike

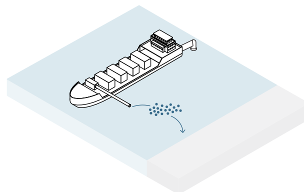


Storm Surge barrier

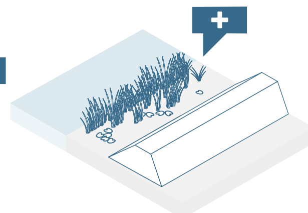


Double Dikes

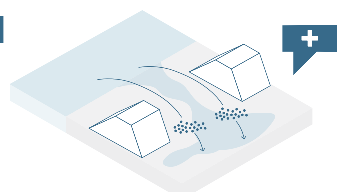
### Soft protection



Suppletion of the coast

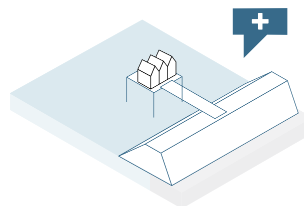


Extra vegetation on the shoreline

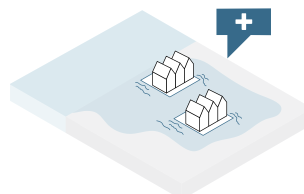


Raise land naturally

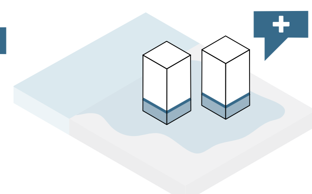
### Accomodation



Raised building

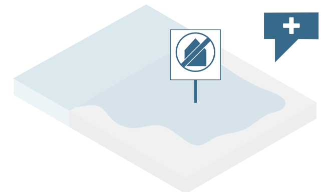


Floating building

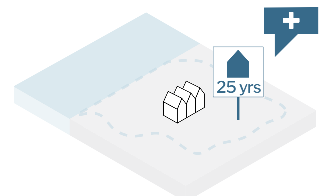


Flood-proof building

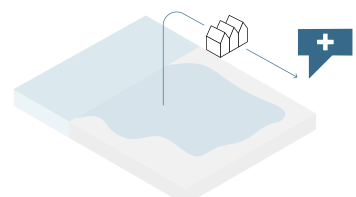
### Retreat



No-building zones

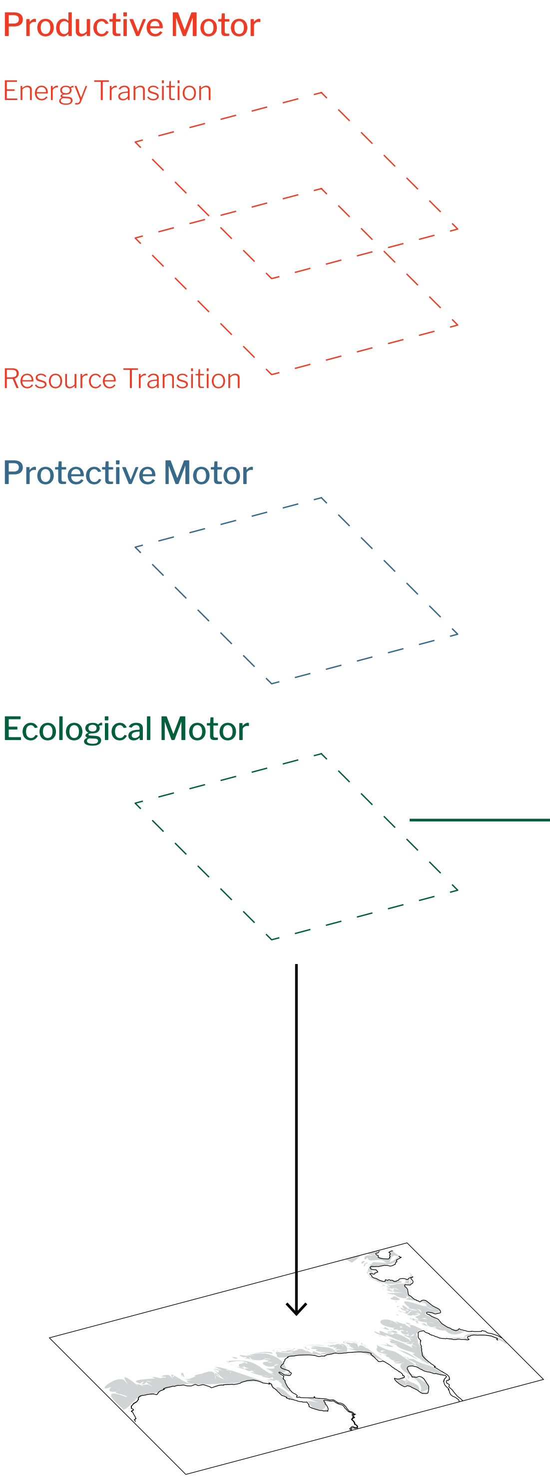



Temproal building zones



Translocate

+
not directly quantifiable, but more space needed compared to today




Transitions in the field of ecology bring new or added spatial claims. They are at least to a large part driven by EU and national policy: from strictly protected zones (e.g. the 30% EU goal) and rewetting projects to CAP-funded eco-schemes and carbon farming pilots. Other pressures include space for biobased crops, tidal and riverbed restoration. These ambitions often overlap or compete (e.g. biodiversity vs. Biomass or dynamic water systems vs. fixed land use). Although some targets exist (like Natuur Netwerk Nederland), the total space demand remains hard to quantify, especially given the fragmented nature of the interventions and the layered expectations of agriculture, nature protection and climate policy.

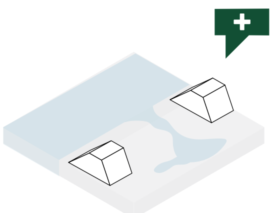
> *Region-wide rewettability is not realistic due to relief and hydrology, which shows the spatial constraints for ecological adaptation*

I-5, Regional Planner (DE)

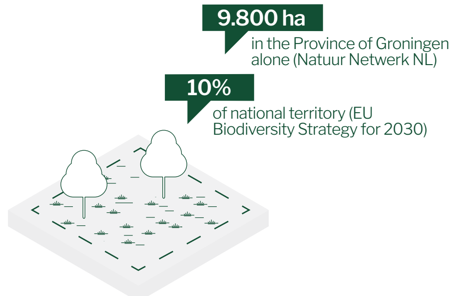
> *The Wadden Sea is an open system, a stepping stone: This makes it the foundation for biodiversity and eventually human life*

I-6, Environmental Officer (DE)

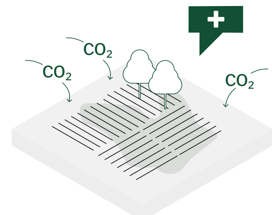
9.7 Matrix of spatial claims ►



Tidal restoration projects

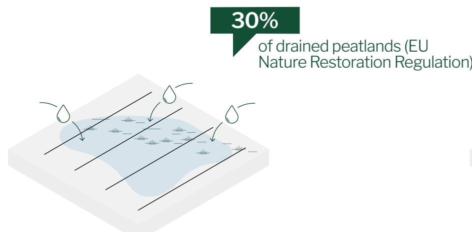



Designation of additional strictly prohibited zones

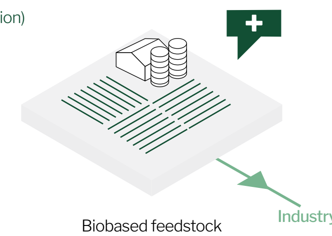



Carbon storage agriculture pilots


Riverbed and floodplain restoration

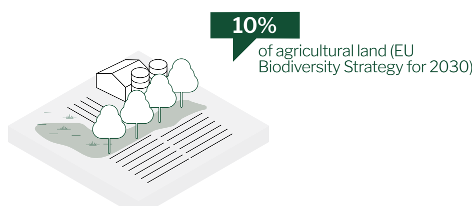



Rewetting of drained peatlands



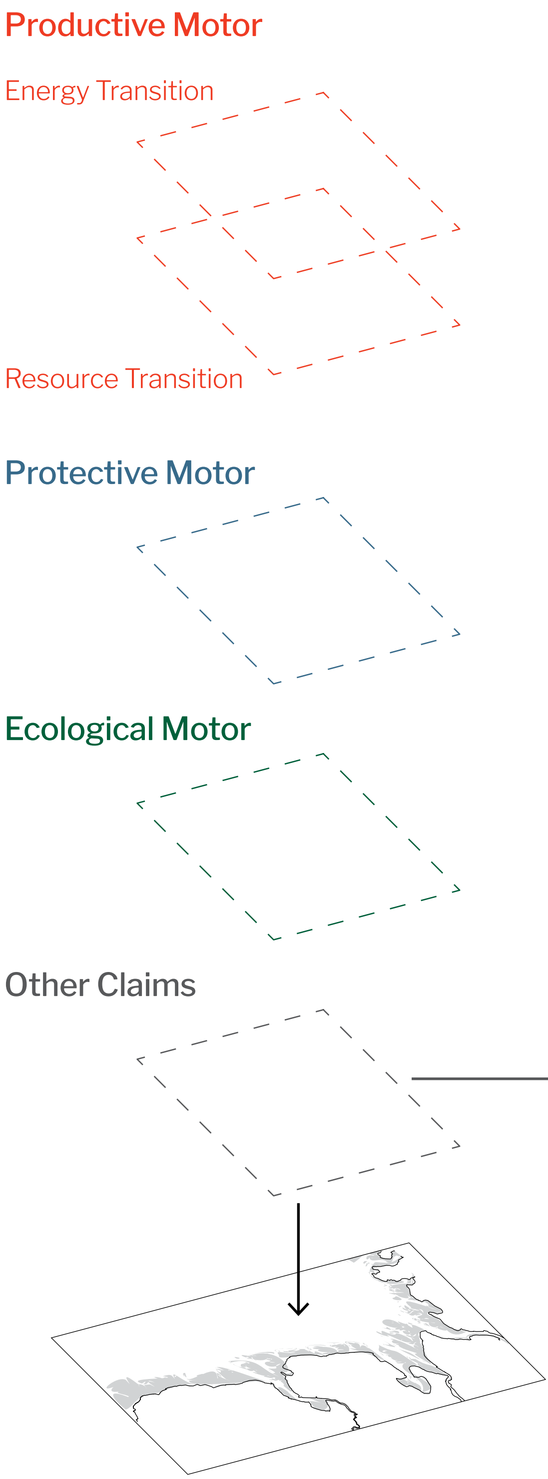

Biobased feedstock

## **Space Claims** brought together




Land for eco-schemes and CAP subsidies

+ not directly quantifiable, but more space needed compared to today




Besides the mentioned transitions, other sectors also claim an increasing amount of space. Military activity is intensifying in the light of geopolitical tensions: in Wilhelmshaven, an expansion of the naval base of 34 hectares is underway (NDR, 2024) while, Eemshaven is set to become a critical military logistics hub for NATO operations. Large parts of the port are being transformed into secured zones for material transfer, training, and deployment, displacing other functions (Dekker, 2025). This overlaps with civil infrastructure, like undersea cables and LNG terminals, increasing spatial tension.

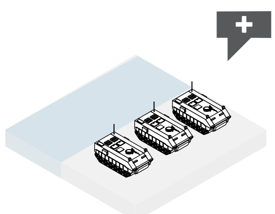
Tourism is another key player: the East Frisian North Sea coast is Lower Saxony's main tourist destination (Mehnen et al., 2023) with the Wadden Sea's ecological value both attracting and suffering from visitor pressure. This significance of the region partly leads to overtourism (Hartman et al., 2022).

Lastly, digitalisation adds demands through hyperscale data centres. AI applications, increasing data traffic and the rise of cloud services require large, energy-intensive facilities. Their spatial footprint is expected to quintuple, with many looking to coastal or port zones with good grid connections, up until now especially in the Dutch part of the Wadden Sea region (Neyt, 2024; BMWK, 2025).

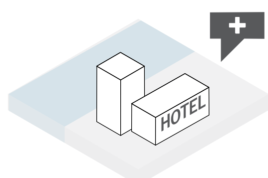
> *There is a strong competition for space: spatial claims are stacked and we see many simultaneous usage requirements (such as logistics, the energy transition, defence, circular economy)*

I-1, Sustainability Officer (NL)

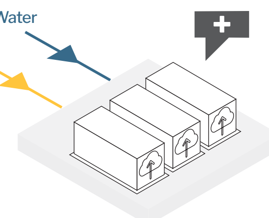
9.8 Matrix of spatial claims ►



Military logistics area



Tourism facilities




Carbon storage agriculture pilots

**Space Claims**
brought together

+
not directly quantifiable, but more space needed compared to today

# From Vision to Collision

## Conclusion of the Ambitions and Relating Space Claims

The Wadden Sea region is running out of space. What seems open or underused from a distance is, in fact, saturated with overlapping and often incompatible spatial claims. Energy, industry, ecological restoration, defence, tourism and digital infrastructure all demand access to the same coastal land. These demands are strongly driven by political ambitions, but their spatial consequences clash. In short: there is not enough space for everything .

> *Every issue comes with a spatial claim.*
>
> I-4, Sustainability Officer (NL)

This spatial tension is further intensified by deep uncertainty and risks that come on top of it. The European Commission identifies ten major risk clusters (Muench et al., 2024, Fig. 9.9), including geopolitical instability, environmental breakdown and technological disruption, that could fundamentally alter Europe's future. These risks are not abstract: each one could derail current ambitions or drastically change spatial needs. Sea level rise may transform coastlines, political shifts may delay transitions. This means that pathways into the future cannot be assumed to stay on track.

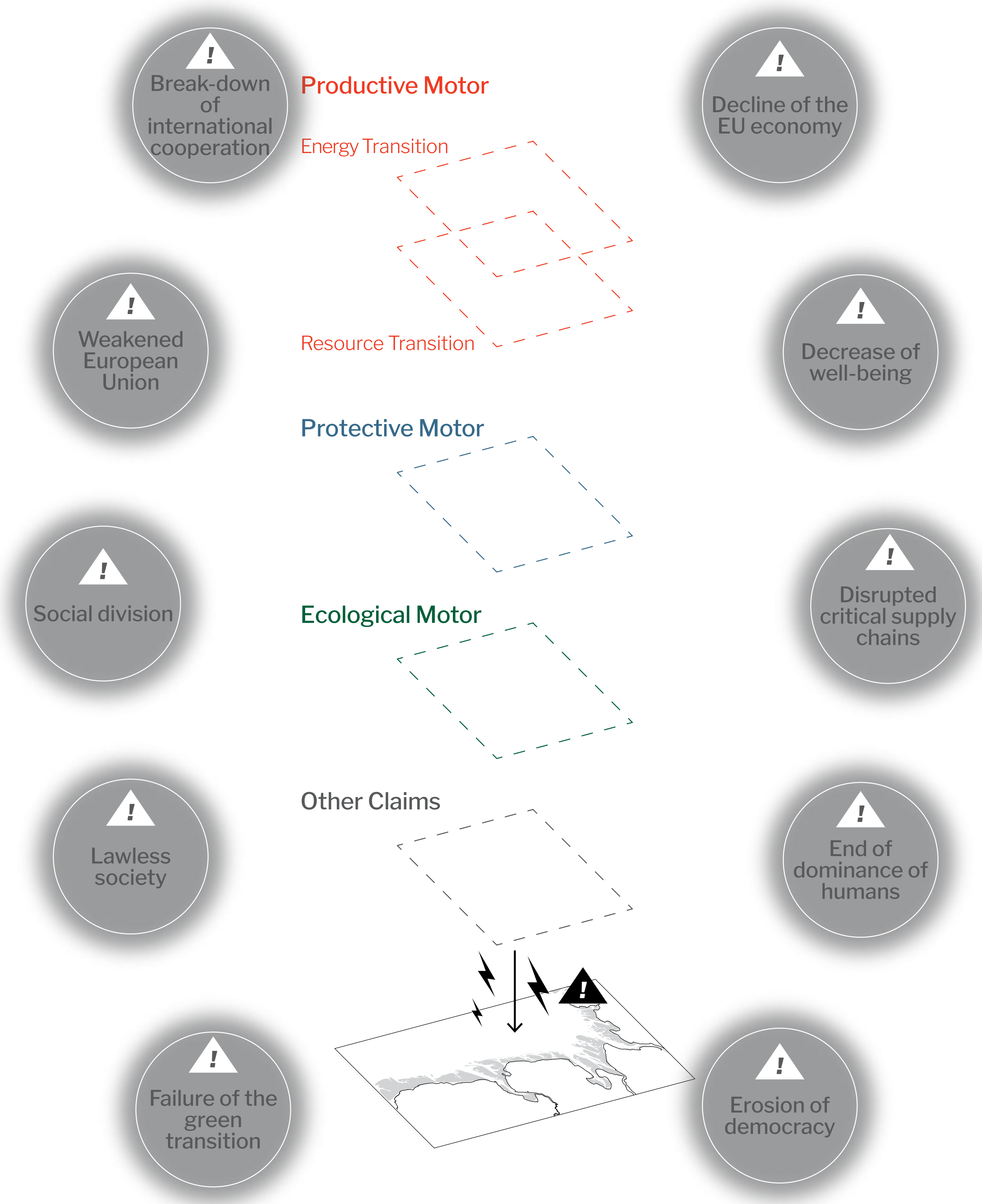
> *Crises can also be productive, as they open time windows for decisions.*
>
> I-5, Regional Planner (DE)

The underlying problem here is not just conflict about space, but a lack of capacity. Current planning remains sectoral and short-sighted (I-5, 2025), which makes it ill-equipped to deal with systemic overlaps and cascading uncertainties. There is no shared method to compare space claims and no tool yet to reconcile incompatible futures. This mismatch between the scale of change and the shortcomings of current approaches defines the urgency of this moment.

### ⟶ It does not fit: time to diverge

As a result, a new approach is needed, that does not pretend certainty, but embraces the likely divergence. Scenarios offer this alternative, because they are a way to explore multiple, plausible futures that reflect both ambitions and risks. They do not eliminate the uncertainty, but help to navigate it with structure and imagination.

9.9 Overview of Clashing Space Claims and Risks until 2100 ►


Break-down of international cooperation
Productive Motor
Energy Transition
Resource Transition
Decline of the EU economy
Weakened European Union
Decrease of well-being
Protective Motor
Social division
Disrupted critical supply chains
Ecological Motor
Lawless society
Other Claims
End of dominance of humans
Failure of the green transition
Erosion of democracy

10

—

# Scenarios

# Framing Different Futures

## Scenario Development

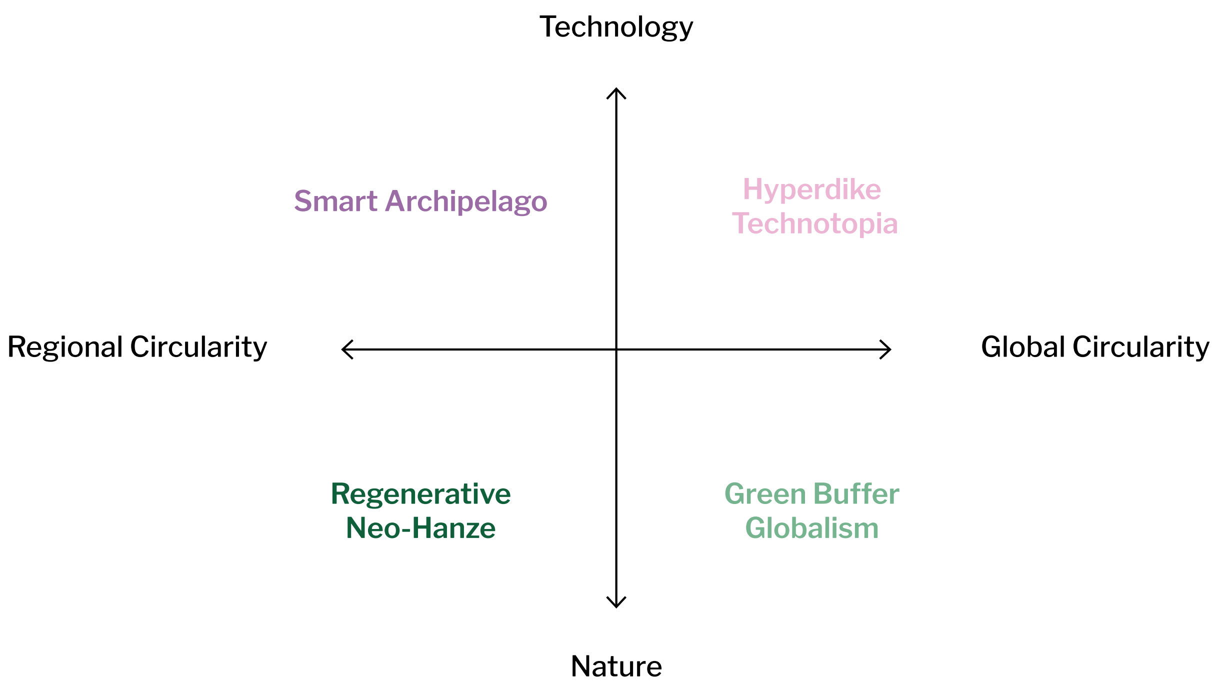
The future cannot be predicted, but it can be imagined and prepared for. Scenarios are not forecasts, but tools to navigate deep uncertainty, complexity and disruption. As discussed in Chapter 4, they allow policymakers, designers and researchers to explore alternative pathways, weigh trade-offs and test assumptions. In a moment of clashing space claims and mounting risks, this chapter introduces four contrasting futures for the region towards 2100, not as prescriptive visions, but as strategic instruments for reflection and orientation.

Regional Circularity ⟷ Global Circularity

This axis reflects tensions between globalised circular economies and locally anchored, place-based ones. As discussed before, large-scale industrial strategies in the Wadden Sea region often follow global logics . By stretching this axis, I can test how different scales of circularity reshape flows, infrastructure and territorial relations in this landscape. The tension between these two poles has recently become a timely issue: It is now a fundamental question whether chaos and protectionism replace the era of free trade and multilateralism, leading to a new world order (Brown 2025).

Nature Based Solutions ⟷ Technology Based Solutions

The second axis contrasts two opposing approaches to resilience: one rooted in ecological processes and the other in technological infrastructures. This opposition is not abstract, but grounded in the spatial and historical reality of a region that is shaped by both environmental vulnerability and technical interventions. This axis allows me to explore whether future resilience might stem from restoring natural cycles or building on current and potentially even inventing new infrastructures that drive the three motors in the region.




These scenarios are not meant to predict what will happen, but to make visible what could happen and accordingly what choices would shape those outcomes. They help to clarify long-term consequences, confront deep uncertainty and uncover leverage points for transformation. The PPPP model by Dunne and Raby (2013; fig. 3.14) provides a conceptual basis for this exercise. By distinguishing between probable, plausible, possible and preferable futures, it expands the scope of what can be imagined. Scenario building thus becomes a means of articulating preferable futures in a moment that is defined by the mismatch between spatial conflicts and systemic risk on one hand and institutional capacity on the other.

The matrix on the right visualises how each of the four scenarios makes use of different strategies to move towards circularity and to transform the three motors of the region: production, protection, and ecology. For the productive motor, six strategies are considered: refusing material consumption, reuse and repair, substitution with renewable resources, sustainable industrial processes, relocalisation, and the export of green energy. These stem from strategies developed by PBL to investigate spatial impacts of circularity (Rood & Evenhuis, 2023, p. 5). For the protective motor, building blocks compiled by Deltares (2022, pp. 38-40) to address sea-level rise are used: hard protection, soft protection, retreat and accommodation. The ecological motor builds on speculative approaches tailored to the landscape of the Wadden Sea region: rewetting, wet or extensive farming; enabling tidal dynamics and coastal wilderness, pixel farming, spatial stacking and high-tech ecosystems. The individual mix of strategies per scenario was the starting point to develop spatialised aspects of circularity in the region.

Strategy choice per scenario ►

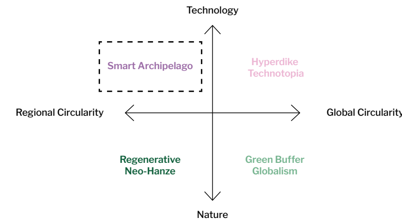
| | |
|---|---|
| ++ | Strong commitment to strategy |
| + | Commitment to strategy |
| o | Neutral / no commitment |
| - | Rejection of strategy |
| -- | Strong rejection to strategy |

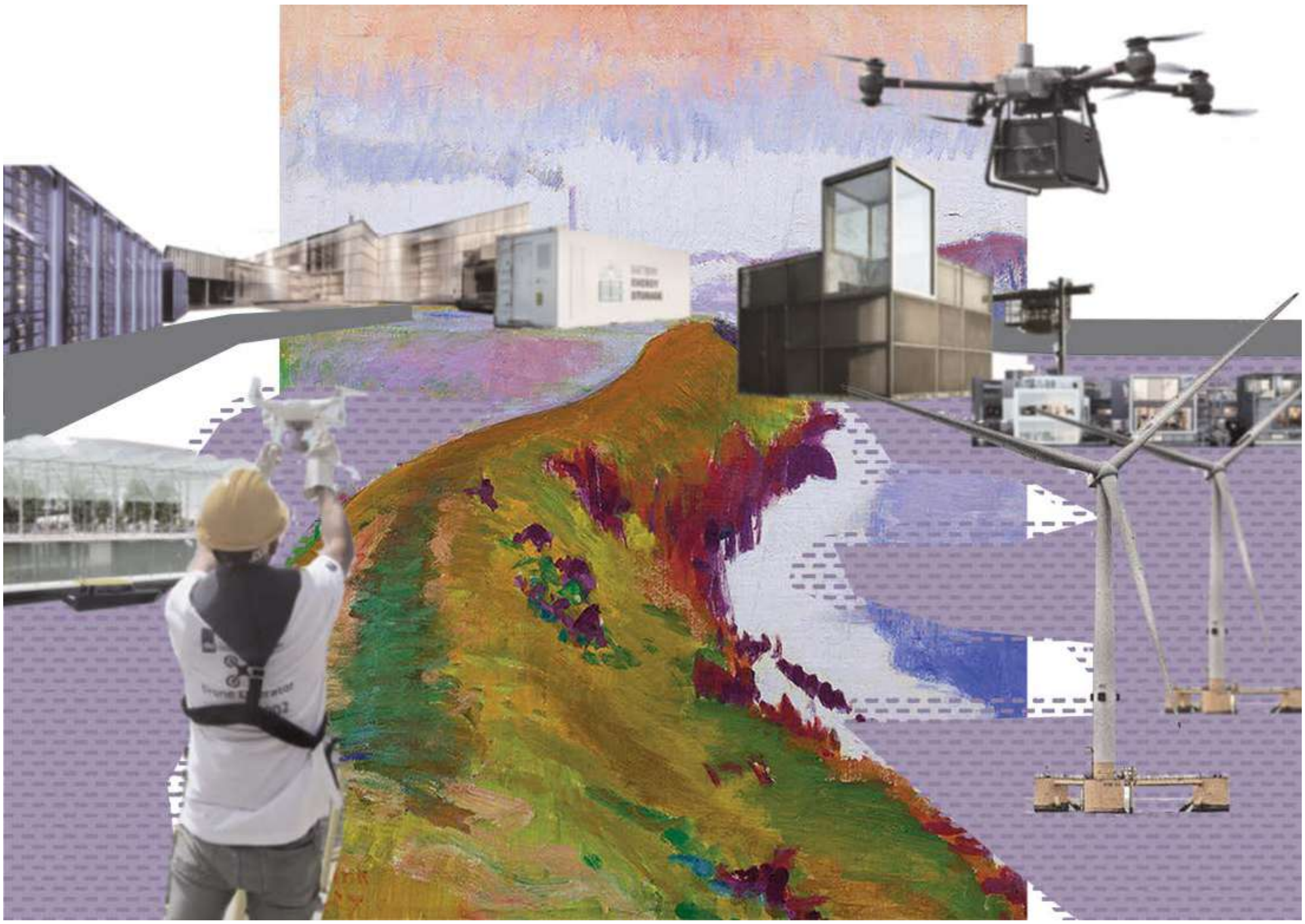
The following pages present the four different scenario passports: each one begins with combining a collage and short description, which explains the possible future. The functioning of the three motors is visualised with text and images. Spatial tiles, based on the system elements introduced in the Inventarisation in Chapter 8, show how these changes could then manifest in space. Finally, a sketched map synthesises all elements and reveals how the spatial organisational principles of each scenario might look like. The shared legend on the right helps to navigate and compare the sketch maps.

| | Smart Archipelago | Hyperdike Technotopia | Regenerative Neo-Hanze | Green Buffer Globalism |
|---|---|---|---|---|
| **Productive Motor** | | | | |
| Less consumption of material goods (refuse) | o | -- | ++ | o |
| Reuse and repair | ++ | o | + | + |
| Substitution with renewable raw materials | + | ++ | o | ++ |
| Sustainable industrial production processes | o | ++ | - | + |
| Lower scale of circles and activities | ++ | -- | ++ | - |
| Reduce fossil and linear activities | ++ | ++ | ++ | ++ |
| Export of green energy as a main business activity | - | ++ | -- | + |
| **Protective Motor** | | | | |
| Hard protection | + | ++ | -- | o |
| Soft protection | o | - | + | ++ |
| Retreat | + | -- | ++ | o |
| Accomodation | ++ | o | ++ | + |
| **Ecological Motor** | | | | |
| Re-Wetting | o | - | ++ | + |
| Wet and/or extensive agriculture | o | + | + | ++ |
| Room for tidal dynamics and nature | + | -- | ++ | + |
| Pixel farming, Stacking, Hightech | + | ++ | -- | o |

# Smart Archipelago

## Scenario Exploration



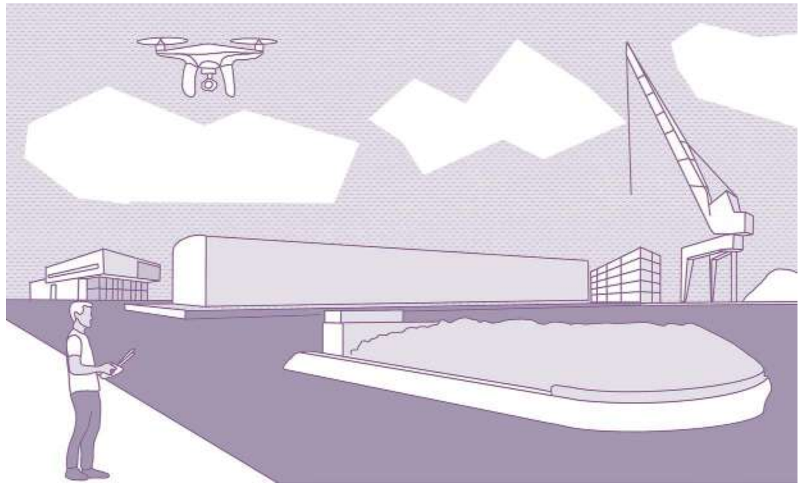



10.1 Scenario Encapsulation
10.2-4 Atmosphere of Each Motor ►

In this scenario, reliance on technology goes hand in hand with a fragmented, less globalised world order. Global structures of trust and cooperation have largely disappeared. Trade treaties are eroded or cancelled, as are many multilateral agreements. Power is concentrated closer to home: rather than in Brussels, The Hague or Berlin in regions that want to be able to manage themselves – technically and economically. The population is not growing, but ageing, so innovation is mainly in the service of efficiency, autonomy and 'smart solutions'. Global supply chains are being phased out and replaced by the closure of regional cycles.

## Productive Motor

A consequence of the changed world order is the decline in global trade flows and their replacement by a regionally anchored economy. Technology is no longer shared, but used strategically for regional autonomy. The same applies to energy: there is a rejection of performing a supply role for other regions, making the wealth of energy a strength of the Wadden Sea region. Yet, there is no spectacular growth, but commitment to stability. With less of imports, consumption must be covered regionally, which is done through recycling, upcycling and reuse. Port areas can partly be reused. There will be a regional market for bio-based materials.

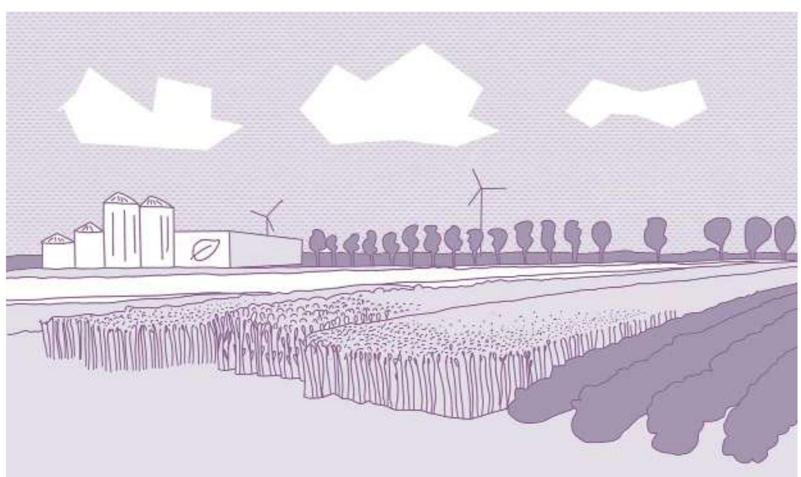


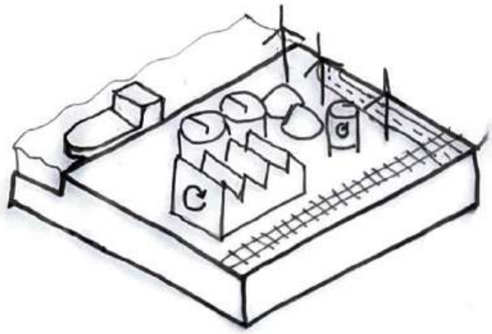
## Protective Motor

The current coastline is preserved, but protected in a technology-driven way. Instead of natural dynamics, a compartmentalisation technique is used: The dike landscape will be divided into sections that can be closed (or let in water) in a controlled way for protection and controlled sedimentation. Ring dykes will be constructed around the largest urban clusters along the coast. In addition, technological innovations such as floating housing areas, agricultural modules and infrastructure will be applied.

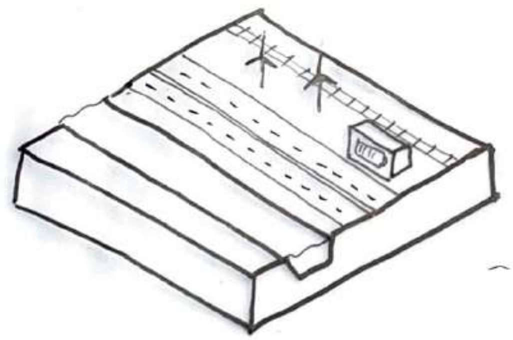
## Ecological Motor

The landscape is conditioned and technical. Natural areas remain, but are not expanded and strictly demarcated. Therefore, buffer zones or transition areas are only minimally present. The rural area beyond these protected islands is focused on technical efficiency in production. Regional demand for biobased materials, as the chemical industry needs to source feedstocks locally, requires a lot of space for growing (fibre) crops. This production of plants such as hemp, flax and algae takes place in high-efficiency plots around the industry on land and water. Food production remains, but is optimised by, for instance, vertical farming.

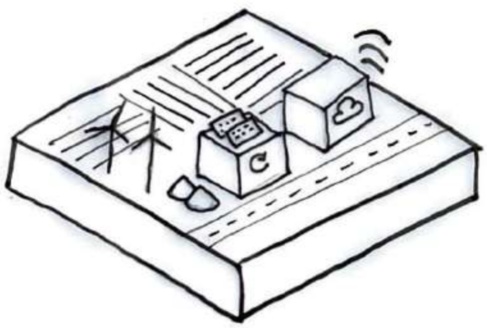




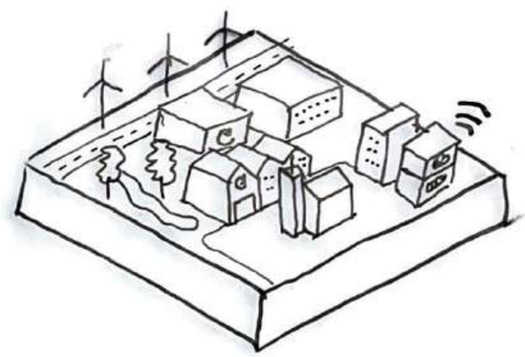
Large industrial clusters are transformed into circular hubs catering mainly for local needs in raw materials and goods. The port function is reduced.



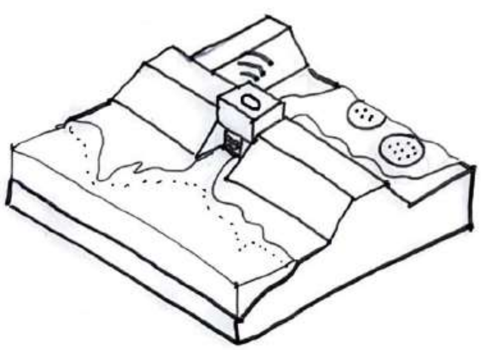
Infrastructure is not expanded further, except for elements that cater for local stability and autonomy, for example in energy supply.



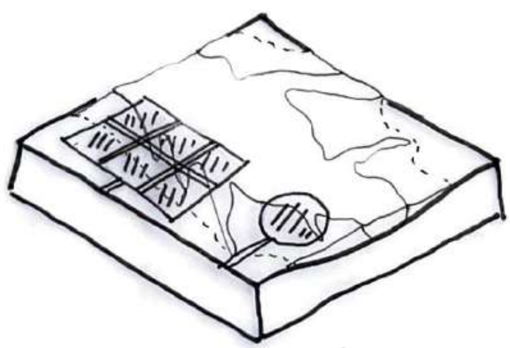
Small industrial locations turn into recycling centres. Smaller-scale data centres are added to cater for local needs, for instance due to increase in AI use.



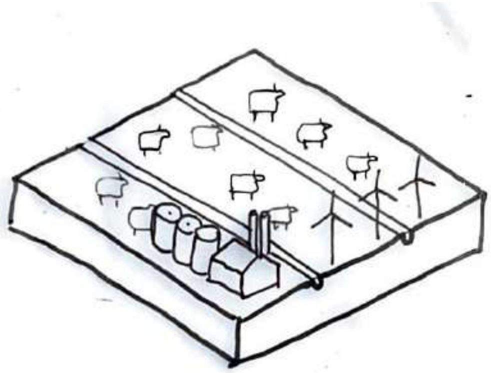
Urbanised areas turn circular by introducing small re-manufacturing and recycling facilities. Digital infrastructur is woven into settlements.



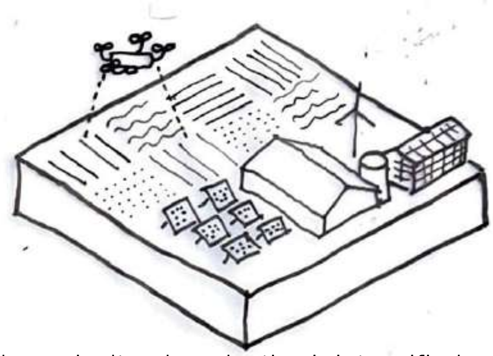
Compartmental dikes and 'smart' sluices are added to the dike system to create controlled buffer zones, where new agriculture is introduced as well.



The remaining Wadden Sea is used more productively with aquatic farms that produce crops like algae or seaweed.

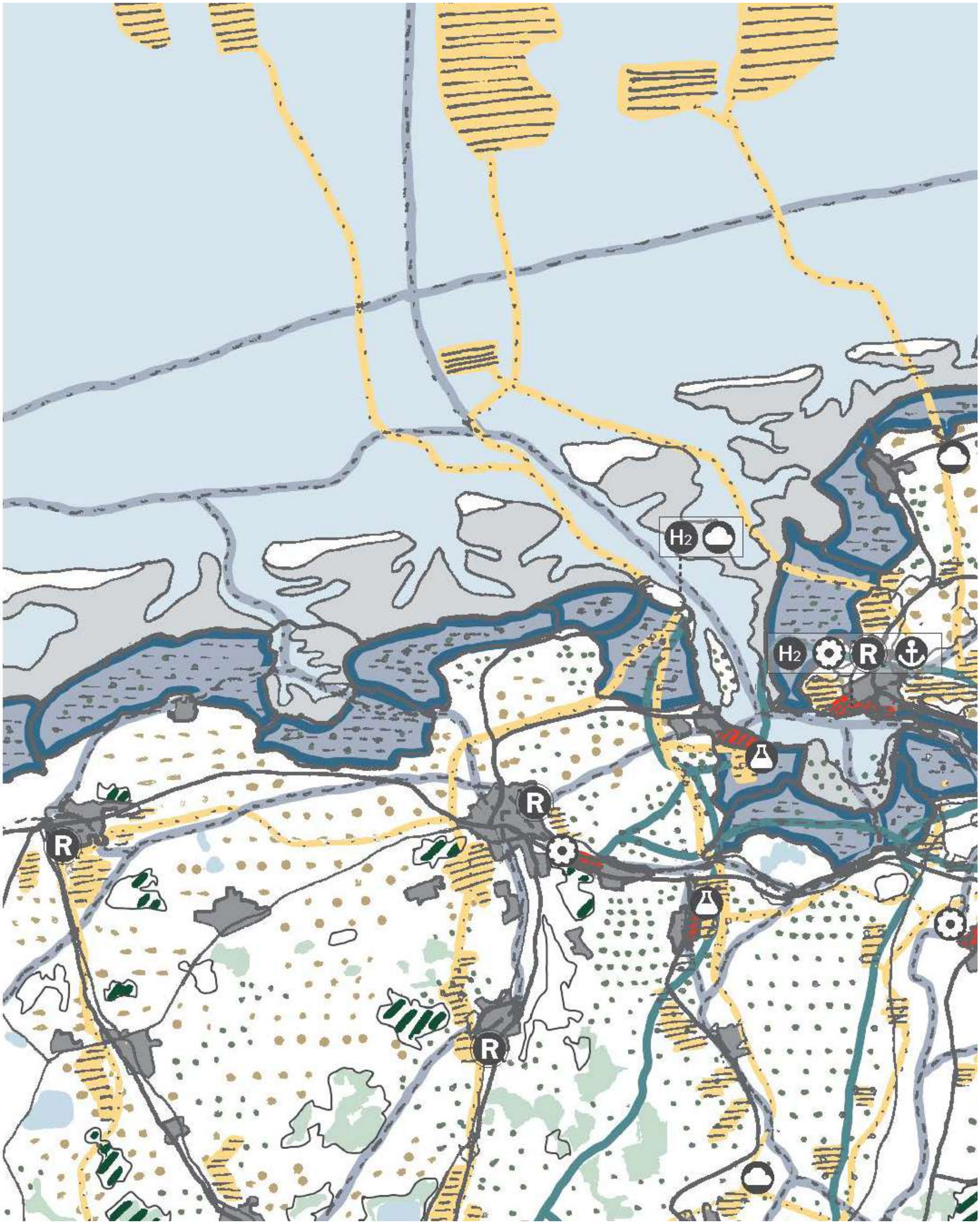


The marshlands remain to be in use for livestock farming, but this type of agriculture is intensified and employs more technology.



The agricultural production is intensified and uses more technology, to cater for growing needs in the biochemical industries and to enable autonomy.

10.5 Spatial Organisation of Scenario ►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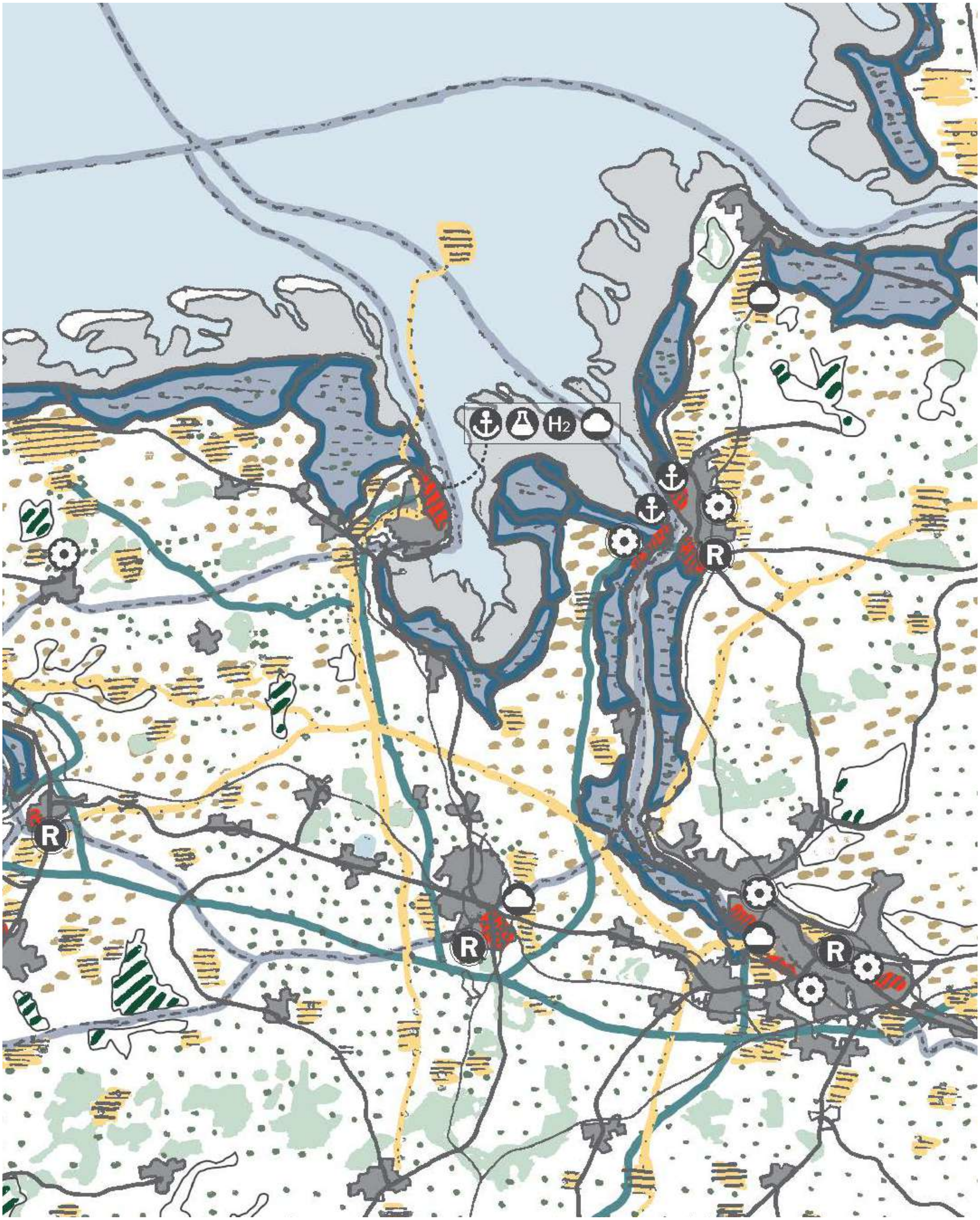
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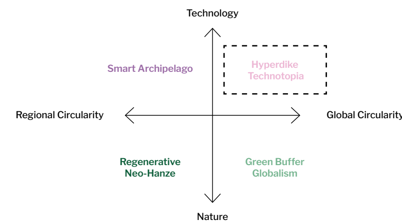
# Hyperdike Technotopia

## Scenario Exploration




10.6 Scenario Encapsulation
10.7-9 Atmosphere of Each Motor ►

Globalisation and economic acceleration dominate in this scenario. The world is completely transformed into a network of technologically controlled hubs. National borders blur; economic blocs dominate. The focus is on global efficiency and safeguarding resource flows. Technological innovations are leading in all sectors. Large-scale hubs compete globally; energy and data traffic are key commodities. To achieve Circularity, the focus is mainly on innovations, but little on social or behavioural change. By exploiting its future strategically beneficial location region becomes an energy factory and a kind of eco-techno laboratory for Europe.

## Productive Motor

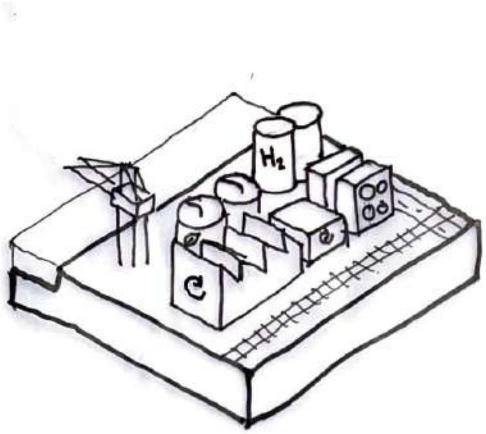
The sustainability transition is ‘green capitalist’: not focused on reduction but optimisation - with technology as the solution. As a result, digital infrastructure is dominant: AI, IoT, big data drive logistics, agriculture, energy and security. Its role as a manufacturing hub is growing, with export-oriented manufacturing (e.g. vehicles, green fuels, synthetic food). In addition to data centres, technological recycling is central: CCS/CCU, thermal processing, high-tech separation of waste streams. Infrastructure projects such as an HSL Amsterdam-Hamburg and a deep-sea port at Rottumerplaat link the region globally and dominate space.

## Protective Motor

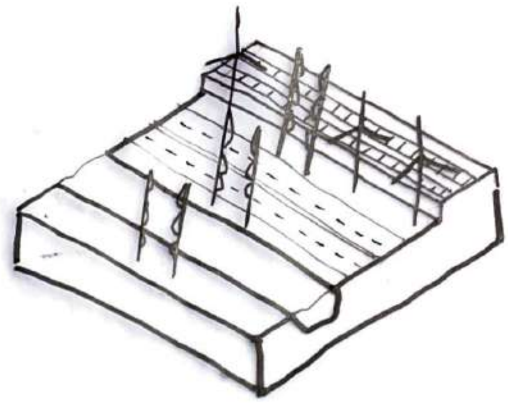
Climate change is not being ‘prevented’ but ‘managed’ through mega-projects. The response to climate change are Delta Works 3.0: The Wadden Islands are physically connected to form a contiguous barrier, the Wadden Sea becomes an artificially regulated inland lake with fresh-salt balance, controlled via locks and pumping systems. New locks at the Jade, Weser and Ems rivers control all water traffic, while Jade Weser Port, the port of Bremerhaven and a new port at Rottumerplaat become important nodes as a result. Eastwards, there will be a large-scale raising and widening of the existing dykes up to the Elbe.

## Ecological Motor

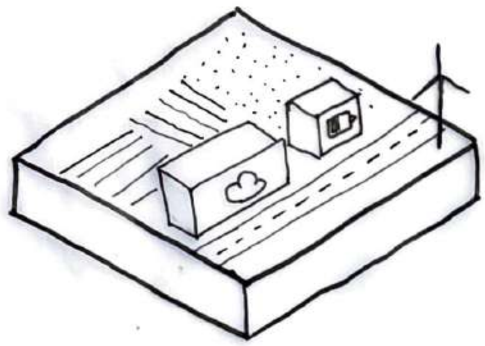
‘Wild’ nature has been reserved to and perfected in existing nature protection zones. Outside these reserves, the landscape is designed, functional, and monitored. The agricultural system with vertical farming for livestock and crops, hydroponics and drones for growth management is manifested as a type of pixel farming that is tailored to the market. Farmers act as data operators and agriculture is mostly outsourced to multinationals. Biomass is intensively extracted from cultivated forests or marine algae in controlled environments. Landscape logics follow infrastructure and data networks, not traditional natural systems.



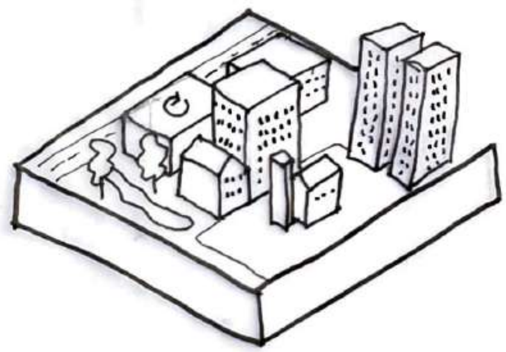

To keep up with the pace and needs of globalisation, production facilities in clusters are expanded. Hydrogen infrastructure and CCS/CCU are added.



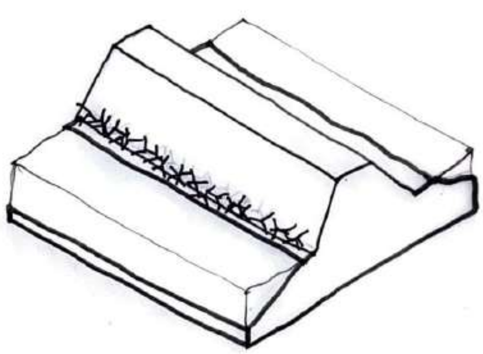
Infrastructure is upgraded and expanded further, for instance with added high-voltage power lines and a HSL Amsterdam - Scandinavia.



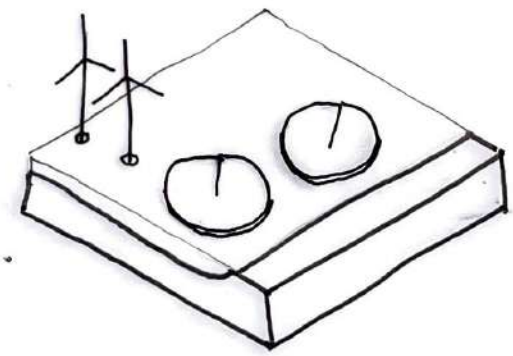
As circular production is concentrated in large clusters due to economies of scale, small locations are repurposed as data centres and battery storage.



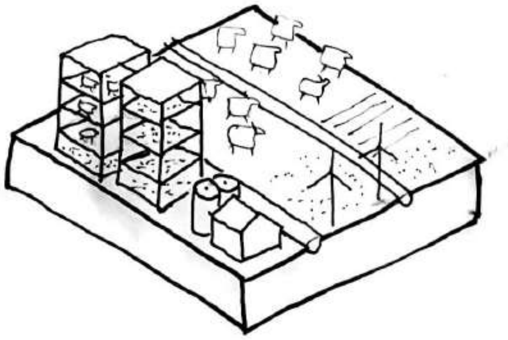
Large urbanised areas, especially around transport nodes, are densified further. While some circular functions are added, the tertiary sector prevails.



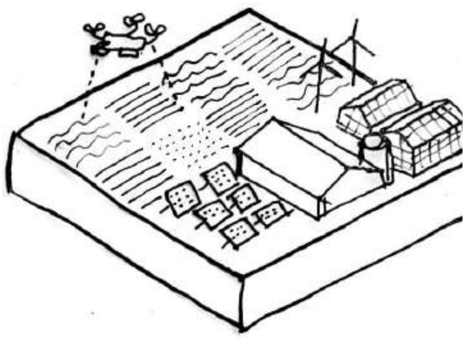
The dike line is replaced by a high-tech superdike structure that is positioned seawards, linking the Wadden Islands.



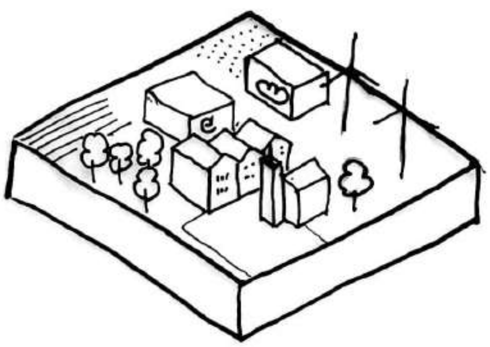
The Wadden Sea turns into a brackish lake, which is used for energy generation and floating agricultural structures.



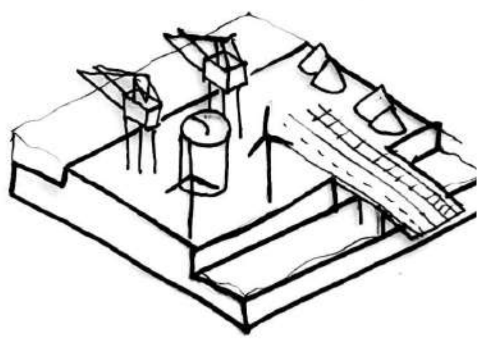
Livestock farming in the marshlands is massively scaled up, for example with vertical farms. This frees up space for biobased feedstock production.



The agricultural production is massively intensified and uses more technology, in line with export and biochemical feedstock needs.

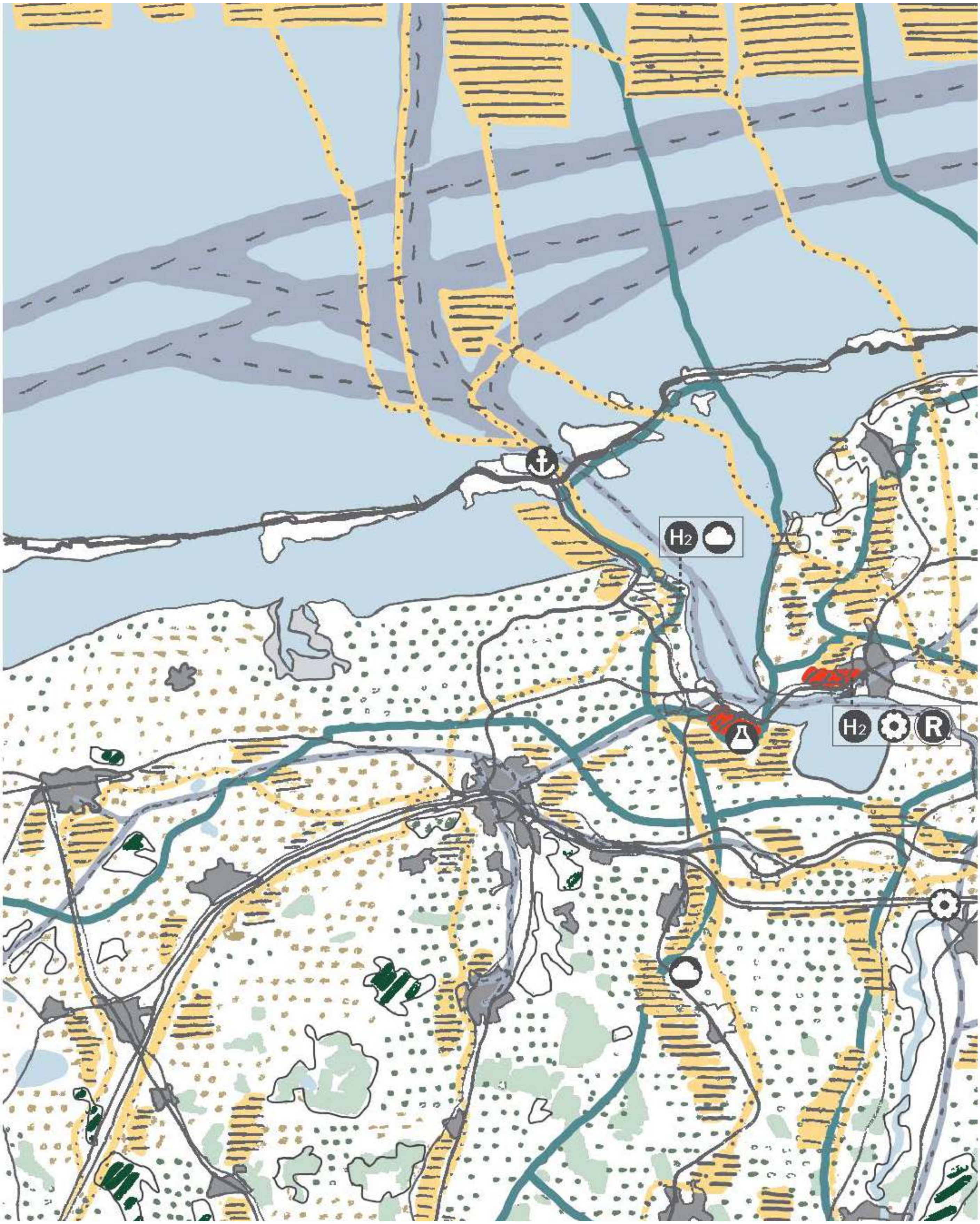


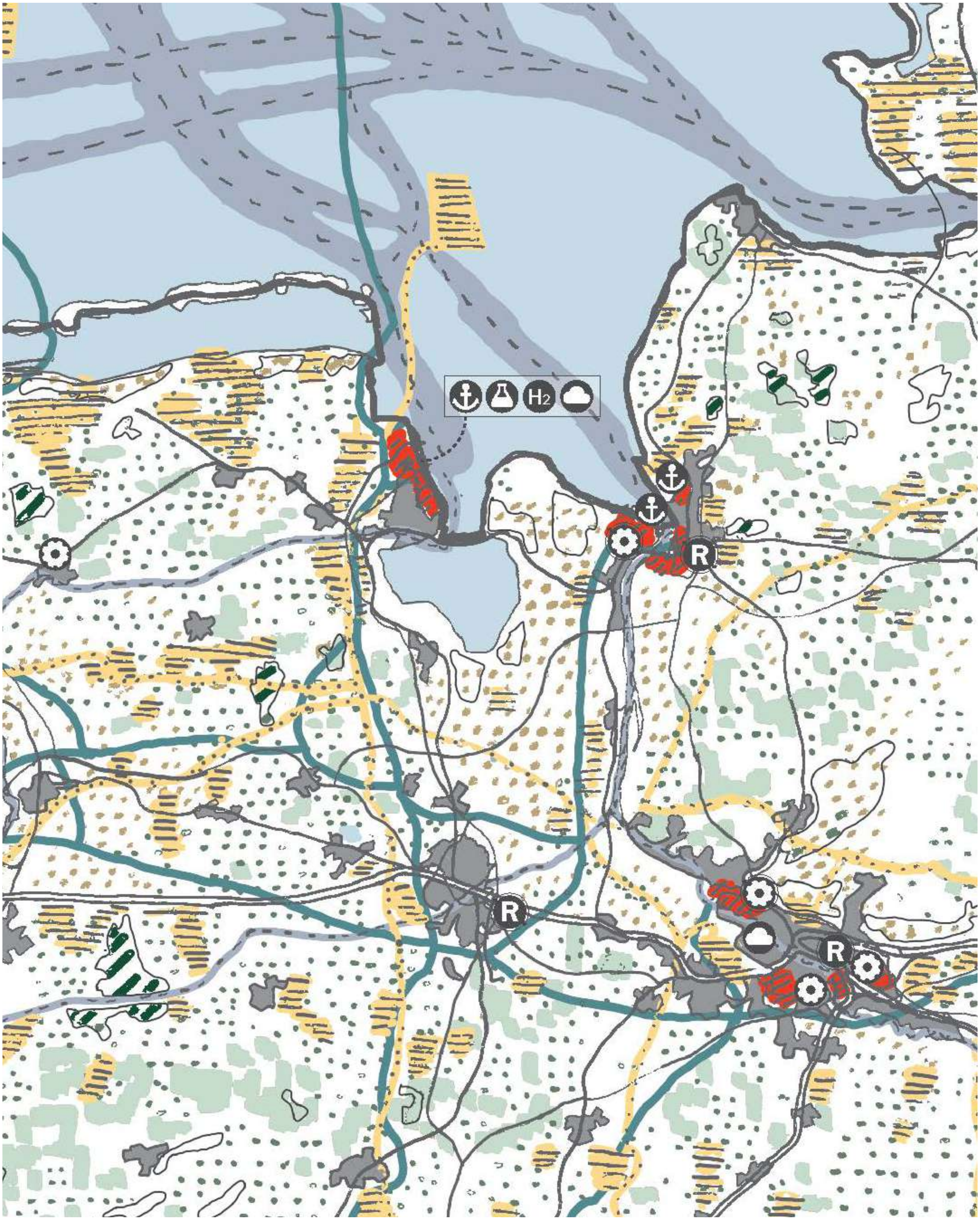
There is a divergent development within urbanised settlements: smaller ones have agreater role by hosting  supporting structures for the industrial system as a whole, i.e. data centres.



Another newly introduced typology in this scenario are the mega-ports that feature deep sea accessibility and are positioned outside of the dike line. Most notable example is the new port at Rottumerplaat.

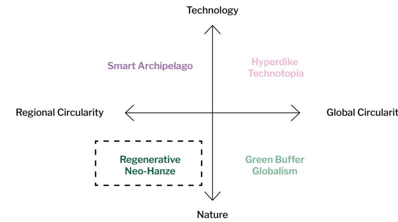
10.10 Spatial Organisation of Scenario ►

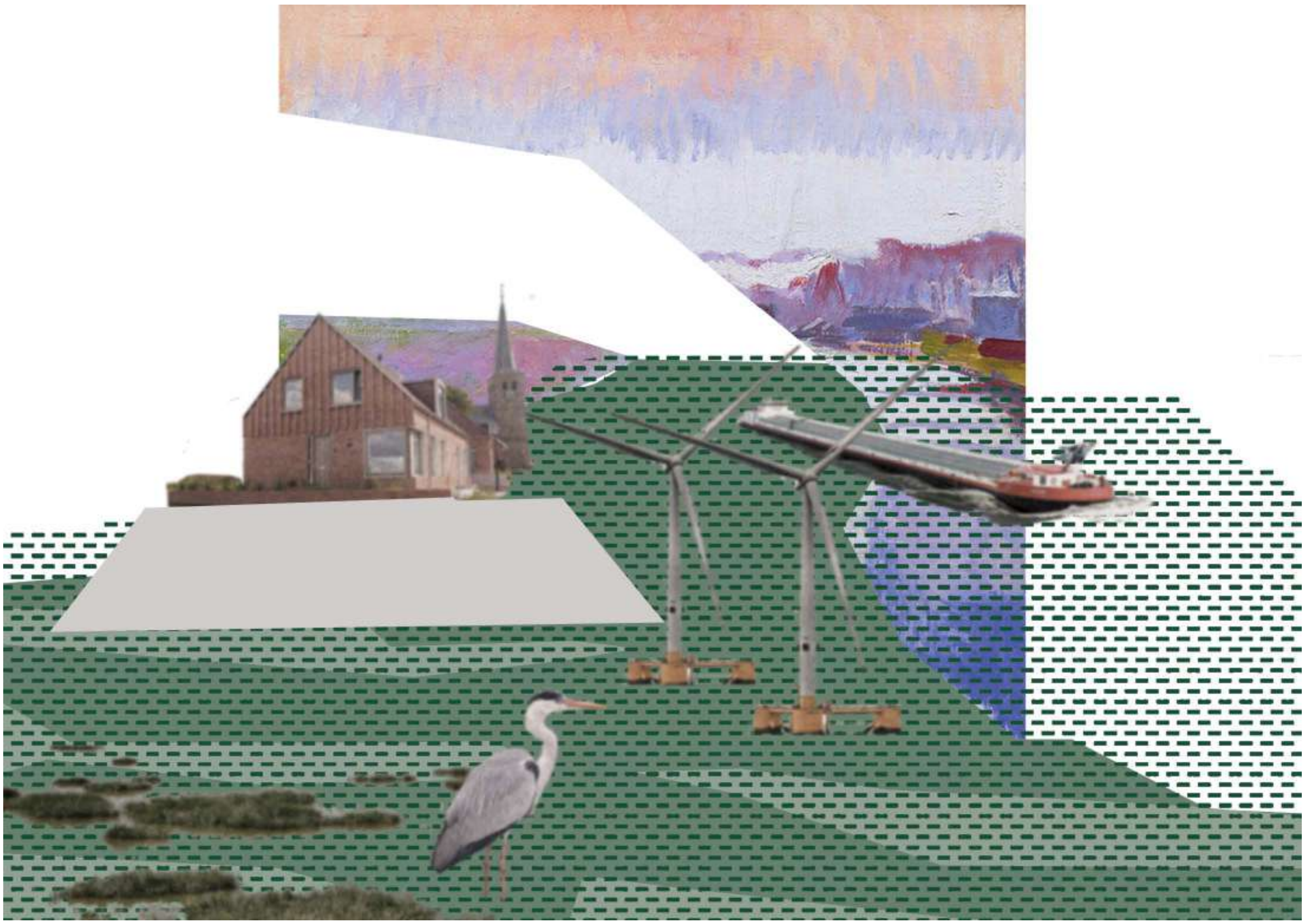




# Regenerative Neo-Hanze

## Scenario Exploration



**10.11 Scenario Encapsulation**
**10.12-14 Atmosphere of Each Motor ►**

The region is organising itself according to the principle of regional self-sufficiency: shorter chains, material autonomy, and ecological resilience. International dependencies decrease; cities and industries restructure themselves along local axes. Former economic seaports become islands in an expanded Wadden Sea and function as nodes in a decentralised network. Spatially, this means more compact cities on higher ground, landscapes returned to water and nature and light infrastructure linking set-tlements. Cities are reconnected to their hinterland through cooperation, not extraction. This would eventually result in economic shrinkage.

## Productive Motor

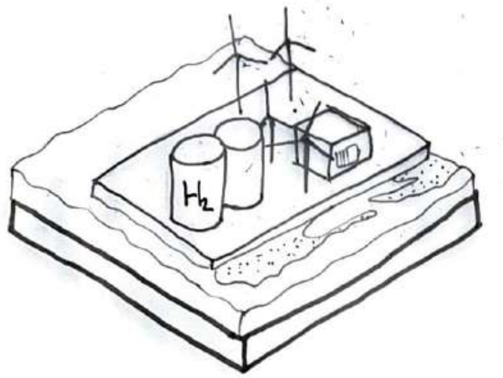
Production is slow, local and regenerative. Instead of global chains and just-in-time logistics, regional material circles are emerging. Industry clusters are smaller and more dispersed, but depending on the current situation, specialised in reuse, bio-based production and assembly. Waste is a raw material within a radius of about 100 km. Ports function as circular hubs with modular units: products are dismantled, repaired or reassembled. There is less reliance on high technology, resulting in low energy consumption. The cross-border region becomes less an exporter of global trade, more a self-sufficient workshop for reparative production.

## Safety Motor

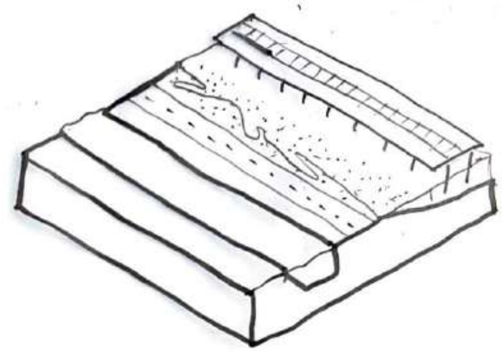
The region is opting for controlled retreat to the south instead of fighting the water. A new Wadden Sea can form itself: a wide, meandering sea with room for sedimentation, salt marshes and brackish water marshes. Instead of reinforcing the coastline, settlements lie on mounds or ring dykes, re-employing historical strategies. Artificial islands such as Eemshaven or Delfzijl function as coast guards in the water: they combine nature, energy and circular production. Thus, the sea does not become an enemy, but an ally. Here, climate adaptation does not mean hardening, but softening - a new symbiosis between people, water and landscape.

## Ecological Motor

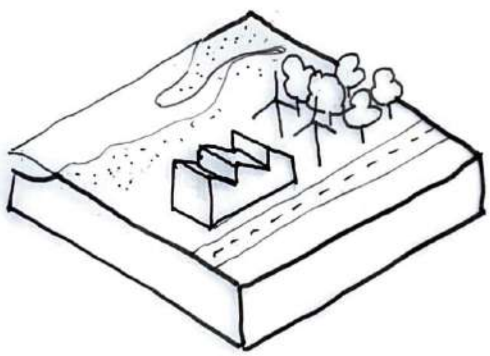
The landscape is a mosaic of wetlands, agro-ecological production and buffer zones. The large, low-lying former peatlands are rewetted on a large scale: they store $CO_2$, act as a water buffer and are habitat for biodiversity. Agriculture is extensive, regenerative and regionally oriented towards food and chemical feedstock production. Small-scale farms alternate crops, cooperate with nature conservationists, and supply local processing units. Transboundary ecological networks replace economic corridors, restoring ecosystems and making them climate-resilient. In these landscapes, production is secondary to carrying capacity.



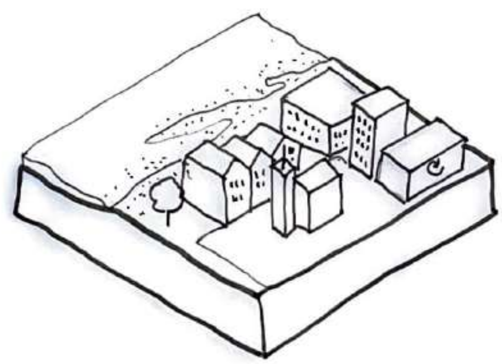

Large industrial clusters become energy islands in the Wadden archipelago, catering for the remaining local energy need. Industry is heavily scaled down.



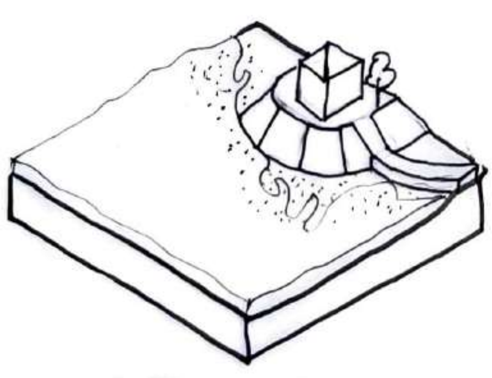
Infrastructure is scaled back. As large parts of the low-lying areas become tidal, some of the remainder needs to be reconstructed on dams/bridges.



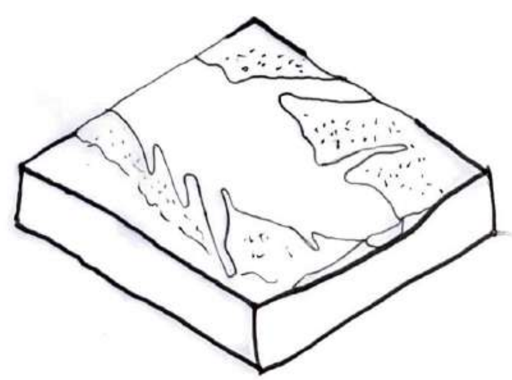
Small industrial locations are the backbone of the regional circularity, with waste as main input within a radius of 100 km.



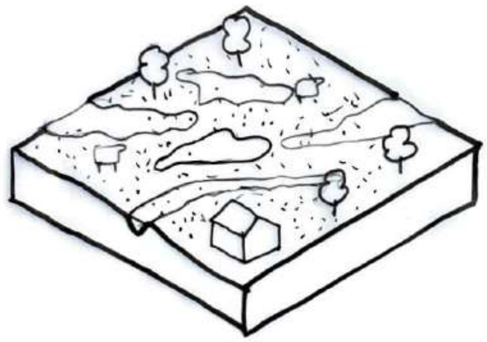
Urbanised areas, now often close to the water have circular facilities (recycling, small production sites) woven into their urban fabric.



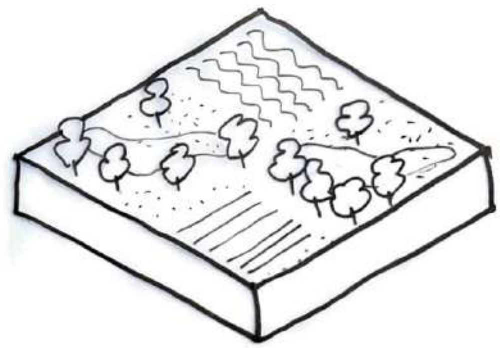
Insted of dykes, the natural dynamic of sedimentation is employed for protection, coupled with the traditional terp structures spread across the region.



The Wadden Sea remains in place and expands, having room to grow by sedimentation and being less polluted and disturbed by human activity.

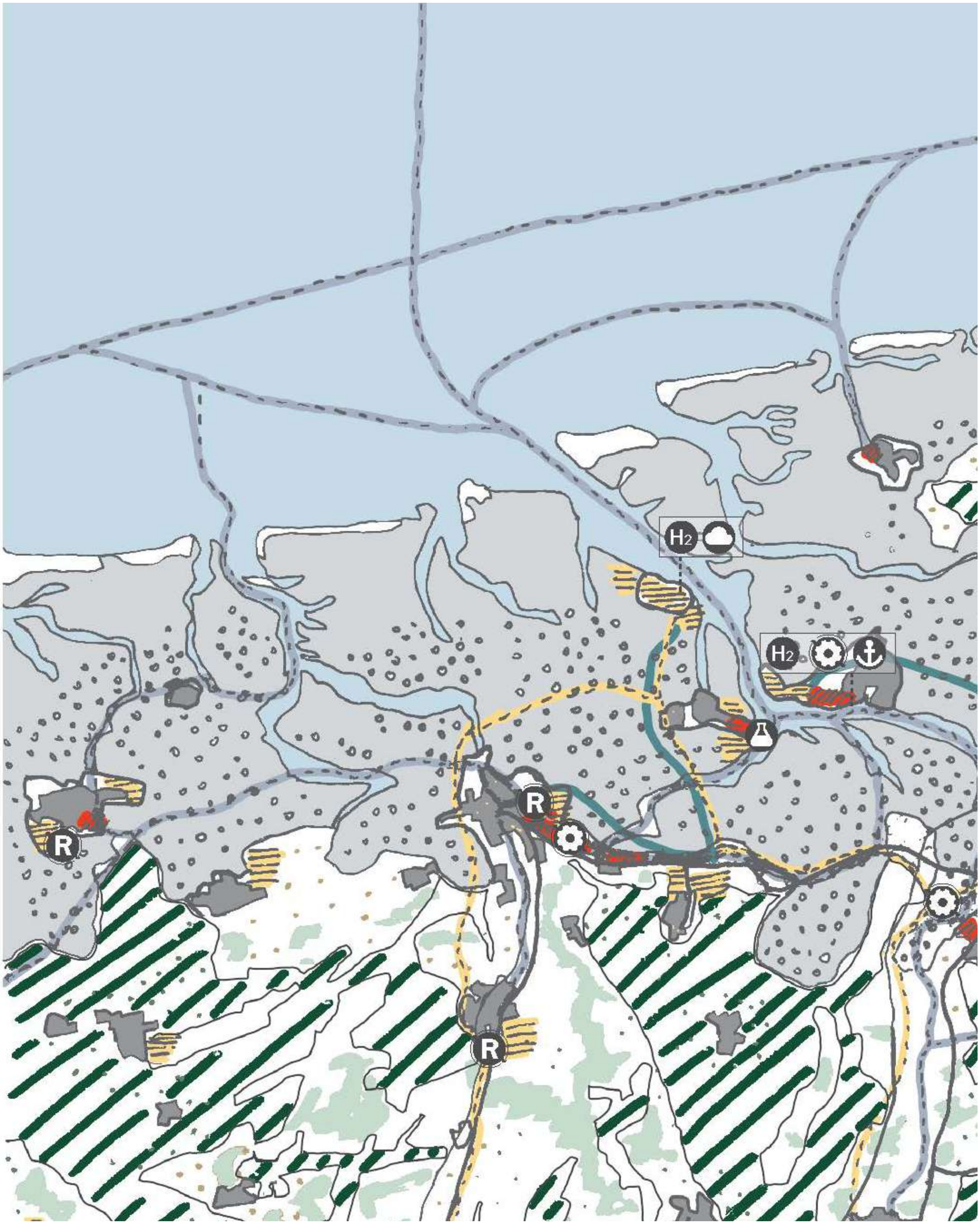


Large parts of the marshlands give room to re-wetted peat landscapes. Small-scale, extensive agriculture for local needs is possible here.



Remaining, mostly higher areas producing crops are partly re-purposed for green corridors. The rest of the area produces varios products, also biochemical feedstocks.

10.15 Spatial Organisation of Scenario ►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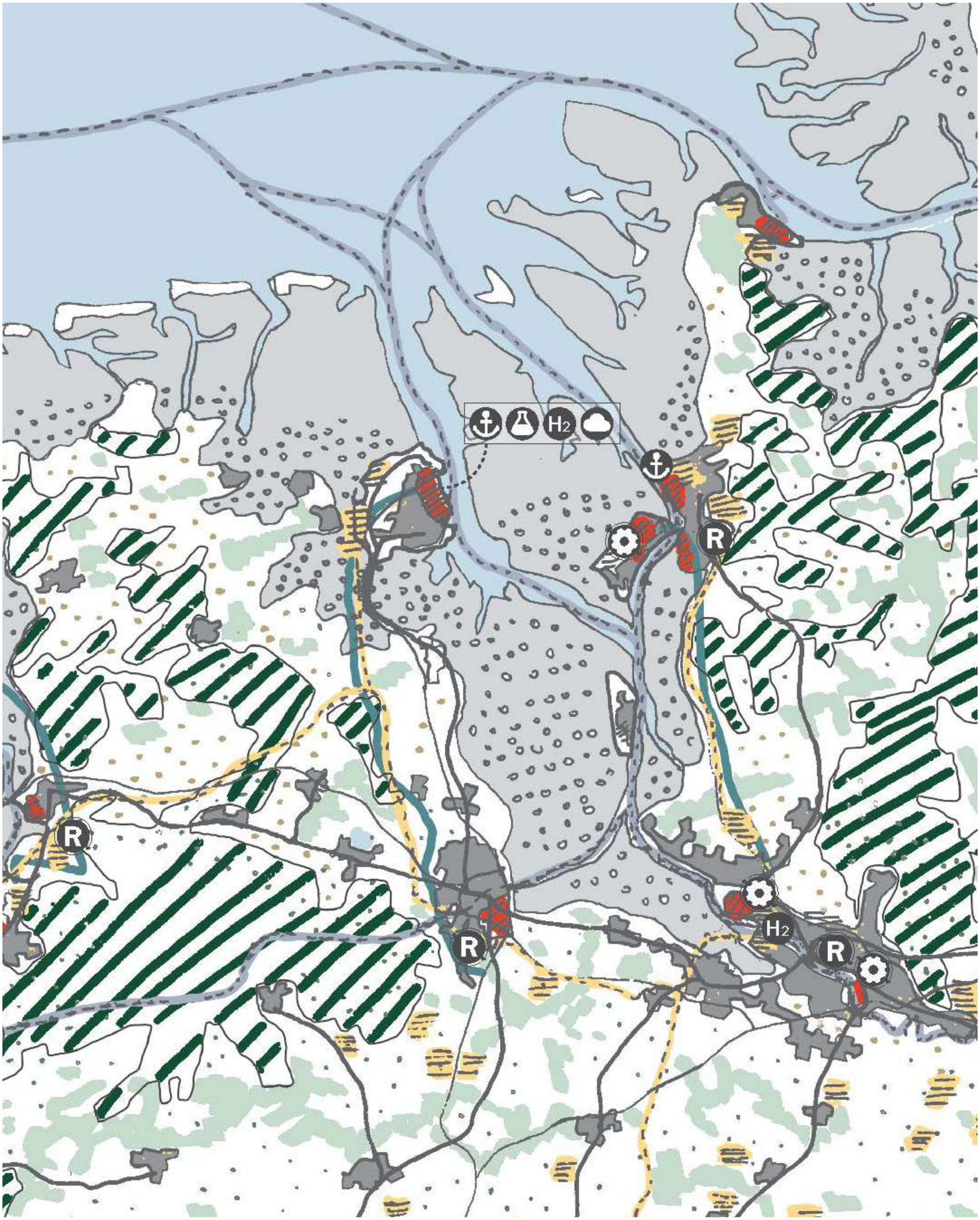
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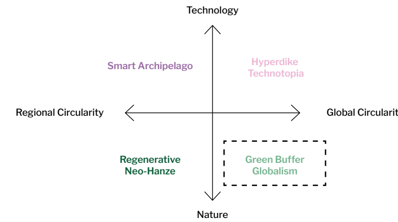
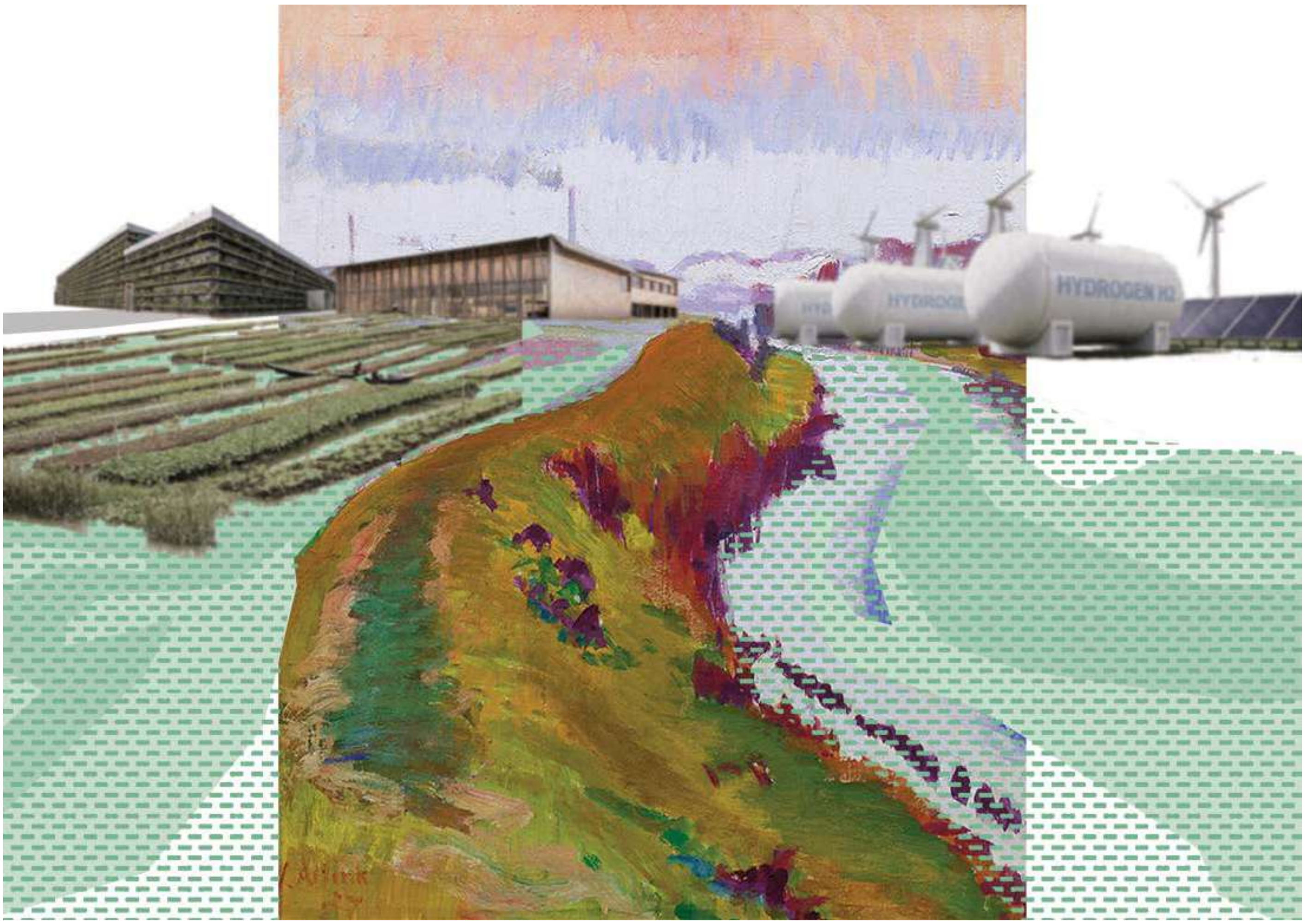
# Green Buffer Globalism

## Scenario Exploration



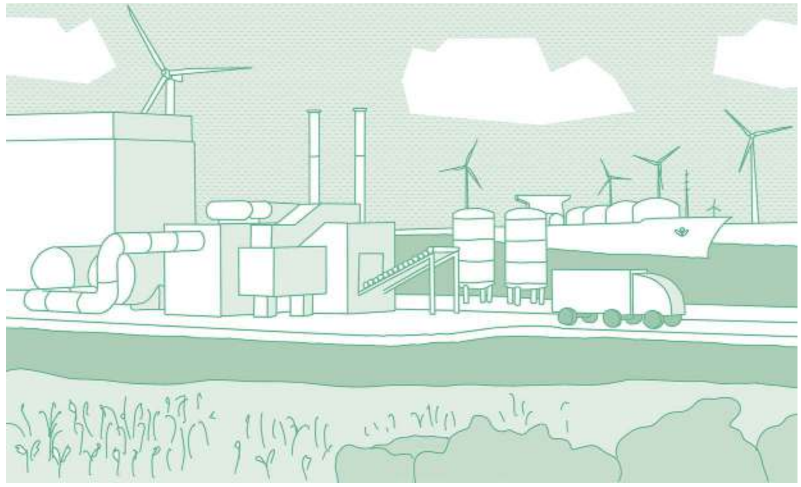




10.16 Scenario Encapsulation
10.17-19 Atmosphere of Each Motor ►

A fundamental shift takes place in a scenario where climate change and biodiversity loss are central to international agendas. Under pressure from ecological crises, countries worldwide are opting for radical greening in a collaborative manner. There is less faith in the disruptive power of technology and AI, more in ecosystemic thinking and restorative processes. The Wadden Sea region is growing into a symbolic “green buffer zone” at the edge of mainland Europe: a place of restoration and interdependence between humans and nature. In this globalised world, import and export remain important, but there is a clear ecological focus.

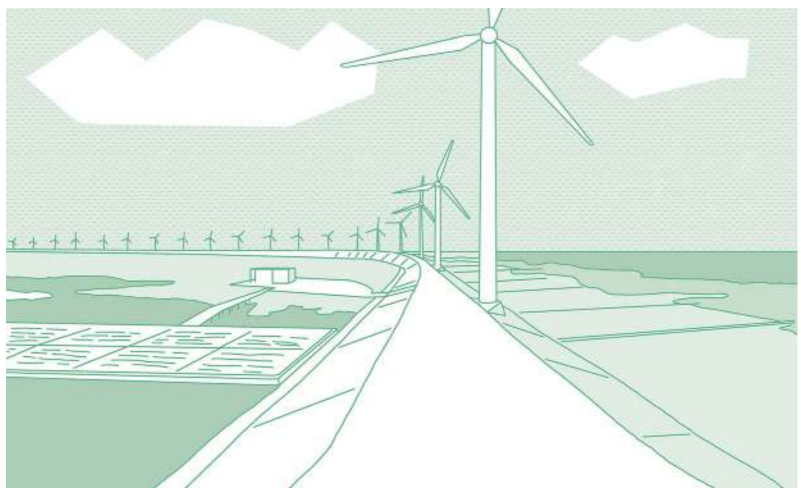
## Productive Motor

The region remains a hub in international trade networks, but there is a shift from quantity to quality: materials and products must meet strict sustainability criteria. Biobased material inputs and landscape-integrated production are dominant. Considerable space is needed for crops such as hemp, fibre crops and willow, but these croplands are combined with ecological functions. Some technology is present, but secondary to ecology and humanity: digital systems are applied with restraint. Renewabl energy and hydrogen is still exported, but the region itself uses less, through behavioural change and conscious policies.



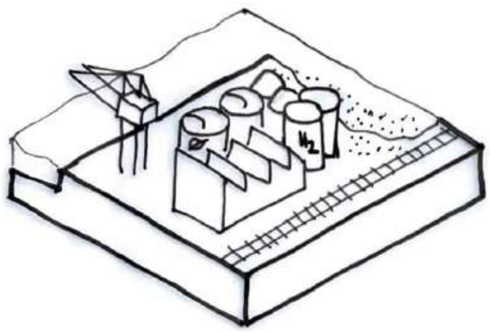
## Protective Motor

The classic 'fight against water' is giving way to a coexistence. Dykes are no longer seen as hard boundaries, but as transitional zones. The broad green dike becomes the new icon of the Wadden coast. Instead of continually raising or enclosing the coastal landscape, flood zones between first and second dike line are created where sedimentation takes place, biodiversity increases and new forms of wet cultivation become possible. Here, new hybrid zones emerge: brackish marshes, tidal wetlands and saline agriculture alternate in a mosaic. Likewise, the estuaries (Dollard, Jade, Weser) are partly given back to natural dynamics.

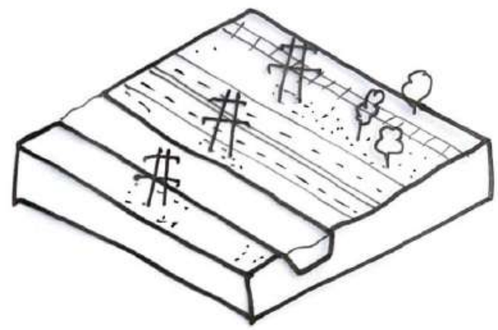


## Ecological Motor

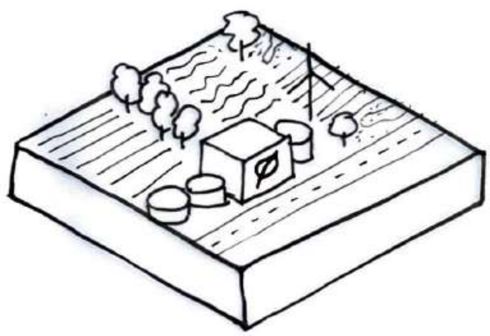
Green networks are the backbone of this scenario. Current Natura 2000 areas are connected through ecological corridors, in which species can move freely. Farmers act as landscape managers and get paid for ecosystem services. A mosaic of new landscapes emerges: nature production areas, where agroforestry, extensive livestock farming, paludiculture and wetland cultivation merge. One part of crop production serves regional biobased industries next to imports. The other part goes to food supplies, which is more frugal and plant-based, in line with changing eating behaviour and policies in the region and across Europe.



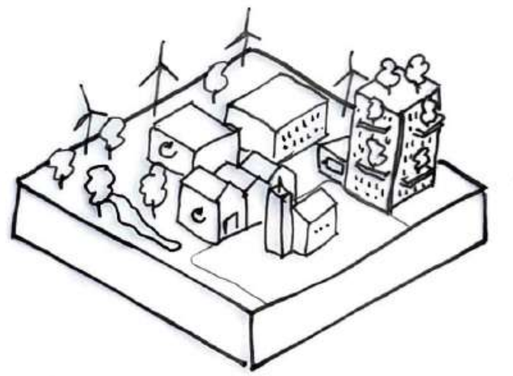
Large industrial clusters run on biobased feedstock, material recycling and become hydrogen production sites. Natural buffer zones are introduced.



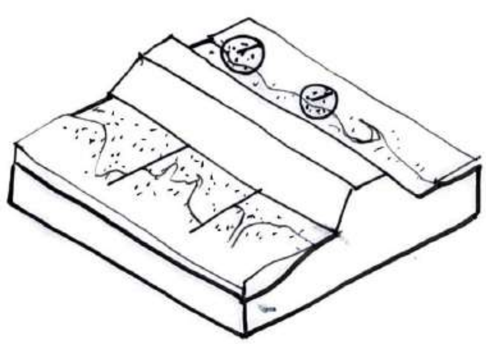
Infrastructure is kept to cater for import/export flows. However, wherever possible, natural elements are added and ecological logics have priority.



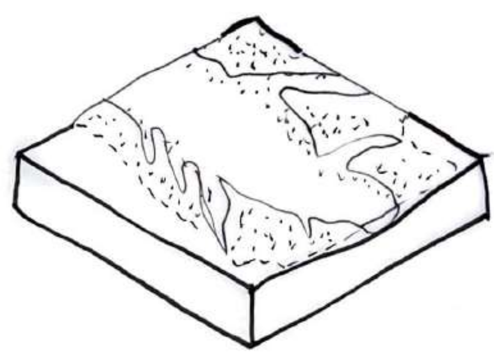
Small production sites are more closely integrated with their natural surroundings, for example by processing locally grown crops for biochemicals.



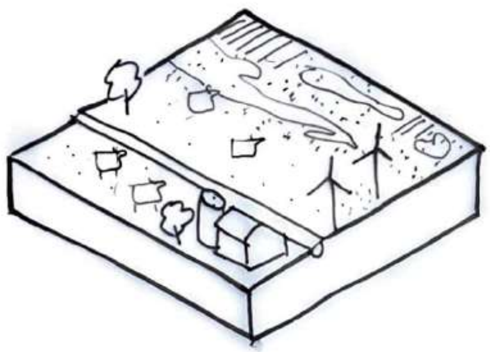
Urbanised areas are re-fitted to suit ecological needs. Local energy generation, circular depots and recycling centres are found in all settlements.



The dykes become ‘double’, with a first dike line that caters for sedimentation processes and can be overtopped by water and a brackish zone behind.



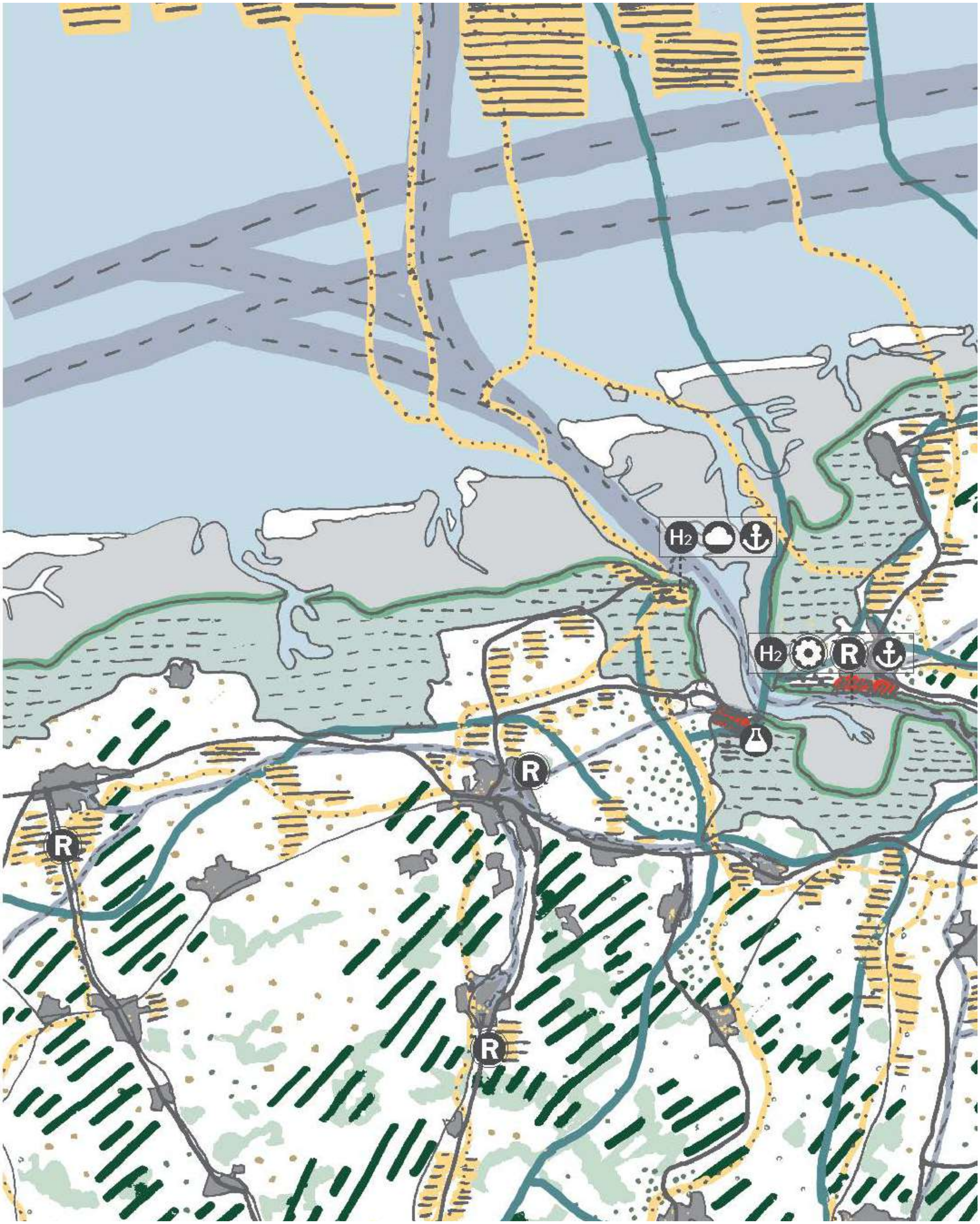
The Wadden Sea remains in place, having room to grow by sedimentation wherever possible.



Some parts of the marshlands, that are not needed for conventional agricultural production, are turned into re-wetted, productive peat landscapes.

The need for agricultural products (e.g. bio-feed-stocks) remains high, which is way most fields are kept, but nature-inclusive elements are introduced.

10.20 Spatial Organisation of Scenario ►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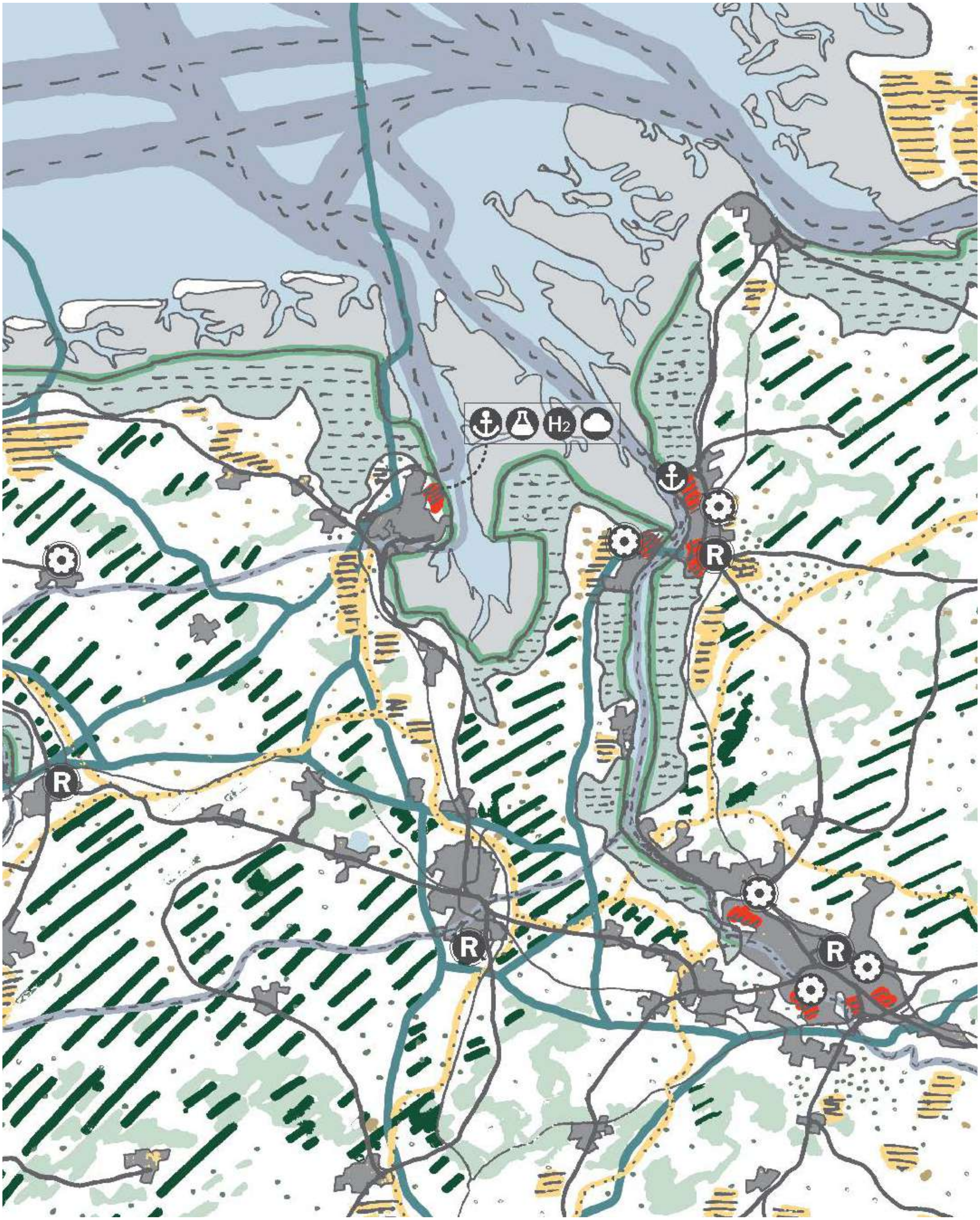
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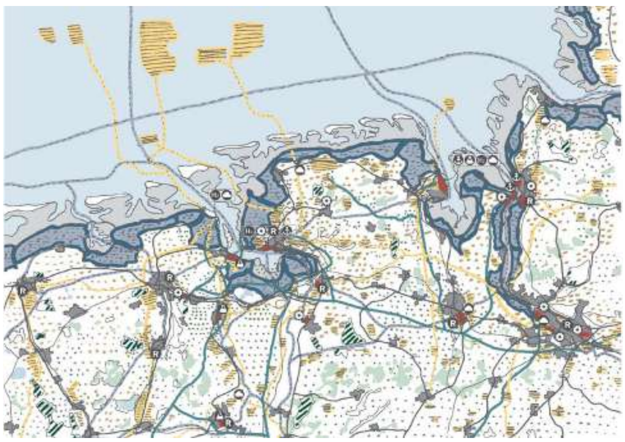
# Weighing Different Futures

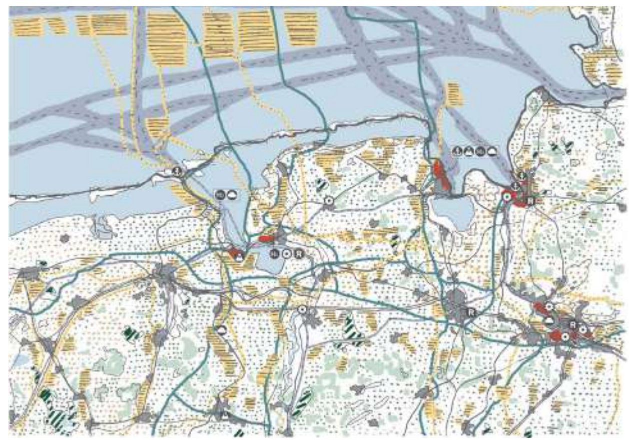
## Scenario Comparison and Assessment

To conclude this chapter, the scenarios are placed side-by-side for a comparative reading. Their positions within the quadrant reflect contrasting spatial logics ranging from centralised mega-structures to decentralised bioregionalism. This layout allows for a comparison of their spatial organisational principles. It also forms the basis for the following structured comparison: first, by confronting them with stakeholder feedback and second, through a multi-criteria evaluation informed by the framework of the overall vision aiming at sustainable cross-border circularity (see Fig. 9.1).

Technology-based

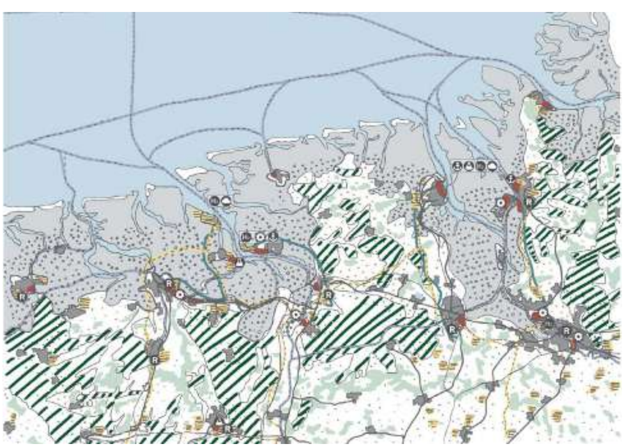


**Smart Archipelago**
Circular hubs spread across the area, defined by technical infrastructure serving the region itself and not other areas.

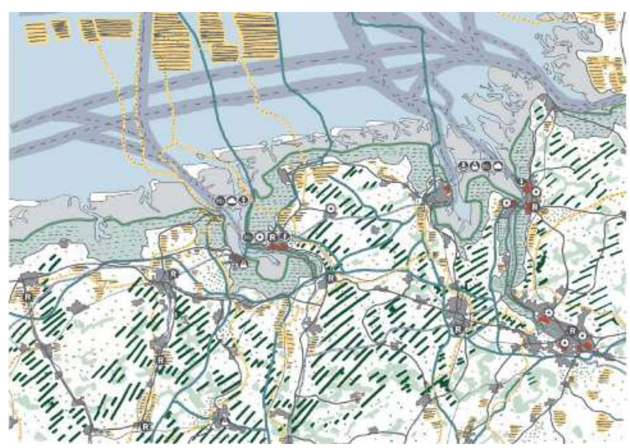


**Hyperdike Technotopia**
Fixed coastline with a massive sea closure, export-driven hubs dominate, hinterlands linked to the global ports via strengthened corridors.

Regional Circularity ← → Global Circularity



**Regenerative Neo-Hanze**
Territorial retreat with compact cities and restored wetlands, port cities become peripheral outposts in a decentralised bioregional network.



**Green Buffer Globalism**
Green buffer development with integration of ecology and productivity. Economic activity remains concentrated in existing hubs, but done differently.

Nature-based

This page summarises key stakeholder responses to the scenarios. Insights were drawn from the semi-structured expert interviews conducted with different German and Dutch institutions (see Chapter 4). While they are not scored against fixed criteria here, reactions in the conversations were grouped by scenario and sorted by theme, conceptual position and spatial reasoning. The selection reflects both common concerns and divergent views. Each scenario is accompanied by indicative quotes and an overarching interview synthesis that highlights perceived strengths and core uncertainties or limitations.

## Smart Archipelago

- "Technology will always be central." (I-5)
- "Energy autonomy can reduce global conflicts" (I-9)
- "Natural functions are assumed to be controllable here, but this requires immense ecological knowledge." (I-6)
- "Strong conditions for vertically layered land use, which is positive" (I-9)

+ **Valued for innovation and modularity**

⚠ **Concerns about oversimplified control logic, upscaling and ecological blind spots**

## Hyperdike Technotopia

- "The Delta Works cost 20% of Dutch GDP. That is just not affordable in a region like this." (I-8)
- "What happens when a dike fails? One breach and the system collapses, overconfidence like in plans from the 1960s" (I-6)
- "The dike is a massive shipping bottleneck." (I-9)
- "Technically interesting, politically unfeasible in Germany's federal governance system" (I-5)
- "However, such a large joint project could also bring the region closer together" (I-8)

+ **Might appeal to high-growth sectors**

⚠ **Socially and ecologically fragile tech-utopia**

## Regenerative Neo-Hanze

- "Ecologically sound, but somewhat naive for the next 50 years." (I-5)
- "Would require a return to the flexible way of living with water of centuries ago." (I-6)
- "This scenario feels uncomfortably unmanageable." (I-8)
- "Social drive is missing for such ecological prioritisation." (I-8)
- "Seen as implying a loss of prosperity." (I-3, 8)
- "Once you start, you can't just step back – this is a one-way path." (I-9)

+ **Praised (by some) as visionary and restorative**

⚠ **Feasibility, economic viability and societal impacts are all fundamentally questioned**

## Green Buffer Globalism

- "Eventually the most realistic." (I-3, 4, 8)
- "Agriculture and nature can regain space here: this is a welcome direction." (I-9)
- "Post-crisis realism: this comes after climate crisis and the following biodiversity shocks." (I-9)
- "Desirable, but I expect this only by 2150." (I-9)
- "The cross-border logic is strong, but cultural/legal barriers persist." (I-6)
- "Scenario approach with nature/global logic seen as promising, but slow." (I-2)

+ **Seen as a desirable long-term systemic transformation**

⚠ **Requires structural shifts in governance, societal mindset, culture and business**

## Multi-Criteria Assessment

To conclude this chapter, the matrix compares the four scenarios for 2100 across eleven evaluation criteria, derived from the vision chapter and using Calisto Friant et al.'s (2024) seven circles of a circular society and strong sustainability principles as the basis. Each element in this Multi-Criteria Assessment is qualitative and informed by internal consistency within the scenario logics and insights from stakeholder feedback. Rather than identifying one preferred future, the matrix exposes synergies, trade-offs and structural risks that are embedded within each trajectory. It reveals how spatial organ-

| | Smart Archipelago |
|---|---|
| Regenerative Impact on Natural Cycles | Natural cycles subordinated to technical management: no significant regeneration, fragmentation remains |
| Material Footprint | Tech-heavy, lifecycle impacts not reduced to a large extent |
| Dependency to Global Developments | Explicit decoupling from global trade, but reliance on advanced tech (i.e. CRM) might result in ongoing strategic dependencies |
| Resilience to Climate Extremes | Engineered resilience increased, but little nature-based, adaptive responses. Risk of technical failure |
| Feasibility and Institutional Readiness | Builds on current regional planning trajectories |
| Cross-Border Implementation Potential | Works within regions but fragmented across national borders. |
| Basis for Broad Prosperity | Regional markets and industries provide jobs. Strong automation could limit inclusiveness and social mobility. |
| Knowledge Infrastructure and Learning Capacity | Innovation is present and strategically guarded. Potentially less input from elsewhere, but exchange within |
| Social Fabric and Inclusion | Efficiency and autonomy dominate over inclusiveness and shared decisions. Ageing as extra risk |
| Systemic Vulnerability | Reliance on technology creates vulnerability to cyber risks and infrastructural failure. Lack of redundancy |
| Territorial Coherence and Identity | Incorporation of regional identity and tailored local solutions. Technocratic but place-based. |

isation, institutional feasibility and social as well as ecological coherence align or clash under the different future logics. The evaluation findings thus becomes a lens through which the next chapter can trace actionable pathways forward.

| Hyperdike Technotopia | Regenerative Neo-Hanze | Green Buffer Globalism |
|---|---|---|
| Nature is functionalised and strictly confined. Regeneration is not a goal but a side effect of system control. | Strong ecological restoration and symbiosis with environment, natural processes take priority. | Natural processes (sedimentation, wetlands, biodiversity) actively embraced and integrated |
| Tech-driven, highly efficient circularity, but high material intensity with large footprints regionally and elsewhere | Low-impact, circular production within regional loops: repair, and reuse dominate over extraction | Shift from volume to value reduces impact. However, this leads to large spatial claims, also elsewhere |
| Embedded in global trade and infra: exposed to geopolitical, economic, supply chain disruptions | Very low, strategic autonomy is built into the new system. Yet scarcity in crucial products/ materials expected | Still globally embedded, which makes the system sensitive to international market or regulatory shifts |
| Engineered resilience through megastructures, but lacks flexibility. System failure would impact massively | Dynamic coastlines and retreat strategies enhance resilience and little money needed, but large scale loss of land | Nature-based adaptation strategies make the system more flexible and absorptive |
| Unrealistic given cost, politics and societal opposition | Very low feasibility without transformative governance | Aligns with existing policy goals frameworks, but implementation is slowed by institutional and societal inertia |
| Requires intense coordination that is unlikely to materialise | Conceptually strong (shared bioregion), but practical alignment difficult due to decentralism and varied governance. | Strong alignment with European Green Deal and ecological thinking, though businesses might not be convinced |
| Strong economic growth and job creation, | Massive loss of welfare because of industrial dismantling that leads to loss of jobs | Prosperity redefined as ecological well-being, but could mean less upward mobility or consumer choice |
| Cutting-edge innovation and tech infrastructure, strong R&D ecosystem, though possibly steered elsewhere in hinterland. | Fall behind in innovation capacity, mostly agricultural knowledge prevails | Strong potential for growth in ecosystem science, agroecology, and hybrid knowledge systems |
| Techno-solutionism dominates over space for participation or equity. Public role might be very little | Citicens as co-creators, inclusion and equal opportunities across the region leads to high social cohesion | Cooperative, but behavioural change may create friction, especially in regions used to high material standards |
| High-tech lock-ins, complex interdependencies and critical infrastructures increase systemic risk | Low-tech, decentralised systems reduce systemic risks and increase adaptability in case of disruptions | Reliance on “soft” ecological processes and restrained use of tech might make it vulnerable to shocks |
| Space shaped by infra and market logics. Strong coherence in function, but little sense of local rootedness | Spatial logic follows ecology rather than market, but loss of large scale characteristic marshland areas | Wadden Sea will stand for fruitful coexistence: restoration and identity both present |

11

# Strategic Framework

# Why Flexibility is the New Stability

## A Strategic Approach Through Adaptation Pathways

The future of the Wadden Sea region cannot be predicted, but it must be planned for. Building on the previous scenario exploration, this chapter makes the transition from speculation to strategy. It presents a framework for navigating this deep uncertainty, grounded with stakeholder perspectives from the interviews and responding to the findings from the Inventarisation.

The approach is structured around adaptive pathways (see Chapter 4), a method selected for its ability to combine directional clarity with temporal flexibility. Rather than prescribing one fixed roadmap to 2100, the framework introduces a phased sequence of decisions that respond to unfolding developments over time. This choice was informed by interviews with regional experts, who emphasised that the transition toward circularity will unfold in steps and that spatial room for manoeuver ("sliding space") is crucial to avoid premature lock-ins (I-2, I-3, 2025).

At the same time, the strategy acknowledges that space is already contested: Chapter 9 revealed that decarbonisation, ecological restoration and water safety all come with overlapping spatial claims. Here, circularity increases spatial demands, as new infrastructures, buffers, and resource loops must be layered onto the already fragmented landscape (I-3, I-4, 2025). To deal with this, the strategy builds on the motor structure developed earlier in the thesis (Chapter 8):

**Productive Motor**
Large-scale industry, fabrication, logistics, energy

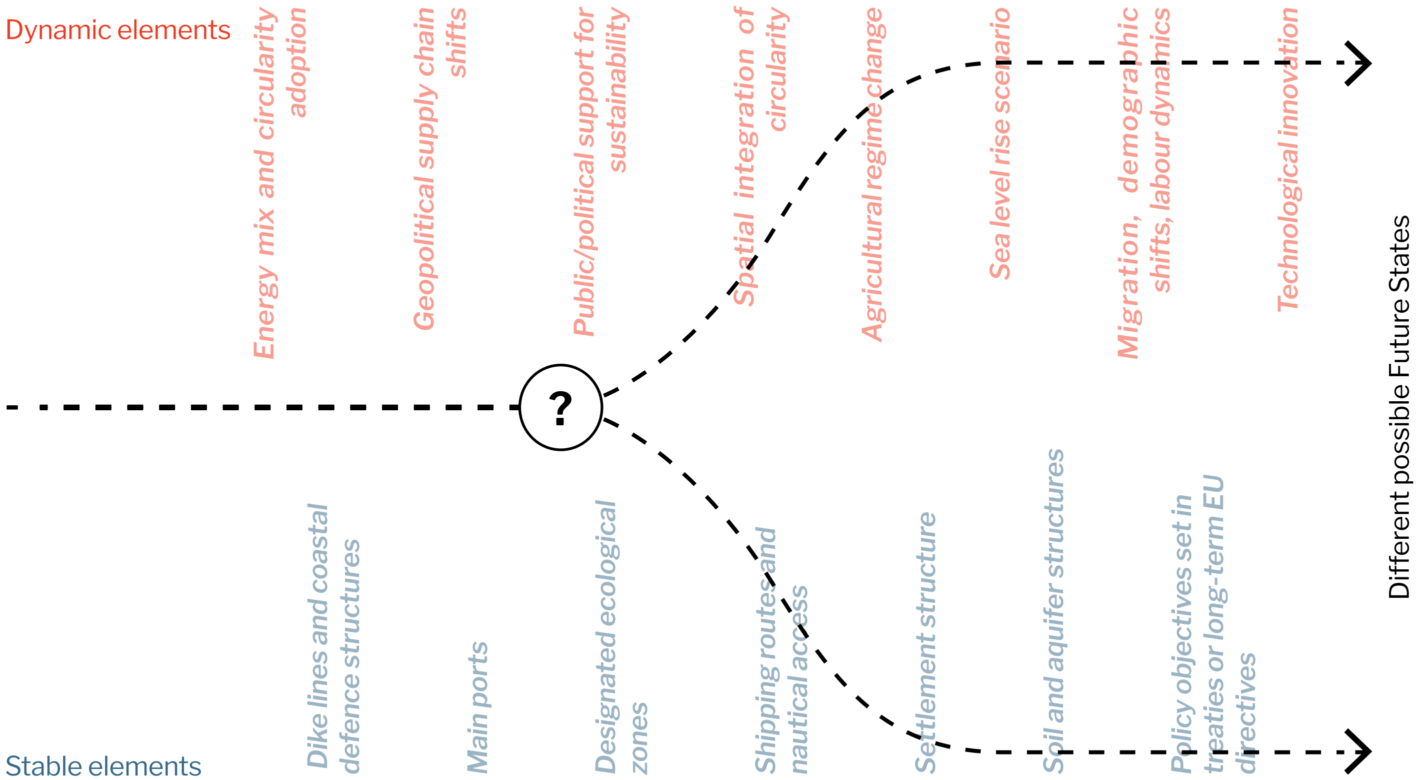
**Protective Motor**
Dykes, defenses, safety systems, risk adaptation

**Ecological Motor**
Flora, fauna, biotopes, soils, ecosystem services

Stakeholder input highlighted that while ambitions on hydrogen, biodiversity, and water safety exist, they are rarely matched by implementable spatial strategies (I-6, I-7, 2025). This chapter therefore translates the vision into an adaptive framework: one that defines shared steps for the near term while keeping multiple futures open. Around 2040, as uncertainty increases, these shared trajectories begin to diverge. Here, flexibility in both planning and design is needed.

> *What is speculative and what becomes inevitable? That's the key policy question.*
>
> I-2, Spatial Policymaker (NL)

> *Flexibility is not about keeping all options open, but about choosing consciously with a clear profile.*
>
> I-1, Sustainability Officer (NL)

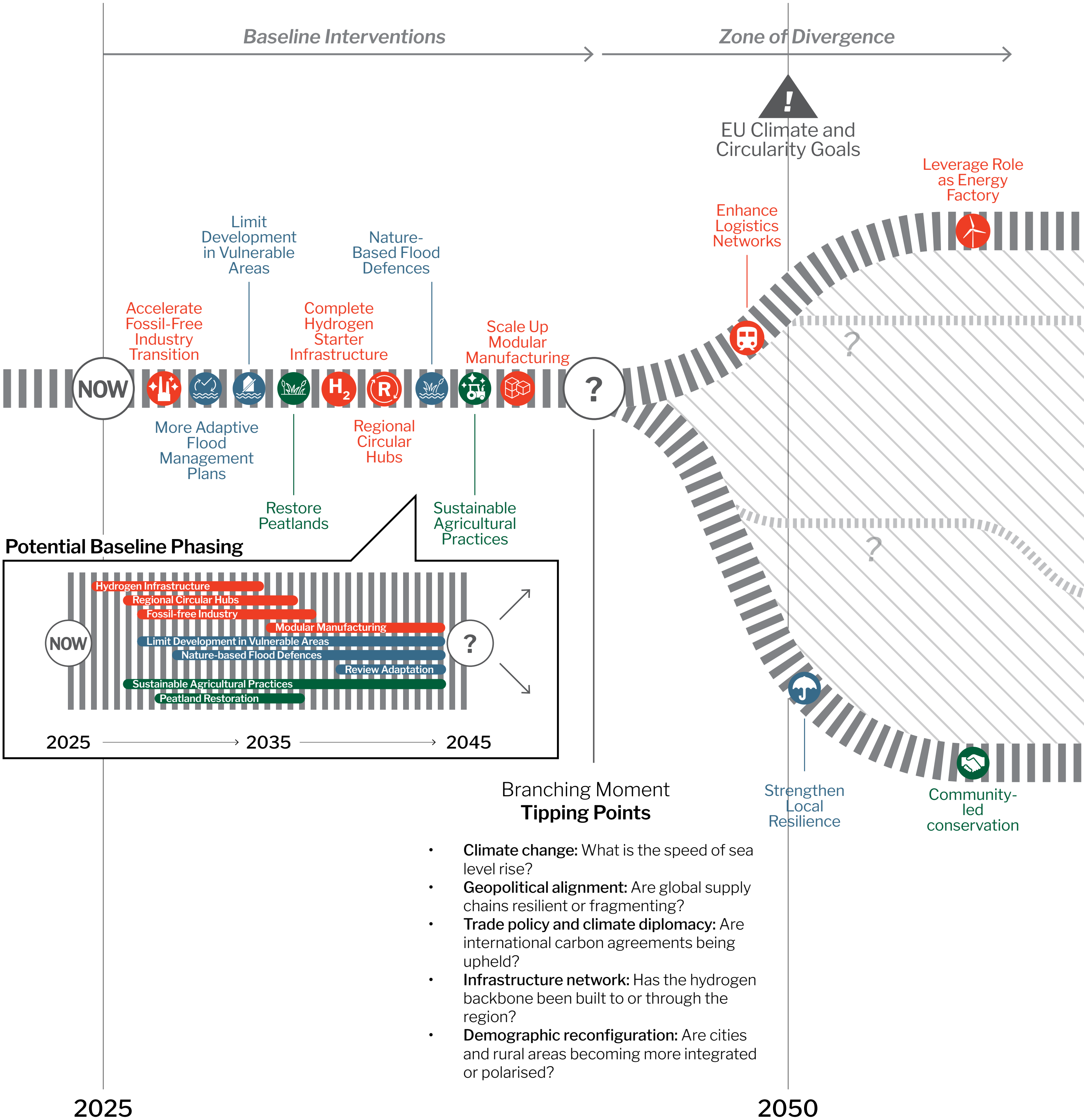



11.1 Principle of the Way of Working of the Strategic Framework

To visualise the adaptive logic introduced on the previous page, this chapter employs a Y-shaped pathway diagram, whose logic is depicted in Fig. 11.1. It begins with a phase of shared early actions, but around 2040, diverging developments, such as climate shifts, geopolitical change or market dynamics, may push the region towards distinct futures.

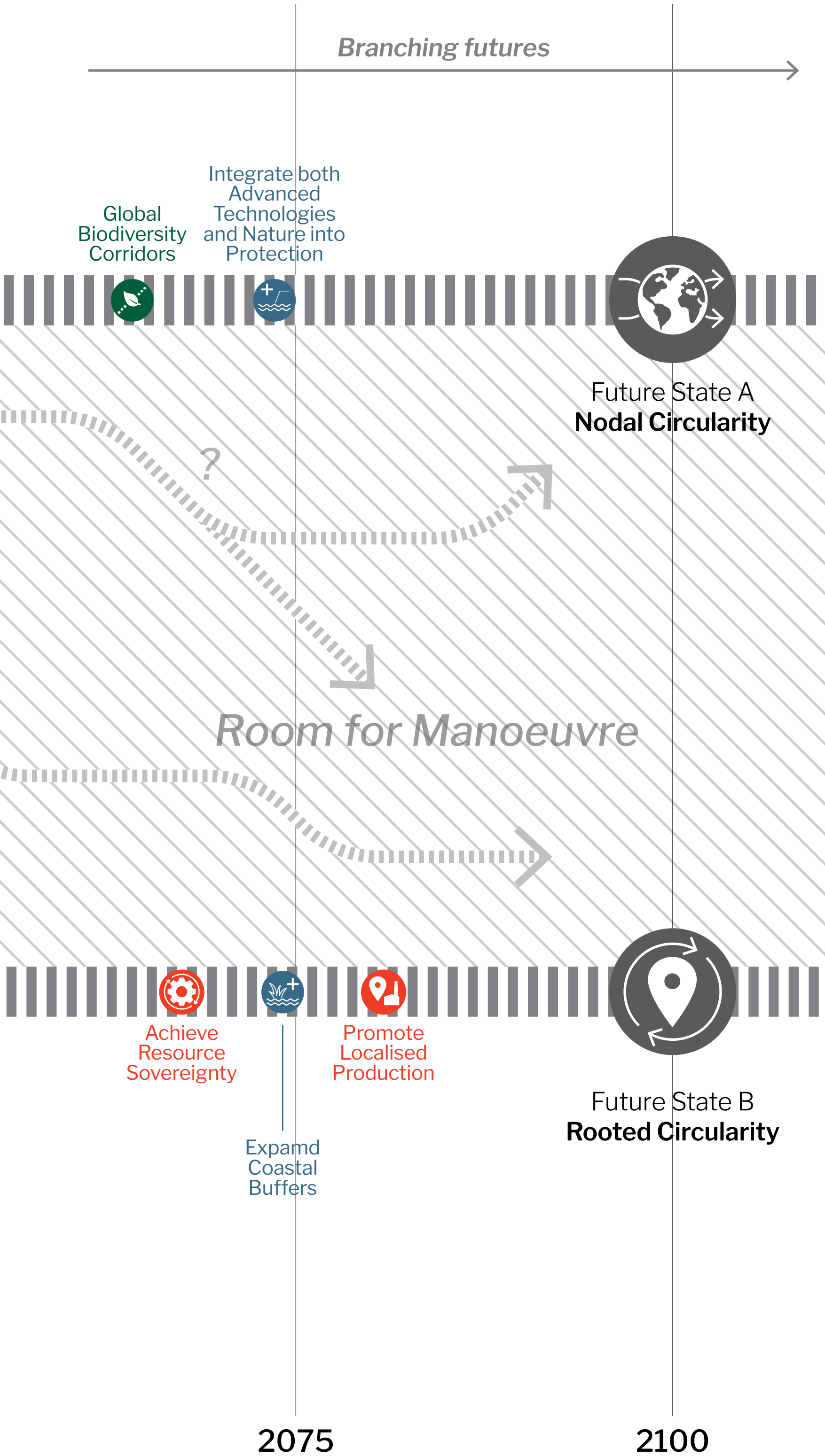
Each pathway navigates a different tension between stable spatial anchors (e.g. dike lines, biodiversity zones, core ports) and dynamic elements (e.g. circular flows, land use, new industries). This diagram is therefore not a masterplan, but a tool for sequencing action, anticipating tipping points, and fostering alignment across disciplines and jurisdictions.

The overall strategic framework that follows in this chapter draws from this structure by being phased, spatially grounded and guided by the three motors introduced earlier. The overall strategic framework that follows in this chapter draws from this structure by being phased, spatially grounded and guided by the three motors introduced earlier. In this context, flexibility thus refers to the ability of the spatial strategy to accommodate diverging developments over time, in service of public, private, and ecological actors operating under uncertainty, by enabling phased and at least partly synergetic spatial decisions. This includes designing buffer zones, multifunctional land uses and policy options that remain open until critical tipping points occur.




Branching Moment
**Tipping Points**

- **Climate change:** What is the speed of sea level rise?
- **Geopolitical alignment:** Are global supply chains resilient or fragmenting?
- **Trade policy and climate diplomacy:** Are international carbon agreements being upheld?
- **Infrastructure network:** Has the hydrogen backbone been built to or through the region?
- **Demographic reconfiguration:** Are cities and rural areas becoming more integrated or polarised?




This strategic framework uses a Y-shaped, branching model to guide circular transitions in the Wadden Sea region. It starts with no-regret actions that create spatial and infrastructural readiness. Around 2040, a branching moment is foreseen, likely influenced by geopolitics and climate dynamics. The response are two diverging paths leading to distinct future states, with room for maneouvre in between. The strategy builds on the three regional motors, productive, protective and ecological. The measures that are envisioned per motor are further detailed on the following pages. The two possible future states are described below.

**Description of this Future State**

This future sees the Wadden region as an upscaled, strategic circular node in global and European supply and energy chains. Infrastructure is kept and partly also expanded to serve energy exports and high-volume logistics, but ecological restoration now supports these productive landscapes. Circularity is driven by efficiency and technological integration, with dominant roles for large firms and state coordination. Socio-ecological dynamics therefore remain mainly continuous with the current state, but the exploitative patterns of the past are avoided through circular practices, technology and embedding ecology.

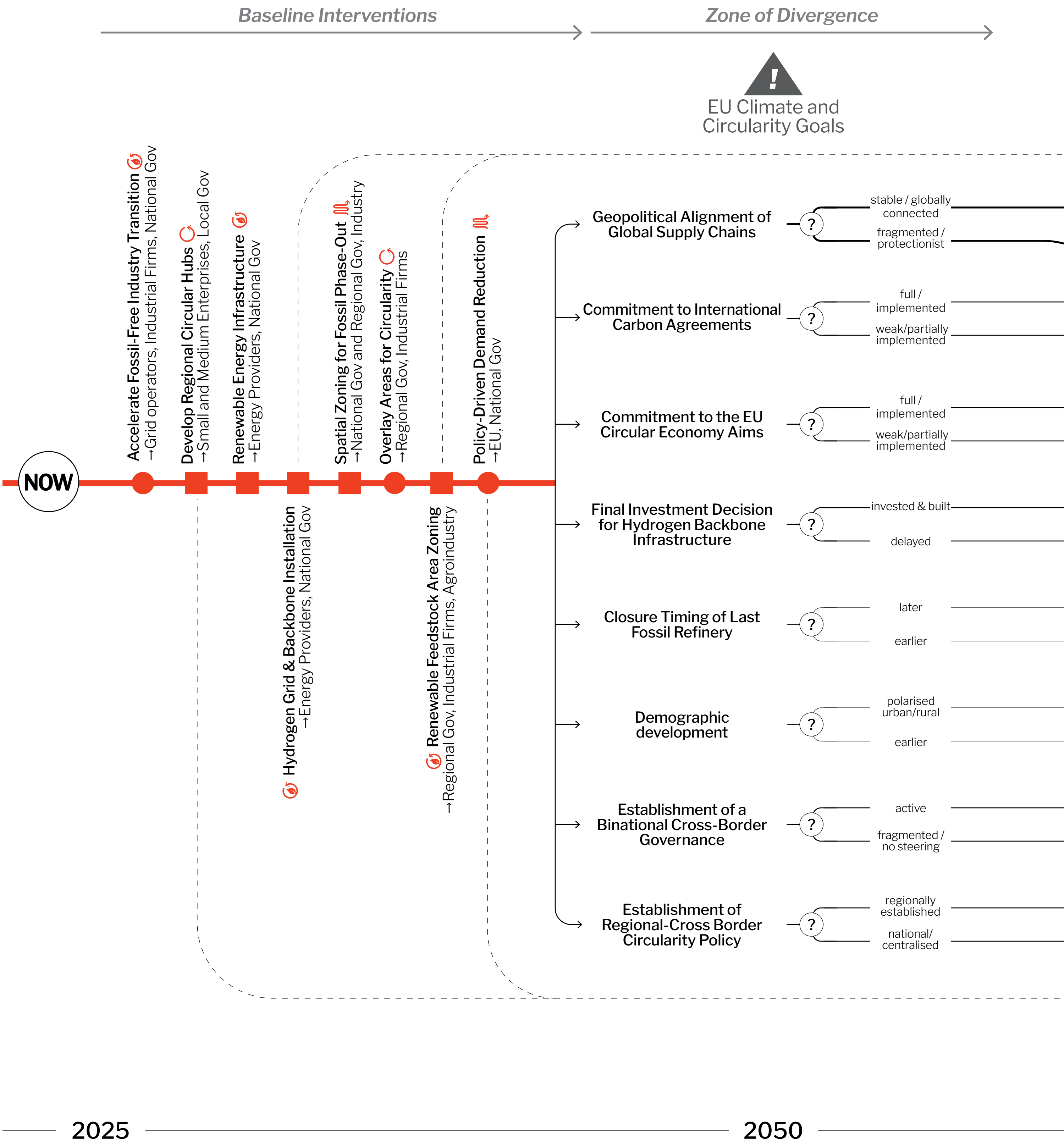
**Description of this Future State**

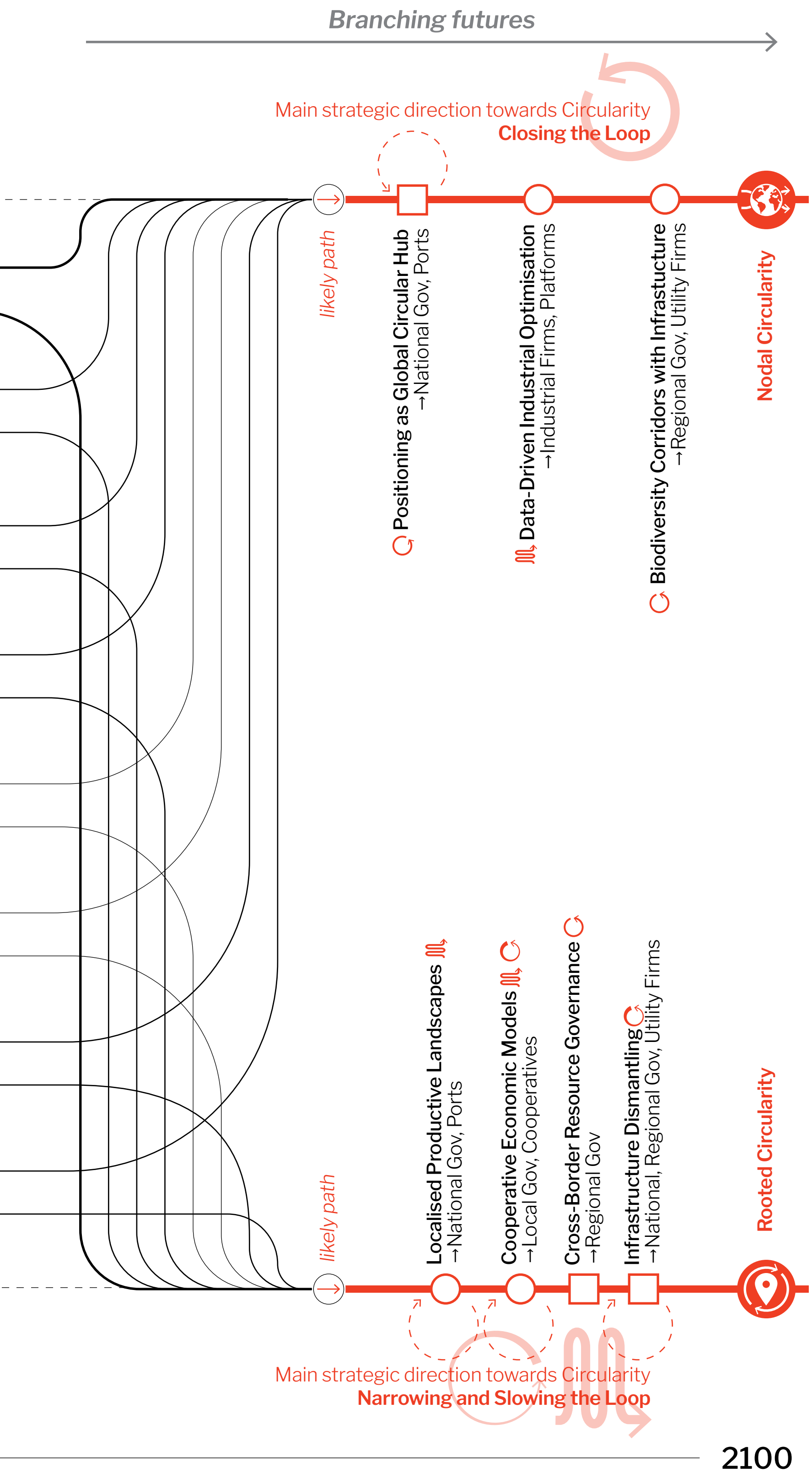
This future imagines the Wadden region as a rooted circular landscape, with more self-sustaining elements that are aligned to local ecological rhythms. Governance is decentralised, with regional actors having a greater say on land use and resource flows. Production is still linked to global chains, but more modular, adaptive and diversified. A normative shift takes place that prioritises sufficiency over scale. The extractive logic that shapes the region in 2025 is therefore rejected altogether to restore ecological and social values.

◄ **11.2 Strategic Framework**

# Industrial Reboot

## Working out the Strategic Framework for the Productive Motor






**Intervention Types**
- Set Intervention – Dynamic: Flexible, variable or seas
- Set Intervention – Fixed: Hard Spatial Anchor
- Speculative Intervention – Dynamic
- Speculative Intervention – Fixed
- Stakeholders involved

**Circularity Strategy that is targeted (see Chapter 3)**
- Close the Loop
- Slow the Loop
- Substitute the Loop
- Narrow the Loop

**Influence on Pathways and Future States**
- Feedback Loop
- Baseline Intervention makes Future State more likely
- Very strong influence of direction
- Strong influence of direction
- Moderate influence of direction

***The Northwest has a positive energy balance: that's an opportunity for new industrial allocation.***

**I-5, Regional Planner (DE)**

***Innovation, such as hydrogen and CCU, is our way of making a difference.***

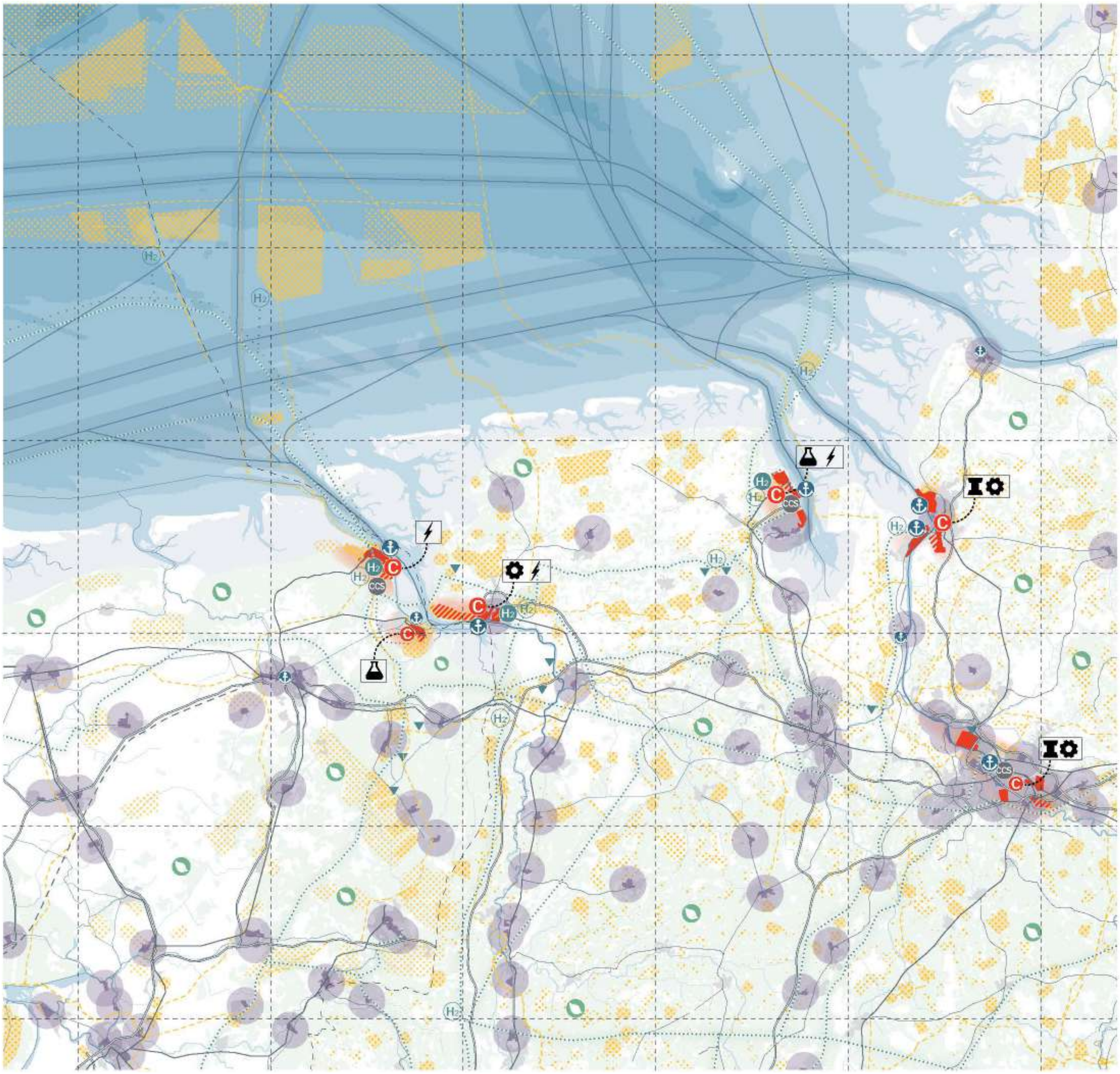
**I-1, Sustainability Officer (NL)**

***Recommended measures: strengthening circular cargo flows (e.g. CO2 export via Bremen), symbolic material innovation (steel, batteries) and spatial intensification.***

**I-9, Environmental Officer (DE)**

The productive motor forms the backbone of the shift from fossil dependency to circular industry in the Wadden Sea region. Here, the Y-shaped pathway of the adaptive strategy (Fig. 11.3) shows robust shared actions in the industrial system and supporting infrastructures until 2040, like grid upgrades, hydrogen and circular hubs. These create spatial readiness and keep options open. Around 2040, tipping points such as hydrogen infrastructure, fossil phase-out, and cross-border governance trigger divergence: the region could consolidate as a global circular node or pivot towards a rooted, modular economy. Each action targets a specific circularity strategy (close, narrow, slow, substitute, see Chapter 3) and is anchored in both policy and stakeholder priorities, such as making use of the regional energy surplus and port infrastructures. The diagram visualises how institutional, technical and spatial feedbacks shape which pathway gains momentum.

**◀ 11.3 Detailed Strategic Framework for the Productive Motor**



| | | |
|---|---|---|
| Sea | | |
| Wadden | | |
| Settlement | | |

**Anchored elements**
- Large Industrial Cluster
- Cluster area
- Localised circular production area
- Energy generation
- Hydrogen backbone
- Hydrogen storage
- Port
- Agriculture (crop production)
- Energy grid
- Hydrogen Production
- CCS facility
- Cluster profile: Basic industry
- Cluster profile: Manufacturing
- Cluster profile: Chemistry
- Cluster profile: Energy
- Biobased production

**Strategic options**
- Cluster expansion
- Energy potential
- Biobased potential
- Potential hydrolyser
- Potential CCS pipeline

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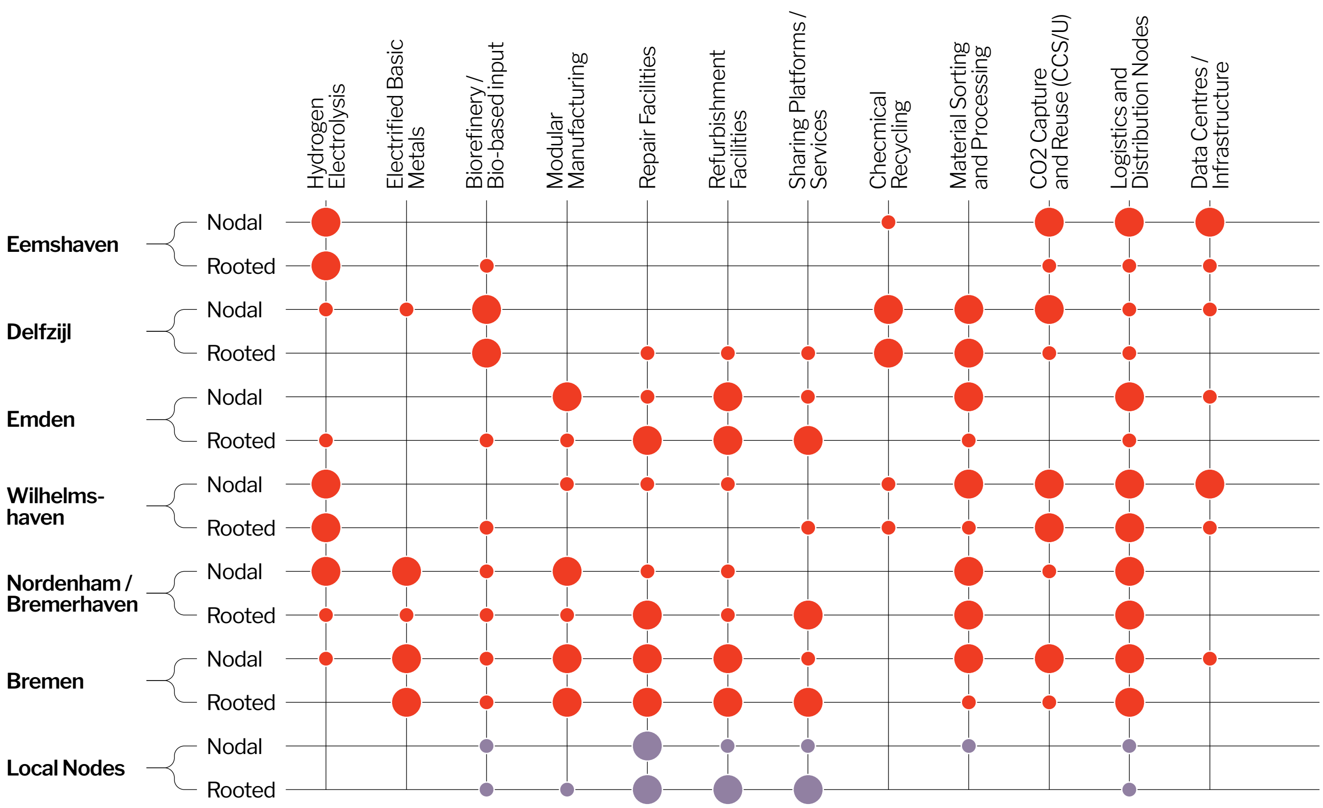
11.4 Strategic Framework for the Productive Motor

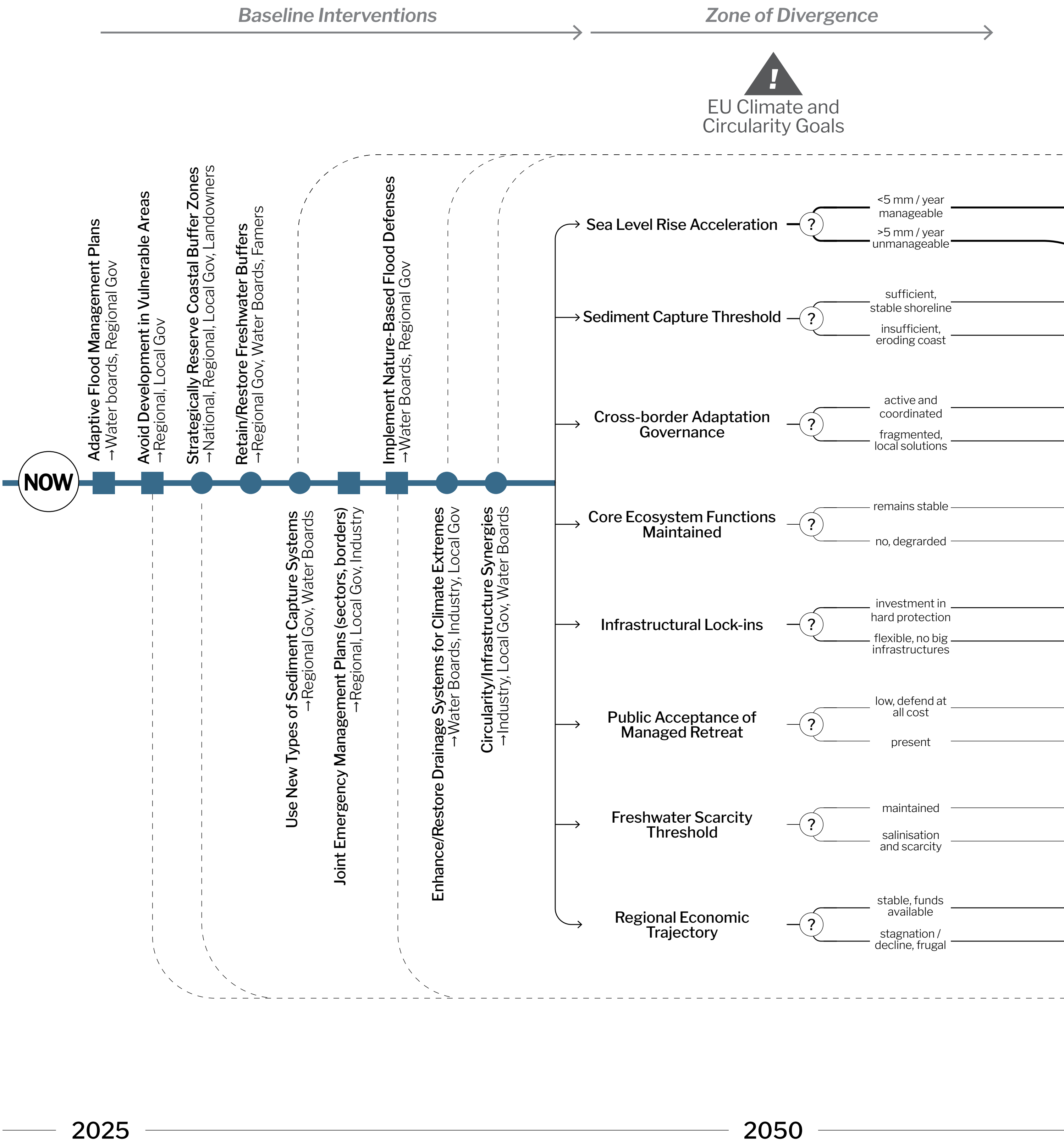
Spatialising the strategic framework, it is important to note that the land-take of circularity varies by direction: Closing the loop (recycling, recovery) concentrates at clusters and ports; Slowing it (repair, reuse, substitution) disperses to smaller, urban, or mixed-use zones (De Kort & van der Wield, 2024) and Narrowing it (changing consumption/practice) requires little space but high societal effort. This means that the map of the Strategic Framework for the Productive Motor shows both the established industrial clusters, such as Eemshaven, Wilhelmshaven, Emden, Delfzijl and the (re-)use of the regional network of smaller industrial sites and other business locations with trimodal access, many of which must be safeguarded and developed to ensure future circular operations (Rood & Evenhuis, 2023).

The circular cross-border metabolism therefore is not just about the big megafactories, but also about anchoring some activities in urban environments. Who runs these sites, local cooperatives, public authorities, or new actors, remains an open question. In the Wadden Sea region, this could take place in cities like Oldenburg, Groningen and smaller places. To deliver on these ambitions, the backbone of the region must first be future-proofed: grid upgrades, hydrogen infrastructure, and reliable feedstock logistics are not options but essential preconditions for a decarbonised industrial system (Deen & Jongsma, 2023). Without them, industry cannot decarbonise, circular hubs cannot emerge, and the risk of stranded assets grows. The Y-shaped pathway made this clear: until 2040, all critical infrastructure must be in place and sites must be designated for flexible, future-ready use. As tipping points, like hydrogen network completion, fossil refinery closures and decisive policy action, arrive, some clusters may scale up as globally connected, high-tech nodes, while others shift towards modular, locally-governed production linked with the localised circularity locations. Bottlenecks, from grid congestion to slow tech adoption and planning inertia, are real and must be addressed head-on (I-1, 2, 4, 6, 2025). Ultimately, this strategic approach therefore keeps adaptive space open to use the current industrial system as the lever for a circular regional future. This is made spatially tangible through a matrix of circular cluster functions shown below.



# Adaptive Edges

## Working out the Strategic Framework for the Protective Motor



**Intervention Types**
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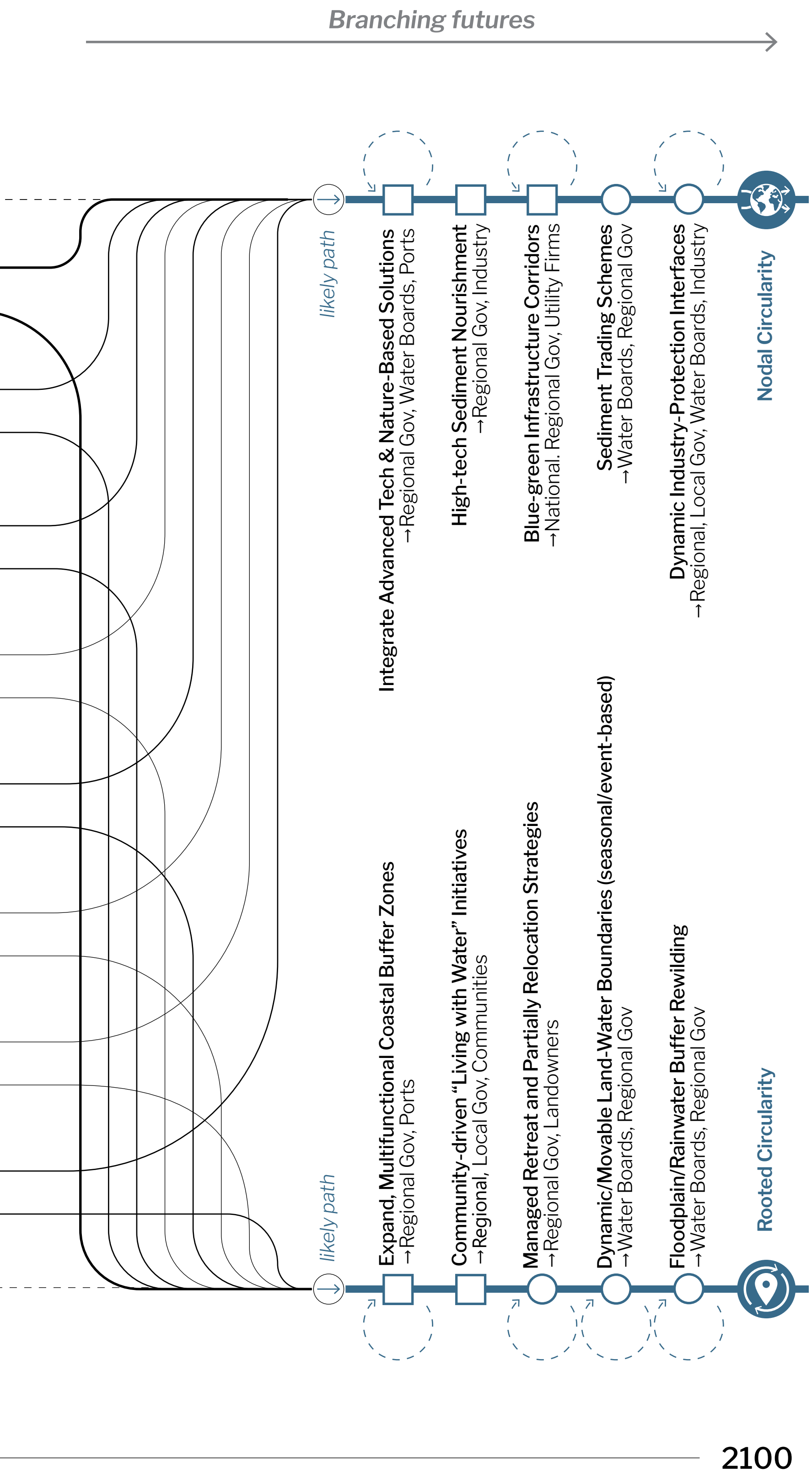
- ■ Set Intervention – Fixed: Hard Spatial Anchor
- ○ Speculative Intervention – Dynamic
- □ Speculative Intervention – Fixed
- → Stakeholders involved

**Influence on Pathways and Future States**
- Feedback Loop
- ··· Baseline Intervention makes Future State more likely
- — Very strong influence of direction
- — Strong influence of direction
- — Moderate influence of direction



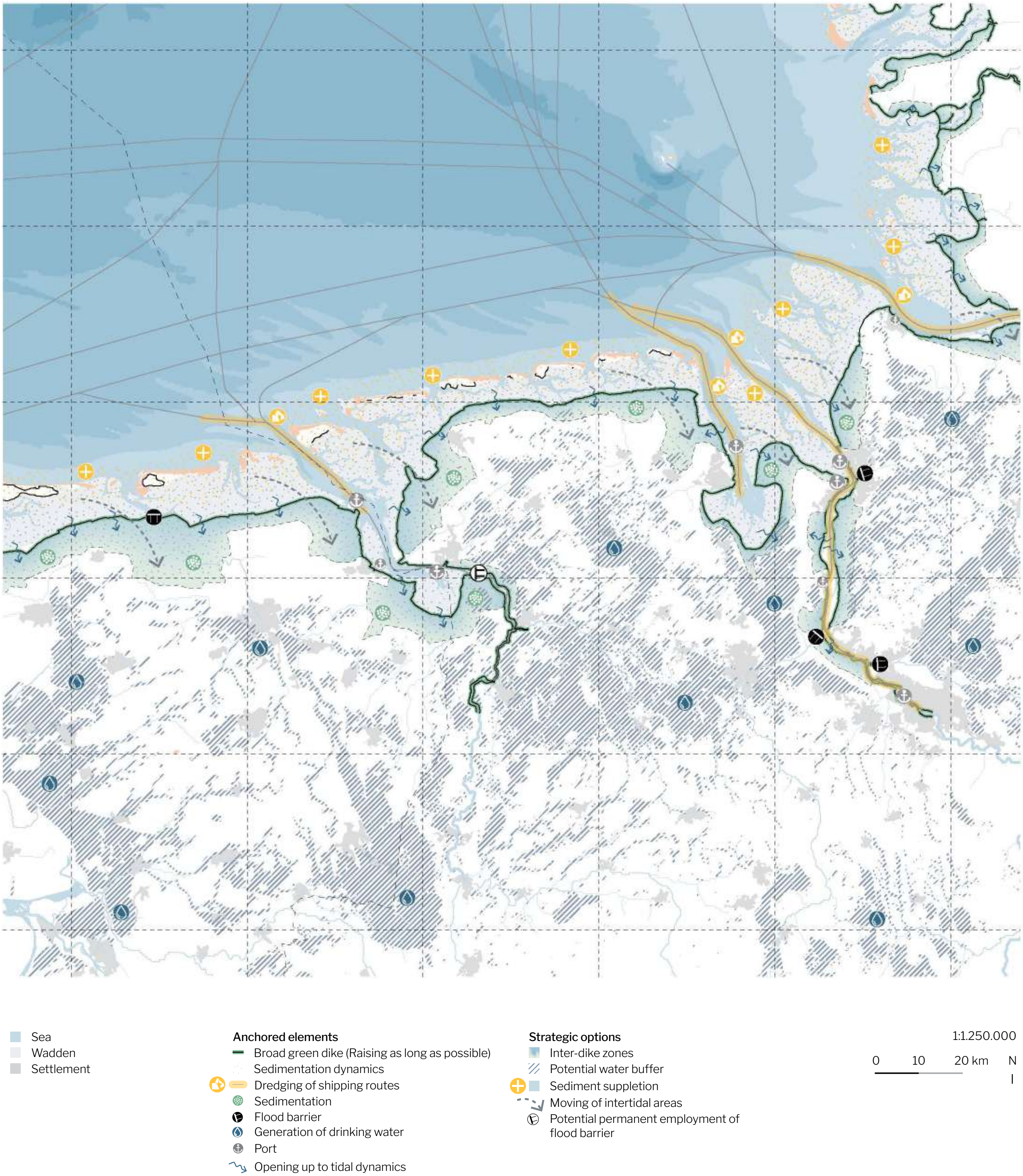

> *I anticipate de-diking and polder opening before 2100.*
>
> I-6, Environmental Officer (DE)

> *Promote adaptive, small-scale solutions and avoid all-or-nothing megaprojects*
>
> I-8, Project Coordinator (NL)

> *Freshwater supply is becoming a blind spot in many areas. We plan too little with water as an active spatial component*
>
> I-8, Project Coordinator (NL)

The protective motor in this framework anchors regional adaptation to climate change in phased, spatial interventions that build resilience in face of uncertainty. Early actions, like reserving buffer zones, upgrading drainage and combining nature-based and engineered flood defenses, prepare the ground for future flexibility. Tipping points such as sea level acceleration or governance shifts mark the divergence: will the region continue to function as a technological bulwark or reorient to living with water and in some areas a managed retreat? By structuring these adaptive choices, this framework keeps options open for now and recognises that protection needs to balance stability, transformation and public acceptance of changing land–water relations.

◀ **11.5 Detailed Strategic Framework for the Protective Motor**




11.6 Strategic Framework for the Protective Motor

The map (Fig. 11.4) visualises the multifunctional coastal buffer zones as potential, spatially anchored measures that build long-term flood resilience. The actions proposed, such as adaptive flood management plans, dynamic sediment capture systems and freshwater retention buffers, are an integral part of the strategic baseline interventions. Below, Langwarder Groden and Brede Groene Dijk show to early pilot manifestations in the region of such new paradigms for living with water. Following in the branched phases, digital floodgate systems would support a nodal trajectory, while managed retreat strategies support rooted adaptation. This spatial approach keeps options open for now, as it is still unknown how climate pressures intensify exactly.

*Soft summer dikes and retreat-based projects (such as Langwarder Groden) show alternatives.*

I-8, Project Coordinator (NL)

**Reference: Langwarder Groden**

In Butjadingen, the Langwarder Groden project transformed a fixed dike into a tidal salt marsh after years of public debate. As a compensation measure for the port in Wilhelmshaven, a new setback dike was built inland and the old dike breached, letting tides create dynamic coastal habitat (Planungsgruppe Grün, n.d.). This could be a model for adaptive flood protection in the region.

11.7 Boardwalk in the Langwarder Groden buffer zone

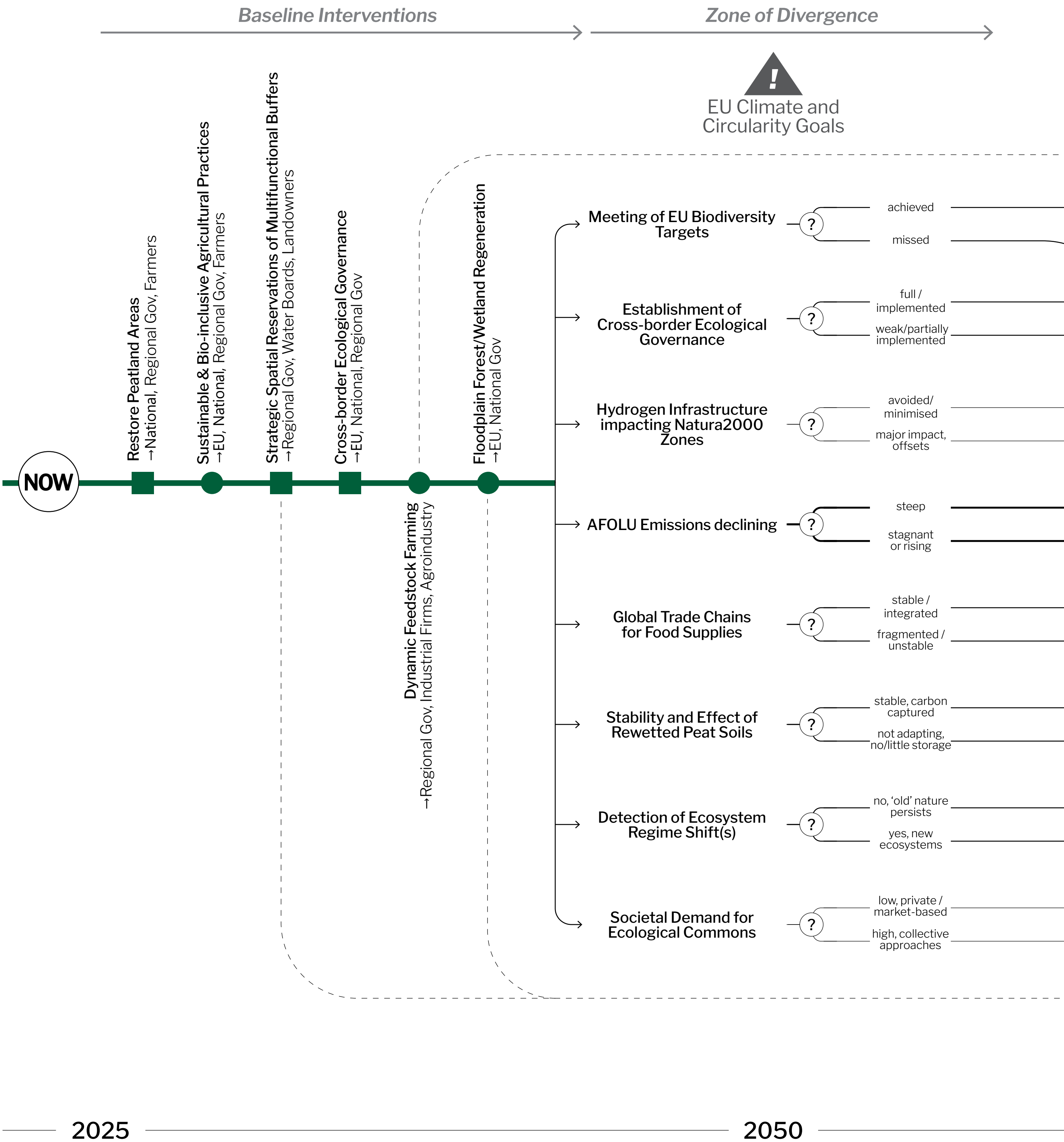
**Reference: Brede Groene Dijk**

Along the Dollard, the Brede Groene Dijk („broad green dike") project (Programma Eems-Dollard 2050, 2025) reinforces sea defenses using locally sourced clay and silt. Material from nearby polders and channels is processed and used to build a broad, nature-friendly dike. This approach benefits both flood safety and wetland ecology, and shows how future dike upgrades can work with natural cycles.

11.8 Clay processing next to the reinforced dike

# Beyond Conservation

## Working out the Strategic Framework for the Ecological Motor



**Intervention Types**
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**Influence on Pathways and Future States**
- Feedback Loop
- Baseline Intervention makes Future State more likely
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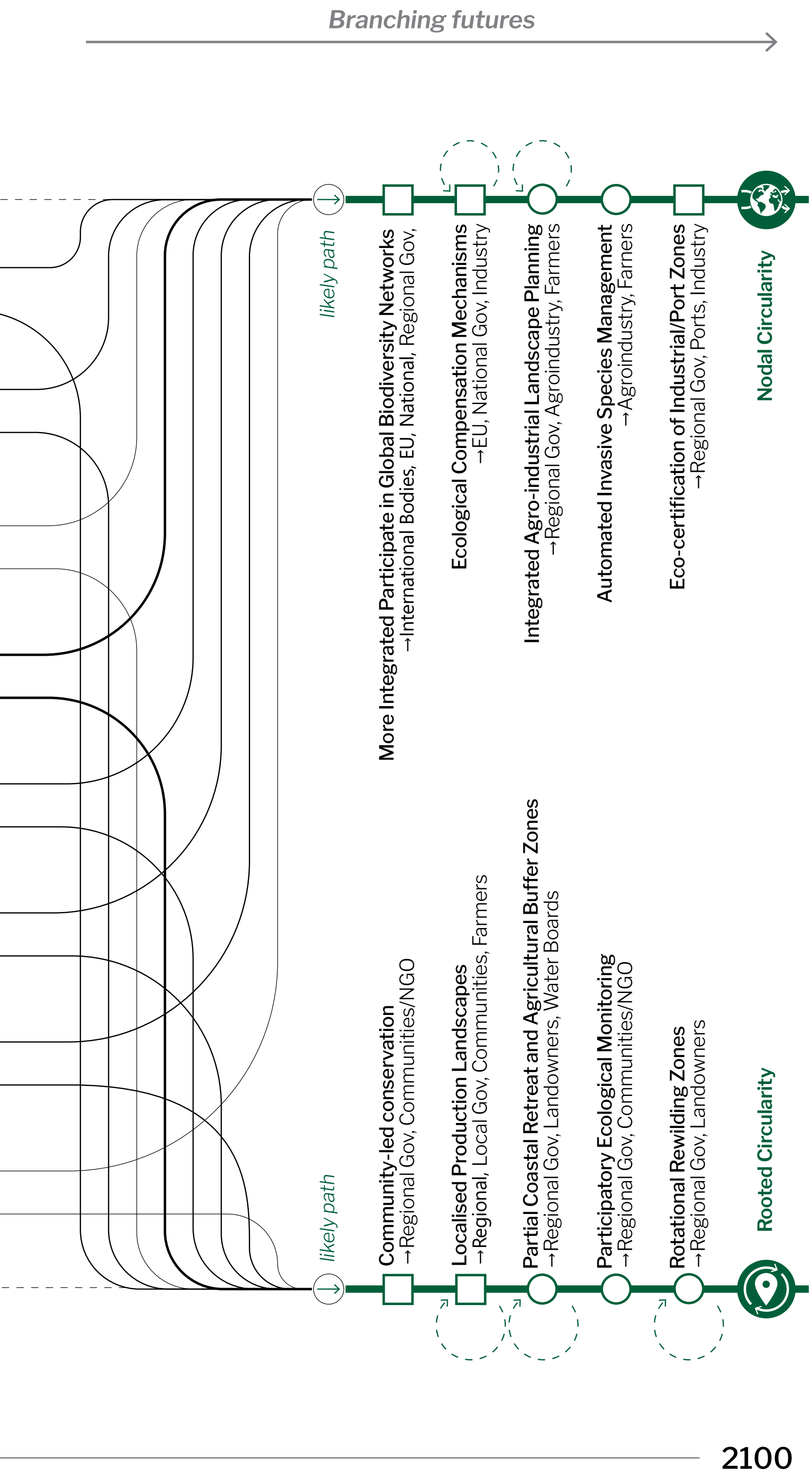
- Moderate influence of direction




*Cross-border ecological thinking is essential.*

I-6, Environmental Officer (DE)

*In my experience, bioeconomy is currently the most strategic domain in circularity.*

I-8, Project Coordinator (NL)

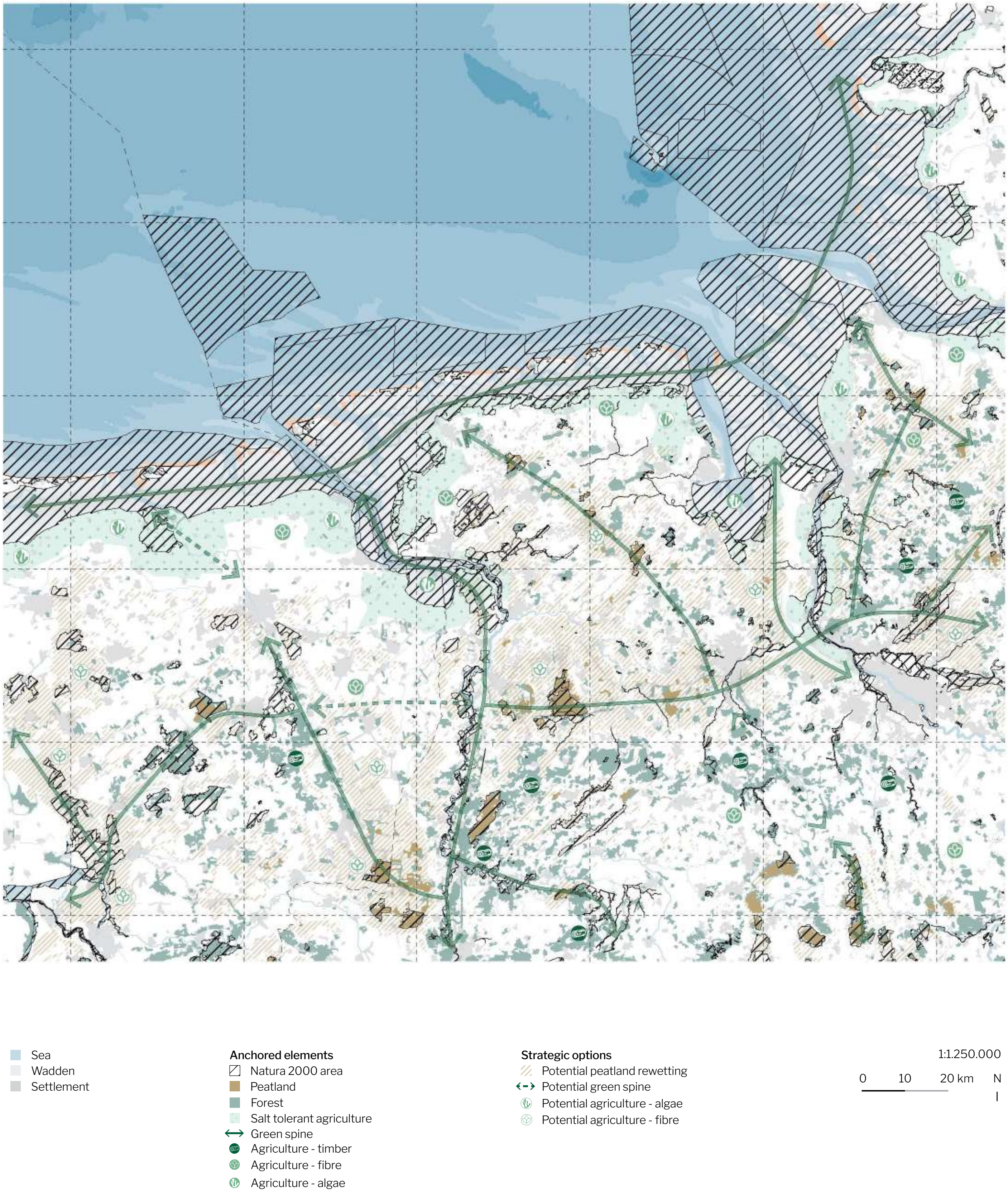
*Nature-based approaches are essential, because not everything can be technologically compensated.*

I-6, Environmental Officer (DE)

The ecological motor anchors climate adaptation and biodiversity recovery as prerequisites for a circular transformation in the Wadden Sea region. Early interventions (peatland restoration, bio-inclusive agriculture and strategic buffer zones) lay a spatial foundation aligned with the other motors. These measures respond directly to stakeholder calls for nature-based, locally adapted solutions, thact acknowledge that technological fixes alone are insufficient. As the region hits key tipping points, such as meeting EU biodiversity targets, the stability of rewetted peat, hydrogen impacts or emergent ecological commons, the potential trajectories diverge. Going in a Nodal direction reinforces technical controls and eco-certification, while moving into a Rooted one accepts regime shifts, empowers communities and rewilds.

◀ **11.9 Detailed Strategic Framework for the Ecological Motor**

PROJECTION




11.10 Strategic Framework for the Ecological Motor

The map shows how the Strategic Framework for the Ecological Motor takes shape: peatland restoration, bio-inclusive agriculture and buffer zones are spatially anchored in zones of vulnerability. These "possibility spaces" offer gains for biodiversity and can shift toward commons or rewilding if needed, according to the future pathways. Key links to productive and protective motors are highlighted through production of biobased feedstock and shared buffer zones. Success depends on cross-border governance, adaptive monitoring and flexibility. This way, ecological outcomes can evolve with choices and feedback loops across all three motors.

*We have to ask ourselves: What forms of agriculture can be practiced in rewetted areas in the future?*

I-8, Project Coordinator (NL)

**Reference: Schwimmendes Moor**

The Schwimmendes Moor floating peat bog at Sehestedt (Niedersachsen), a rare remnant outside the main dike, is a living showcase of how the coast of the Jade bay once looked before the diking started at a large scale: soft, dynamic and shaped by water. Its shifting boundaries and biodiversity show the value, but also the fragility, that process-based, nature-driven adaptation can hold.

11.11 Peat bog next to the Jadebusen coast

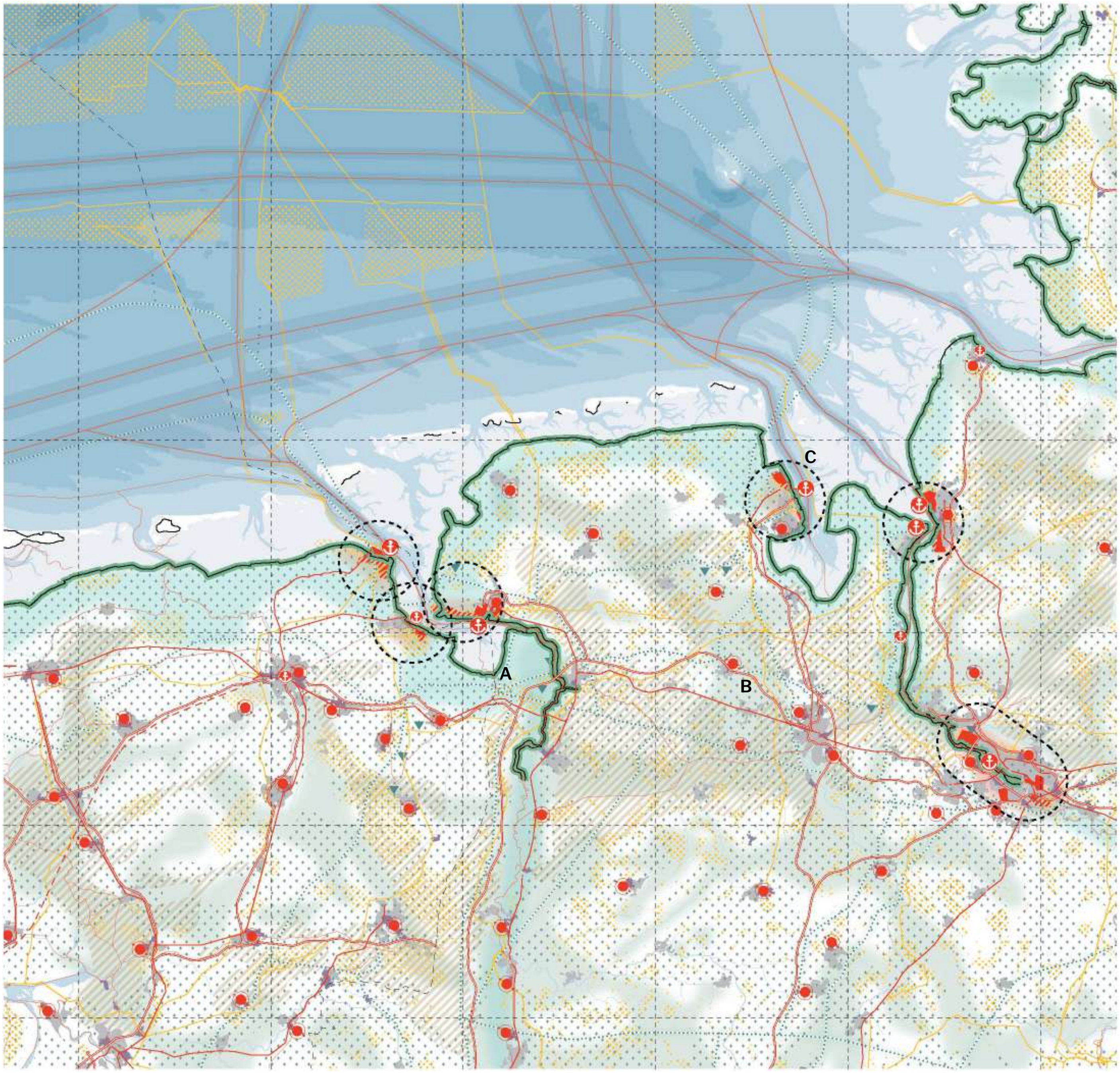
**Reference: Buffer Noordoost**

Buffer Noordoost at Bargerveen (Drenthe) is a 20-hectare water buffer that stabilises the hydrology in a raised bog and enhances habitats for rare species by creating varied wet and dry zones. While paludiculture is not yet viable here for bio-based feedstock, the buffer serves as a pilot for wetland restoration and small-scale experimentation about new types of agriculture (Prolander, 2020).

11.12 Experiments with paludiculture in Bargerveen Noordoost

# How Everything Could Come Together

## Overlaying and Synthesising the Three Motors




Sea
Wadden
Settlement

Large Industrial Cluster area
Potential Cluster expansion
Large Cluster
Local Circular Hub
Energy area
Mobility network
Energy grid
Broad green dike (Raising as long as possible)

Green spine
New water landscapes
Potential rewetting

1:1.250.000
0 10 20 km N

**11.13 Overall Strategic Framework**

*Planning is still sectoral and often lacks holistic territorial thinking.*

I-5, Regional Planner (DE)

*Vertical double land-uses will become much more likely – I welcome that.*

I-9, Environmental Officer (DE)

*We must prioritise between the energy and circularity transitions.*

I-3 Business Representative (NL)

*Circular economy is far too product-based – we need a systemic understanding.*

I-5, Regional Planner (DE)

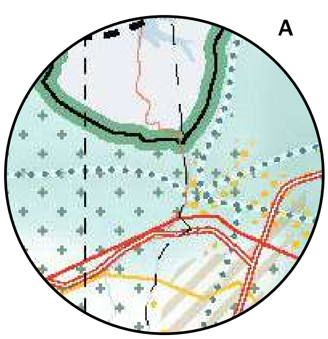
Overlaying the three motors, productive, protective and ecological, shows that a circular future in the Wadden Sea region demands more than spatial optimisation. Each motor brings with it distinct logics and claims and their alignment is not automatic, but has to be negotiated. This spatial synthesis of the Strategic Framework addresses a persistent shortfall raised by stakeholders: the lack of territorial, cross-sectoral thinking. Where buffers, decentralised bioproduction and circular hubs overlap, synergies emerge, but so do frictions. Competing demands for land, Natura2000 constraints, and diverging infrastructure claims require prioritisation.

What is at stake here goes beyond resource efficiency in material loops. This Strategic Framework aims to achieve the vision of a Circular-Cross-Border Metabolism (see Chapter 9). This in turn built on the concept of the circular society (see Chapter 3), where circularity touched the seven interlinked cycles of biogeochemistry, ecosystems, resources, politics and power, wealth, knowledge and care (Calisto Friant et al., 2024). With this synthesis, the Strategic Framework pursues a broader aim than just material resource efficiency: it responds to spatial tensions and uncertainties and embeds care for landscapes, labour and life into adaptive, place-based transitions towards circularity.

Three spatial lenses below illustrate where the motors interact and the seven broader cycles become visible. These various types of focal points show friction fields and synergy to test the Strategic Framework in place.

The diagram that follows on the next page builds on the Hypthetical Spatial Flow Map (Fig. 7.8) and visualises one possible metabolic future of the region to connect these insights with the spatial organisation of flows.

Oldambt / Dollard

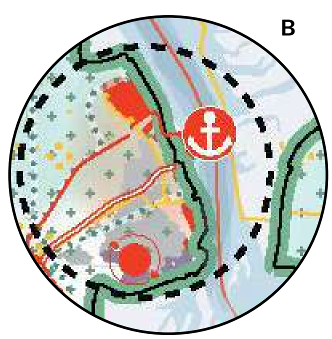



Rewetting, retreat and circular agriculture in a sensitive transition landscape

**Protective** (buffer + retreat), **Ecological** (peatland + biodiversity), **Productive** (biobased loops)

Biogeochemical (Peat rewetting stores carbon), Care (Requires long-term land stewardship), Wealth (Supports rural circular economies), Ecosystem (Enhances species resilience and habitat connectivity)

Wilhelmshaven

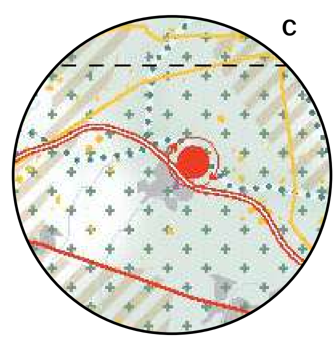



Large-scale hydrogen infra and nature-based protection close to an urban environment

**Productive** (global hub), **Protective** (dynamic sedimentation), **Ecological** (coastal nature potential)

**Power** (Strong governance needed to balance conflicting transitions), **Ecosystem** (Potential for ecological-industrial regeneration), **Knowledge** (Need for integrative, adaptive design)

Westerstede

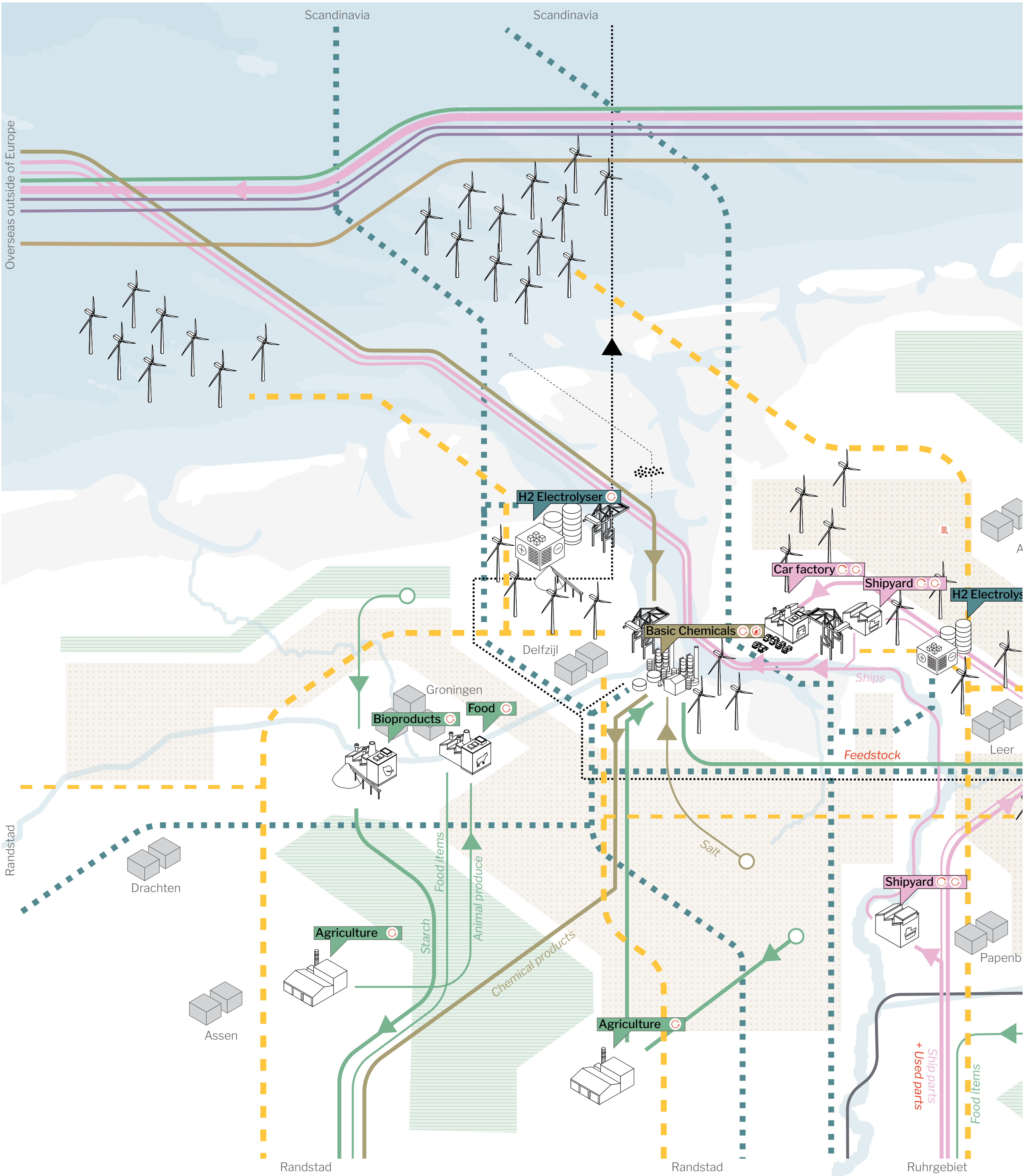



Small-scale circular production meets water buffering and biobased strategies

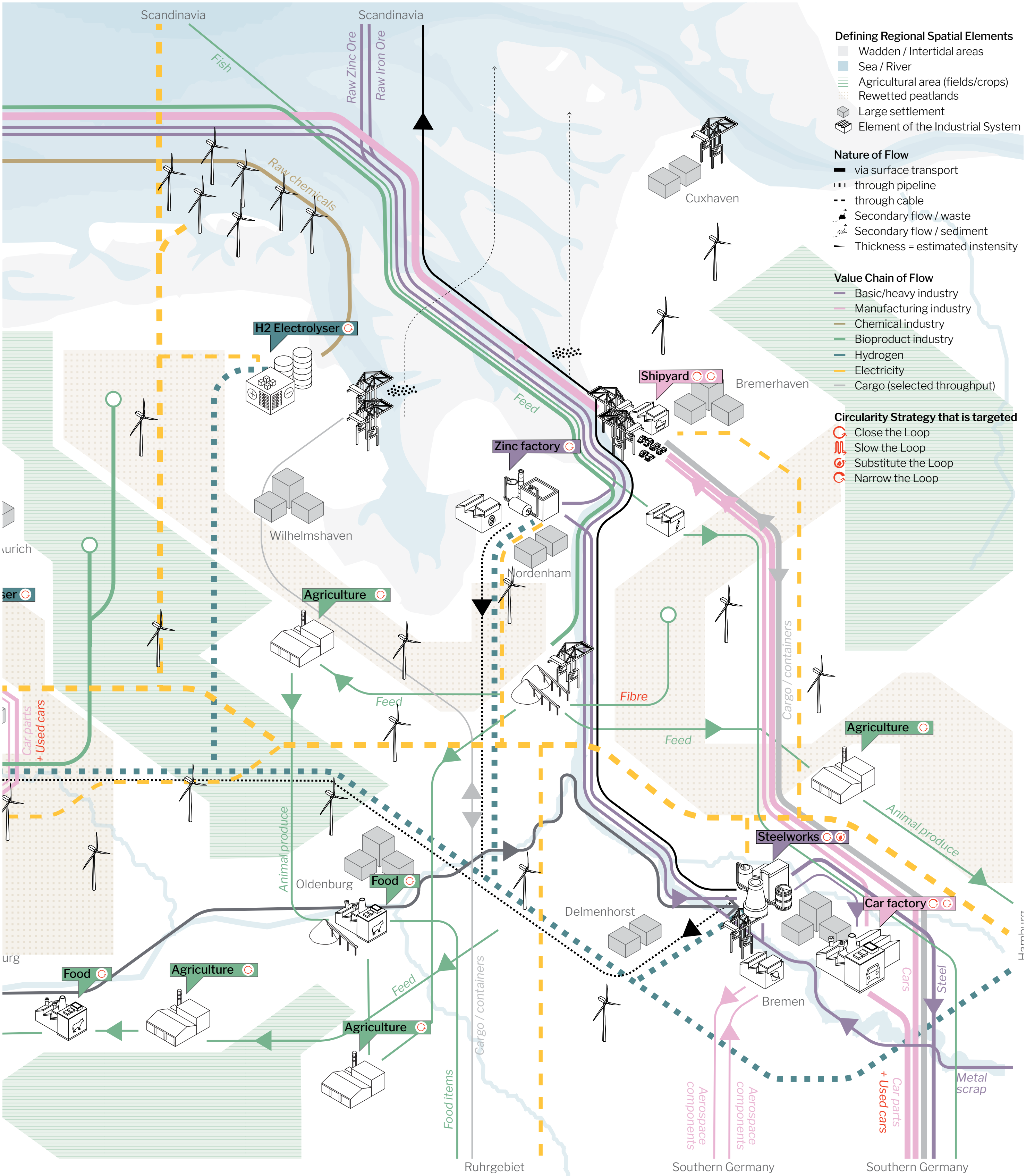
**Productive** (modular, biobased), **Ecological** (landscape corridors), **Protective** (re-wetting zones nearby)

**Care** (Local actors sustain place-based circularity), **Knowledge** (Innovation in agro-ecology and fibre chains), **Biogeochemical** (Water + carbon cycle restoration), **Wealth** (Diversified rural livelihoods)

PROJECTION




11.14 Potential Future Spatial Flow Map



Scandinavia
Scandinavia
Fish
Raw Zinc Ore
Raw Iron Ore
Raw chemicals
Defining Regional Spatial Elements
Wadden / Intertidal areas
Sea / River
Agricultural area (fields/crops)
Rewetted peatlands
Large settlement
Element of the Industrial System
Nature of Flow
via surface transport
through pipeline
through cable
Secondary flow / waste
Secondary flow / sediment
Thickness = estimated instensity
Value Chain of Flow
Basic/heavy industry
Manufacturing industry
Chemical industry
Bioproduct industry
Hydrogen
Electricity
Cargo (selected throughput)
Circularity Strategy that is targeted
Close the Loop
Slow the Loop
Substitute the Loop
Narrow the Loop
Cuxhaven
H2 Electrolyser
Shipyard
Bremerhaven
Feed
Zinc factory
Wilhelmshaven
Nordenham
Agriculture
Fibre
Feed
Feed
Cargo / containers
Agriculture
Animal produce
Car parts + Used cars
Animal produce
Steelworks
Oldenburg
Food
Delmenhorst
Car factory
Food
Agriculture
Feed
Cargo / containers
Agriculture
Bremen
Cars
Steel
Metal scrap
Food items
Aerospace components
Aerospace components
Car parts + Used cars
Ruhrgebiet
Southern Germany
Southern Germany


Emden Port
Emden Lock
VHF 13

12

# Zoom-In Exploration

# Emden as Testing Ground

## Introduction of the Zoom-In

This chapter zooms in on Emden, one of the six industrial clusters identified in Chapter 8, to test how the strategic framework presented in Chapter 11 actually lands in space. Emden is not just a miniature version of the whole region, but a friction zone where mono-industrial structure, post-war planning and tidal landscape meet the open questions the Wadden Sea area faces.

Strategically positioned on the Außenems and shaped by layered infrastructural development, Emden is dominated by the Volkswagen factory and its export harbour. The planned implantation of the VW plant in the 1960s on vacant polder lands further cut through historic ditch structures and added another layer of fragmentation onto the city spatial logic. Today, this poses a challenge, but the uncertainties about the industrial future are also a unique opportunity to think about spatial circularity from the ground up.

The zoom-in serves three purposes:

- Spatial prototype:  testing how strategic principles, like co-locating ecology and industry or transforming mono-functional zones, manifest in place.
- Design hypothesis: exploring how long-term divergence between Nodal and Rooted pathways takes shape physically.
- Methodological experiment: re-applying lenses (like territorial metabolism) at local scale to test their grip on urban complexity.

Chosen for its legibility, scale and systemic relevance, Emden was already analysed in Chapter 8 as a fragmented industrial node with clear infrastructural dominance and weak spatial integration. The aerial photograph (Fig 12.7) shows the zoom-in extent. Below, selected images highlight spatial and morphological conditions that reappear in the following design spreads


12.1 Ratsdelft: Historic core of the city


12.2 Post-WW2 buildings in the centre


12.3 Remnants of the 1900s industrial glory


12.4 Underutilised transition zone to the ports


12.5 Most of the inner port is intensively used


12.6 The VW factory is beyond human scale


12.7 Aerial photograph, showing the urban fabric, the ports and the Zoom-In area

1:90.000

0 1 2 km N

# Historical Anchors for Future Times

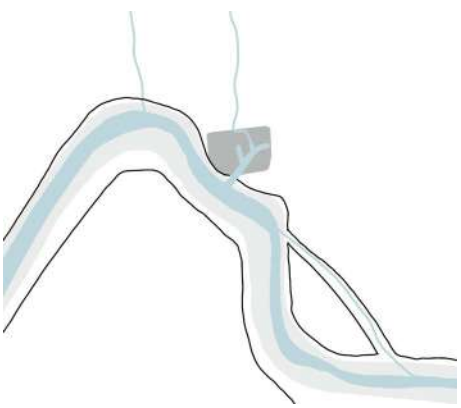
## Historic shifts in Emden's spatial structure

This historical overview of Emden explores how the city's spatial logic evolved, at times aligning with, at times diverging from, the broader territorial development in the Wadden region. Chapter 5 revealed a transition from adaptive settlement to top-down control: visible in dikes, infrastructure and extractive land use. In Emden, this trajectory is particularly stark: from tidal coexistence along the Ems (1500) to today's fragmented urban structure, disconnected from river and sea. Key spatial decisions, such as harbour dredging, poldering, the establishment of the VW factory, drove a wedge between city and estuary. Industry now overscales and fragments the urban grain, which reduces morphological and ecological permeability (Stadt Emden, n.d.).

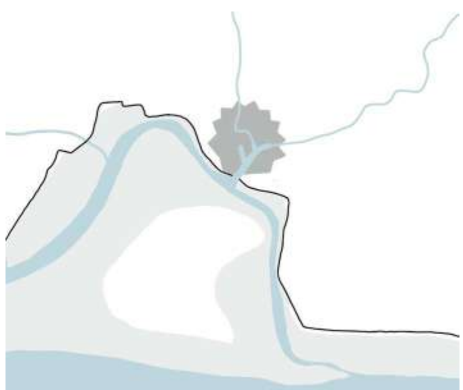
1500

1600

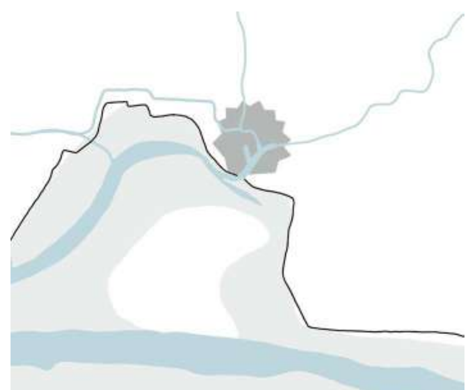
1850



**River-City Symbiosis**
The Ems still flows past Emden before the Dollard is formed. Trade and tides align in a fluid way.



Trade thrives mainly due do Dutch traders, but sediment blocks the port. A guiding dam fails against the tidal force.



The Harbour is silted and trade bypasses Emden. The drained hinterland remains spatially inert.

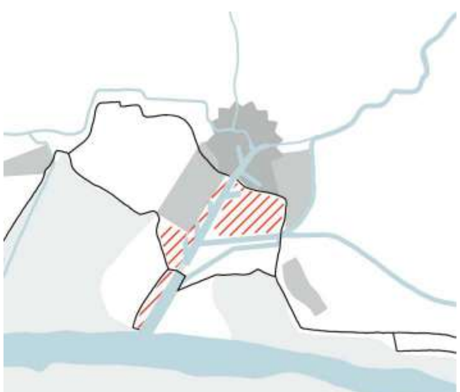
**12.8 Historical Timeline of Emden**

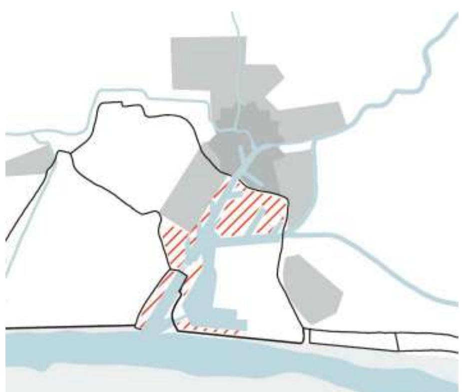
The timeline unpacks how spatial regimes were layered, erased or imposed. By doing so, it clarifies what the current conditions inherited and what room for change they still contain. For instance, Dutch architectural traces in streets refer to a time of interdependence between urban life, trade and water. Recognising these can help identify what directions future spatial transitions towards the circular future states could take.

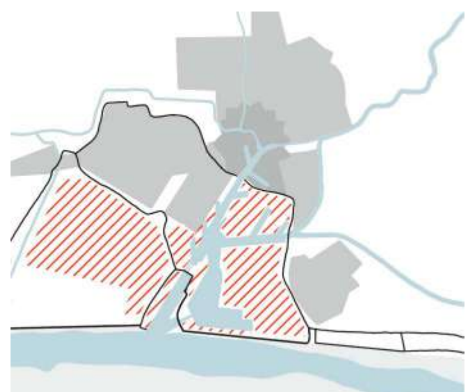
1910

2025

1960







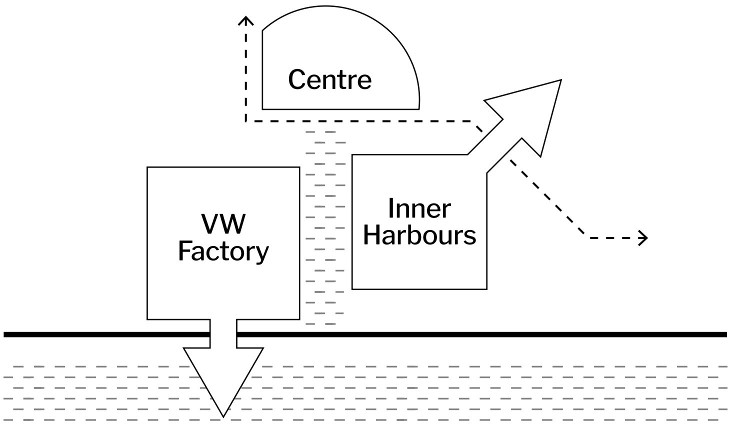
Docks, dikes and polders reshape the coast. Emden is tied into the industrial value chains of the Ruhrgebiet.

After destruction in WW2, some of the polders are still agricultural. The city is fragmented by layered infrastructure.

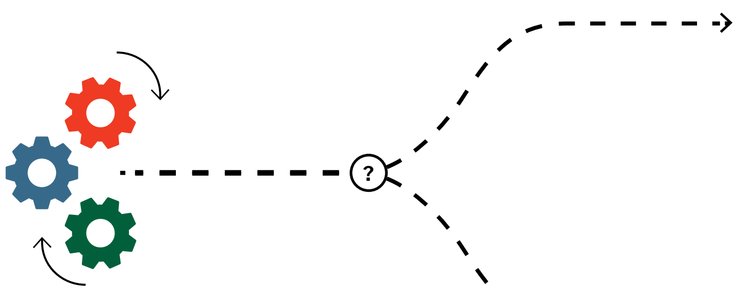
The VW factory dominates in function and scale, the city and the Wadden Sea are clearly divided by industrial areas.

# Emden in Transition

Making a Link between Past, Present and Future




12.9 Functional Logic




12.10 Overall Strategic Framework

## Logics of the Urban Structure

The spatial logic of Emden unfolds along a gradient: from the compact centre through the more fragmented inner harbours to the outward, large-scale site of VW. The harbours are not fully integrated, but as areas within the dikes with finer grain and mixed use, they offer spatial leverage. The VW zone enforces a singular logic: but it can be re-layered. Rather than grieving about the past, this reading engages with what is and what could be.

## Link to Strategy

This zoom-in acts as the strategic hinge where regional pathways meet the local complexity. Emden is the test to examine how the phases of baseline measures, divergence and future states translate into spatial form. It might also reveal frictions between the three motors (productive, protective, ecological). These tensions are signals rather than flaws: they show where phasing matters, where trade-offs arise and where design gains its grip.

## Strategic Starting Points

These three spatial starting points translate the strategy into grounded interventions. Each connects to the motors and also cross boundaries. Together, they prepare the terrain: to anchor short-term change, test divergence and hold space for long-term transformation.

1. Activate the inner harbours for city-linked, mixed-use circular functions.
2. Use the VW site to pilot reversible, circular spatial interventions linked to global chains
3. Stitch back landscape and protection through layered green-blue and infrastructural systems

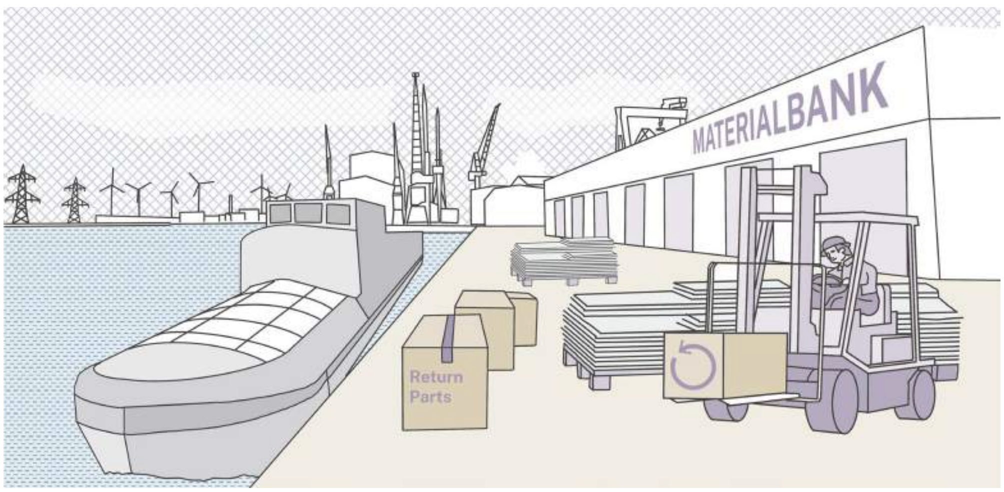
12.11 Inner Harbours: Defined by various functions but also empty plots, this area can anchor circularity within urban reach.

12.12 VW Car Factory: Along the vast factory edge, the scale and stillness hint at unrealised flexibility.

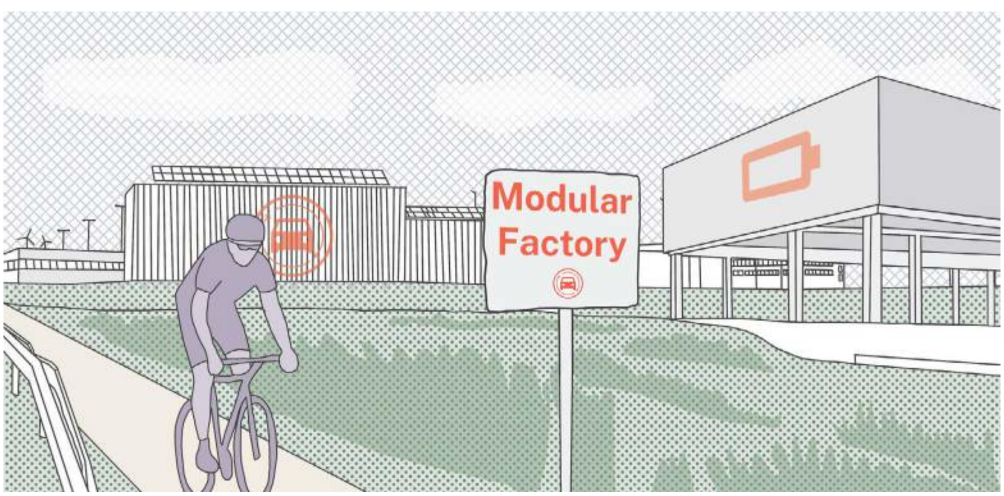
# Baseline Emden

## Strategic Framework until the 2040s

Emden in the 2040s shows a morphology that remains largely intact, while subtle shifts mark the beginning of the transition. The Inner harbour zones host early circularity pilots, for example in ship recycling. They are still modest in scale, but well connected within the existing grain. The VW factory still dominates the city, but the first buffers hint at ongoing spatial negotiation. Behind the dike, a lithium refinery was built in a modular and reversible way, thus anticipating change rather than cementing form. New hydrogen infrastructure, including a cross-border link to the Netherlands, prepares for future flows. Most strategic action happens in the productive motor, but the others remain moving, even though not yet aligned. The landscape is stable and the situation is still structurally open. Rather than locking in one future, this baseline phase prepares a range of options through light, flexible interventions that stabilise without scripting.

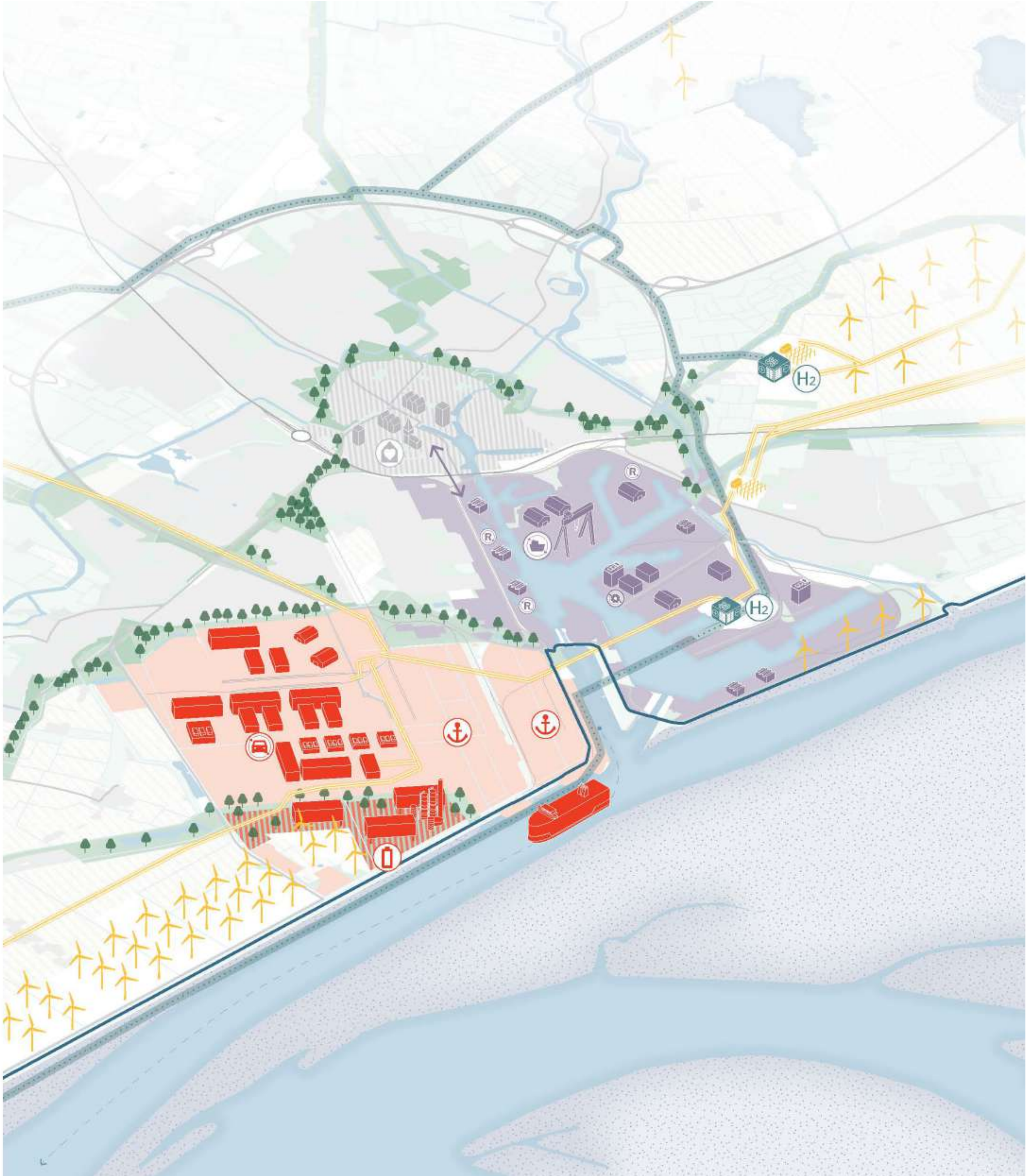



12.13 Potential view of the Inner Harbors in the Baseline Situation




12.14 Potential view of the VW factory  in the Baseline Situation

12.15 Potential axonometric view of Baseline Emden ▶

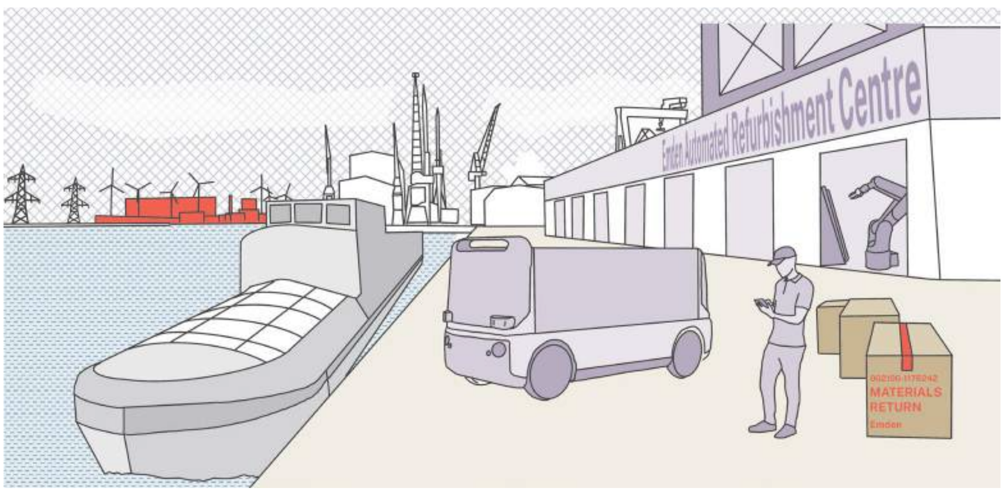



- Emden City Centre
- Circular Car Production
- Car Shipment Port
- Lithium Refining / Batteries
- Ship Recycling
- Repair and Refurbishment
- Recycling and Material Sorting
- Hydrogen Electrolyser

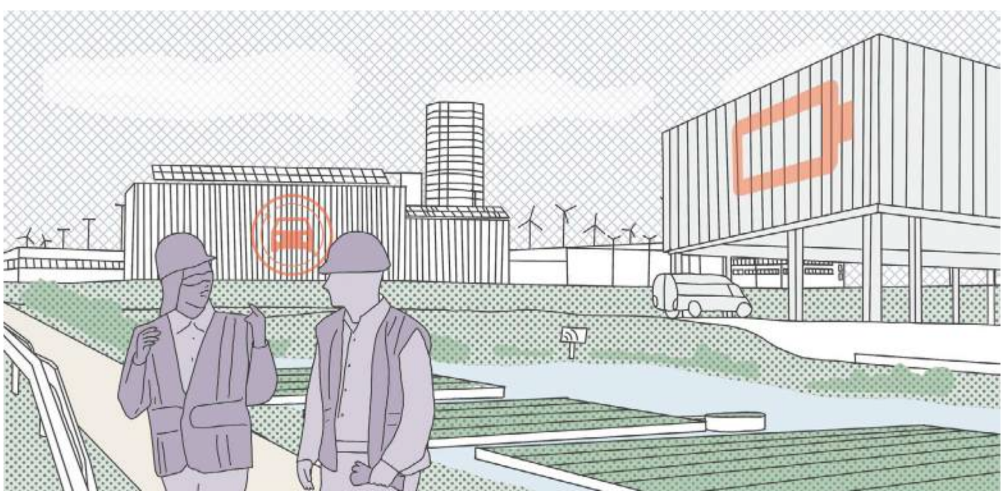
# Nodal Emden

## Strategic Framework until the 2040s

In the Nodal pathway, Emden further scales up as a logistics and energy hub within European (and potentially global) circular networks. The VW cluster is intensified in use and area, flanked by new modular battery and EV industries. Battery recycling, hydrogen conversion, and data-driven logistics dominate the productive motor. Flows and functions take the lead and infrastructure continues to influence the urban form. Biodiversity zones and water buffers are present but more subordinate, as they are shaped to fit the throughput nature. Yet, there is overlap between the different motors, as parts of the extended modular car manufacturing lie outside of the dike on raised structures. Here, production, sedimentation, new habitats and energy generation all take place simultaneously. On the other side of the harbour area, in the East of the city, the locally grounded circularity zone expands due to growing material consumption along the Ems-Jade-Kanal. The hydrogen and substation area in Borßumer Hammrich is further expaned to grow into an energy factory on its own. In this future state of Emden, the landscape becomes a sort of platform. It is engineered, adapted to flows, but still offering layered potential for circular cohabitation of humans and other species.




12.16 Potential view of the Inner Harbors in the Nodal Future



12.17 Potential view of the VW factory  in the Nodal Future

12.18 Potential axonometric view of the Nodal Emden ►

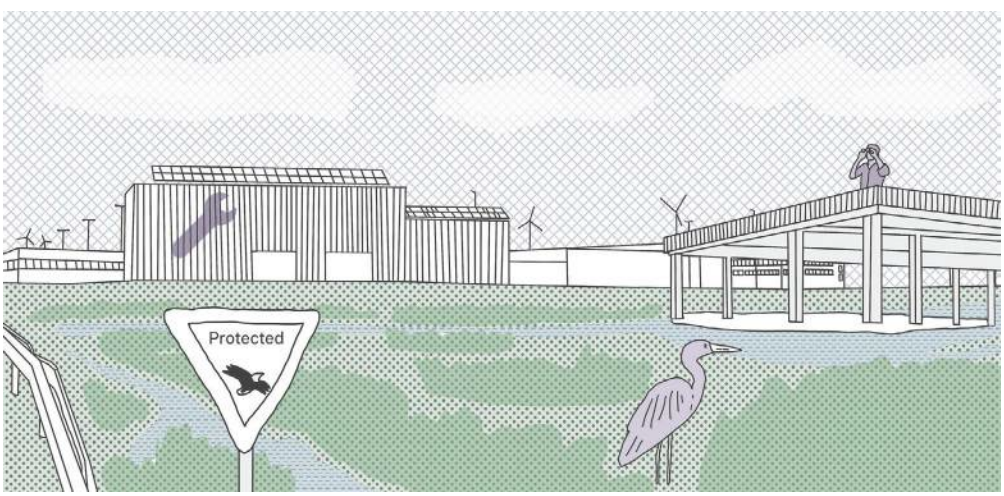

Emden City Centre
Circular Car Production
Car Shipment Port
Battery Recycling
Ship Recycling
Repair and Refurbishment
Recycling and Material Sorting
Hydrogen Electrolyser

# Rooted Emden

## Strategic Framework until the 2040s

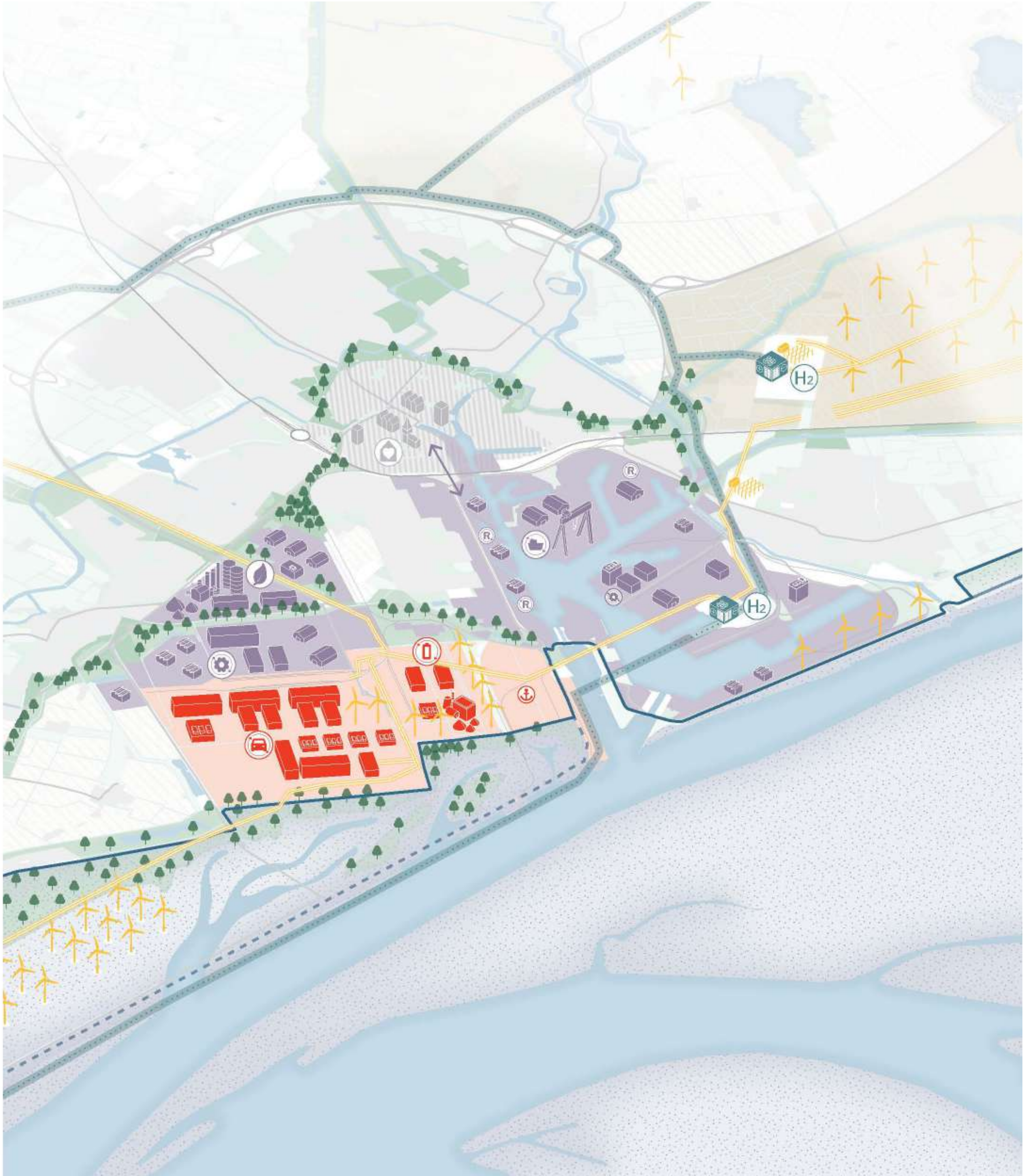
In the Rooted future, Emden reorganises its spatial priorities toward sufficiency, care, and local resilience. The VW site shrinks and diversifies: one part becomes a circular repair zone for agricultural machinery, another is re-wetted, while the former export terminal at the Außenems transforms into battery recycling. North of the factory, new biomass facilities work in sync with rewilded peatlands in the region. The dikeline moves back, creating salt marshes and sediment buffers. The inner harbours grow in their role as anchor zones for productive and social rooting. They are densified, fine-grained, and stable. Local loops dominate: spatial flows turn inward and shared assets replace throughput. Landscape and city re-engage, as sediment, saline crops and green corridors structure a slower metabolism. The three motors are interwoven, but only after accepting friction and limits, for example when the VW factory had to give up land. What returns in this future state is still not the past, but a reclaimed identity: one that is slower, more entangled with the landscape and more collectively shaped.


12.19 Potential view of the Inner Harbors in the Rooted Future




12.20 Potential view of the VW factory  in the Rooted Future

12.21 Potential axonometric view of a Rooted Emden ►




- Emden City Centre
- Circular Car Production
- Car Shipment Port
- Battery Recycling
- Ship Recycling
- Repair and Refurbishment
- Recycling and Material Sorting
- Biomass Processing
- Hydrogen Electrolyser

Zooming in,

# what have we learned?

This zoom-in shows how an abstract strategy can become spatial form. In Emden, circular transitions are not drawn from scratch but need to be layered onto existing logics, like the succession from the compact city, through the fragmented harbours, to the outer VW zone. Key strategic elements, such as co-locating industry and ecology, modular reuse and layered buffers, are grounded here in a specific place with its own history and identity. The Nodal and Rooted futures illustrate how divergence materialises here: one accelerates flows, the other reclaims spatial care. What emerges is not one final design, but a strategic elaboration, that reveals frictions, phasing needs and spatial trade-offs. This shows that Territorial Metabolism gains traction when scaled down: it clarifies where abstract flows meet spatial friction. Emden shows that design is not an afterthought to strategy, but its proving ground. The transition towards Circularity becomes concrete here, across urban morphology and landscape systems.

13

# Conclusions

This thesis addressed the challenge of reimagining regional development in the Wadden Sea region in Germany and the Netherlands: An ecologically vulnerable, semi-peripheral zone that currently has the role as an operational hinterland. The region is now shaped by intensive infrastructural throughput and linear industrial activity. As the effects of climate change intensify and global production chains change, the traditional spatial logic of the region reaches its limits: This necessitates a fresh approach for sustainable transformation.

The primary objective has been to propose a circular and sustainable industrial system that responds to these challenges. The core research question examines how the industrial production system can be spatially transformed into a circular model, while considering its influence on functions, morphology, society and ecosystems. The current state was inventorised through an analysis of the regional historical development and the combination of a territorial perspective and a metabolist approach. This foundation enabled an exploration through research by design of how a circular cross-border metabolism can materialise.

Four subquestions structured this investigation and their answers are detailed in the subsequent section before a discussion of the results follows. This chapter closes then with a reflection on the approach I took and the learnings I take away from this graduation project

## Answering the Research Questions

**SQ1: What spatial patterns and historical developments have shaped the industrialisation of the Wadden Sea region, and which territorial, ecological and infrastructural logics determined the localisation of key activities?**

The industrialisation of the Wadden Sea region unfolded happened adaptive spatial patterns shaped by ecological constraints, infrastructural availabilities and historical shifts. The relation between land and water was crucial: Coming from one, Frisian origin, it was first fluid (settlements on terps), then fragile (first dike system) and later controlled (hydrological engineering of the marshlands and draining of peatlands). While key urban centres first formed on higher soils, later industrial clusters emerged along the coast, especially where to deepwater access, flat land, and other transport infrastructure came together, as can be seen in the Zoom-in Location in Emden.

Contrary to the initial assumption that industrialisation happened in a uniform way, German parts of the region developed earlier than the Dutch counterparts. This reflecting differences in political priorities and in desired territorial capital (such as gas in Groningen). The localisation of activities consistently needed to balance flood risks with connectivity to global flows and embedded the region as a semi-peripheral operational hinterland.

Four structural logics emerge:
(1) Historical anchoring: earlier spatial decisions constrained or enabled future development.
(2) Resource cycles: shifts (such as that from peat to fossil fuels to renewables) repeatedly reshaped landscapes.
(3) Crisis-led innovation: environmental and energy shocks spurred transformative responses, from dikes to hydrogen initiatives.
(4) Scalar development: punctual adaptations (e.g. terps) scaled into regional infrastructures (e.g. dikes), which implies that circular strategies must operate across multiple scales.

The results from the analysis, compressed in the four logics, reveal how circular transition strategies must align with historical and environmental foundations.

**SQ 2: How do the territorial and metabolic dynamics of industrial production and supporting infrastructure influence and entangle with the socio-ecological and spatial systems of thee Wadden Sea region?**

The territorial and metabolic dynamics of industrial production in the Wadden Sea region form a tightly interwoven system that puts pressure on and reshapes the surrounding socio-ecological fabric. As an operational hinterland, the region functions through a linear, throughput metabolism, concentrated in nodes like Bremerhaven and Delfzijl, that

channels material and energy flows, fragments landscapes and strains fragile ecosystems. Infrastructures such as ports, grids and transport corridors reinforce external dependencies.
The combined analysis findings revealed eight recurring space types, from large industrial clusters to dikes and marshlands, each expressing a distinct logic of production, protection or ecology. These three territorial 'motors' expose the forces that drive the region and illuminate how infrastructural and ecological systems co-evolve. Notably, industrial activity is often disconnected from urban density, as seen in Eemshaven. This reveals an unevenness between metabolic intensity and social reach.

This entanglement generates trade-offs: infrastructure enables economic gain but accelerates ecological degradation and social disparities. Furthermore, administrative borders hinder ecosystem-wide management. The findings reaffirm the initial hypothesis: a sustainability transition is urgent. Only by a reconfiguration of the regional socio-technical systems can this vulnerable yet vital hinterland evolve towards circularity and sustainability. By making the spatial footprint and trade-offs of this type of industrial metabolism visible, this analysis offers a foundation for designing more equitable and ecologically coherent circular futures.

**SQ 3: What spatial pathways and leverage points can guide the transformation of the industrial system in the Wadden Sea region towards circularity and sustainability, accounting for uncertainties and competing priorities?**

The three interwoven territorial 'motors'of the industrial system, production, protectio, and ecology, cannot be addressed in isolation: Leverage points must target their systemic entanglement. Key transitions, towards renewable energy (e.g., hydrogen), circular material flows and restoration (e.g., peatland rewetting), offer pathways to rewire the current metabolism. Yet these transformations would materialise within a contested and uncertain spatial reality. The seemingly open region faces a stacking of spatial claims, from energy infrastructure to military use. This makes simultaneous ambitions appear physically incompatible. Layered on top are deeper uncertainties: geopolitical instability, climate impacts, institutional erosion.
In response, scenario planning was used as a speculative, yet spatially grounded method to explore divergent pathways. Four scenarios combined global/local circularity with nature-/technology-based approaches and visualised their trade-offs through maps and eyelevel impressions. Though intentionally exaggerated, they made tensions visible: between ecological integrity and technological control, global systems and regional agency.
A multi-criteria assessment revealed that there is not one single perfect solution, but instead made divergent spatial logics and consequences clear. Grounded in dialogues with regional experts, the scenarios supported a reflection on priorities, realism and transformation. This approach clarifies that under deep uncertainty, sustainability requires not just technical fixes but conscious spatial choices that acknowledge competing priorities and long-term trade-offs.

**SQ 4: Which strategic measures ensure actionable outcomes for functions, morphology, society and ecosystems and how can the approach be spatially translated into local design elaborations?**

To ensure actionable outcomes for functions, morphology, society and ecosystems, the strategy must work with and not against deep uncertainty. Sea level rise, trade dynamics and political volatility limit the usefulness of fixed masterplans. Instead, the project introduces dynamic adaptation pathways along the three regional motors. This allows circular transitions to be sequenced over time, with early baseline interventions that keep multiple options open.

The strategic fork between "Nodal" and "Rooted Circularity" creates two diverging, but plausible future states. This Strategic Framework is spatialised through design elaborations, most concretely in the Emden zoom-in. Here, the adaptive approach translates into modular port transformations, reversible industrial extensions and the gradual introduction of tidal wetlands. These spatial applications reflect how small interventions can prefigure systemic change.

Functionally, the strategy reduces dependency on linear and fossil-based flows by establishing cross-border structures for energy and material reuse. Morphologically, spaces are made reversible: from modular factories on floodable soils to reprogrammable quay surfaces. These interventions break with the legacy of linear infrastructure and

create space for future change. Socially, especially the Rooted trajectory supports place-based stewardship. However, just outcomes depend on the right governance structures, especially in moving away from large single actors and integrating local voices into those long-term transitions.
Ecologically, strategies like sediment dynamisation and peatland rewetting repair earlier systemic damage and allow ecosystems to co-shape the future uses. Together, these measures show how circularity can be planned as an adaptive process rather than a fixed implementation. The Emden design elaborations make this approach tangible on eye-level.

## Discussion

**Interpretation and Critical Analysis**
To critically interpret my products and findings, I assess their alignment with Calisto Friant et al.'s interdependent cycles of a circular society (2024) which I used earlier to build my Conceptual Framework. These seven angles reveal which aspects of a holistic perspective on circularity were substantively addressed and where further work would be needed.

The strongest integration occurred regarding the resource, ecosystem, and biogeochemical cycles, from using the R-ladder to shape strategies to acknowledging biodiversity loss and decarbonisation goals.. Economic and knowledge cycles were also substantively addressed, particularly through education-based development pathways and regional inequality as structural issue. The political and social cycles, although touched upon, remain less central, pointing to potential blind spots in governance mechanisms and a greater focus that is needed for care infrastructures within the circular transition. An important side note here is that several cycles (most notably biogeochemical, but also resource, economic and political ones) typically circulate beyond the regional scale. This reminds us that territorial interventions must be situated within larger systemic dependencies and power relations.

Alongside this, a second conceptual backdrop to the thesis was the notion of strong sustainability (Dietz & Neumayer, 2007). This model highlights that certain natural resources (i.e., clean air, water, climate stability) are non-substitutable and must be preserved as a precondition for any form of long-term prosperity. It acknowledges the risk of irreversible loss and emphasises the ethical duty of preservation. In my approach, Planet was weighted most heavily to serve as the baseline for defining risks and necessary transitions, such as ecological restoration or decarbonisation. People came second, primarily through questions of regional equity and the framing as an operational hinterland. Profit played a rather subordinate role, because it was framed as a means rather than an end within systemic redesign. This prioritisation reflects the concept of strong sustainability, where ecological integrity is treated as a foundation for, and not a trade-off against, social and economic development.

**Methodological Reflection**
The chosen methodology, particularly research-by-design, proved valuable for iteratively exploring spatial options and synthesising pathways, with results such as the Y-shaped strategic framework. While this methodology is highly helpful at navigating complexity, it does not put a focus on quantitative precision, especially regarding tracking material flows. Working on a large regional, cross-border scale resulted in unique insights within a geographical frame that is not often selected. One the other hand, this choice of scale it limited in-depth analysis of specific sectors. The combined use of territorial capital and a metabolist lens allowed spatialised readings of metabolism, which helped to propose interventions that are grounded in the regional logic. This combination of methods could hold potential for other contexts where operationalising and spatialising circularity remains abstract. As the chosen combination of methods was a situated, interpretive approach, it also required ongoing reflexivity. These thoughts are further elaborated in the personal reflection at the end of this chapter.

**Implications for Theory, Policy, and Practice**
This thesis eventually fulfils the societal and scientific relevance that was set as a goal in Chapter 4: it articulates optimistic, yet actionable spatial pathways for circular transitions in a semi-peripheral region, while operationalising abstract concepts like

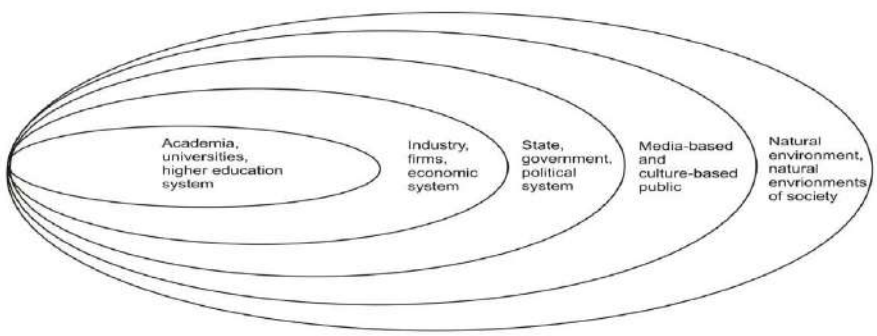
| | Not addressed | Touched upon | Covered | Substantially engaged |
|---|---|---|---|---|
| **Biogeochemical Cycles** Key cycles like water and carbon were addressed through historical, present, and future lenses, particularly in relation to resource flows and decarbonisation strategies. | | | x | |
| **Ecosystem Cycles** The historical degradation and contemporary revaluation of ecosystems (e.g., peatlands, wetlands) featured prominently, including their role in proposed leverage points | | | | x |
| **Resource Cycles** The R-ladder formed a foundational framework for scenario development and strategy, anchoring material and energy flows within circular transitions. | | | | x |
| **Political Cycles of Power** Power asymmetries surfaced in flow mappings and branching moments, though governance and corporate roles require further elaboration in implementation. | | x | | |
| **Economic Cycles of Wealth** Uneven regional development was problematised as a key issue, addressed through rooted pathways aiming to redistribute productivity and benefit. | | | x | |
| **Knowledge Cycles** Education and skill-building were seen as vital enablers of transition, from regional human capital to localised workshop hubs and global linkages. | | | x | |
| **Social Cycles of Care** The care dimension emerged indirectly through health and equity impacts of pollution and labour conditions, but remains underdeveloped conceptually. | | x | | |

13.1 Assessment of Engagement with the Seven Circles by Calisto Friant et al. (2024)

metabolism and circularity in a cross-border setting. The work also critiques the often technical nature of metabolic frameworks, arguing for a spatialised, historically grounded lens. Policy-wise, although stakeholders face near-identical challenges (as noted in interviews: “aardrijkskundig hebben we letterlijk dezelfde opgaven”), spatial planning culture and related instruments differ starkly. For instance, the draft Dutch Nota Ruimte (MinBZK, 2024) with its many maps also on future perspectives contrasts with the Landesraumordnungsprogramm of the German state of Niedersachsen (Niedersächsische Staatskanzlei, 2017), which is by far more text-heavy. This thesis can be a help to bridge that divide. For practice, the results offer ways to visualise uncertainty and use design to generate strategic spatial scenarios. Again, a method less embedded especially in the German context, but essential for steering conversations about long-term transformation under complex conditions.

## Limitations

Although this thesis was guided by strategic choices, some constraints proved difficult to avoid. The scarcity of robust material flow data limited precision — a common issue in circularity studies (Williams, 2021). Likewise, the spatial implications of circular goals remain hard to define, unlike for example housing targets, circular strategies rarely come with quantifiable land demands. The broad regional scope mentioned earlier offered systemic insight but inevitably sacrificed local granularity. An attempt to bridge this at least for one location was working with a Zoom-in in Emden. A final blind spot emerged around governance: while institutional dynamics shape implementation, this dimension remained underexplored. The quadruple or even quintuple helix frameworks (Carayannis et al., 2012; Fig. 13.2) that includes nature as a stakeholder (particularly relevant as the Wadden Sea itself might get legal personhood (Waddenacademie, 2022)), illuminate where successive works would need to target investigation. Future work in this field could benefit from tools like power–interest matrices.




13.2 Quintuple Helix (Carayannis et al., 2012)

## Directions for Future Research

Future research can take the results of this thesis into account by advancing metrics of circularity, including developing proxies for material flows, to overcome the current data limitations. Detailing a single location or flow/sector (such as the automotive or biochemical sector) would enhance the granularity of the proposed regional strategies. There is also scope to deepen cultural-ecological synergies, especially regarding water relations. One example by reinterpreting the remnants of the historic dike system as assets in future-proof circular design. On the governance side, cross-border prototypes, building on Euregio initiatives around the Eems-Dollard-Regio, that integrate spatial design, stakeholder mapping,and circularity goals could be fruitful. More broadly, synthesising ecological, economic, and institutional knowledge into territorial design for circularity offers a fertile ground for interdisciplinary research and policy innovation.

## Personal Reflection

**1. What is the relation between your graduation project topic, your master track (A, U, BT, LA, MBE), and your master programme (MSc AUBS)?**

My graduation project explores territorial metabolism in the cross-border Wadden Sea region, focusing on circular transitions in a semi-peripheral, ecologically fragile landscape. While the topic of industry is not the most common in urban design, indeed, one potential mentor even suggested it might lie outside our professional scope, I have found this intersection between landscape and industry to be not only spatially remarkable but politically urgent. What kind of spatial quality do we demand from large-scale production landscapes? And how will that change in the age of climate change?
The project aligns closely with the studio focus the ecological and socio-economic transition, offering a systemic lens that weaves together flows and the territory. It also resonates with the integrated perspective of the Urbanism track combining strategic planning, landscape thinking, regional design and with the broader MSc programme as an interdisciplinary and trans-scalar degree.

**2. How did your research influence your design/recommendations and how did the design/recommendations influence your research?**

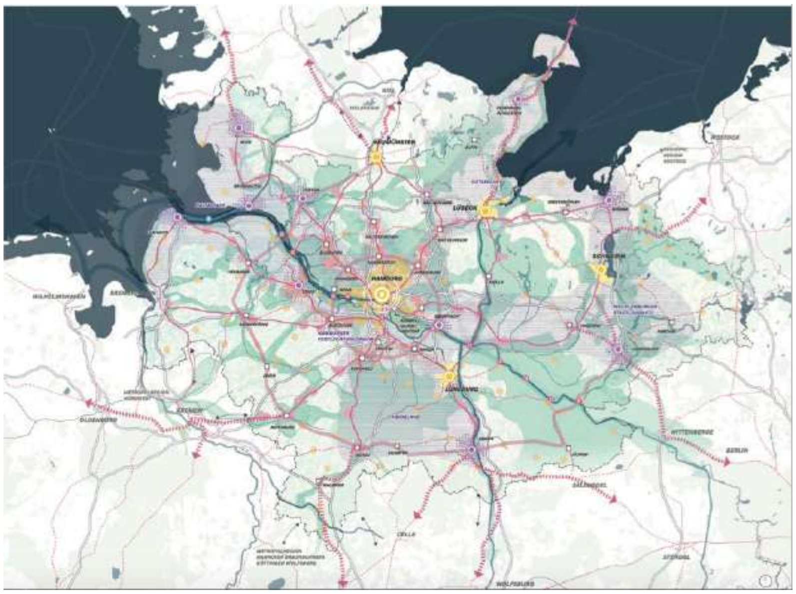
*My starting point*
Initially, I approached the project as a sequential experiment: first the research, then the design. Background research, mapping, flow analysis: these were meant to build a comprehensive understanding before proposing spatial interventions. I worked in packages, almost like a Cartesian scientist preparing an experiment. The design would then visualise alternatives and develop leverage points, not to solve complexity, but to imagine paths through it. My mentor feedback, however, revealed a gap: I needed more spatial imagination, more narrative courage. Inventarising alone was not enough: I needed to begin designing to learn, not just to assemble findings.

*The shift: ADP Method*
The breakthrough came during the March workshop on the Delft Method (Analyse–Design–Present). I realised that research and design in urbanism do not need to be separate steps, but can be one integrated process. Mapping becomes design when it selects and frames; design becomes research when it tests assumptions. I started jumping between the two more and earlier, which helped me think through the issues more clearly. This iterative rhythm not only advanced the work, but it also helped me to trust in design as a form of knowledge.

*Role of design*
Design, as I have come to realise, is not just about developing finished solutions. It is a method to find the gaps: to slow down at times, reflect and make complexity graspable. My scenario maps and zoom-in experiments helped me test ideas in space and sharpen the strategy. Through design, I did both learn to understand the system better but also to propose it differently.

**3. How do you assess the value of your way of working (your approach, your used methods, used methodology)?**

*Methods*
My research began with territorial reading through layered mapping. The method of diachronic landscape analysis turned out to be highly effective in revealing structural patterns, especially across institutional divides. Concepts like Territorial Capital and Metabolism were new to me but expanded my graphical vocabulary and understanding of value in space.
Yet, there were limits. Data availability constrained metabolic analysis. Looking back, I also wondered whether using other methods like for example the Pattern Language could have revealed other kinds of systemic logics. That said, the choice to work spatially and visually, especially about the German side, where this is less common, felt valuable in itself.
One of the few precedents from ths context I found was the Leitbild Metropolregion Hamburg (MRH, 2024), which became a key inspiration to me because it demonstrated the potential of design-driven regional strategy in a German context. (fig. 13.3.)



13.3 Leitbild Metropolregion Hamburg 2045

*Working independently*
Without a fixed assignment or client, it was initially challenging to set direction and define the ambition of the project. Prioritising among things I still needed to do felt overwhelming at times. What helped most was collaboration: sparring with peers on the zoom-in, or simply talking things out. I learned that I need exchange to thrive, and that I can strategically seek out these feedback loops in future projects to strengthen both the process and the outcomes.

*Making decisions*
In developing the storyline, I often felt torn between what came up in one mentor meeting as ethos, pathos and logos. Ethically (ethos), I felt a responsibility not to impose premature interventions onto a landscape I know and deeply care about. Emotionally (pathos), my connection to the Wadden Sea region made it harder to imagine radical change: I feared proposing futures that might erase its character. Rationally (logos), I knew I needed to move forward, but I hesitated without a feeling of full understanding. What helped me with this tension was the shift towards scenarios and pathways. Yet, a mentor asked whether my idea of adaptive pathways was a way to avoid taking a clear stance. It was a good provocation. I am still learning how to balance openness and decisiveness in storytelling.

*Planning and Execution*
Over the course of this project, I learned how crucial it is to maintain a sense of overview and priority in complex, multi-layered work. Initially, I struggled with the fragmented nature of my own work packages, which left me zoomed in too far and unsure how all the parts fit together. Under time pressure, I learned to refocus and see the bigger picture. I now better understand that as a designer, time will always be limited, so becoming skilled at setting priorities and pacing oneself is fundamental.

**4. How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?**

This project contributes to academic thinking by linking territorial design and circular economy through a metabolic lens, offering a layered spatial reading of cross-border regions. It encourages scholars and practitioners to consider semi-peripheral regions not as voids but as complex infrastructural landscapes where future transitions are already underway. Societally, the project makes spatial dynamics legible, beyond the narrow logics of individual policy sectors, by showing how infrastructure, ecology and industry are entangled. It warns of the risk of techno-fixes (like hydrogen) reproducing extractive logics, unless spatialised and politicised. Ethically, it advocates for intergenerational justice often overlooked in large-scale plans.

Yet the question of scope remains partly open: Who is the client? Public authorities, clearly (from provinces to ministries) but also private actors, who often drive strategic investments in my focus area. As a graduate student, my role shifted from observer to mediator: someone whose maps and concepts can act as mirrors or provocations. I am also sometimes still torn between wanting to be a visionary and someone who makes pragmatic, implementable proposals. My regional familiarity (growing up in Bremen, having lived in Groningen) helped, but also risks bias. Being self-aware about these positionalities is essential.

**5. How do you assess the value of the transferability of your project results?**

The methods and approaches I used can be applied in other European border or semi-peripheral regions. Particularly useful is the dual lens of territorial form and socio-ecological flow. That said, while the tools are transferable, the outcomes are not: the specific landscape histories, governance cultures and regional urgencies deeply shaped my conclusions. Examples of comparable regions might include Northern France, New England, or the Severn Estuary: tidally influenced industrial zones with a need for renewal.

Regarding transferability, the German-Dutch comparison was eye-opening. Not just in planning cultures (map-rich Dutch policy vs. text-heavy German ones) but in working styles, data access and institutional behaviour. Interviews in Germany often needed formal clearance, while Dutch stakeholders were quicker to engage informally. Here, transfering insights form one side of the border to the other might be challenging but could prove fruitful.

**6. How do personal and cultural background influence academic behavior and learning patterns – and how can self-awareness become a design skill?**

Having navigated both German and Dutch acaNext to the institutional differences between Germany and the Netherlands which I have discovered during my graduation project, I have also become more aware of how national norms shape learning styles. German traditions, which I used to grow up with, emphasise mastery and precision, which is useful for thoroughness, but can sometimes be paralysing. The Dutch academic setting, which I got to know at TU Delft, by contrast focuses more on openness and iterative learning, even if things are imperfect. These differences surfaced in how I approached approaching my project and even self-evaluation. Dutch culture encouraged me to try things, reflect, and adjust.

This bi-cultural awareness has become a skill. I now recognise that spatial planning, too, is shaped by these cultural undercurrents. And being able to read and adapt to them is crucial. More personally, I have also started to accept my own habits, like the need to mentally prepare before acting, and to work more with them, not against them. As such, the project became more than a thesis: it became a rehearsal space for a professional identity that is both critical and adaptive.

**7. In what ways did embracing uncertainty throughout this project affect my design process, and how has this shifted my attitude towards 'not knowing'?**

In the early stages of this project, uncertainty often unsettled me. I felt the need to map everything in advance: to foresee the whole terrain before setting foot into it. This tendency led to paralysis, especially on slow mornings filled with endless tabs and anxious scrolling. I tried to eliminate the unknown, only to find that it kept returning.

Over time, I began to see uncertainty less as an obstacle and more as a general condition of the work that is present, no matter what. Reading about concepts like "deep uncertainty" (Walker et al., 2003) helped shift my mindset. As a designer, I will never have complete information. Instead of waiting for clarity, I learned to act within the fog, through sketching, prototyping, and what I came to call "micro-actions". A draft, an imperfect map, a note: small gestures that eventually opened larger paths.

This change made my process more iterative, but also more alive. It taught me that not knowing is not necessarily a weakness. It can also become a space of possibility which turns into a source of energy rather than of fear.

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# Appendix

# List of Interviews

The following interviews were conducted as part of the thesis research. All information has been anonymised to protect the confidentiality of participants. Interview codes (I-1 to I-9) are used.

| Code | Date | Role/Function | Institution Type | Location |
|---|---|---|---|---|
| I-1 | 23 April 2025 | Senior Officer – Sustainability | Public Infrastructure Organisation | Northern Netherlands |
| I-2 | 25 April 2025 | Spatial Policy Advisor | National Planning Authority | Netherlands |
| I-3 | 28 April 2025 | Representative – Regional Business Network | Private–Public Development Entity | Northern Netherlands |
| I-4 | 28 April 2025 | Programme Manager – Regional Planning | Provincial Government | Northern Netherlands |
| I-5 | 30 April 2025 | Planner – Regional Development Programme | Interregional Planning Body | Niedersachsen |
| I-6 | 8 May 2025 | Environmental Officer | National Park Administration | Niedersachsen |
| I-7 | 8 May 2025 | Project Staff – Renewable Energy Transition | Large Utility Company | Niedersachsen |
| I-8 | 9 May 2025 | Project Coordinator | Regional Development Organisation | Northern Netherlands |
| I-9 | 20 May 2025 | Environmental Officer | Public Infrastructure Organisation | Bremen |

# Data Management Plan

## Plan Overview

*A Data Management Plan created using DMPonline*

**Title:** Where Industry Meets the Tides – Anchoring Sustainable Spatial Circularity in the Wadden Sea Region

**Creator:**Maximilian Theye

**Affiliation:** Delft University of Technology

**Template:** TU Delft Data Management Plan template (2025)

**Project abstract:**

This thesis explores pathways for transforming the industrial production system of the Wadden Sea region into a circular and sustainable model. By examining historical spatial patterns, territorial metabolism and the current morphology of industry, the study seeks to identify leverage points for systemic change. Through scenario development, it contrasts nature-based and technology-driven solutions, as well as global and local metabolic loops, to illustrate the potential spatial implications of these pathways.

Empirical insights are planned to be gathered through semi-structured interviews with experts from government, industry, urban design and research institutions, conducted during site visits across Groningen, Niedersachsen and Bremen (potentially also Friesland, Drenthe). Where applicable, structured expert feedback will further refine findings.

By integrating spatial analysis with expert knowledge, this study provides a foundation for reimagining industrial landscapes and will offer perspectives on the circular transition of this cross-border maritime region.

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# Where Industry Meets the Tides – Anchoring Sustainable Spatial Circularity in the Wadden Sea Region

## 0. Adminstrative questions

**1. Provide the name of the data management support staff consulted during the preparation of this plan and the date of consultation. Please also mention if you consulted any other support staff.**

The DMP has been shared with my thesis supervisor **Alexander Wandl** via DMPonline, and reviewed by them on ***27 February 2025.***
**Janine Strandberg**, Data Steward at the Faculty of Architecture and the Built Environment, has reviewed this DMP on***[date of review]***.

**2. Is TU Delft the lead institution for this project?**

- Yes, the only institution involved

## I. Data/code description and collection or re-use

**3. Provide a general description of the types of data/code you will be working with, including any re-used data/code.**

| Type of data/code | File format(s) | **How will data/code be collected/generated?** *For re-used data/code: what are the sources and terms of use?* | Purpose of processing | Storage location | Who will have access to the data/code? |
|---|---|---|---|---|---|
| Personally Identifiable Information (PII): participants' name, email, work address, company name, mobile number | .pdf, .xlsx | Contact information for participants taking part in interviews, received from professional network and online research. Informed consent forms are signed (digitally) and contain participants' name + email. | For administrative purposes: obtaining informed consent and communicating with participants | TU Delft OneDrive Physical forms (temporary, only immediately after the interviews) | Master's student Maximilian Theye + supervisor (s) Alexander Wandl, Teake Bouma |
| Audio-recordings of interviews with professionals from both government and industry in the region | .mp3 | Interviews are conducted during on-site visits to Groningen, (Friesland, Drenthe), Niedersachsen, Bremen. Audio-recordings are made on an external device, before being moved to OneDrive Recordings are deleted after transcription. | Capturing the opinions on industrial development and transformation, environmental conservation and protection, spatial development and urban design responses from participants (experts on these topics) | External recording device (temporary storage) + TU Delft OneDrive (primary storage) | Same as above |
| Anonymous transcriptions of interviews | .docx | Anonymous transcriptions created manually based on audio-recordings. Participants are asked to review the transcriptions of their interview before the transcript is finalised. | Privacy-preserving data from participants (experts on topics listed above) | TU Delft OneDrive | Same as above |
| Non-personal GIS data, non-personal statistical datasets and non-personal historical data (e.g., maps) | .pdf, .csv, .gpkg, .tif | Datasets and data found on publicly accessible databases from both Germany and the Netherlands (state-level, province-level) | Non-personal GIS data, non-personal statistical datasets and non-personal historical data (e.g., maps) will be utilised in the project to produce maps, diagrams and texts which will be used in the Master thesis. The used datasets will be cited in the thesis. | TU Delft OneDrive | Same as above |

## II. Storage and backup during the research process

**4. How much data/code storage will you require during the project lifetime?**

- 250 GB – 5 TB

**5. Where will the data/code be stored and backed-up during the project lifetime? (Select all that apply.)**

- Another storage system – please explain below, including provided security measures
- TU Delft OneDrive

OneDrive: Primary research data storage. Only TU Delft team members (Master's student and supervisors) have access. Structured feedback and interview data will be stored in separate folders, and within the interview folder, there are separate folders for audio-recordings and anonymous transcriptions. Informed consent forms and contact information are encrypted separately from research data to minimise

risk of re-identification.
External recording device: Used as a temporary storage location for recorded on-site interviews. Interviews will be deleted from device as soon as they are moved to OneDrive.
Printed forms: Temporarily, I may potentially use printed out, physical signed informed consent forms. Those will be scanned immediately after the interviews, with the scans then stored in the TU Delft OneDrive and encrypted separately from research data to minimise risk of re-identification. The physical forms will then be destroyed.

## III. Data/code documentation

**6. What documentation will accompany data/code? (Select all that apply.)**

- Data – Methodology of data collection

## IV. Legal and ethical requirements, code of conducts

**7. Does your research involve human subjects or third-party datasets collected from human participants?**

***If you are working with a human subject(s), you will need to obtain the HREC approval for your research project.***

- Yes – please provide details in the additional information box below

I intend to apply for ethical approval from the Human Research Ethics Committee, but have not yet done so.

**8. Will you work with personal data? (This is information about an identified or identifiable natural person, either for research or project administration purposes.)**

- Yes

The research data collected in the project will be anonymised, but processing of personal data is required for conducting the research project.

**9. Will you work with any other types of confidential or classified data or code as listed below? (Select all that apply and provide additional details below.)**

***If you are not sure which option to select, ask your Faculty Data Steward for advice.***

- No, I will not work with any other types of confidential or classified data/code

**10. How will ownership of the data and intellectual property rights to the data be managed?**

***For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question***

This is an internal TUD MSc thesis project. The student conducts the research independently, and is the owner of the interview and structured response data.

**11. Which personal data or data from human participants do you work with? (Select all that apply.)**

- Free text fields (for instance, in questionnaires) in which participants could unintentionally share personal data
- Proof of consent (such as signed consent materials which contain name and signature)
- Audio recordings
- Telephone number, email addresses and/or other addresses as contact details for administrative purposes
- Names as contact details for administrative purposes

Participant data for interviewees is anonymised when recordings are transcribed.

**12. Please list the categories of data subjects and their geographical location.**

Interview participants are experts on industrial development and transformation, environmental conservation and protection, spatial development and urban design in Groningen, (Friesland, Drenthe), Niedersachsen, Bremen.

**13. Will you be receiving personal data from or transferring personal data to third parties (groups of individuals or organisations)?**

- No

**16. What are the legal grounds for personal data processing?**

- Informed consent

The HREC informed consent guide and template will be used to create the informed consent forms for the interviewees (template 2 in the HREC guide).

**17. Please describe the informed consent procedure you will follow below.**

The researcher will inform the potential participants about the goals and procedures of the research project. The researcher will also inform them about the personal data that are being processed and for what purpose. A digital copy of the information will be emailed to participants before the interview, and all participants will be asked for their consent for taking part in the study and for data processing by signing a physical or digital informed consent form before the start of the interview and the structured feedback.

**18. Where will you store the physical/digital signed consent forms or other types of proof of consent (such as recording of verbal consent)?**

Digital informed consent forms and contact information are stored in the TU Delft OneDrive and encrypted separately from research data to minimise risk of re-identification.
Temporarily, I may potentially use printed out, physical signed forms. Those will be scanned immediately after the interviews, with the scans then stored in the TU Delft OneDrive and encrypted separately from research data to minimise risk of re-identification. The physical forms will then be destroyed.

**19. Does the processing of the personal data result in a high risk to the data subjects? (Select all that apply.)**

***If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data in your research project.***

***If any category applies, please provide additional information in the box below. Likewise, if you collect other type of potentially sensitive data, or if you have any additional comments, include these in the box below.***

***If one or more options listed below apply, your project might need a DPIA. Please get in touch with the Privacy team (privacy-tud@tudelft.nl) to get advice as to whether DPIA is necessary.***

- None of the above apply

**23. What will happen with the personal data used in the research after the end of the research project?**

- Anonymised or aggregated data will be shared with others

The anonymised research data consists of anonymised interview transcripts, and anonymous data from the structured feedback. These data will be used in the body of the thesis, but will not be shared in a data repository.

**24. For how long will personal research data (including pseudonymised data) be stored?**

- Other – please state the duration and explain the rationale below
- Personal data will be deleted at the end of the research project

Audio-recordings of interviews as well as recordings of the structured feedback are destroyed after completion of anonymised interview transcriptions. All other personal research data will be destroyed at the latest 1 month after the end of the project.

**25. How will your study participants be asked for their consent for data sharing?**

- In the informed consent form: participants are informed that their personal data will be anonymised and that the anonymised dataset is shared publicly

All participants will be asked for their consent for data to be shared anonymously in the body of the MSc thesis, which is made publicly accessible in the TU Delft Repository. Participants who do not consent to their data being included publicly in the thesis will not be included in the research project.

## V. Data sharing and long term preservation

**27. Apart from personal data mentioned in question 23, will any other data be publicly shared?**

***Please provide a list of data/code you are going to share under 'Additional Information'.***

- All other non-personal data/code produced in the project

Non-personal GIS data, non-personal statistical datasets and non-personal historical data (e.g., maps) will be utilised in the project to produce maps, diagrams and texts which will be used in the Master thesis. The used datasets will be cited in the thesis.

**29. How will you share research data/code, including those mentioned in question 23?**

- I am a Bachelor's/Master's student at TU Delft and I will share the data/code in the body and/or appendices of my thesis/report in the Education Repository

Anonymised data collected during the project will be included in the body of the MSc thesis, made available in the TU Delft Repository.

**31. When will the data/code be shared?**

- As soon as corresponding results (papers, theses, reports) are published

## VI. Data management responsibilities and resources

**33. If you leave TU Delft (or are unavailable), who is going to be responsible for the data/code resulting from this project?**

Thesis supervisor, Alexander Wandl, Associate Professor of the Department of Environmental Technology and Design: a.wandl@tudelft.nl

**34. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?**

Research data are only shared within the MSc thesis: no additional resources are required.

**35. Which faculty do you belong to?**

- Faculty of Architecture and the Built Environment (ABE)

# Interview Summaries

## I-1, Sustainability Officer (NL)

**Perceived challenges / problems in space**
Strong competition for space: spatial claims are stacked - many simultaneous usage requirements (e.g. logistics, energy transition, defence, circular economy)
Infrastructural bottlenecks, especially electricity grid
Lack of cooperation with Emden: “no business case” despite shared geographical challenges Lack of resilient governance structures across borders
Unclear role of the fishery in scenarios, although potentially strongly affected

**Key statements on future images & vision**
Port locations must continue to have a future - but only with a clear profile
Important change: from purely petrochemical clusters to bio- and residue-based processes with greater social acceptance
New industrial utilisation needs more space, fewer emissions, but more visibility Combination of diversification + flexibility + distinctive specialisation as a strategy for the future

**Reaction to scenarios / divergences**
Scenario with dam enclosure was discussed as extreme but relevant
Emphasised that ‘land + sea access’ remains essential for port functions
Scenario approach is seen as helpful - especially with regard to spatial consequences (e.g. location issues in the case of deeper nature integration)

**Recommended strategies & measures (pathways)**
No-regret: Expansion of hydrogen & CCU (carbon capture & utilisation) as a resilient entry point
Critical: electricity grid as a bottleneck - infrastructure must be planned in advance Strategic: Targeted valorisation of existing areas through infill & functional change Governance: More focus on strategic feedstock selection & transport avoidance (shift to sea instead of road)

## I-2, Spatial Policymaker (NL)

**Perceived challenges / problems in space**
CE spatial demand remains highly uncertain: studies range from 4–10% additional need, plus 10–30% for circular industry
Strong spatial conflict: energy vs agriculture, especially in wind energy zones
Circular transition needs “sliding space” over time – but where, when, and how much remains undefined
Groningen Seaports faces the Waddenzee as both ecological asset and spatial constraint

**Key statements on future images & vision**
CE will gradually replace linear processes, requiring both space and sequencing
CE not just technological: requires legal, financial, organisational, and communicative tools to steer transformation
A future-proof system must build in uncertainty tolerance and avoid early lock-ins

**Reaction to scenarios / divergences**
The four-quadrant scenario matrix (tech/nature × global/regional) was described as “uncommon” and “provocative”
Particularly noted the novelty of combining loop scales (global/regional) with material basis (nature/tech)
Scenario with strong nature-based regionality seen as speculative yet visionary

**Recommended strategies & measures (pathways)**
No-regret: spatial flexibility to accommodate shifting CE logics
Build adaptive instruments across law, finance, communication, and organisation Consider pilot areas and experimental governance zones to avoid rigid national gridlock

## I-3 Business Representative (NL), I-4, Sustainability Officer (NL)

**Perceived challenges / problems in space**
Every sustainability measure creates spatial claims – currently clashing or unresolved Fragmentation between the energy transition and raw material transition
CE adds production steps - creates spatial and energetic pressure
Dutch system is inefficient and contradicts CE goals
Skepticism: “Many pretend to have solutions – but the trust is low”

**Key statements on future images & vision**
CE will not reverse globalisation, but will shorten and reconfigure flows Spatial strategy must avoid over-planning and instead sequence Fundamental tension: CE needs more space and energy – not less Urgency still too low to trigger tough spatial choices

**Reaction to scenarios / divergences**
Regionalised nature-based futures seen as speculative and negative for the regional economy and prosperity
I-4 acknowledges tension between nature and tech, but sees their combination as inevitable Critical: some scenario elements may be too neat for the messiness of real-life trade-offs

**Recommended strategies & measures (pathways)**
Prioritisation between energy and materials transitions is essential
Spatial planning must allow for CE-specific steps (e.g. reprocessing stages) Consider cross-border knowledge exchange, especially for materials No-regret options: pilot CE sites, infrastructure for bio-based flows

## I-5, Regional Planner (DE)

**Perceived challenges / problems in space**
Spatial pressure from energy infrastructure: hydrogen hubs, ports, renewables Conflicts of use between environment, industry, and agriculture
Planning is still sectoral, lacks holistic territorial thinking
Freshwater availability and salinisation emerging as blind spots
Unequal distribution of burdens from national energy strategy
Moors and their drainage as historic transformation with ongoing ecological consequences (GHG emissions, biodiversity loss).

**Key statements on future images & vision**
NW Germany should not be seen as peripheral – it is a core energy region
The region as a “real-world lab” for energy transformation, not a passive hinterland. Framing NW Germany as a testbed for new spatial typologies and actor constellations. Positive energy balance opens industrial opportunities
Dual identity: ecological responsibility + industrial driver
Systemic circular economy must integrate biogenic flows, hydrology, and agriculture

**Reaction to scenarios / divergences**
Regional scenario: inspiring, but seen as implying loss of prosperity
Technology-first logic dominates: “Technology will always be central”
Critical view: circular visions are too product-based, lack systemic integration Discussed crisis as driver: how shocks (e.g. dike failure) shape strategic flexibility
Emphasis that agricultural practices must be part of scenario logic, not just “industry and nature”.

**Recommended strategies & measures (pathways)**
Adopt strategic, cross-sectoral instruments (e.g. RegioStrat)
Encourage re-use of existing infrastructure (e.g. gas grids, ports)
Explore regional energy pricing to balance national burdens
Embed water considerations into energy infrastructure planning
Use narrative-based communication to increase local legitimacy
Area-wide rewettability not realistic due to relief and hydrology – suggests spatial constraints for ecological adaptation.
Interlinking regional planning with regional development is seen as a must, not a bonus – implies governance innovation.
Intermunicipal instruments are named as needed, especially for dealing with cross-cutting land use tensions.

## I-6, Environmental Officer (DE)

**Perceived challenges / problems in space**
Wadden Sea is increasingly under pressure from energy infrastructure, shipping, emissions, and cumulative pollution
Ecological functions only work at large spatial scales – fragmentation threatens resilience Cumulative impacts of nitrogen, mercury, sediment shifts, and wastewater
Conflicting planning logics: climate adaptation vs. industrial expansion
German-Dutch differences in how natural dynamics are treated (room for natural processes even if undesired originally in Germany vs. engineered recovery in the Netherlands)

**Key statements on future images & vision**
The Wadden Sea must remain an open system and stepping stone for biodiversity
It is foundational for both ecosystem services and human life
Major spatial and societal adaptation needed: de-diking, flexible settlement, letting go of certain zones
Nature-based approaches are essential – not everything can be technologically compensated

**Reaction to scenarios / divergences**
Regional/Nature: Ecologically strong, but seen as naive unless long-term change is embraced Global/Nature: Viewed as eventually most realistic: embraces gradual retreat and dynamic adaptation
Technology scenarios: Risk of overconfidence – ecosystem functions can't be 'steered' technically
Historical reference: Unrealised Jadebusen plan from the 1960s (Tappe-Plan, closing off natural dynamics and massive industrialisation) as a cautionary tale

**Recommended strategies & measures (pathways)**
Anticipate de-diking and polder opening before 2100
Soft summer dikes and retreat-based projects (e.g. reference project Langwarder Groden) show alternatives
Need for cross-border ecological thinking
Promote infrastructure reuse, but also question continued industrial expansion in sensitive areas
Push for ecosystem-centred flexibility and a strategic view on cumulative impacts

## I-7, Utility Planner (DE)

**Perceived challenges / problems in space**
Hydrogen infrastructure requires more spatial volume than natural gas (larger voids in salt caverns)
Environmental impacts of storage: land subsidence, brine release, sound emissions Coordinating constant H2 demand with volatile renewable supply is structurally difficult Existing gas network is dense in NL, but adaptation in DE is slower
Electrolysis with salt water at sea or in coastal zones is very costly due to desalination needs

**Key statements on future images & vision**
Northwest Germany as nucleus for hydrogen transformation
Reuse of gas infrastructure is a no-regret move
Storage is non-optional (crucial) if hydrogen is brought to full scale, it is the "missing link" Energy systems will be more integrated, transnational, and layered (e.g. LNG-ready = H2- ready)
H2 must remain an open infrastructure, not captured by single sectors or firms

**Recommended strategies & measures (pathways)**
Plan infrastructure with spatial reuse & zoning of compatible uses Use already approved gas corridors – avoids delays
Develop cross-border storage solutions
Maintain dual systems (H2 and gas) for resilience
Policy focus on bridging logics rather than binary shifts
Enhance public trust by showing fast rollout is technically possible (e.g. Huntorf post- Russian war in Ukraine)

## I-8, Project Coordinator (NL)

**Perceived challenges / problems in space**
Climate adaptation and coastal protection need cross-border alignment, but there's no integrated planning yet
Circular economy is slow to advance due to lack of economic scale and incentives
Rurality and fragmentation of the region hinder large-scale investment or single flagship solutions
Deep concern about financial feasibility of large-scale tech solutions (e.g. Hyperdike)

**Key statements on future images & vision**
The region is tightly emotionally and economically connected to the landscape – especially the Wadden Sea
Bioeconomy seen as strategic entry point for circularity
Region will likely grow together, socially and economically, through shared challenges
Export orientation may bring in funding, but should not dominate everything

**Reaction to scenarios / divergences**
Nature/regional (Regenerative Neo-Hanse) scenario: "socially unmanageable", risks societal fragmentation
Global/tech: unlikely due to high costs, especially for small rural economies
Cross-border cooperation is seen as the most plausible and desirable axis for transformation

**Recommended strategies & measures (pathways)**
Focus on interregional funding instruments to unlock circularity
Promote adaptive, small-scale solutions and avoid all-or-nothing megaprojects Emphasise emotional and cultural identity in spatial strategies
Advance climate adaptation with binational pilot projects
Invest in transport connectivity across the border for resilient logistics

## I-9, Environmental Officer (DE)

**Perceived challenges / problems in space**
nflexible port geographies (limited space, high investment locking) hinder transformation
Competing land uses make circular development hard to implement
German federalism leads to fragmented climate adaptation, esp. in coastal protection
Societal inertia is a major obstacle: "not enough societal force to act"

**Key statements on future images & vision**
Circularity is the only viable future – but realisation is slow
Recycling ports (e.g. for ships, rare earths, batteries) are emerging and strategic
Coastal regions like the Wadden area have key conditions for industrial relocation (sun, wind, surface area, electrolysis potential)
Circularity must be part of conflict-avoidance strategies globally

**Reaction to scenarios / divergences**
Regional/Nature: least realistic due to lack of societal drive for ecological prioritisation
Global/Technology: coastal defence differences (NL vs DE) hinder feasibility across region
Regional/Technology: promising, strong conditions for regional autonomy & layered land use
Global/Nature: desirable but only realistic by 2150, due to societal inertia

**Recommended strategies & measures (pathways)**
Strengthen rail corridors and free up logistics (e.g. $CO_2$ export via Bremen instead of Bremerhaven) for circular cargo
Support material leadership: e.g. steel scrap recycling and battery treatment
Embrace vertical land-use overlaps (e.g. marshland for energy and food)
Recognise port identity conflicts: port function vs. urban liveability
Use lighthouse projects to symbolically anchor transformation

# Policy Scan

| Document | Datum | Type | Authority | Probleem |
|---|---|---|---|---|
| **Green Deal** | Dec 19 | Strategic, with legally binding follow-up | EU: European Commission | * Climate Change as defining challenge<br>* However, current policies will only reduce greenhouse gas emissions by 60% by 2050 (not meeting the goals). |
| **Fit for 55** | Oct 23 | Legally binding | EU: European Commission (proposals)<br>European Council & European Parliament (co-legislators) | *EU is not on track to meet its climate objectives under current policies.<br>*Greenhouse gas emissions must be reduced by at least 55% by 2030 to stay on course for climate neutrality by 2050 |
| **EU Circular economy action plan** | Mar 20 | Strategic, with legally binding follow-up | EU: European Commission | * Current linear economic model is unsustainable, leads to overuse of resources, dependency on raw material imports, pollution and waste.<br>* EU uses nearly half of global extracted materials and only 12% of secondary materials are re-entered into the economy.<br>* Climate and biodiversity goals will not be met without a shift to circularity |
| **EU Clean Industrial Deal** | Feb 25 | Strategic | EU: European Commission | * European industrial competitiveness is under pressure due to increasing energy costs, high dependence on imported fossil fuels and technologies and the slow pace of scaling net-zero industries<br>* Need to ensure Europe does not fall behind in clean tech and remains resilient during the green transition |

| Centrale boodschap + doelen | Ontwerpkansen | Kritische vragen |
|---|---|---|
| * **No Net Emissions of GHG in 2050**<br>* economic growth is decoupled from resource use.<br>* **EU's greenhouse gas emission reductions target for 2030 to at least 50% and towards 55% compared with 1990 levels**<br>* deployment of innovative technologies and infrastructure, such as smart grids, hydrogen networks or carbon capture, storage and utilisation, energy storage, also enabling sector integration. Some existing infrastructure and assets will require upgrading to remain fit for purpose and climate resilient.<br>* Climate and resource front runners by 2030: Priority areas include clean hydrogen, fuel cells and other alternative fuels, energy storage, and carbon capture, storage and utilisation<br>* The natural functions of ground and surface water must be restored.<br>* To ensure a toxic-free environment, the Commission will present a chemicals strategy for sustainability. This will both help to protect citizens and the environment better against hazardous chemicals and encourage innovation for the development of safe and sustainable alternatives.<br>* Introdcution Emissions Trading System<br>* carbon border adjustment mechanism, for selected sectors, to reduce the risk of carbon leakage (potentially) | * Infrastructural adaptation & retrofitting (particularly for hydrogen, CCU/S and renewable power grids)<br>* Green-blue networks restoration (wetlands as carbon sinks) | * How will member states translate broad targets into coherent spatial and legal frameworks before 2030?<br>* How are land use conflicts between renewable energy expansion, agriculture and nature restoration resolved spatially?<br>* Will the carbon border mechanism exacerbate geopolitical frictions? |
| * Reduce EU GHG emissions by at least 55% by 2030 and reach climate neutrality by 2050<br>* Expand and strengthen the EU Emissions Trading System (ETS), incl. maritime & aviation, reaching zero in 2040<br>* Introduce a Carbon Border Adjustment Mechanism (CBAM), fully in force by 2036<br>* Set new effort sharing targets for Member States in sectors like transport, agriculture, and waste<br>* Increase land use, land-use change and forestry (LULUCF) carbon sinks (target: 310 $MtCO_2e$ net removals by 2030)<br>* Emissions from Agriculture, Forestry and Other Land Use (AFOLU) net zero in 2035<br>* Create a Social Climate Fund to support vulnerable groups<br>* Introduce stricter $CO_2$ standards for vehicles (100% reduction for new cars/vans by 2035)<br>*Promote renewables (42.5–45% by 2030) and improve energy efficiency (11.7% reduction target by 2030)<br>*Improve energy performance of buildings (all new buildings zero-emission by 2030; existing stock transformed by 2050)<br>* 40 GW electrolysis capacity for hydrogen by 2030 | * multi-scalar energy landscapes, esp. around hydrogen, renewables, EV recharging networks<br>* Landscape-led carbon sinks | * How can spatial and design disciplines translate the fragmented directives into territorial strategies rather than siloed sectoral implementations?<br>* Will economically weaker regions be able to match the infrastructure demands and investment pace without worsening inequality? And how can spatial justice and transitional fairness for agricultural communities be guaranteed?<br>* How will flexibility for adaptive phasing be ensured across divergent spatial typologies? |
| * Make sustainable products the norm in the EU<br>* Empower consumers and public buyers with right-to-repair, product passports, and transparency<br>* Focus on key value chains: electronics, batteries, packaging, plastics, textiles, construction and food<br>* Reduce waste generation and improve high-quality recycling<br>* Support circularity through innovation, investments, and digital tools<br>* Introduce harmonised separate waste collection and strengthen extended producer responsibility | * Spatial integration and design of circular hubs<br>* New spatial logics for production and consumption<br>* Potential to support regional circular economy zones in the Wadden Sea region, e.g., around bio-based construction or recycling in port/industrial flows | * Convincing direction, but how will regions like the Wadden area implement it without industrial density or infrastructure parity?<br>* How can spatial strategies help resolve trade-offs between land-intensive circular infrastructures and other territorial claims (e.g., ecology, housing)?<br>* What governance frameworks can be implemented to handle cross-border circular flows, e.g., between Dutch and German ports and hinterlands?<br><br>Can design disciplines push beyond product-scale innovation and translate these circular principles into territorial typologies? |
| *Establish the Clean Industrial Deal as the industrial arm of the European Green Deal<br>* Strengthen competitiveness while accelerating climate-neutral industrial transformation<br>* Scale net-zero technologies across sectors like hydrogen, CCS, batteries, heat pumps, etc.<br>* Enhance support via finance, infrastructure, workforce skills and streamlined permitting<br>* Deepen coordination between EU, national and regional efforts<br>* Position EU as a global circular economy leader by 2030 | * Spatial planning can allocate zones for CCUS infrastructure, green hydrogen plants, and electrified industry<br>* Reposition port and industrial regions | *How will spatial planners deal with the tension between urgent decarbonisation needs and slow permitting processes?<br>* Is there a risk that "Net-Zero Valleys" concentrate support in a few areas, sidelining peripheral regions like Northern Netherlands or the German Wadden coast?<br>*How will circularity be embedded in the industrial transformation — the focus is heavy on clean tech, but less on resource loops?<br>*The Clean Deal aims to make EU industry competitive — but how can spatial strategies ensure local ecosystems (landscape, ecology, logistics) benefit as well? |

| | | | | |
|---|---|---|---|---|
| **EU Biodiversity Strategy for 2030** | May 21 | Strategic | EU: European Commission | biodiversity crisis: 81% of habitats and 63% of species are in poor condition, pollinators are declining, and the EU failed to meet its 2020 biodiversity targets (p. 1–3). The fragmentation and degradation of ecosystems threaten food security, climate resilience, and human well-being. |
| **Nature Restoration Regulation** | Feb 25 | Legally binding | EU: European Parliament and Council | * Widespread degradation of ecosystems across the EU, threatening biodiversity, climate mitigation capacity, food security and human health.<br>*Only 15% of habitats are currently in good condition |
| **EU Hydrogen Strategy** | Jul 20 | Strategic, with legally binding follow-up | EU: European Commission | * EU must drastically decarbonise its energy system to reach climate neutrality by 2050, but sectors like industry and heavy transport are difficult to electrify.<br>* Hydrogen, especially renewable hydrogen, is seen as a crucial vector to decarbonise these sectors and reduce reliance on imported fossil fuels<br>* Also, EU risks falling behind in global hydrogen leadership and losing industrial competitiveness. |
| **Klimaatakkoord** | Jun 19 | Strategisch (with select **hard goals** through legislation or implementation tracks like SDE++, $CO_2$-heffing) | NL: Rijksoverheid (via Klimaatberaad; co-signed by Ministries of EZK, I&W, LNV, BZK) | * NL must reduce greenhouse gas emissions by **49% by 2030** compared to 1990 levels to limit climate change, meet international obligations (e.g. Paris Agreement), and reduce vulnerabilities in energy, agriculture and infrastructure.<br>* **current linear, fossil-based system** creates environmental degradation, economic risks and social inequality. |
| **Een Nationaal Programma voor Versnelde Verduurzaming van de Industrie (NPVI)** | Mar 23 | Strategisch (with links to regulatory and financial instruments like CCS subsidies, $CO_2$-heffing, maatwerkafspraken) – added documents ("routekaart") | NL: Ministerie van Economische Zaken en Klimaat (MinEZK) | * Dutch industrial sector causes 35% of national $CO_2$ emissions, concentrated in a few large clusters (incl. Delfzijl/Eemshaven)<br>* pace of emission reduction is too slow due to technical complexity, uncertain investment climate,and a mismatch between infrastructure planning and decarbonisation needs. * There is also insufficient policy coordination and institutional speed. |
| **Nationaal Programma Circulaire Industrie 2023-2030** | Feb 23 | Strategic | NL: Rijksoverheid (ministeries van I&W, EZK, LNV, BZK, VWS, Financiën) | * Dutch economy is still mostly linear, leading to high grondstoffengebruik, $CO_2$-uitstoot, biodiversiteitsverlies en afhankelijkheid van importstromen<br>* A sustainable, secure, and resilient economy is not achievable without a system change.<br>* The gap between ambition and actual structural change is growing. many circular pilots remain “los zand” |
| **Programma Energiehoofdstructuur** | Mar 24 | Strategic | NL: Ministerie van Economische Zaken en Klimaat (MinEZK) and Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (MinBZK) | * Urgent mismatch between the fast-growing demand for sustainable electricity, hydrogen, heat infrastructure and the spatial, procedural and technical capacity to deliver it.<br>* Energy system under pressure due to insufficient grid capacity, uncoordinated spatial claims and lagging permit procedures |

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| * Legally protect 30% of EU land and sea, including 10% under strict protection<br>* Restore degraded ecosystems across the EU through binding nature restoration targets<br>* Transform at least 10% of agricultural area into high-diversity landscape features<br>* Reverse pollinator decline by 2030<br>* Plant at least 3 billion trees and green urban spaces<br>* Ensure full implementation and enforcement of existing environmental legislation | * Spatial embedding of the 30% protection target and 10% strict protection<br>* Rewilding or wetland restoration as pilot projects in agricultural areas | * How can the ambition of strict protection be reconciled with agricultural and energy transition claims on land, especially in densely used coastal deltas like the Wadden Sea?<br>* Are member states ready to operationalise landscape-level ecological coherence and avoid isolated protection pockets?<br>* Can the restoration strategy effectively deal with systemic pressures* |
| * Legally restore at least 20% of the EU's land and sea areas by 2030<br>* Restore ALL degraded ecosystems in need of restoration by 2050.<br>* Specific binding targets for habitats (e.g., peatlands, grasslands), species recovery, pollinator populations, urban green space:<br>** Member States must restore at least 30% of degraded terrestrial, freshwater, and coastal habitats by 2030, 60% by 2040,and 90% by 2050<br>** Agriculture: Improve biodiversity indicators such as grassland butterfly index, soil organic carbon and share of landscape features like wetlands or ponds on farmland<br>** Restore and rewet at least 30% of drained peatlands by 2030 (with at least a quarter rewetted), 40% by 2040 and 50% by 2050 (some exceptions allowed however)<br>** Rivers: Member States must remove barriers (e.g. dams, culverts) to restore at least 25,000 km of rivers to free-flowing status by 2030, which also benefits wetland floodplains | * Integration of restoration measures into spatial and territorial planning<br>* Rewilding and rewetting projects in low-lying Wadden Sea regions could be structurally co-supported and institutionally backed<br>* weave restoration goals into energy and agricultural transition areas | * How will restoration be reconciled with ongoing infrastructural developments in coastal-industrial nodes like Ems-Dollard?<br>* Will Member States like the Netherlands align spatial planning fast enough with legally binding ecological targets?<br>* Are governance capacities (provincial, municipal) equipped to translate EU-level targets into measurable landscape interventions before 2030? |
| * Develop a European hydrogen ecosystem through a phased approach:<br>Phase 1 (2020–24): Scale up electrolyser capacity to at least 6 GW and produce up to 1 million tonnes of renewable hydrogen<br>Phase 2 (2025–30): Expand to 40 GW electrolysers and produce 10 million tonnes of renewable hydrogen<br>Phase 3 (2030–50): Enable large-scale use across all hard-to-abate sectors<br>* Focus on renewable hydrogen, but accept low-carbon hydrogen as a transitional step<br>* Create lead markets in steel, chemicals, and heavy-duty transport<br>* Support infrastructure development (pipelines, storage, ports), and common standards | * Position Wadden Sea region ports and industrial areas as hydrogen gateways with accompanying infrastructure<br>* Cross-border collaboration<br>* Preallocate dedicated hydrogen zones near industrial clusters, rail and inland shipping corridors | * Will spatial footprint of hydrogen infrastructure (electrolysers, terminals, storage) create new land-use conflicts?<br>* Is there a risk that focus on hydrogen sidelines material circularity or low-tech decarbonisation approaches, such as electrification and energy sufficiency?<br>* Challenge to make hydrogen infrastructure legible and accepted, especially in contested landscapes with strong ecological identities?<br>* Are regional actors involved in shaping the rollout of hydrogen corridors or is it a top-down strategy? |
| * Achieve 49% $CO_2$-reduction by 2030 (vs. 1990 levels)<br>* Transition to a sustainable, low-carbon economy in five sectors: electricity, built environment, industry, mobility and agriculture/land use<br>* Ensure a fair transition for all (klimaatrechtvaardigheid)<br>* Deploy instruments such as $CO_2$ pricing, subsidies (e.g. SDE++), regulatory changes and public-private agreements<br>* Create sectoral route maps with implementation tracks and monitoring (e.g. Regional Energy Strategies – RES)<br>* 2030 realisatie Waterstofnetwerk NL<br>* Elektrolysecapaciteit: 3 à 4 GW in 2030 (Klimaatakkoord), streefdoel 8 GW in 2032<br>* EU: 42% van industrieel waterstofgebruik afkomstig van hernieuwbare brandstoffen van niet-biologische herkomst in 2030 en 60% in 2035 (Renewable Energy Directive III)<br>*2030: Verbod op de inzet van fossiele brandstoffen in verwarmingsprocessen zonder afvang bij uitbreiding, nieuwbouw en vervanging van industriële productie-installaties (NL) | * Cluster-based decarbonisation of heavy industry (e.g. Eemshaven, Delfzijl): design hydrogen/heat infrastructure to future-proof regional economic nodes<br>* Energy-efficient housing retrofits: spatial planning of heat networks and circular construction hubs<br>* Multi-benefit landscapes: integrate carbon sequestration, biodiversity and new forms of circular farming in rural zones<br>* In governance regions (RES) to align decarbonisation with spatial quality and local agency | * Despite detailed implementation tracks, many goals are non-binding or left to market incentives. how enforceable is the climate ambition?<br>* How does the Klimaatakkoord structurally prevent lock-ins in existing industrial or energy infrastructures?<br>* Are RES-regio's equipped to meaningfully integrate spatial circularity and ecosystem resilience, or do they focus narrowly on $CO_2$ targets?<br>* How are cross-border spatial and ecological effects (esp. Wadden Sea as UNESCO site) taken into account in energy and infrastructure planning? |
| * Accelerate emission reduction in the Dutch industry toward the 2030 climate targets<br>* Create regional cluster plans and connect these to a national spatial-industrial transition<br>* Align public-private cooperation, infrastructure development, and subsidy instruments (e.g. SDE++, CCS/CCU, groene waterstof)<br>* Move from abstract policy to "implementatiemodus" with regional maatwerkafspraken, sectorale routekaarten, and fast-track infrastructure investments<br>* Ensure long-term competitiveness and license to operate for sustainable industry | * synergy in design of infrastructure (heat, hydrogen, $CO_2$, electricity)<br>* Reconfigure spatial relationships between ports, hinterlands, and energy clusters, e.g., redefining Eemshaven and Delfzijl's role<br>* Enable circularity hubs<br>* Apply the 'maatwerk in de regio' to explore specific plans for Wadden Sea region | * How do energy transition needs (waterstof, CCS, elektrificatie) translate into territorial design decisions beyond zoning and permitting?<br>* To what extent are ecosystem limits and nature-based synergies considered within cluster development (especially near the Wadden Sea)?<br>* How flexible are the plans for infrastructure routing if future technologies or supply chain shifts emerge? |
| * Accelerate the transition to a volledig circulaire economie in 2050, with a halving of primary resource use by 2030<br>* Target five priority value chains: Biomassa & voedsel, Kunststoffen, Bouw, Consumptiegoederen en Maakindustrie<br>* Address three systemic barriers: 1. ontwerp & productie, 2. markt & gedrag, 3. beleid & organisatie<br>* productlevensduur, hergebruik, hoogwaardig recyclen<br>* mix: verplichtingen, prikkels, en normering | * Ruimtelijke verankering van ketenaanpakken in industriële regio's zoals Delfzijl<br>* Ontwerpen van publieke infrastructuren (water, logistiek, digitaal) om hergebruik, reparatie en circulaire ketens te ondersteunen<br>* circulaire hubs op knooppunten / logistiek, vooral voor Bouw en Maakindustrie | * Worden ruimtelijke randvoorwaarden zoals biodiversiteit, waterschaarste en vestigingsdruk al goed meegenomen in de circulaire (infrastructuur)ontwikkeling?<br>* Kunnen gemeenten en regio's met het huidige instrumentarium echt sturen op systeemverandering? |
| * Establish a coherent spatial energy backbone to meet 2030/2050 climate goals.<br>* Integrate energy infrastructure planning with spatial and environmental planning.<br>* Identify strategic energy functions (e.g., electricity transport, hydrogen backbone, hydrogen storage, battery storage, potential areas for nuclear energy) and steer national coordination for space reservation and realisation<br>* Prioritise infrastructural planning to enable offshore wind landfall, hydrogen corridors, storage and backbone system<br>* Develop regional implementation agendas through the PEH Uitvoeringsagenda | * Anchor the hydrogen backbone spatially along industry clusters and ports; opportunities to co-develop infrastructure corridors<br>* Use the PEH as spatial lever to direct overlapping energy and industrial ambitions at nodal points | * How will spatial justice be safeguarded in areas facing disproportionate energy infrastructure burdens?<br>* Is the PEH a shift from an infrastructural focus to a design-oriented spatial strategy that links energy to broader socio-ecological transitions?<br>* Is there a risk of lock-ins (e.g. blue hydrogen or nuclear?) |

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| **Brief Kabinetsvisie Waterstof** | Mar 20 | Strategic | NL: Ministerie van Economische Zaken en Klimaat (MinEZK) | * current Dutch energy system is heavily reliant on fossil fuels. To meet the climate goals and reduce $CO_2$ emissions (especially from industry and heavy transport) and to maintain energy security and economic competitiveness, there is an urgent need to develop sustainable energy carriers.<br>* Hydrogen can play a key role in decarbonising hard-to-abate sectors and providing flexibility in a renewable energy system. |
| **Routekaart Waterstof** | Nov 22 | Strategic | NL: Nationaal Waterstof Programma (NWP, public-private partnership), commissioned by Ministerie van Economische Zaken en Klimaat (MinEZK) | * energy system must decarbonise rapidly to meet Dutch climate goals. Some sectors (particularly heavy industry, transport, and seasonal energy storage) cannot be fully electrified and need alternative carriers.<br>*Hydrogen is positioned as a key solution to decarbonise these sectors, improve system flexibility, mitigate dependency on fossil imports. |
| **Nota Ruimte (Voorontwerp)** | Jun 24 | Strategic | NL: Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (MinBZK) | * NL faces intensifying spatial pressure due to climate adaptation, energy transition, housing, agriculture, nature restoration and industrial demands.<br>* available space is insufficient to accommodate all societal ambitions in a spatially efficient and ecologically safe way.<br>*Fragmented governance, lack of coherence in spatial decisions, and conflicting claims on limited land are central problems. |
| **Visie Landbouw, Natuur en Voedsel** | Sep 18 | Strategic | NL: Ministerie van Landbouw, Natuur en Voedselkwaliteit (MinLNV) | * Current NL agriculture causes too much pressure on climate, nature, soil, water and air and contributes to biodiversity loss, nitrogen overload, animal welfare issues, and social resistance to intensive farming.<br>* The system is highly dependent on global markets and vulnerable to shocks, while it creates little added value in some chains. |
| **Agenda voor het Waddengebied 2050** | Dec 20 | Strategic | Ministerie van Infrastructuur en Waterstaat (MinIenW) (together with regional organisations) | * Dutch Wadden Sea region faces intensifying spatial and ecological pressure due to sea-level rise, biodiversity loss, energy transition, agricultural tensions, tourism impacts, economic restructuring.<br>* Climate change and cumulative spatial claims threaten the unique values of this UNESCO World Heritage site |
| **Tiende Voortgangsrapportage Natuur** | Nov 24 | Strategic, linked to obligations via EU-rules | NL: Interprovinciaal Overleg (IPO) and ministerie van Landbouw, Visserij, Voedselzekerheid en Natuur (MinLVVN) | * Decline in biodiversity and habitat quality in the Netherlands, despite years of investment and efforts.<br>* continued pressure from nitrogen, climate change, urbanisation, soil degradation |
| **Deltaprogramma 2025** | Sep 24 | Strategic (with embedded legal basis ) | NL: Ministerie van Infrastructuur en Waterstaat (MinIenW) / Deltacommissaris | * NL faces increasing risks from climate change, including sea level rise, salinisation, flooding and drought.<br>* Spatial development is placing additional pressure on the delta's water systems and adaptive capacity is not yet guaranteed everywhere<br>* Wadden region faces a multidimensional vulnerability: rising sea levels, soil subsidence (veenoxidatie, gaswinning) and a complex water system under pressure from both climate and economic development. Salinisation, freshwater availability, and environmental degradation challenge both nature and agriculture |

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| * Green hydrogen is seen as a key pillar of the climate-neutral energy system<br>* Goal: Establish a leading position in the European hydrogen economy<br>* Focus on: Scalable electrolysis capacity (cost-effective and sustainable; Development of a robust hydrogen infrastructure (national and cross-border); International cooperation for imports and certification; Stimulating hydrogen use in industry, heavy transport, and as storage buffer<br>* Supportive measures include public-private cooperation, regulation, investment schemes (SDE++, IPCEI), and knowledge development | * Spatially plan for **hydrogen clusters** near industrial zones with access to offshore wind, ports, and pipelines | * Will the strategy sufficiently consider the spatial footprint and land use of electrolysis, buffering, logistics?<br>* Is the current ambition level for domestic electrolysis capacity realistic given grid bottlenecks and renewable upscalining speed?<br>* How will social and ecological effects (e.g. nature, water use, social justice) be weighed in location decisions? |
| * Develop a robust, integrated hydrogen value chain (production, infrastructure, demand)<br>* Target of 3–4 GW electrolysis capacity by 2030<br>* Focus on green hydrogen but include blue hydrogen in the transition phase<br>* Hydrogen should be prioritized for:<br>Industry (as feedstock and fuel)<br>Heavy transport and shipping<br>Long-term storage for grid balancing<br>*Stimulate collaboration across government, industry, knowledge institutions (triple helix model)<br>*Align Dutch hydrogen developments with EU strategy and infrastructure corridors | * hydrogen can be spatial logic: locate production near wind power & ports, use former gas pipelines as corridors<br>* Integrate multi-functional hubs: link hydrogen with port functions, $CO_2$ networks, circular industry | *How will hydrogen infrastructure be governed across spatial scales and jurisdictions (e.g. national, provincial, EU)?<br>*To what extent are nature and space constraints being considered (e.g. nitrogen, water use, landscape impact)?<br>*Does the roadmap go beyond tech and economics to address social license to operate in affected regions?<br>*How will blue hydrogen phaseout be governed to avoid lock-ins?<br>*What mechanisms ensure that hydrogen demand evolves in sync with infrastructure and renewable capacity? |
| * Create a shared national spatial framework to guide coherent decisions across levels<br>* Define the 'ruimtevragende opgaven': energy, nature, housing, mobility, agriculture, and economy<br>* Introduction of a 'ruimtelijk afwegingskader': a spatial decision logic based on environmental and societal values<br>* As a result, Promote clustering of infrastructure, housing, and production where possible to reduce spatial footprint<br>* Embed spatial justice, livability, landscape identity into planning<br>* Strategically protect open space and natural systems, while guiding transformation zones | * Using the proposed layering approach to spatially coordinate circular and industrial transitions with ecological values<br>* Translate abstract national logics into adaptive, regionally differentiated design frameworks (e.g. for the Wadden Sea region) | * How will trade-offs be made between conflicting goals (e.g. biodiversity vs. economic clustering)? Who decides?<br>* Does the document provide enough spatial criteria to prioritise between functions (e.g. energy vs. housing)?<br>* Will the non-binding nature of the "afwegingskader" be strong enough to influence regional and sectoral plans?<br>* How can this abstract framework be effectively translated into actionable and region-specific interventions?<br>* Does it offer tools to navigate uncertainty or is it still too static? |
| * Complete transition to a circular agriculture system by 2030.<br>*Key goals include:<br>Closing nutrient and raw material cycles, reducing dependency on external inputs<br>Regional production and valorisation: more local feed, use of residual flows, and regional chain-building<br>Improving soil health, biodiversity, and water quality<br>Reducing nitrogen, $CO_2$, and methane emissions through system redesign and precision farming<br>Fair income for farmers, stronger consumer-producer connection, and more resilient rural economies | * Regionally specific circular landscapes, with spatial typologies adapted to ecological conditions and residual flows<br>* Landscape inclusive designs<br>* Circular agro-hubs | * How can the vision be aligned with recent court rulings about significant nitrogen emission reductions by 2030? The government's decision to delay reduction targets to 2035 contradicts these rulings<br>* How will circular agriculture be aligned with existing spatial frameworks and the reality of land ownership?<br>* How will the strategy ensure economic viability for farmers while aiming for de-intensification?<br>* 2030 horizon is clear, but intermediary steps, territorial differentiation and enforcement are vague |
| * Secure the natural and landscape qualities of the Wadden area for future generations<br>* Develop a resilient socio-economic system that supports quality of life and employment in the region<br>* Align national ambitions (energy, water, biodiversity) with regional interests in a balanced, place-based approach<br>* Use the Wadden Agenda 2050 as a shared framework for coordination, decision-making and long-term coherence | * Gradual transition zones that buffer between ecological core and economic activity<br>* adaptive infrastructures | * How can conflicting functions (e.g. energy infrastructure vs. nature values) be spatially meditated/layered without eroding the local character?<br>* What spatial governance is needed to manage long-term coordination? |
| * Restore and connect nature through the Natuur Netwerk Nederland (NNN) – 80.000 ha by 2027 (not on track however, by end 2024, only 63% realised)<br>* Strengthen the coherence between nature policy, climate adaptation and agricultural transition.<br>* Meet the EU Biodiversity Strategy 2030 targets, including designating 30% of land as protected and 10% under strict protection<br>* Continue with area-specific approach (gebiedsgerichte aanpak) and expand nature inclusive practices | * reconfiguring fragmented landscapes into cohesive ecological corridors<br>* adaptation: integrating NNN and climate buffers<br>* Integration of biodiversity, climate, and land-use transitions in hotspots such as the Wadden Sea or Groene Hart | * How can the ambitions for NNN completion be combined with ongoing infrastructural and housing developments in densely populated areas?<br>* Given the lag in biodiversity recovery, is the current tempo of nature development projects (2023–2027) sufficient to reverse ecological decline in time to meet EU 2030 goals? |
| * Keep the Netherlands safe and liveable in 2120 and beyond through timely, adaptive and integrated delta management<br>* Main goals include:<br>Flood risk reduction (veiligheidsnormen)<br>Freshwater availability (zoetwatervoorziening)<br>Climate-proof spatial adaptation (klimaatadaptatie in RO)<br>Long-term, adaptive planning via the subprogrammes<br>* In the Wadden Sea Region:<br>Realise dike upgrades before 2050, with a strong preference for Building with Nature principles.<br>Leverage climate adaptation to deliver spatial co-benefits (nature, habitability, regional identity)<br>Establish an adaptive, robust and climate-resilient delta system that secures safety, freshwater, and environmental quality in the Wadden area. | * Integration of climate adaptation with spatial development opens design opportunities for multifunctional dikes, nature-based flood buffers, and groundwater-sensitive planning<br>* In regions like the Wadden area and Eemsdelta, transitions in agriculture and industry can align with water robustness and soil subsidence mitigation | * How can spatial claims from climate adaptation (e.g., river room, dike reinforcements) be balanced with industrial/agricultural needs<br>* Is there enough binding commitment from non-state actors (e.g., private landowners, industry) to realise water robustness ambitions? |

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| **Deutsche Nachhaltigkeitsstrategie** | Jan 25 | Strategic | DE: Bundesregierung | Fehlende systemische Integration von Nachhaltigkeit in Sektorstrategien; globale Ungleichgewichte; Ressourcenübernutzung; sozial-ökologische Transformation stockt |
| **Nationale Kreislaufwirtschaftsstrategie** | Dec 24 | Strategic | DE: Bundesministerium für Wirtschaft und Klimaschutz | Hoher Rohstoffverbrauch, starke Abhängigkeit von Primärrohstoffen, unzureichende Kreislaufschließung (p.6, p.8) |
| **Wasserstoffstrategie Deutschland** | Jul 23 | Strategic | DE: Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV) | Hohe Abhängigkeit von fossilen Energieimporten; unzureichende H2-Inlandsproduktion für Industrie- und Klimaziele |
| **Importstrategie für Wasserstoff und Wasserstoffderivate** | Jul 24 | Strategic | DE: Bundesministerium für Wirtschaft und Klimaschutz (BMWK) | Deutschland kann nicht genug grünen Wasserstoff selbst erzeugen; Importe (50–70%) sind notwendig für Klimaziele & Industrie |
| **Systementwicklungsstrategie 2024** | Nov 24 | Strategic | DE: Bundesministerium für Wirtschaft und Klimaschutz (BMWK) | Fossile Abhängigkeit, unzureichende Netzkapazitäten, fehlende Infrastrukturplanung und hohe Komplexität gefährden die Energiewende und Versorgungssicherheit |
| **Nationale Strategie zur biologischen Vielfalt 2030** | Dec 24 | Strategic | DE: Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV) | Anhaltender Verlust biologischer Vielfalt; Zerschneidung von Lebensräumen; mangelnde Integration in Raumplanung |
| **Ackerbaustrategie 2035 (Diskussionspapier)** | Dec 19 | Strategic | DE: Bundesministerium für Ernährung und Landwirtschaft (BMEL) | Ackerbau steht unter Druck durch Klimawandel, Biodiversitätsverlust, wirtschaftliche Unsicherheiten und Zielkonflikte zwischen Produktionssicherung, Umwelt- und Klimaschutz |
| **Deltaplan voor het Noorden**<br><br>**(Bouwstenen voor het Deltaplan (April 2021); Analyse Deltaplan Noordelijk Nederland – Deel B (Mar 2022); Bijlage 1 – Perspectief 2050 ( Oct2024))** | ongoing | Strategic, exploratory documents without binding content | Samenwerkingsverband Noord-Nederland; Multiple regional stakeholders including provinces Drenthe, Fryslân, Groningen; plus Rijksoverheid as eventual decision maker | * Underinvestment and demographic stagnation in Northern Netherlands compared to the Randstad<br>* Lack of spatial-economic cohesion and accessibility (esp. by rail) limits Northern potential<br>* Climate and energy transitions require space, innovation zones, and resilience, which the North can provide, but lacks structural support<br>* Inequality in labor market access, infrastructure quality, and national policy attention |
| **Cluster Energie Strategie Noord Nederland 3.0** | | Strategic, non-binding planning framework, aligned with national planning | Collaboration of public and private organisations in Industrial Cluster Noord Nederland | * Regional energy system not yet ready to handle large-scale renewable generation, buffering, industrial transition.<br>*Key issues: Grid congestion blocks scaling-up of renewable energy production; Lack of transport and storage capacity for hydrogen and $CO_2$; Mismatch between energy supply/demand and spatial capacity; Industrial sectors struggle with affordability and infrastructure readiness for electrification and hydrogen |

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| * Orientierung am SDG-Rahmen, mit 6 „Transformationsbereichen“ als nationale Leitplanken (u.a. Kreislaufwirtschaft, Industrie, Mobilität); ressortübergreifendes Mainstreaming von Nachhaltigkeit<br>* CO2 Neutralität bis 2045<br>* National targets based on SDGs (not regionally specified):<br>** Doubling the circular material use rate by 2030.<br>** Reducing land take to <30 hectares/day by 2030.<br>** Decreasing nitrogen surplus to 70 kg/ha by 2030.<br>** Raising share of renewable energy in final energy consumption to 30% by 2030. | Nachhaltigkeit als Querschnittsauftrag für Raum- und Infrastrukturentwicklung; viele Ziele auf regionalem Maßstab konkretisierbar (z. B. Mobilität, Energie, Industrieflächen) | Wie können Design und Raumplanung als Querschnittsdisziplin systematisch in das Monitoring und die SDG-Zielarchitektur eingebunden werden? |
| Kreislaufwirtschaft bis 2045<br>* Ziel 1: Schließung von Stoffkreisläufen<br>* Ziel 2: Rohstoffsouveränität und Rohstoffversorgungssicherheit erhöhen<br>* Ziel 3: Vermeidung von Abfällen<br>Circular Material Use Rate: doubled 2021 - 2030 | Design-for-recycling als Gestaltungslogik auf Produkt- und Raumsystemebene; Raum für zirkuläre Hubs, Rücknahmestrukturen, Recyclinginfrastruktur | Wie lassen sich zirkuläre Geschäftsmodelle räumlich verankern — z.B. für Textil, Elektronik, Bau? Welche räumliche Sprache spricht eine echte Kreislaufwirtschaft — jenseits von Deponien und Sortierzentren? |
| Deutschland will bis 2030 Leitanbieter für Wasserstofftechnologien werden; Aufbau eines H2-Kernnetzes (1.800 km) + 10 GW Elektrolyseleistung; große Rolle für Importe (50–70%) | H2-Importterminals und Backbone-Pipelines als hybride Räume gestalten; systemdienliche Hubs im Norden (zB Wilhelmshaven) als neue territorialen Knoten denken | Wie können Importterminals, Speicher und Hubs als gestaltete Landschaften gelesen werden – jenseits der rein technischen Logik von "H2-ready"? Welche räumliche Typologie erzeugt dieser neue Energiesektor? |
| Aufbau langfristiger, diversifizierter Importbeziehungen; Förderung internationaler H2-Projekte; gezielte Nutzung in Industrie, Energie & Mobilität | Importterminals, Zwischenlager & Konversionsanlagen als gestaltbare Typologien; norddeutsche Häfen als Energie-Knoten zwischen Globalem Süden und Binnenland | Was bedeutet es räumlich, wenn Stahlwerke, Raffinerien und Verkehrskorridore "H2-ready" werden? Wie sieht eine produktive Importlandschaft an der Schnittstelle von Infrastruktur, Industrie und Landschaft aus? |
| Sektorübergreifende, resiliente Transformation des Energiesystems bis 2045; Basis: Erneuerbare, Flexibilität, Netzausbau; Strom direkt nutzen, H2 gezielt für Industrie, Verkehr, Speicher | Gestaltung von H2-Korridoren, Speicherlandschaften, Wärmeinfrastrukturen und neuen Netz-Knoten; Lesbarkeit der Transformation im Raum; flexible Räume für Industrie & neue Energiestrukturen schaffen | Wie sieht ein räumliches Leitbild für ein flexibles, vernetztes, klimaneutrales Energiesystem aus? Wie werden Netze, Speicher, Kraftwerke und Industrieanlagen räumlich sichtbar, produktiv und akzeptiert gestaltet? |
| * Biodiversitätsverlust stoppen, Ökosysteme wiederherstellen, Transformation von Wirtschaft & Planung<br>* mind. 30 % Schutzfläche, 10 % streng geschützt<br>* Wiederherstellung von mindestens 20 % der geschädigten Ökosysteme in DE bis 2030<br>* Im Küstenraum: explizit Bezug auf die Umsetzung von Natura 2000 im Wattenmeer; Maßnahmen gegen eutrophierung und Sedimentverschiebungen | Nature-based coastal infrastructure, grüne Korridore, biodiversitätsfreundliche Industrieareale; Blau-grüne Gewerbe als neue Raumtypologie | Wie lässt sich Biodiversität in industriell genutzten Regionen wie Emden oder Wilhelmshaven konkret verankern? Können Dekarbonisierung und Renaturierung überhaupt räumlich zusammengedacht werden? |
| *Ein resilienter, klima- und umweltverträglicher Ackerbau bis 2035.<br>* Reduktion von Pflanzenschutzmitteln<br>* Ausbau humusaufbauender Fruchtfolgen<br>* Stärkung agrarökologischer Maßnahmen<br>* Beitrag zum Erhalt der Biodiversität & Klimaschutz durch $CO_2$-Speicherung im Boden | Integration von Fruchtfolgen, Ackerrandstrukturen, Agroforst in regionale Raumplanung; Rücknahme oder Umwidmung industriell genutzter Flächen für biodiversitätsorientierten Ackerbau;Gestaltung von Pufferzonen zwischen Schutzgebieten und Intensivackerflächen; Regionale Modellflächen für humusorientierten Aufbau | Wie lassen sich Zielkonflikte zwischen ökonomischer Wettbewerbsfähigkeit und Umweltzielen planerisch auflösen?; Fehlt eine räumliche Priorisierung: Wo genau soll biodiversitätsfördernder Ackerbau zuerst greifen (z. B. Marschland, Übergänge zu Schutzgebieten)? |
| * Create a long-term spatial-economic impulse for the Northern Netherlands via integrated investments in:<br>Rail (Lelylijn, Nedersaksenlijn, Zwolle opwaardering)<br>Housing: +220,000 homes beyond baseline demand<br>*Infrastructure improvements are said to have beneficial effects on:<br>Clusters: green chemistry, hydrogen, digital, water tech, agrofood, logistics<br>Circular and sustainable development aligned with climate and energy goals<br>* Stimulate demographic, economic, and ecological balance between core and periphery within the Netherlands<br>* Contribute to national tasks (housing, energy, biodiversity) by leveraging Northern spatial capacity and livability | * Wadden Sea coastal hinterland (incl. Delfzijl/Emden/Eemshaven) as a hydrogen–circularity gateway, linking ecological and industrial logics<br>* Backbone for connected industrial systems<br>* North as testing lab for socio-ecological transitions | * Deltaplan lacks binding commitments from the national government: Does regional ambition turn into national investment?<br>* Does focusing on economic agglomeration risk repeating centralist logics (mimicking the Randstad) instead of developing alternative, place-based models of prosperity?<br>* Is the assumption of housing and growth as purely positive sufficiently nuanced in light of landscape capacity, ecological vulnerability (e.g. peatland, ecology)?<br>*To what extent is the Deltaplan process inclusive of bottom-up, local visions — or is it a top-down agenda disguised in spatially democratic language?<br>* How resilient is it by relying on one major infrastructural scheme (Lelylijn) |
| * Build an integrated, future-proof energy system that aligns renewable generation (e.g., offshore wind) with regional industrial decarbonisation<br>* Coordinate infrastructure development (electricity, hydrogen, heat, $CO_2$) with spatial planning and industrial clustering<br>* Achieve key milestones:<br>2030: Green hydrogen production (electrolysers in Delfzijl, Eemshaven).<br>2032: Large-scale electrolysers operational (buffering offshore wind).<br>2030+: Salt cavern storage for hydrogen.<br>2030+: CO2nstance project: $CO_2$ transport pipelines to Norway<br>*Balance short-term feasibility with long-term system vision (hybrid heat, flexibility, new carriers) | * clustering hydrogen and $CO_2$ infrastructure offers a chance to spatially anchor new industrial ecologies | * Can the spatial concentration of infrastructure (Eemshaven/Delfzijl) avoid new mono-functional dependencies and instead foster modular, resilient networks?<br>* How can spatial equity be ensured across the three provinces: will they remain a transit zone, or can they co-develop value-added hubs?<br>* What governance mechanisms can safeguard long-term coordination across energy carriers (electricity, $H_2$, $CO_2$), considering different maturity levels and stakeholders?<br>* Does the current pace of infrastructure rollout match the 2030 ambitions, or will strategic spatial claims outpace implementation? |

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| **Generalplan Küstenschutz Niedersachsen/Bremen** | Mar 07 | Legally binding | Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN)<br>Commissioned by: Bundesländer Niedersachsen & Bremen | * increasing flood risk due to sea-level rise, climate change, and subsidence<br>* Higher frequency of extreme weather events requiring improved protection infrastructure<br>* Obsolete or under-dimensioned coastal defenses in several areas |
| **Niedersächsisches Gesetz zur Förderung des Klimaschutzes und zur Minderung der Folgen des Klimawandels (NKlimaG)** | Dec 23 | Legally binding | DE: Land Niedersachsen | * Anthropogenic climate change and its consequences, including extreme weather events, sea level rise, and biodiversity loss.<br>* The act acknowledges the need for urgent emissions reduction and regional adaptation efforts. |
| **Landesraumordnungsprogramm Niedersachsen (LROP)** | Sep 17 | Legally binding | DE: Land Niedersachsen | * Spatial fragmentation, demographic change, and imbalances between regions threaten sustainable development<br>* Environmental pressures, especially from settlement expansion, transport infrastructure, and energy transition, require spatial coordination<br>* Increasing conflicts between uses (e.g. agriculture, energy, nature conservation) require hierarchical guidance |
| **Bremisches Klimaschutz- und Energiegesetz (BremKEG)** | Mar 23 | Legally binding | DE: Land Freie Hansestadt Bremen | * Identification of climate change and high greenhouse gas emissions from energy use as the central challenges.<br>*Specifically, $CO_2$ emissions from primary energy consumption in Bremen is the issue to be mitigated |

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| * Ensure long-term, climate-resilient coastal protection for 670 km of coastline and 1,220 km of dikes<br>* Maintain and update the defined protection goals for all defended areas<br>* Integrate new projections for sea-level rise and storm surges into planning standards (1.1m SLR by 2100)<br>* Where possible include a more adaptive, dynamic, and nature-based protection strategy (e.g., foreland development, sediment use) | * potential to include hybrid/nature-based design solutions that align with both safety and ecological goals | * To what extent is there flexibility to align rigid coastal safety standards with emerging climate resilience approaches, particularly those involving ecological dynamics and spatial transitions?<br>* How can this Generalplan be better coordinated with circular and industrial transformation agendas (e.g., hydrogen infrastructure or landscape rewetting in inland peat zones)?<br>* Is a perspective from 2007 still adequate for the current challenges? |
| * Niedersachsen commits to climate neutrality by 2040.<br>* Sectoral targets are implied, especially for buildings, mobility, and energy infrastructure<br>* Public institutions must act as climate role models and integrate climate goals in decision-making.<br>* All new state buildings must meet stricter energy performance standards.<br>* Municipalities must develop heat plans, climate protection concepts, and maintain energy and land-use reports. | * Integration of regionalised heat networks and zoning in climate-resilient urban/rural design.<br>* Opportunities for nature-based flood protection, as municipalities are obligated to plan for climate adaptation.<br>* Potential for green infrastructure in state property or coastal protection projects with multifunctional benefits. | * Does the fixed 2045 target for climate neutrality include concrete sectoral pathways (e.g., agriculture, industry, transport) or does it risk being aspirational without implementation clarity?<br>* How will municipalities with fewer resources (e.g., in rural Wadden areas) meet the legal demands for climate concepts, energy reporting, and heat planning?<br>* Is there enough integration between this law and regional flood protection (Generalplan Küstenschutz) or spatial development strategies? |
| * Ensure coherent spatial structure for sustainable development<br>* Strengthen urban-rural linkages and prevent decline in peripheral areas<br>* Designate and protect priority zones for wind energy, nature conservation, flood protection, and agriculture<br>* Promote climate adaptation, with attention to coastal zones and flood plains | * The formalised spatial zoning (e.g. wind priority areas, flood risk zones) opens design opportunities at the regional scale, especially in low-lying coastal areas<br>* planning requirements could be translated into multifunctional landscape design, such as combining dyke systems with ecological corridors<br>* The promotion of urban-rural “anchor” functions (Zentrale Orte) supports spatial strategies that redistribute growth and innovation beyond core cities | * Flexibility under pressure: How adaptable is the LROP to the acceleration of energy transitions (e.g. hydrogen, grid expansion) that postdate 2017? Will this legal framework hinder or enable such infrastructure in spatially sensitive areas like the Wadden Sea coast?<br>Cross-border spatial coordination: * How does this program align with Dutch strategies along the Wadden Sea cost? Are there mechanisms to resolve transboundary conflicts or synergies (e.g. marine protection vs. offshore infrastructure)?<br>* Implementation capacity: With so many functional goals (housing, mobility, climate, biodiversity, energy), is there enough design and planning capacity at the regional and municipal levels to implement a spatial synthesis? |
| * $CO_2$ Reduction Goals relative to 1990:<br>60% by 2030<br>85% by 2033<br>95% by 2038<br>(with interim steps from 2023–2029)<br>*Energy Transformation: Shift to renewable, low-risk, and cost-efficient energy systems<br>* Climate Adaptation: Resilience-building across sectors, with updated strategies every 5 years<br>* Legal Priority for Renewables: Renewable energy projects are declared to be in the “overriding public interest"<br>* Sectoral $CO_2$ targets: Specifically for energy transformation, transport, households, industry, etc.<br>* Annual monitoring: Binding reporting obligations on $CO_2$ and other emissions | * Renewable Energy Corridors<br>* Climate-Resilient Public Realms<br>* Innovation Testing Grounds | * The law mandates targets and reporting, but spatial consequences (e.g. for land use, infrastructure design, industrial restructuring) remain vague. Who ensures alignment between this law and regional or zoning plans?<br>* Given Bremen’s industrial base (steel, ports), are the $CO_2$ goals achievable without a structural industrial transformation and how can spatial design support this? |