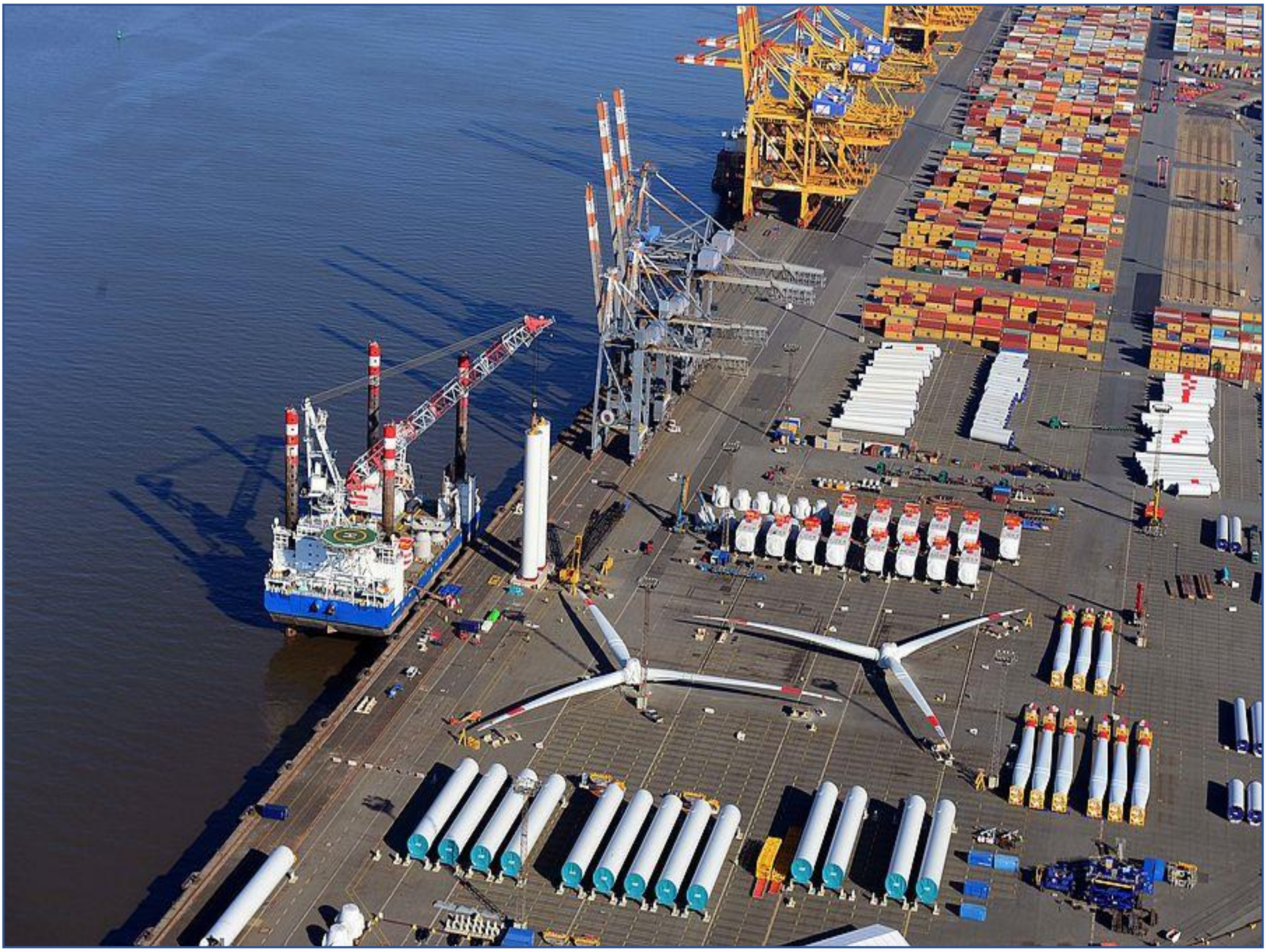
MASTER THESIS

Can the ports located in the Wadden Sea region be front runners in the energy transition and environmental planning?



Author: Zakaria Abdishakur Mohamed

Student Number: s4540417

Double Degree:

Environmental and Infrastructure Planning - University of Groningen

Water and Coastal Management – University of Oldenburg

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Author: Zakaria Abdishakur Mohamed
Student Number: s4540417
z.a.mohamed@student.rug.nl
Zakaria.mohamed@uni-oldenburg.de

Research Supervisor:

1. Dr. F.M.G. Van Kann
2. Apl. Prof. Dr. Ulrich Scheele

Double Degree Master: DDM Water and Coastal Management
Study program 1: Environmental and Infrastructure Planning
Educational Institute: University of Groningen
Faculty of Spatial Sciences
Department of Spatial Planning and Environment Landleven 1
9747 AD Groningen
Study program 2: Water and Coastal Management
Educational institute: University of Oldenburg
Master cluster - COAST
COAST - Centre for Environment and Sustainability
Uhlhornsweg 84, 26129 Oldenburg

Cover Photo: Aerial view of Offshore wind turbine assemblage and transshipment in Bremerhaven. Retrieved from: http://www1.eurogate.de/en/Products/Wind-energy

Abstract

The ports located in the Wadden sea region are facing peculiar challenges; on the one hand the energy transition provides governance challenge due to non-linear developments, irreversible changes and complex web of actors whose interlinkages and interconnectedness makes it really complicated to manage. On the other hand facing the growing environmental concerns linked to the negative externalities of the energy transition that are particularly significant in the wadden sea region. The research analyses these challenges using theoretical lenses of transition theory and management.

Multiple case study approach is undertaken to explore how these challenges are approached by the ports located in Wadden sea region. Semi- structured interviews are conducted with stakeholders in the governance of the selected ports, and with experts from knowledge institutes and environmental initiatives.

The results show stiff competition between the case ports, fragmentation of measures and approaches, uncoordinated projects and endeavors, and lack of cross-border cooperation between the case ports.

The research proposes an area-based planning approach which embeds renewable energy and hydrogen economy related projects in physical and socio-economic landscape. A shared governance that aims for consensus building, and spatial diversification and specialization among the case port is necessary to navigate the governance challenge posed by the energy transition and the environmental concerns. Furthermore, cross-border cooperation requires institutional harmonization which entails the cooperation and coordination between various institutional frameworks that guide different sectors and actors to mitigate environmental risks while enabling synergies between the energy transition and environmental planning.

Key words: Energy transition, hydrogen economy, spatial and environmental planning, Area-based planning, energy landscape, transition theory and management, multi-level governance, ports, Wadden Sea

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List of Abbreviations

EU	European Union
UNESCO	United Nations Educational Scientific and Cultural Organization
UNCTAD	United Nations Conference on Trade and development
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
CO_2	Carbon dioxide
H_2	Hydrogen gas
LNG	Liquefied natural gas
NGOs	Non-Governmental Organizations
PSSA	Particular Sensitive Sea Area
MSFD	Marine Strategy Framework Directive

1 Introduction

1.1 Research background

The energy transition is a cornerstone pillar in the National strategic visions of the Netherlands and Germany towards meeting the targets of Paris climate agreements and it entails a transition from the dependency on fossil fuels to renewable energy. The strategies of both countries include ramping up the production of renewable electricity from offshore wind farms in the North Sea to meet the high demand of renewable electricity and storing or converting the excess power to green hydrogen or other suitable energy carriers.

As the energy transition unfolds in Europe, Germany and the Netherlands are forging a pioneering path to unlock the full potential of Hydrogen as a key element in accelerating the energy transition from fossil-based to the EU's carbon-neutral energy targets of 2050. Hydrogen can be used as a fuel or an energy carrier and storage, and has numerous applications across industry, transport, power and built environment.

Both countries have developed hydrogen strategies that draw a transformation roadmap; 1) from current large scale industrial production and consumption of grey hydrogen which is the production of hydrogen from high carbon materials such as fossil fuels, 2) to low-carbon blue hydrogen produced from fossil fuels, with the resulting CO_2 emissions captured and stored, 3) and to green hydrogen which is production of hydrogen by electrolysis of water using renewable electricity sources by 2050 (BMWI, 2020; Cleijne *et al.*, 2020).

According to these hydrogen strategies, blue and green hydrogen will play a major role in smart combination with renewable electricity in decarbonizing the industrial processes and economic sectors where reducing carbon emissions is both crucial and difficult to reach. In the short term (2020-2035), blue hydrogen based on applying carbon capture and sequestration to existing grey hydrogen will be pivotal in accelerating the decarbonization process while medium to long term (2035-2050 and onwards), green hydrogen will propel the transitioning to a net zero EU emissions targets (Wang et al., 2020). These transformations will require supply of abundant renewable electricity, interdependent industrial cluster of hydrogen users that create the critical mass demand for blue-green hydrogen economy, supplemented by a well-developed hydrogen transport infrastructure as well as supportive political and social acceptance atmosphere (ibid).

In line with these ambitions, both countries are scaling-up their renewable electricity generation capacities from offshore wind farms in the North Sea in-order to meet the electricity demands for the planned hydrogen economy. Thus, the North Sea coastal states and provinces of both countries are vital players for the success of these strategies.

The five North Sea German states have launched the transformation processes of installing 500 MW of electrolysis capacity by 2025 and at least 5 GW by 2030 (BMVI, 2019). The Dutch North Sea provinces have also similar targets of 500 MW of installed capacity by 2025 and 3-4 GW of installed capacity by 2030 (Cleijne *et al.*, 2020). The states and provinces also aim for large-scale importation of mostly green hydrogen via their ports. TenneT is the offshore grid developer for the Netherlands and the German part of the North Sea. They have currently connected a total of 8,600 MW of offshore wind power to onshore grids of the two countries and have called for the ramp-up for more wind farms installation in the North Sea to meet the renewable electricity demands for planned hydrogen economy (TenneT, 2019).

However, the deployment of more wind farms in the North Sea can cause significant spatial implications and conflicts with the conventional users of the sea such as shipping routes, fishing zones and protected areas (Gusatu *et al.*, 2020). The North Sea is the busiest sea in the world with hardly limited capacity to accommodate the multitude of commercial interests vying for space. The current North Sea marine spatial plans are not prescriptive enough in neither facilitating conflict resolution nor in deterring the unsustainable use of the North Sea (Howes, 2004). Moreover, the different regulatory frameworks on both sides of the border form roadblocks to cross-border energy integration, collaboration and learning. Therefore, there is a need for a transnational perspective and co-operation to maritime spatial planning to facilitate the energy transition of both countries.

The ports located at the Wadden sea coast are important entry points for the energy produced in the North Sea because of their geographical location at the interface of sea and land. Currently some German and Dutch North Sea Ports are receiving points for electricity transmission cables from offshore wind farms, while some ports have long been receiving points for natural gas from the North Sea (Hydrogen Council, 2017). These ports have a great potential for being the primary node in the hydrogen economy network as they have the industrial capacity and infrastructure needed for receiving stations, conversion plants, and storage facilities. They also possess networks for distribution of energy to inland end users, as ports are connected to the hinterland by extensive infrastructures such as road, rail, water, pipelines and cables (Laes et al., 2014). In addition, ports have substantial maritime expertise that could facilitate offshore wind deployment at an increasingly rapid pace. This entails large amounts of wind turbines, long electricity cables, pipelines and platforms, as well as power hub islands that need to be built in-order to reach the renewable energy productions targets for both countries (Wang *et al.*, 2020).

The expansion of the port areas to accommodate an industrial cluster that is integral to the hydrogen economy is envisioned. This has spatial implications on land use policies; raise conflicts with the current land users of the area and the social acceptance of the broader public on these developments is not ascertained.

The ports as commercial entities compete with regard to the provision of services to the shipping sector and also for the activities for offshore wind farms. However, all these developments and transformations processes in the southern North Sea pose risks and potential threats to the Wadden Sea which is a UNESCO world heritage site. The potential threats linked to increased shipping activities are operational emissions (noise, water, and air pollution), accidental influences (loss of loads, collusion and oil spills) and prohibited discharges (WSF, 2020) . The risks of increased traffic for the construction, maintenance and the dismantling at a later stage of wind farms that will partly have to transit the Particulary Sensitive Sea Area (PSSA) of the Wadden Sea are of a major concern to the UNESCO world heritage site (Bahlke, 2019). Moreover, the construction of large-scale transmission cables in the Wadden Sea and maintenance of damaged cables pose a significant threat as these activities contribute to mudflats getting heated, thereby possibly causing a permanent change of species community along the cables (Rösner, 2012).

Therefore, it is necessary to analyze how can the ports contribute to the energy transition as well as how can they mitigate the environmental risks to the Wadden Sea that are associated with energy transition

1.2 Research objectives

Due to their geographical location at the interface of land and sea, ports are crucial in facilitating the energy transition and in the development of a hydrogen economy. The ports located along the Wadden sea region are facing a peculiar challenge; on the one hand the need to be front runners in the energy transition (Damman & Steen, 2021; DNV GL, 2020b) and on the other hand to deal with growing environmental concerns linked to the negative externalities of the energy transition that are particularly significant in the wadden sea region(Baer & Nehls, 2019; WSF, 2020) . Therefore, this study aims to first identify the current developments and planned transformation linked to energy transition and hydrogen economy developments in the Netherlands and the German parts of the North Sea.

Secondly, ports are organized on a global scale of networks, such as carriers, terminal operators and logistics service providers however, the structure of the governance of the ports vary across the globe (Verhoeven, 2011). Thus, the study aims to identify the functions and structure of the governance of the ports located along the Wadden sea region. Finding these functions and governance structure can enhance the understanding on how these ports can facilitate the connection of the energy produced in the North Sea to the existing coastal energy infrastructure.

Thirdly, the energy transition is complex web of interrelated actors and networks (governments, citizens, companies, NGOs) and interdependent sectors (transport, industry, housing, tourism, nature etc.) which are very difficult to oversee and grasp. In such a complex system, no one actor has the capacity to direct it or alter it as ownership and power is fragmented (de Boer & Zuidema, 2013). Transition theory as argued by (Van Der Brugge et al., 2005; Verbong & Geels, 2007) and transition management by (Loorbach, 2010) provide an epistemological perspective to understand and categorize such a complex web of actors, networks in the economic, social, physical and institutional sense. Their multi-level perspectives draw interlinkages between the actors in the complex web in the different levels while as the multi-phase perspective identifies the different phases of the transition. Thus, this study applies theoretical frames of transition theory and management to understand the current developments in the North Sea linked to the energy transitions, the phase of the transition that we are in, and which actors are involved on which level.

Finally, as the developments linked to the energy transition and hydrogen economy are taking place on both sides of the shore, an integrated coastal zone planning approach is necessary to strength the preservation of the fragile wadden sea ecosystem (de Boer & Zuidema, 2013; Gusatu et al., 2020; Spijkerboer et al., 2019). All socio-economic activities in marine environments have environmental impacts that should be mitigated. However, the Wadden sea is particularly sensitive area which calls for a comprehensive attention on the negative externalities of the energy transition on the Wadden sea and embedding renewable energies in the physical and socio-economic landscape. Therefore, the study explores which ways can these ports deal with the potential environmental risks associated with hydrogen economy developments to the Wadden Sea.

With this study, recommendations can be made to both the governance of the energy transition in the Wadden sea region and the environmental planning of Wadden sea. To answer the research questions and to come up with these recommendations, document analysis will be done followed by semi-structured interviews with stakeholders of the ports in two out of the three countries that share a coastline along the Wadden sea: The Netherlands and Germany.

1.3 Research question and Sub-questions.

To explore how the ports located along the Wadden sea coast can contribute to the energy transition as well as mitigating environmental risks to the Wadden sea, I propose the following central research question and sub-questions to demarcate the scope of my study.

Primary research question

What do the prospects of hydrogen economy and spatial developments in the North Sea linked to the energy transition mean for the governance and environmental consequences for the Dutch and German ports located along the Wadden Sea coast?

Secondary research questions

1. What are the current developments and planned transformation linked to hydrogen economy developments and to energy transition in the Netherlands and the German parts of the North Sea?
2. Can transition theory and management aid in understanding the energy transition and hydrogen economy developments, the actors involved and how they are interlinked?
3. How can ports facilitate the connection of the hydrogen energy produced in the North Sea to the existing coastal energy infrastructure? How are these developments linked to the ports of the respective countries?
4. Who are the stakeholders in the governance of the ports located along the Wadden sea coast?
5. What are the challenges and opportunities for these ports in the developments of a hydrogen economy?

6. In which ways can these ports deal with the potential environmental risks associated with the energy transition and hydrogen economy developments to the Wadden Sea region?

1.4 Research relevance

1.4.1 Scientific relevance

The study aims at exploring the hydrogen strategies for the Netherlands and Germany and zooms in to the role of ports in these strategies. The position of hydrogen economy development and the energy transition of both countries is analyzed through the lenses of the transition management and transition theory. There is well-developed literature on governance of the port entities and the technical literature on port construction and economics of port operations, logistics and supply chains. However, there is a knowledge gap on the role or Impacts of the ports located along the wadden sea coast can have on the energy transition as well as on the Wadden sea.

This research elaborates on the need of an integrated coastal area-based planning approach that integrates renewable energies not only in the physical landscape but also socio-economic landscape. Furthermore, the research highlights the need for shift from centralized, sectoral and top-down governance approach to a decentralized, shared governance based on consensus building approach to facilitate collaboration, co-operation and co-ordination in the spatial developments that are related to the hydrogen strategies of Northern Germany and the Netherlands.

The aim of this study is to develop recommendations for the ports located along the Wadden Sea region of the Netherlands and Germany in terms of governance and environmental arrangement in the prospects of hydrogen economy and spatial developments in the North Sea.

1.4.2 Societal relevance

First, the study is socially relevant as it aims to increase the knowledge on the position of hydrogen economy in the energy transition processes. It is currently not clear what are the governance, spatial and environmental implications arising from the pursuit of hydrogen as a key element in the energy transition processes in the context of ports located along the Wadden Sea region.

Secondly, the findings of the research also provide empirical knowledge which can create environmental awareness on the disruptions linked to hydrogen economy developments in the North Sea on the Wadden Sea, which is a world heritage site where natural processes should proceed undisturbed.

Thirdly, the findings of this research can highlight the need for the institutional harmonization and alignment of regulatory frameworks. Institutional harmonization facilitates regional and cross-border cooperation and coordination between various institutional frameworks that guide different sectors and actors to mitigate environmental risks while enabling synergies between the energy transition and spatial/environmental planning.

1.4.3 Expected Results for planning practice

One of the main objectives of the research findings is to propose recommendations in terms of governance arrangements and environmental planning for the ports located along the Wadden sea region in their pursuit for opportunities arising from the planned hydrogen economy.

Planning practitioners can also find these recommendations useful in navigating the complexities and uncertainties related to energy infrastructure planning especially during the current energy transition process.

The research's focus on integrated coastal zone planning approach and the findings provides suggestions for stakeholders in the governance of ports and conservation initiatives in developing ways of working together in reaching sound and sustainable decisions together.

1.5 Research guide

#	Content	Sub-questions
Chapter 1	Introduction and background of the research, outline of the research objective, research question and research relevance	
Chapter 2	General overview of the different types of Hydrogen, their applications and the stepwise integration in the energy transition	1,
Chapter 3	Outlines on the one hand the environmental risks to the Wadden sea linked to the negative externalities arising from the energy transition and hydrogen economy development, and on the other hand the forms a theoretical background by applying transition theory and transition management frame of reference to understand about the governance of energy transition and capacity of ports to influence spatial and environmental planning. The theoretical framework used here led to conceptual model that is consistently used throughout the research	1, 2, 3,
Chapter 4	Elaborates on the research strategy and the corresponding methods that are used for in this study	
Chapter 5	Answers to sub-questions 1, 3, 4, 5 are derived from the results of semi-structures interviews and document analysis and question 5 ends with a SWOT analysis matrix	1, 2, 3, 4, 5
Chapter 6	Provides an answer to the discussion sub-question 6. The answers to sub-question 6 are derived from the semi-structured interviews with the experts and the port stakeholder	6
Chapter 7	Formulates an answer to the main research question, draws recommendations for the stakeholders in governance of the port and ends with a reflection of the research itself	Primary question

Table 1. 1 Research guide

2 Position of Hydrogen in the energy transition

2.1 Hydrogen production, storage and distribution

The European project CertifHy developed the standards for the production, storage and distribution of hydrogen and has classified it into three types: grey, blue and green Hydrogen (Barth et al., 2015). Hydrogen produced from fossil-fuel based feedstock such as natural gas, oil and coal without capturing the carbon is known as "grey hydrogen". "Blue hydrogen" is obtained when carbon capture and sequestration is applied during the production of hydrogen from fossil-fuel based feedstock. "Green Hydrogen" is the production of hydrogen from the electrolysis of water using electricity/energy that is derived from renewable sources (ibid). Box 1 gives a detailed description of the production, storage and distribution of hydrogen.

Box 1: Hydrogen production, storage and distribution

Production

There are currently two main pathways used to produce hydrogen: chemical method through electrolysis and thermal method such as gasification and reforming. There are other methods like biological and photo-electrochemical that are in the development and exploratory research stages(Kim *et al.*, 2014).

Hydrogen obtained through electrolysis results into zero greenhouse gas emission depending on the source of electricity used (Lulianelli and Basile, 2014). The electrolysis of water is the process in which an electric current is passed through water to initiate a redox reaction that yields Hydrogen and Oxygen (Götz *et al.*, 2016). Hydrogen can also be produced from other electrolysis technologies: alkaline electrolysis (AEL), polymer electrolyte membranes (PEM) and solid oxide electrolysis (SOEC). The main parameters for electrolysis technologies are efficiency, lifetime and flexibility. The overall energy efficiency of the electrolysis technologies is currently 55- 70%, that is energy value of hydrogen produced in relation to the amount of electricity and electrolyte used (ibid).

Gasification and reforming are the processes in which steam and air/oxygen are passed under high pressure through fossil-fuels to produce Syngas which is primarily consisting of carbon monoxide, hydrogen, methane and water vapor (Steinberg and Cheng, 1989). The main difference between them is that gasification uses solid fossil fuels such as coal while reforming used gaseous fossil fuels such as methane. Afterwards the Syngas can be further converted to Hydrogen and Carbon dioxide only through further catalytic reactions. These thermal methods have been predominantly used in industrial processes and constitute the biggest share of hydrogen production and usage presently. The efficiency of gasification and reforming is 68 -75 % depending on the type of fossil fuel used (ibid).

Storage and Distribution

There are numerous technologies developed for the storage of hydrogen and they can be classified on the scale and duration of storage. For short-term and small-scale hydrogen storage purpose, hydrogen can be stored physically in high pressure tanks either in gaseous form (compressed gas) or at cryogenic temperatures in liquid form whereas chemically it can be stored in metallic hydrides. Caverns, aquifers and depleted gas fields can serve as long-term and large-scale hydrogen storage (Kayfeci and Keçebaş, 2019; Rivard, Trudeau and Zaghib, 2019) The appropriateness of the storage system depends on the given application. For any given application, the key performance indicators for the practical application depends on the gravimetric energy densities (energy stored relative to mass) and volumetric energy densities (energy stored relative to space) (Götz *et al.*, 2016).

Hydrogen stored in tanks can be put in containers and distributed via all the existing transport infrastructure such as railway, road and shipment (Iulianelli and Basile, 2014). It can also be transmitted via the existing natural gas pipelines infrastructure. By retrofitting the natural gas pipelines to accommodate hydrogen not only reduces the costs of constructing new hydrogen pipelines but also reduces the depreciation of the natural gas pipeline infrastructure (Mori and Hirose, 2009). However, as the demand for hydrogen grows a hydrogen dedicated pipeline infrastructure will be necessary (ibid).

2.2 Stepwise Integration in the Energy Transition.

The EU aims for the exponential increase in the production of renewable energy to meet the targets of zero GHG emission by 2050 (European commission, 2021). Wind energy (onshore and offshore) is planned to contribute a significant share of the needed renewable energy to meet the zero emission targets. In line with these ambitions, Germany and the Netherlands are scaling-up their renewable electricity generation capacities from offshore wind farms in the North Sea in-order to meet the electricity demands for the planned hydrogen economy. Thus, the North Sea coastal states and provinces of both countries are vital players for the success of these strategies. The five North Sea German states (Bremen, Hamburg, Lower Saxony Mecklenburg-Western Pomerania, and Schleswig-Holstein) have launched the transformation processes of installing 500 MW of electrolysis capacity by 2025 and at least 5 GW by 2030 (BMVI, 2019). The Dutch North Sea provinces (Groningen and Friesland) have also similar targets of 500 MW of installed capacity by 2025 and 3-4 GW of installed capacity by 2030 (Cleijne *et al.*, 2020).

TenneT is the offshore grid developer for the Netherlands and the German part of the North Sea. They have currently connected a total of 8,600 MW of offshore wind power to onshore grids of the two countries and have called for the ramp-up for more windfarm installation in the North Sea to meet the electricity demands for planned hydrogen economy (TenneT, 2019). Due to the high variability of offshore wind power, and the inability of the present electricity grid to adapt to such variability of power, a lot of renewable power gets wasted by shutting down the wind turbines. Hydrogen can be the solution to this challenge as it can fulfil the role of energy storage by converting the excess renewable electricity to green hydrogen (ibid).

Currently grey hydrogen is produced in large-scale from fossil fuels and primarily used as a raw material and feedstock in industries and in the production of fertilizers for agricultural purposes (Ministry of Energy, 2020). The Netherlands and Germany are the largest producers of grey hydrogen in Europe and their experience with integrating hydrogen into the industrial energy mix is mature as both countries have large existing industries that have been using grey hydrogen for the last couple of decades (WEC, 2017).

Both countries have developed hydrogen strategies that draw a transformation roadmap; 1) from current large scale industrial production and consumption of grey hydrogen which is the production of hydrogen from high carbon materials such as fossil fuels, 2) to low-carbon blue hydrogen produced from fossil fuels, with the resulting $C02_2$ emissions captured and stored, 3) and to green hydrogen which is production of hydrogen by electrolysis of water using renewable electricity sources by 2050 (BMWI, 2020; Cleijne *et al.*, 2020).

According to these hydrogen strategies, blue and green hydrogen will play a major role in smart combination with renewable electricity in decarbonizing the industrial processes and transportation (maritime) sectors where reducing carbon emissions is both crucial and difficult to reach. In the short term (2020-2035), blue hydrogen based on applying carbon capture and sequestration to existing grey hydrogen will be pivotal in accelerating the decarbonization process while medium to long term (2035-2050 and onwards), green hydrogen will propel the transitioning to a net zero EU emissions targets (Wang *et al.*, 2020).

In the long-term green from 2050 and onwards a hydrogen produced from the electrolysis of water using electricity that is derived from renewable sources will be core of the integrated energy mix. Hydrogen acts as a buffer as it facilitates storage of excess renewable energy produced and avails these energies when and where needed. Hydrogen is a versatile energy carrier as it has numerous different end-users and applications.

It can easily be produced, stored, distributed, converted or conditioned to meet peculiar energy demands. By means of fuel cells, hydrogen can be changed to different energy carriers like electricity and heat which can be used in transportation, built environment and industries. Hydrogen and electricity are complementary energy carriers as both of them satisfy a large range of energy services that are not easily met by other energy carriers. Besides hydrogen is readily utilizable as a fuel and chemical feedstock in numerous industrial processes that range from metal ores refining to oil and steel manufacturing which are the hardest to decarbonize (Hydrogen Council, 2017). Figure 2. 1 below illustrates the above discussed steps.

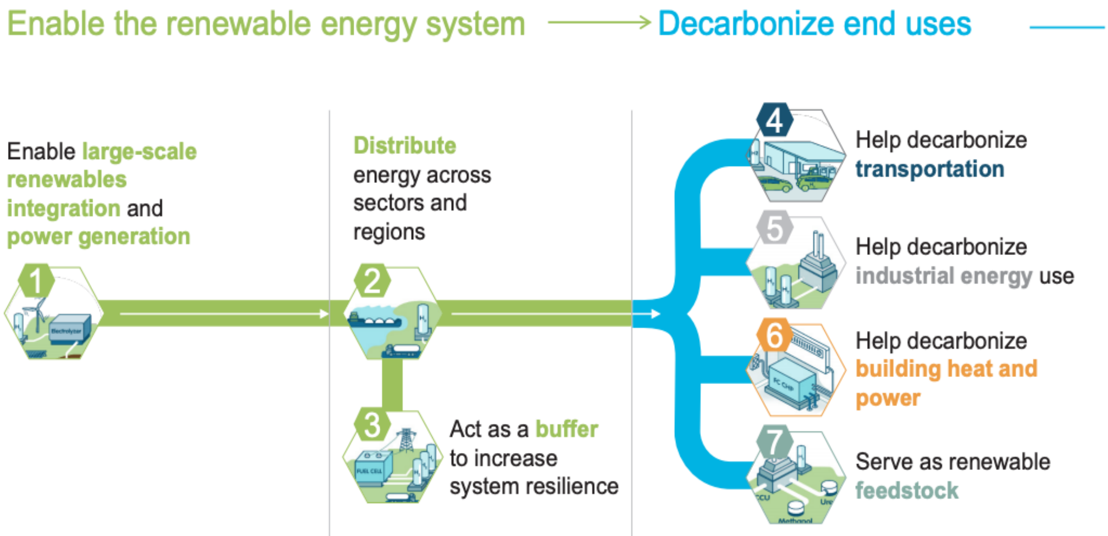

Figure 2. 2 Stepwise integration of hydrogen in the energy transition (source; Hydrogen Council, 2017)

3 Theoretical framework

This chapter outlines on the one hand the environmental risks to the Wadden sea linked to the negative externalities arising from the energy transition and hydrogen economy development, as well as the socio-economic activities linked to the ports and maritime sector to the Wadden sea (section 3.1 & 3.2). On the other hand, the chapter formulates a theoretical background by applying transition theory and transition management frame of reference to understand about the governance of energy transition and capacity of ports to influence spatial and environmental planning (section 3.3 & 3.4). The theoretical framework used here led to conceptual model that is consistently used throughout the research (section 3.5).

3.1 Risks associated with ports and shipping

The quality and integrity of the Wadden sea is currently deteriorating due to intense pollution from various socio-economic activities such as shipping, energy explorations, tourism and fishing. A report done by the world-wide fund came to the conclusion that socio-economic activities linked to ports, shipping and offshore energy installations can interfere and disturb the natural processes that are important for the integrity and quality of the Wadden sea (WWF, 1991). Therefore, the whole Wadden sea is designated by the International Maritime Organization as a Particular Sensitive Sea Areas (PSSA) in order to enact and enforce strict protection against marine pollution(Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas, 2005). The ports located along the Wadden sea are multi-functional and are engaged in various activities such as container depot and service points, transshipment of various cargo, export points of energy, cars and heavy-duty equipment and some also have import facilities for oil, gas and coal terminals and many other activities (Bahlke, 2019; Schultze & Nehls, 2017; WSF, 2020). The expansion of port areas seawards to accommodate space for offshore wind turbine assemblages, construction and storage is envisioned by ports. The expansion of ports sea wards results in destruction of natural areas and taking space away from nature. Furthermore, “This development interferes with characteristic elements such as the openness, serenity and identity of the landscape, the topography of the landscape, the biodiversity and the cultural-historic remnants” (CWSS, 2010, p. 28). Due to the multi-functionality of the ports located along the wadden sea, there is high traffic of maritime vessels crossing the PSSA as they enter and leave these ports (Bahlke, 2019; WSF, 2020). This increases the vulnerability of the Wadden sea to the potential threats associated with shipping. The figure 3. 1 below shows the international shipping corridor (in blue) and numerous shipping routes (in brown /orange) traversing the Wadden sea (in green) to access the harbours located in the Wadden sea coast (source: Wadden sea planning portal, WSF, no date).

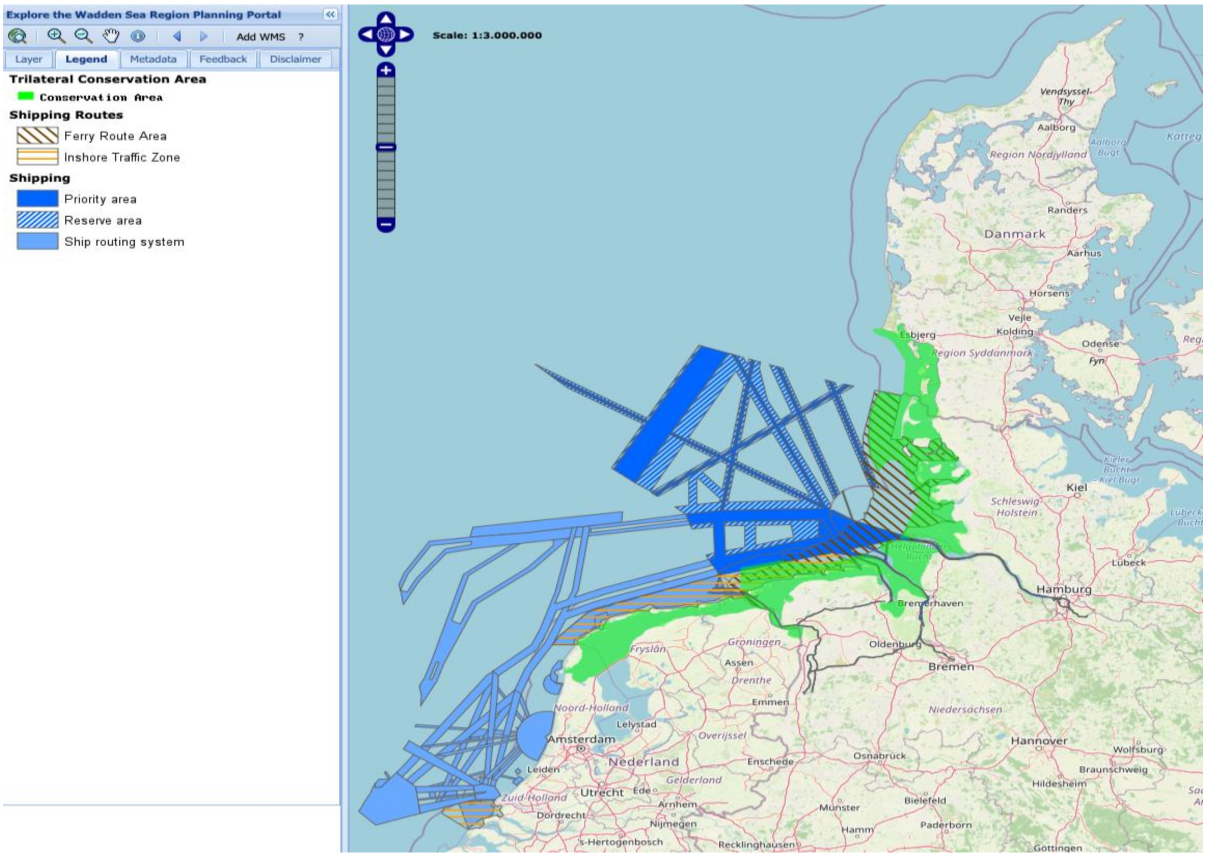

Figure 3. 1 shows the intense local maritime routes and international shipping corridors traversing the PSSA areas (WSF, n.d.)

Furthermore, the increase in shipping traffic in the PSSA is projected to increase sharply due to the energy transition demand for huge quantities of renewable energy from offshore wind farms (Bahlke, 2019). This entails rapid installation of offshore wind farms in the North Sea and near the Wadden Sea and the continuous monitoring, maintenance and repair services for the wind farms (ibid). The potential threats linked to increased shipping activities in the Wadden sea are elaborated further in Box 1.

The energy transition from fossil-fuels to renewable energies of both Germany and the Netherlands also rely heavily on the importation of green hydrogen within Europe and from other global sources ((BMWI, 2019; Kemp, 2010). The Wadden sea ports are planned to have the vital role of facilitating the import and export of hydrogen due to their strategic proximity to the world's busiest maritime routes with multiple shipping corridors.

Box 2: The potential threats linked to increased shipping activities in the Wadden sea

1. Operational emissions

   - As sound travels 4.5 times faster in water than in air, ship propellers and engines amplify underwater background noise levels which poses catastrophic effects on marine mammals such as harbor porpoises and fish who use sound for navigation, feeding and communication. Leakage of heavy metals, toxic antifouling paint and the discharge of bilge and ballast water leads to the pollution of the water column whereas the emissions from the ships cause air pollution (Schultze and Nehls, 2017).

2. Accidental influences

   - leakage of oily water and substances have adverse effects on the species and have led to the poisoning of the pristine habitat. Currently oiled birds make up 50% of the guillemots washed up dead. Additionally, loss of cargos and collisions are also major sources of pollution to the PSSA (WSF, 2020).

3. Prohibited discharges

   - Due to the difficulties of monitoring ship discharges, oil, lubricants, contaminated wastes and tank wash waters are also main sources of pollution linked to shipping in PSSA (Schultze and Nehls, 2017; WSF, 2020)

4. Visual Disturbance

   - The presence of ships and vessels scares species out of their accustomed and feeding habitats, the marine mammals and birds who are sensitive to disturbances lose their resting, feeding and breeding grounds as they avoid ship traffic disturbance (Schultze and Nehls, 2017; Bahlke, 2019; WSF, 2020).

The energy transition has beneficial impacts on the quality of the wadden sea as it calls for eco-friendly vessels and green shipping technology which means ships and vessels that have minimal if not null GHG emissions and reduction in underwater noise through using alternative fuels, non-combustion engines and energy saving technologies (Wan et al., 2016). However, these beneficial impacts do not eliminate or reduce the shipping traffic in the PSSA, moreover it leads to an increase in shipping traffic which disturbs the natural processes in the fragile environment of the wadden sea ((BFN, 2013; WSF, 2020).

Increased shipping traffic also intensifies the regular dredging of sediments in the waterways and channels (Schultze and Nehls, 2017). The harbors, shipping lanes and channels in the Wadden sea coast require regular dredging due to sediments building up in waterways that obstruct the movement and navigation of ships and vessels (OSPAR Commission, 2017b). The river estuaries of Weser, Ems, Jade and Elbe account for a large share of the dredging activities in the

Wadden Sea. According to the OSPAR Commission (2017), 90% of the dumped sediments are dredged in the southern North sea and the Wadden Sea. Dredging affects the integrity of the marine environment as it directly removes the benthic fauna and flora resulting in severe decrease of species diversity, community biomass and decrease in local population sizes in the sediments. The loss of rich biomass has adverse effects on the food availability for birds, fish and marine mammals in the fragile wadden sea habitats (ICES, 2014; Schultze & Nehls, 2017). Additionally, the dredging vessels emit underwater noise which is unbearable by the marine mammals and fish and is linked to physiological and behavioral changes to species such as harbor porpoises and seals (ICES, 2014, 2016).
The Figure 3. 2 below shows the locations and average dredged sediments per year (2006-2013) within the Wadden Sea areas of the Netherlands, (orange symbols), Germany (green and blue symbols), Denmark (red symbols) and the shipping lanes within the rivers Ems, Jade, Weser and Elbe (Source: Schultze and Nehls, 2017)

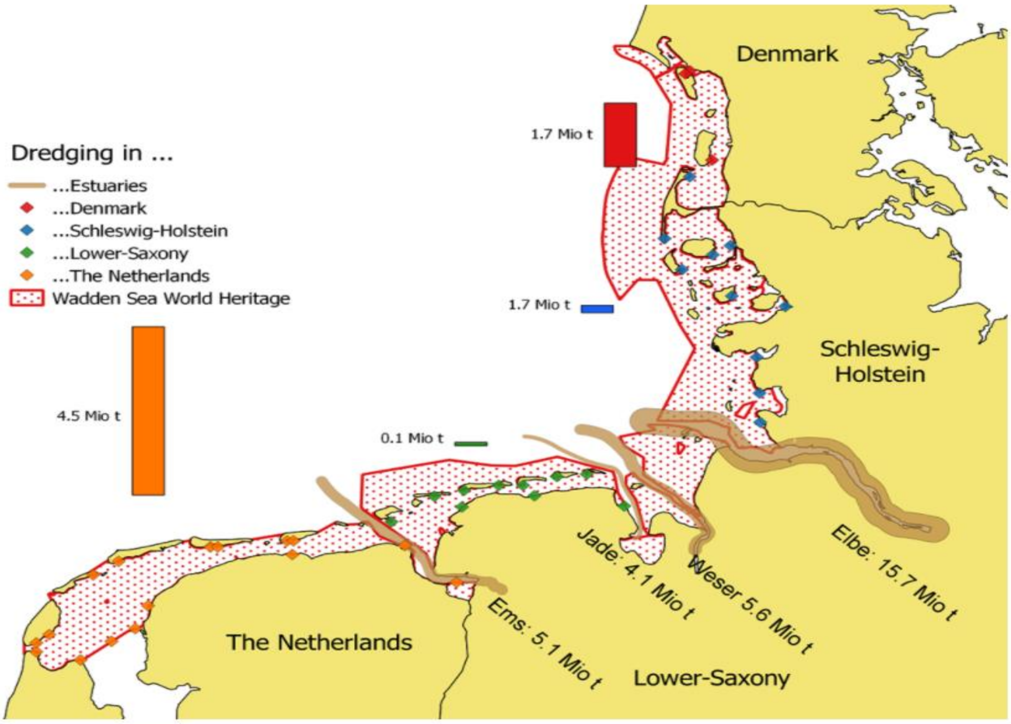

Figure 3. 2 Shows the locations and average dredged sediments per year (2006-2013) within the Wadden Sea areas (Source: Schultze and Nehls, 2017).

3.2 Risk associated with the energy transition

The deployment of offshore wind is so far the largest-scale human intervention in the North Sea and its implication on the ecosystem and marine habitats and environments is still under intensive study (BFN, n.d). Although the installation of the offshore wind farms is taking place outside the Wadden sea the underwater noise from pile driving can reach far distances and affect the fauna in the Wadden sea as well (ibid). These wind farms also need continuous operational and maintenance services as they are exposed to harsh conditions of the sea (salt, high humidity, salt water spray, hydrodynamics and fast and strong wind). Additionally, the decommissioning and dismantling of non-functional wind turbines will partly have to transit the Wadden sea area which is of a major concern to the UNESCO world heritage site (Bahlke, 2019).
Power generated by offshore wind farms will have to be connected to the mainland grid using high voltage direct cables (HVDC) buried in the sea floor which will have to transit the PSSA in the Wadden Sea. The laying and embedding of these HVDC in the sea floor using specially equipped vessels have several impacts on the PSSA that include:

1. Underwater noise- The specialized vessels that lay and embed the cables emit underwater noise in the process of maneuvering in the PSSA (Koschinski & Lüdemann, 2013)

2. Sediment replacement - the benthic community and demersal species are impacted by the excavation and removal of sediments in the embedding on the HVDC (ibid)

3. Heat and electromagnetic fields- when the HVDC are in operation they release heat and electromagnetic waves, the temperature rise affects the metabolism species in the benthic communites and can lead to mudflats getting heated thereby causing permanent changes in the community species along the HVDC. The electromagnetic fields affect the hunting behavior of the demersal fishes and disrupts the navigation of migratory fish species who use earth's magnetic field for navigation (BFN, 2013; Koschinski and Lüdemann, 2013).

Finally, Wadden sea is paramount for the existence of 52 populations of the 41 migratory species that primarily migrate along the East Atlantic flyway shown below in Figure 3.3 below.

Figure 3. 3 East Atlantic flyway (source: (Dolch et al., 2017)

It is only in the wadden sea that these birds can find abundance of food that can enable them to complete their journeys of thousands of miles crossing the whole world (Fox & Petersen, 2019; Mangi, 2013). The threats presented to migratory birds by offshore wind farm are avoidance of offshore turbines by birds therefore prolonging the distance of the journey. The risk of collusion from the turbine structures and pylons acting as barriers to movement of birds especially at night and in adverse weather conditions is high. However, the threat to collusion has been shown to be low as migratory birds have been documented to generally avoid the turbine from a distance (Fox and Petersen, 2019).

The environmental risks associated with the socio-economic activities in the Wadden sea discussed above have a transboundary effect such as the pollution caused by shipping activities. Due to the transboundary nature of the problem, there are numerous measures, instruments, regulations, agreements, and laws that are all applicable to generate a centralized guidance for the port authorities to follow. For instance(Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas, 2005; OSPAR Commission, 2017a; Seanergy, 2012; WSF, 2020) ;

1. MARPOL protocol lists the measures ports can take to reduce pollution at sea, such as provision of port reception facilities, there are several annexes of MARPOL that provide measures and instruments for dealing with specific pollutants,
2. UNCLOS provides laws that govern the activities for offshore installations,
3. OSPAR adopts legally binding regulations related to marine environmental protection in the North Sea,

4. IMO provides guidelines and standards for maritime activities related to shipping and vessels,
5. EU's MSFD, Habitat and birds' directives provides framework for ports to adhere to nature conservation and planning,
6. Common Wadden Sea secretariat- coordinates and facilitates the cooperation between the three countries that form the Trilateral Wadden Sea Cooperation.

All these measures, instruments, laws and regulations steer and stimulate national and transnational / cross-border cooperation between ports to mitigate environmental risks to the marine environment (European Commission, 2010; IMO, 2005; OSPAR Commission, 2017; Seanergy, 2012; WSF, 2020). However, climate change mitigation measures such as the energy transition can no longer be approached only through top-down activities from international, European and national actors. Therefore, there is the need to shift from environmental planning based on centralized standards to a more a communicative and coordinative planning approach that aims for consensus building (De Roo, 2016). Spatial integration of renewable energies requires local(municipalities) and regional (provinces and *Bundesländer*) actors such as port authorities to have a crucial role in delivering public policies that can unlock the potential for integrated coastal area-based planning approach. Furthermore, there is the need for institutional harmonization to facilitate interregional level cooperation and coordination between the different Wadden sea regions.

3.3 Understanding transition in port governance and functions

The energy transition is one of the major climate mitigation pathways adopted by the IPCC, and it entails a shift from the dependency and extraction of fossil fuels to the reliance on renewable energies and sustainable energy use (DNV GL, 2020b). Currently, ports are large consumers of fossil fuel-based energy for the provision of fuel to ships and vessels, energy needed for port operations and activities and for the provision of energy to industries located in port areas (DNV GL, 2020b, 2020a). In the wake of the energy transition, adopting and gradually transforming ports to be dependent on renewable energy is important. To find an answer to the sub-question 2, Section 3.3 discusses ontological findings on the evolution of the governance of the ports (sub-section 3.3.1) whereas sub-section 3.3.2 outlines the scope for ports to enable system change and how ports can have an impact on the energy transition. Section 3.4 outlines an epistemological perspective that leads to a theoretical framework based on transition theory and management and finally Section 3.5 conceptualizes the theoretical concepts in a conceptual model that is used as guidance throughout this research.

3.3.1 Governance of ports

Ports have evolved from being mere bureaucratic gateways at the interface between water and land to logistical hubs in the global value-driven chain system (Brett & Roe, 2010; Pettit & Beresford, 2009; Robinson, 2002). They have become catalysts of economic development as they handle more than 80% of the world's trade (UNCTAD, 2018). This evolution of ports introduced a paradigm shift in port governance: - from port authority as a public entity that provides commercial and maritime services as well as enforcing regulations - to development companies with strong market-orientation governance (Verhoeven & Vanoutrive, 2012).
The market -oriented governance is grounded on competition, efficiency and effectiveness of service delivery with the aim of profit maximization. The governance of ports has two dimensions: (1) internal actors who run the day-to-day operations of the port and are influential private players organized on a global scale of networks, such as carriers, terminal operators and logistics service providers with the aim of profit maximization, and (2) external actors from various

institutions who can be grouped into economic, societal and policy-making stakeholders that represent the interests of the local governments, environment, NGOs, and citizens (Verhoeven and Vanoutrive, 2012; Damman and Steen, 2021).

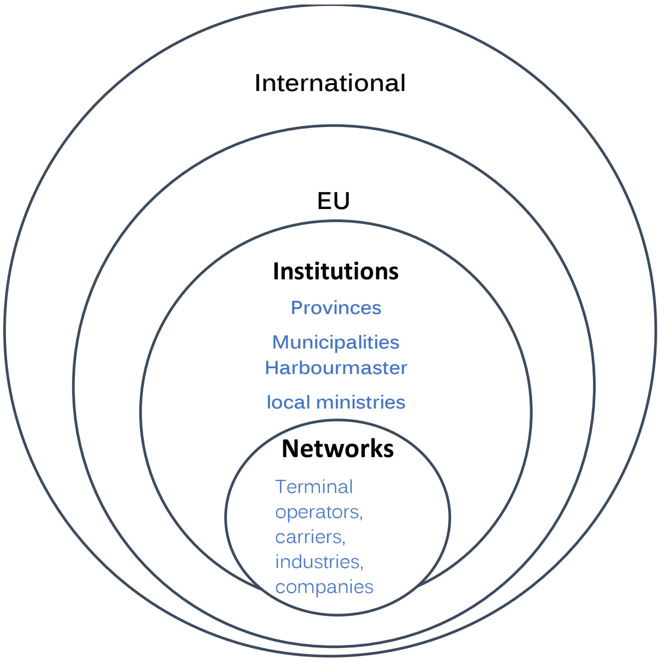

Figure 3. 4 European port governance structure. (Source Author, adopted from Verhoeven, 2010)

The two dimensions merge into a hybrid governance structure in which the port authority has a corporate management system at the internal level which is mainly involved with maintaining and expanding the port networks, activities and operations and community manager at the external level which stays in background and monitors the interests of the stakeholders and the broader public (Verhoeven, 2010, 2011).

Furthermore, zooming out from the port authority, the ports are also in multilevel governance setting in which the port activities and operations are highly influenced and bounded by instruments, laws, conventions and agreements at the global level(Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas, 2005; Seanergy, 2012), European level (directives such as MSFD), regional level (OSPAR) and at the national and local level are regulations set by the country the port is located (Seanergy, 2012). These differentiated levels of influence illustrated in figure 3.4 are part and parcel of the overall governance of the ports and for instance can exert pressure on the port authorities to take meaningful steps towards decarbonization of the port activities, operations and co-located industries (DNV GL, 2020a, 2020b;

Verhoeven, 2011; Seanergy, 2012; Damman and Steen, 2021) and also taking measures for abating environmental risks and hazards (IMO, 2005).

3.3.2 Scope for ports to facilitate sustainable energy transition

Ports offer suitable locations for the development of a hydrogen hub, referring to the convergence of hydrogen provision (production, storage and distribution), critical industrial mass demand of hydrogen and the logistics of exportation and importation of hydrogen (BMVI, 2019).

Despite ports being at the nexus of global trade and maritime transportation little attention has been given to ports in the research of sustainability transition (Bosman et al., 2018; Damman & Steen, 2021). Moreover, the port's physical infrastructure, networks and the institutions regulating it can be both facilitators and barriers to radical transformation (Damman and Steen, 2021).

However, a recent report by DNV GL, (2020b) highlights that ports can be the front runners in the energy transition as they can provide avenues for decarbonization in port activities, operations and equipment that are energy intensive, reduce pollution at berth by power supply for maritime vessels that call the ports, electrification of co-located industries, integrating renewable energies in port energy mix via transformation of energy from one carrier to another using hydrogen and finally institutional changes that form roadblock to radical change. Furthermore, ports can contribute to upgrading of the environment through enabling sustainable maritime transportation by facilitating access to emission compliant fuels, sanctioning or rewarding specific users, adopting innovations with null ecological footprints and enacting rules and networks that gravitate towards sustainable port development (Verhoeven, 2010; Damman and Steen, 2021).

There are four main functions of ports in literature that have crucial impact and can shape Environmental planning, land-use planning and Infrastructure planning as shown in figure 3.5

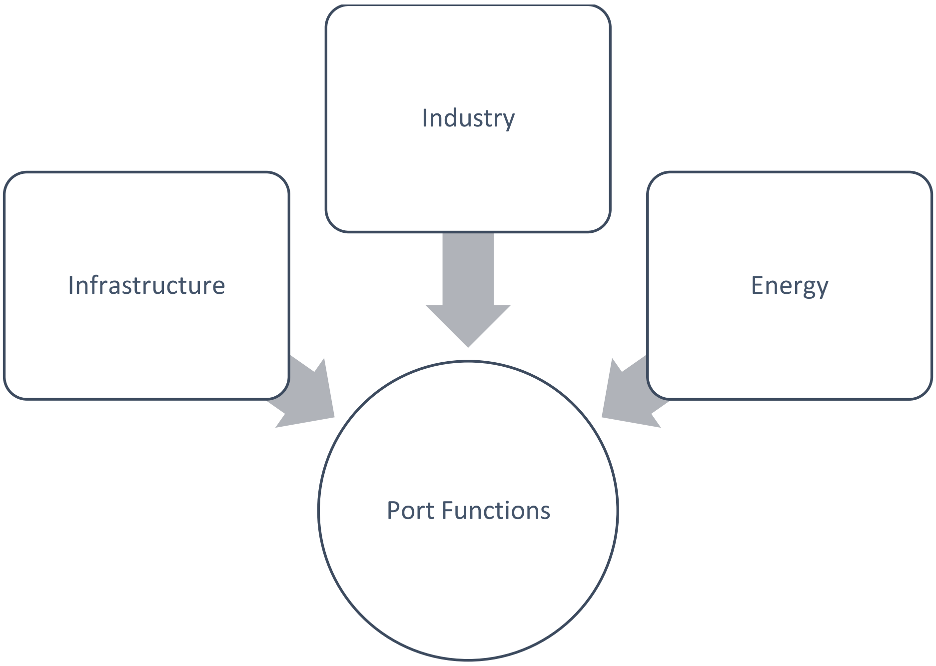

Figure 3. 5 Functions of the ports (Source Author, adopted from Verhoeven, 2010)

1. In Infrastructure planning, port are ***multi-modal transport hubs*** having links with other transport infrastructures such as pipelines, inland waterways, road, railway and air routes. They are also ***logistical hubs*** as they facilitate flow of goods, natural resources, information, and services across the global maritime trade corridors and contribute to the national and regional economic growth (Interreg, n.d.).

2. In Land-use planning ports are ***industrial hubs*** in which various industries converge at these ports to benefit from the swift importation of raw materials or exportation of bulk matter. As more companies and firms converge in or around ports, clusters and synergies emerge between sectors. Furthermore, the development of a hydrogen economy is predicted to not only create industrial clusters in or around the ports but also will attract more industries from other regions who use hydrogen or its derivatives as feedstocks (DNV GL, 2020b, 2020a).

3. In Energy transition planning ports are ***energy hubs***. The availability of facilities and capacity for importing and exporting different energy carriers (oil, gas, coal, LNG, hydrogen etc.) and the potential for onshore power production and supply and the ability to connect offshore energy to the mainland (Damman and Steen, 2021). These multiple energy carriers can be converted or conditioned and stored in the ports areas where they can be retrieved when need be. Multiple energy carriers are necessary to meet the diverse energy demands

of the numerous port activities and industries located in these ports (DNV GL, 2020b). For example, these ports provide bunkering services for ships and vessels (oil, gas) and electrical power, the port itself has various power intensive activities such as terminal operation, cold storage and lightning

According to Verhoeven (2010) the functions of institutions managing ports (port authority) have a substantial impact on the pace and direction of the energy transition. These functions as illustrated in figure 3.6

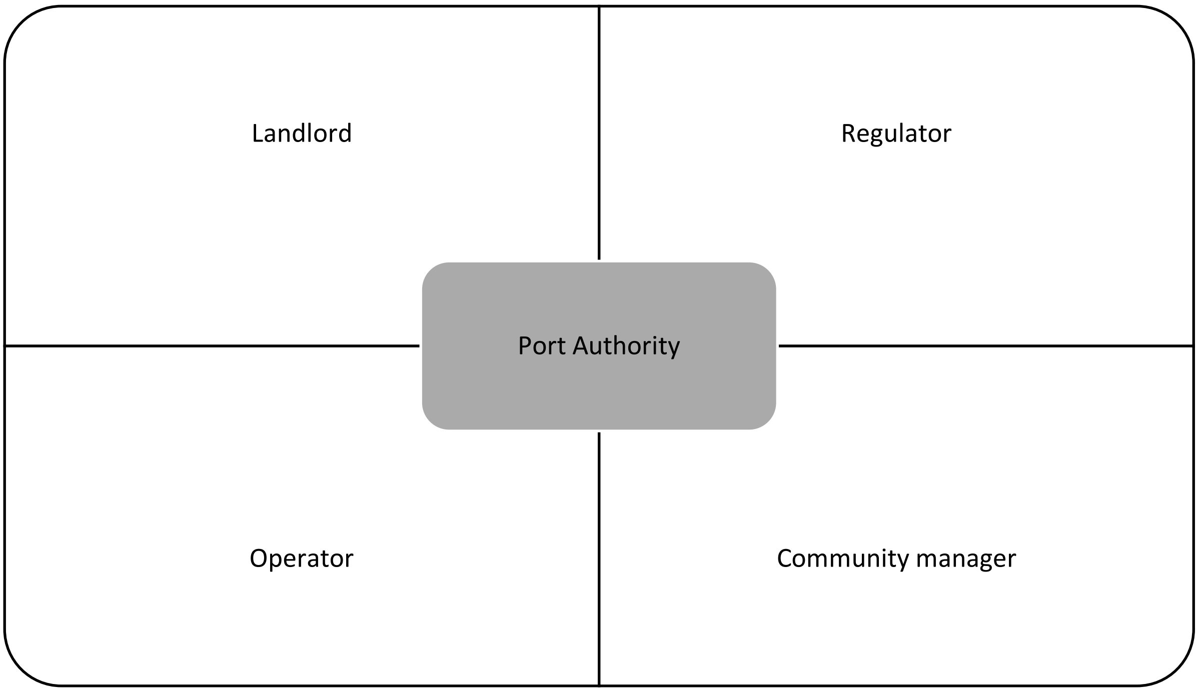

Figure 3. 6 Function of the port authority (Source Author, adopted from Verhoeven, 2010)

1. As landlords, they lease land, facilities and basic infrastructure to farms and companies.
2. As regulators, they enforce regulations, policies, environmental standards, set tariffs and are responsible for the long-term spatial planning of the port areas.
3. As operators, they provide services, equipment and infrastructure for ships and vessels calling at the port.
4. As community managers, they bring together port users, networks, and stakeholders to enhance performance (economic dimension) and also enhance collaboration and positive externalities for the environment, local government, community (social dimension).

Through these four functions ports authorities can steer and accelerate the energy transition of the port from fossil fuels towards sustainable and efficient use of renewable energies (Poulsen et al., 2018; Verhoeven, 2011).

Figure 3. 7 below brings together the governance, physical functions and functions of the port authority to facilitate system change

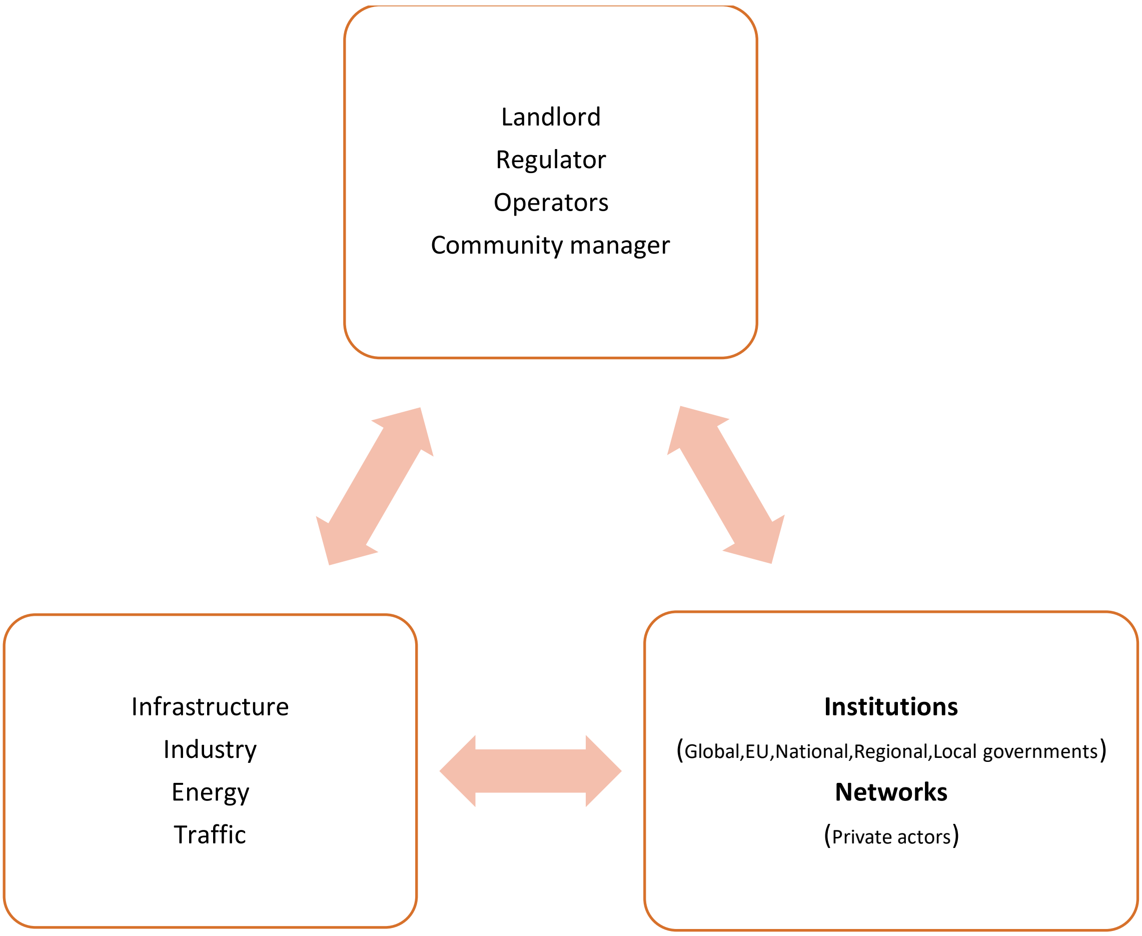

Figure 3. 7 Scope for ports to enable or facilitate system change adopted from Damman and Steen, 2021

3.4 Transition theory and Transition Management

The ongoing political developments such as the Paris Climate Agreement, the European Green Deal and the national energy transition strategies indicate that the shift from fossil fuels to renewable energy is already an ongoing process(DNV GL, 2020a).

The Netherlands and Germany's national energy transition strategies present instruments such feed in tariffs, incentives and tax breaks for the production of renewable energy from solar, biomass and wind (Energiewende, 2019; DNV GL, 2020a). Such incentives act as pull factors that are attractive for the society, investors and firms to invest in renewable energies therefore making renewable energies more competitive to fossil-fuels. concurrently, both countries are emboldening investments in alternative innovative energy carriers such as hydrogen, batteries and LNG to supplement the adoption of renewable energies across the sectors (Industry, built environment, transport and in agriculture) (ibid). The energy transition strategies also aim for introducing carbon tax, strict emission standards and ultimately phasing-out the fossil-fuel power plants therefore discourage investments in fossil-fuel power plants. These push and pull factors are causing disruptions to the current fossil-fueled energy landscape and are leading to irreversible changes in the energy supply systems (de Boer & Zuidema, 2013; Meadowcroft, 2009).

For analysing such a non-linear processes and irreversible systemic changes, (Geels, 2011) transition theory by (Geels, 2011; Van Der Brugge et al., 2005; Verbong & Geels, 2007) and transition management by (Loorbach, 2010; Loorbach & Raak, 2006) provide an epistemological perspective to understand and categorize such a complex web of actors, networks in the economic, social, physical and institutional sense. Van Der Brugge, Rotmans and Loorbach, (2005); Verbong and Geels, (2007); Geels, (2011) argue that the multi-level perspective draws interlinkages between the actors in the complex web in the different levels (landscape, regime and niche) while as the multi-phase perspective identifies the phases of the transition (predevelopment, take-off, acceleration and stabilization). Applying the multi-phase perspective aids this study in identifying the current phase of the energy transition and hydrogen economy in the Wadden sea region. Whereas the multi-level perspective aids in identifying which level the stakeholders in the port governance are positioned relative to the other actors involved in the energy transition and hydrogen economy development in the Wadden sea region.

To start with multi-phase concept (Van Der Brugge, Rotmans and Loorbach, 2005) argue that the transitions phases differ in the perspective of the speed at which changes occur. As the Wadden sea is environmentally sensitive and fragile area, the environmental impact of the negative externalities of the energy transition to Wadden sea slows down the speed at which the energy transition will progress such as the offshore wind farm deployment and exportation and importation of hydrogen.

3.4.1 The Multi-Phase perspective on the energy transition

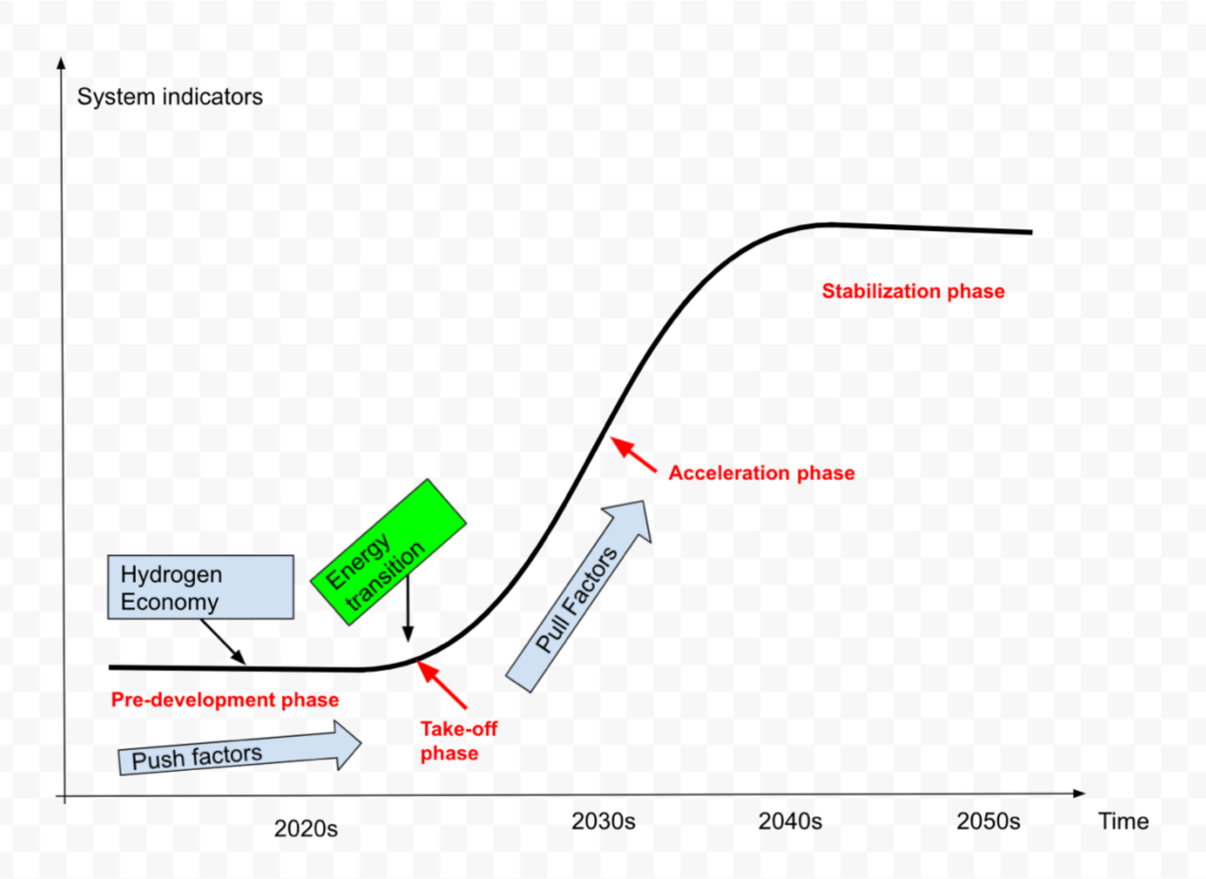

Figure 3. 8 The phases of the energy transition edited from (Van Der Brugge, Rotmans and Loorbach, 2005).

1. At the pre-development phase changes are taking place but are not significant enough to cause disruption in the current energy landscape (Van Der Brugge, Rotmans and Loorbach, 2005).

In this phase the port authorities utilize their landlord and operator function to allocate space for renewable energies in port areas and the integrating renewable energies and hydrogen in the port energy mix. The function of ports as industrial, energy and logistical hubs act as pull factors that stimulate ports to be front runner in the energy transition while on the other hand the urgency of phasing-out coal and other fossil-fuels act as push factors that transform the ports and co-located industries to adopt renewable energies as their main source of energy in the long-term. Currently, there are projects and experimentation on the production, transportation, application and storage of hydrogen. Thus, hydrogen economy can be placed at the pre-development phase as there are no sufficient dedicated renewable energies for hydrogen production as well as no transmission and storage infrastructure now in the Wadden sea region.

2. At the take-off phase the changes reach a critical threshold that can cause shocks in the current energy landscape and a shift starts to emerge in the expansion of renewable energies and hydrogen economy.

The renewable energies such as solar and wind farms can be placed at this phase as they are already competing with fossil-fuels and are increasingly contributing a fair share of the energy of the Netherlands and Germany (TenneT, 2019). Push factors such grants, funding, investments and supportive legal and social framework can stimulate port authorities to pursue the opportunities linked to being front runners in the energy transition. For hydrogen economy to progress from pre-development phase to take-off phase, the port authorities can use their community manager roles to stimulate its stakeholders adopt hydrogen as fuel or for heating in the port operations, in co-located industries and maritime sector. This is important as a critical mass demand for hydrogen is necessary for the development of a hydrogen hub which is a prerequisite for the formation of a hydrogen economy.

3. Acceleration / Breakthrough in which constructive interaction between the social domains reinforce each other leading to structural changes.

4. Stabilization- a new dynamic equilibrium is reached in which the structural change forms a new normal.

The remaining phases are currently absent in Wadden sea region as they are described by a broad acceptance by society via learning processes and structural changes such as a consolidation of the new energy landscape and the development of hydrogen economy (Loorbach, 2010; Loorbach & Raak, 2006). Therefore, this research identifies the energy transition is currently at the second phase (take-off phase) while hydrogen economy development to be in the first phase (pre-development phase). These two phases are relevant for the port authorities at the moment.

The environmental risk linked to the energy transition in Wadden sea might be low at the early stages (2020s-2030) but in the acceleration and stabilization (2030-2050 onwards) we have hydrogen (pipelines, storages etc.) and renewable energies infrastructure (i.e wind turbines, cables) altering the marine physical landscape, then these environmental risks might significantly increase. Therefore, port authorities addressing these risks in the upcoming process might be much more relevant.

3.4.2 Multi-level perspective on the energy transition

As argued by the Van Der Brugge, Rotmans and Loorbach, (2005); Verbong and Geels, (2007); Geels, (2011) that the multi-level perspective draws interlinkages between the actors in the complex web and classifies them in the different levels (landscape, regime and niche). Using such a frame to view the world, we could understand the complex web of actors involved in the energy transition and their interlinkages and influences on each other. By applying these levels, we could position the climate change, changes to culture, societal and political awareness to the impact of current fossil-fueled energy paradigm on the environment as changes on the landscape level that create pressures for change to the economy and energy landscape and pushes for an energy transition. The European green deal and the current national states' energy transition and hydrogen strategies can be represented as landscape changes on the Macro-level. These in turn influence the Meso-level/ regime actors to align with the developments happing at the landscape level.

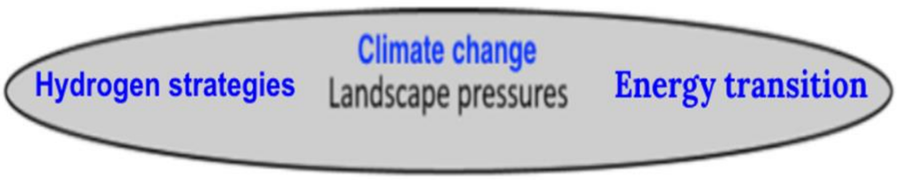

Figure 3. 9 The landscape level changes that are an impetus to the system change (by author)

The port authorities and the existing energy paradigm based on fossil fuel are examples of such a regime whereby there are networks and institutions set up that enact rules, regulations, provide incentives and subsidies for the extraction, production, distribution and consumption of fossil fuels. Furthermore, a lock-in in the dependence of fossil fuels is evident across sectors in industries, transportation, agriculture and the built environment have co-evolved over decades with the growth of the fossil fuel paradigm (Meadowcroft, 2009;

Damman and Steen, 2021). These networks, institutions and societal dependence on fossil fuels strive to optimise the current system rather than shifting to a whole new energy landscape (Verbong and Geels, 2007; Rotmans et al., 2001). The port authorities can use their functions of landlord, regulatory, operators and community managers to either facilitate the energy transition or can block the development of the energy transition. This figure 3.10 below adopted from Damman and Steen, (2021) illustrates how ports can contribute or block system change

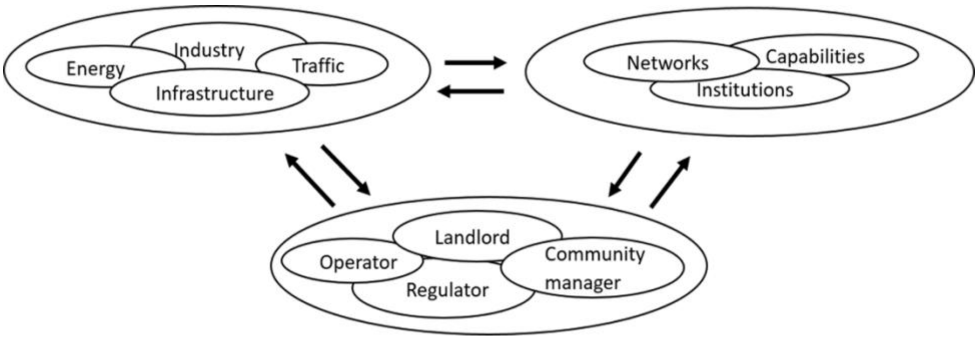

Figure 3. 10 Scope for ports to enable or facilitate system change adopted from Damman and Steen, (2021)

According to the multi-level perspective, at the micro level, new innovations, ideas and social practices that are foreign to the fossil-fueled energy landscape are driven by individual actors and alternative technologies. These niche developments push for transformation and changes to the status quo (Van Der Brugge, Rotmans and Loorbach, 2005). The emerging energy paradigm based on renewable energies is such an example of niche development whereby the several innovations (LNG, hydrogen, batteries etc.) compete for integration or disruption of the current energy paradigm (Damman and Steen, 2021). The regime blocks the wide acceptance of these innovations in order to maintain the status quo. However, the developments in the landscape and niche levels can match and reinforce each other (such as energy transition and hydrogen) thereby creating enough pressure for the regime to change (Verbong and Geels, 2007; Meadowcroft, 2009; Damman and Steen, 2021).

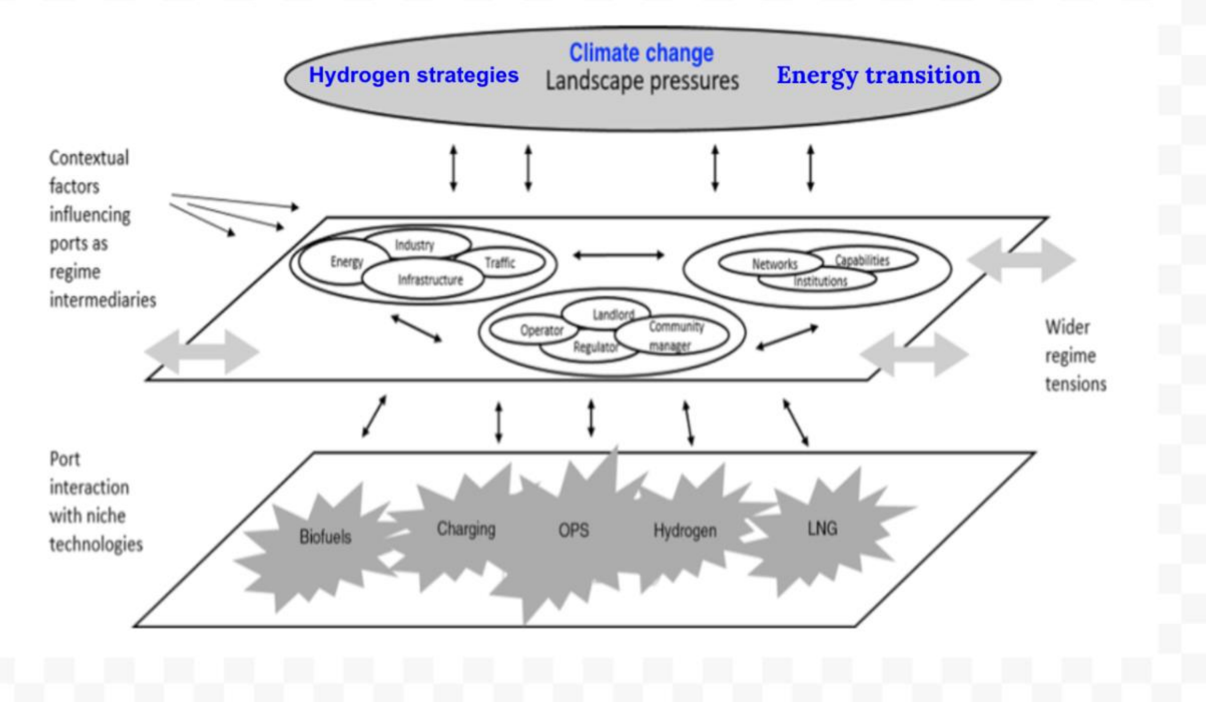

Figure 3. 11 The multi-level interlinkages between the actors involved in the port energy transition edited from Damman & Steen, (2021).

Transition thinking frames niches as innovations, technologies, new practice driven by individual actors. Framing niches as such results in sustainable energy projects to be viewed as initiatives to test new experiments, practices or new technologies in isolation from their physical and socio-economic context (de Boer & Zuidema, 2013). The context in which these innovations and technologies emerge is relevant and how can these new innovations and technologies be embedded in the physical landscape as well as in socio-economic landscape (ibid).

Therefore, this research henceforth follows an area-based approach and tries to explore the type of governance, social, economic and ecological approaches that are fit for integrating these niche developments in their physical and socio-economic landscape are analyzed. Area-based planning approach creates a complex web of interrelated actors and networks that make it difficult to steer transitions and therefore necessitates a shift from the traditional top-down centralized planning approaches in which a single or a group of stakeholders are involved in decision-making process with a certain goal in mind and the ways to achieve it (Allmendinger, 2017). The stakeholders in the governance of the ports have the challenge to engage in interactive dialogue with other stakeholders from the public, environmental NGOs and other relevant actors to find synergies between renewable energies and the local conditions. A Planning approach that is participatory and aims for consensus building is fundamental to ensure that society can accept and endorse changes to the physical landscape and socio-economic landscape bearing in mind the various actors, their interests and environmental impacts as well (De Roo, 2016)

3.4.3 Transition management

The final concept in transition's thinking is transition management (Loorbach, 2010). As argued by Loorbach (2010), managing transition takes a process-oriented approach which aims for long-term sustainability through coordinating multiple actors and stakeholders across various levels (Loorbach, 2010). It aims for sustainability which is inherently inter-subjective with multiple interpretations across the actors involved (De Roo, 2017). Transition management takes an adaptive and anticipatory approach to deal with the uncertainties and complexities associated with the non-linear long-term changes and interactions that involve diverse actors with different expectations, norms, values, ideas and perception of the world (Rotmans and et al, 2001). Using such a frame to understand how actors can steer transition, Loorbach, (2010) proposes transition management framework in which four different governance activities are drawn up. These activities develop in a cyclical and integrative ways as shown in figure 3.12:

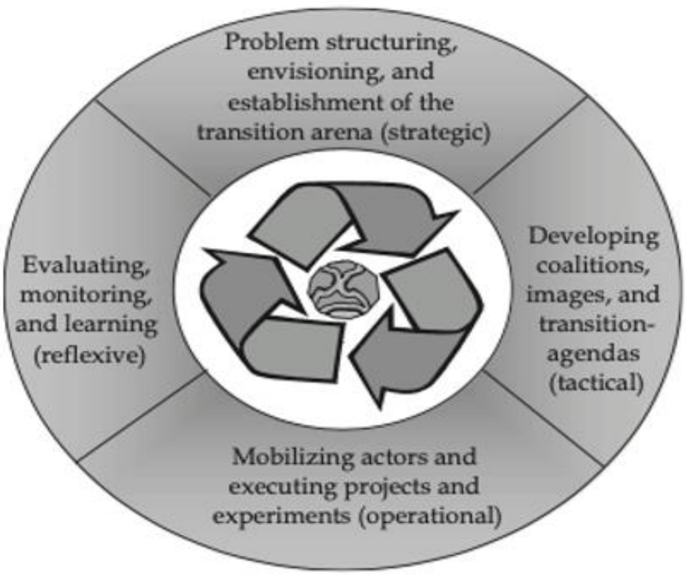

Figure 3. 12 The transition management framework by Loorbach, (2010).

1. Strategic activities

   - encompass all the activities that are associated with culture of the society or landscape system. A transition arena is established that brings together frontrunners who are diverse actors who can influence the transition. Long-term visions are developed through anticipation and collective goal and norm setting (Loorbach, 2010).

- At this level, the hydrogen strategies and their timeline of targets provides strategic visions and pathways that guide the transition arena which consists of actors from the various domains in the port governance and functions. They reach a common understanding of which pathways the port should follow in integrating hydrogen in the port energy mix. The port authority's community manager and regulatory functions are relevant at this level to form the transition arena and the formation of port strategic vision that is aligned with the national and regional hydrogen strategies.

2. Tactical activities

- Include all the steering activities carried out by the dominant regime of a subsystem that form the transition agenda where the long-term visions are transformed into plans, projects and scenarios (ibid).

- At this level, the port authority is systematically deliberating different agendas and policies that enable the adoption of hydrogen as an energy carrier at the port and transformation of co-located industries, operations and activities at the port to gradually shift to reliance on renewable energy and hydrogen. Development of incentives or penalties for vessel operators who meet/ don't meet the port's new agenda and policies. The port authority's' landlord and regulatory functions are relevant to this level as they engage users of the port areas and services.

3. Operational activities

- Entails all the niche experiments, new technologies, practices and actions that are carried out by individual actors with a short-term focus. These have minimal impact and don't lead to transition unless reinforced by landscape development (Ibid).

- At this level, experimentation and exploration of how hydrogen can be part of the port energy mix are undertaken. The port authority's operator and landlord function are relevant to operationalize the application of the hydrogen in the port activities and operations.

4. Reflexive activities

   - These are monitoring and learning activities and are embedded in all the three previous steps. Evaluation and monitoring the advancement of transition processes while enabling social and institutional learning.

   - The accrued mistakes, challenges, hurdles and success that have been experienced along the path of transitioning to renewable energy form the basis for the port's expertise. This learning by doing is an ongoing process across the three other levels.

3.5 Conceptual framework

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In the conceptual framework in figure 3.13 below, the top box is linked to what has been discussed in chapter 2 and forms the basis for chapter 5 section 5.1 , whereby the energy transition and hydrogen economy form the background of the study. The energy transition poses a governance challenge which is one component of the hydrogen economy, and the other component is the environmental risks arising from the negative externalities of the energy transition to the fragile and pristine wadden sea.
The conceptual model brings together the transition management and analysis on the environmental risks into, on the one hand understanding the growing environmental risks and that are particularly significant in the wadden sea region. On the other hand, the energy transition provides a governance challenge due to non-linear developments that lead to rapid and irreversible changes as well as a complex web of actors whose interlinkages and interconnectedness makes it really complicated to manage. Following this chapter is the empirical part of the study, where we find out what these developments on the various phases of the energy transition and the various actors inter-linked at different levels given particular environmental concerns that are there, and which roles could the port authorities play in these phases.

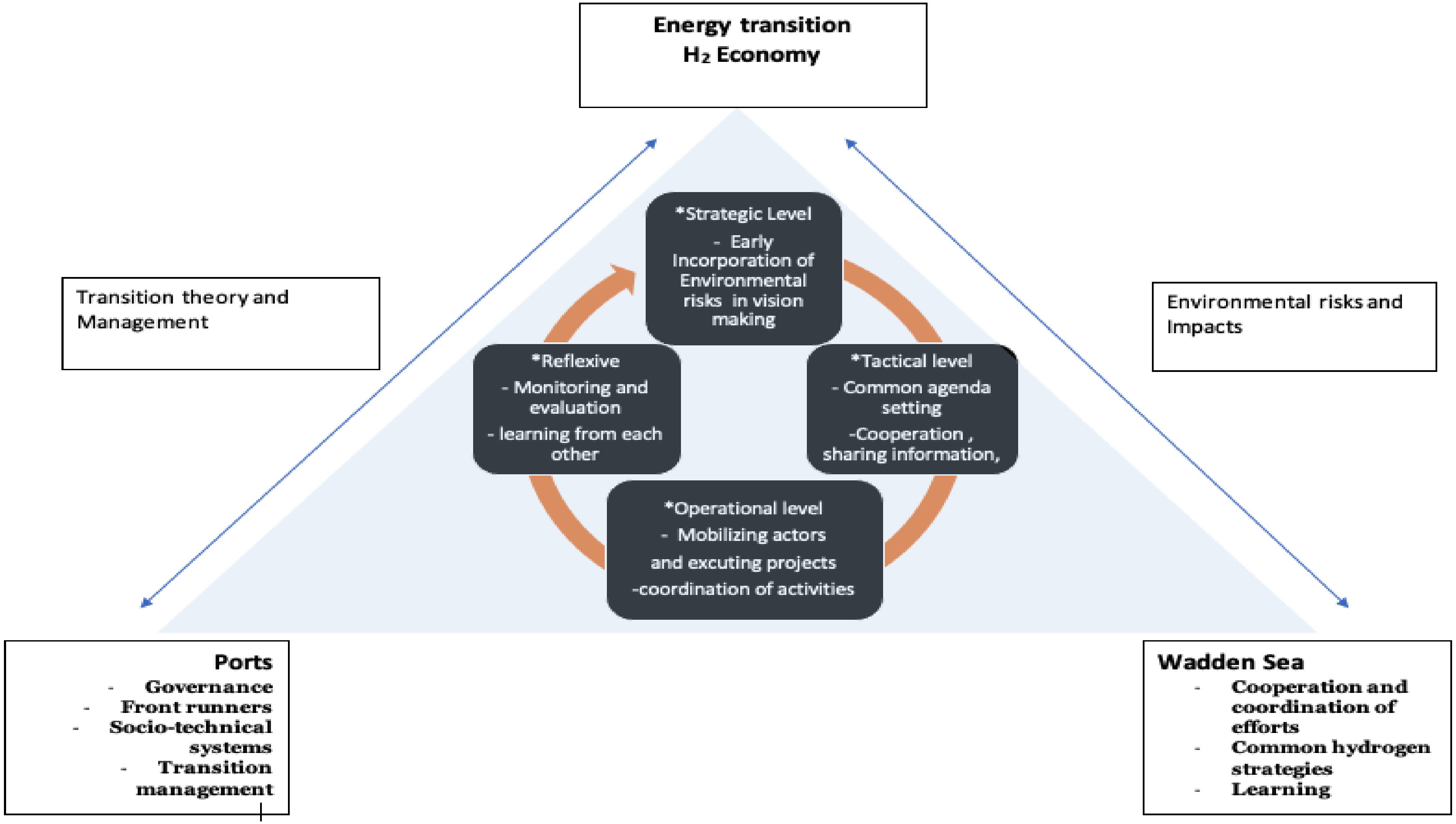

Figure 3. 13 Conceptual Model

4 Methodology

This chapter elaborates on the research strategy and the corresponding methods that are used for this study; Section 4.1. Section 4.2 introduces the selected ports and elaborates on the criteria for selection. Section 4.3 then elaborates on the document analysis and short-list the main documents that were used to find the spatial developments in the North Sea linked to the energy transition. Section 4.4 then elaborates on the research methods that have been executed to handle the gathered data. Section 4.5 Provides an overview of data collection and the respondents. Section 4.6 explains how the data collected was analyzed and section 4.7 elaborates on the ethics and limitation of qualitative research approach and generalization

4.1 Research Strategy

A case study provides detailed information about a phenomenon (hydrogen economy and energy transition) and the context (Wadden sea region) it is situated by analyzing events, persons, projects, policies, institutions, and other systems (Yin, 1994).

A multiple case study approach is suitable for answering the research question "What does the prospects of hydrogen economy development in the North Sea region linked to the energy transition mean for the governance and environmental consequences for the Dutch and German ports located along the Wadden Sea region".

The spatial focus on this study is the ports located along the wadden sea coast which includes, the wadden sea regions (Dutch provinces and German *Bundesländer*) and the Wadden sea area (wadden sea marine environment) where I want to explore the governance of the energy transition in the wadden sea region and the environmental concerns of the energy transition in the wadden sea area.

A case study is a suitable research method as this research explores and analyzes the interlinkages between ports, marine environment and the energy transition. With a statistical large- N analysis, understanding the attitudes of stakeholders in ports, NGOs and environmental organizations would be more difficult. The aim of this research is to understand and explore in-depth how the ports located along the Wadden sea coast can mitigate the environmental risks to the Wadden sea as well as to be front-runners in the energy transition, from which recommendations will be drawn to come up with a framework. Doing such a multiple case study as an iterative process, where understanding the combination of environmental risk and transition management, the differences and similarities between the ports can be understood. Furthermore, it will be possible to analyze the data both within each country and between different countries or situations (Yin 1994). A multiple case study allows for replication, so cases which confirm relationships can enhance confidence in the validity of the relationships and can provide lessons for other countries or ports.

4.2 The selection of the case ports

The ports can be categorized into groups according to the regional jurisdictional boundaries (national and regional) and management systems.
Due to the very large number of ports and harbor in the Wadden sea region, it was necessary to apply a selection criterion that allowed to zero-in to ports that can have an impact on the energy transition. These allowed to classify ports and retrieve the most relevant ports to the research topic. The originally selected ports for research are shown are shown in the table 4.1 and 4.2 below.
The selection criteria are;

1) They are located along the Wadden Sea coast or have a waterway channel that traverses the Wadden sea.
2) They are part of core Trans-European Transport Network (TEN-T) ports. The TEN-T is European-wide network of transport infrastructure (railways lines, inland waterways, roads, maritime shipping routes, airports, ports). The main objective of the TEN-T policy framework is to reduce environmental impact, improve energy efficiency, increased safety and improve the flexibility, quality and durability of the infrastructure (European Commission, 2015).
3) They function as industrial hubs, energy hubs and infrastructural and logistical hubs.
    - Energy hub means the capacity of importing and exporting energy, potential for onshore power production and supply and the ability to connect offshore energy to the mainland (Damman and Steen, 2021).
    - Industrial hub refers to convergence of similar industries in or around the ports / co-location of industrial clusters in or around the port (ibid).
4) They are managed as a group of at least two ports under one port authority. Table 4.2 shows the selected ports, their port authority's and functions

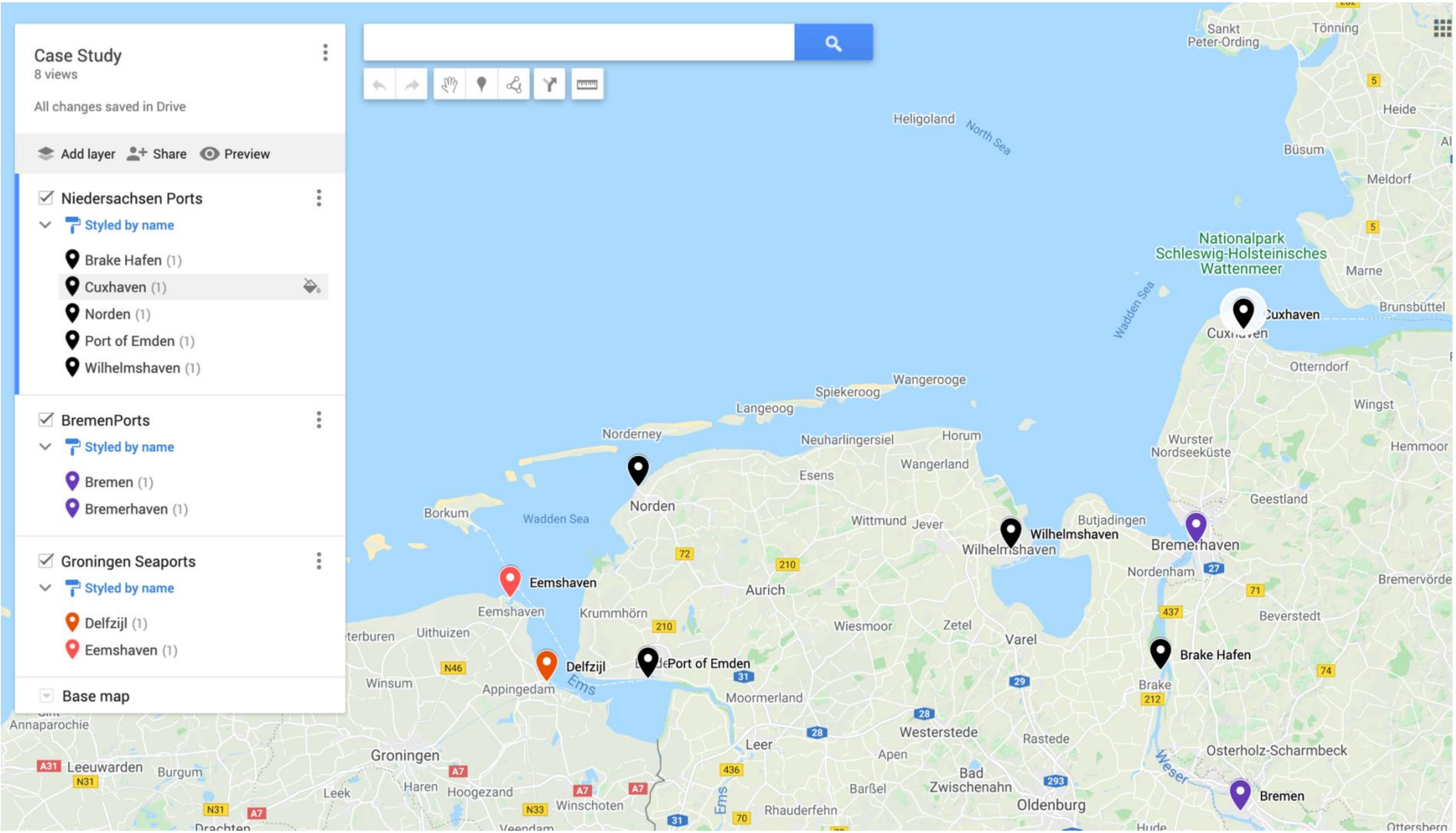

Table 4. 1 The list and location of the case ports

Selected ports

Wadden Sea ports		Country	Logistics hub	Industrial hub	Renewable energy		Fossil Fuel	
					Onshore	Offshore	Onshore	Offshore
Niedersachsen Ports	1. Brake 2. Cuxhaven 3. Emden 4. Norden 5. Stade 6. Wilhelmshaven NB; and 9 more small ports	Germany	X	X	X	X	X	X
Groningen seaports	1. Delfzijl 2. Eemshaven	The Netherlands	X	X	X	X	X	X
Bremen ports	1.Bremen 2.Bremerhaven	Germany	X	X	X	X	X	X

Table 4. 2 Functions of the selected ports

4.3 Research methods

Within the case study, a mixed methods approach has been used, combining different approaches with the aim for data triangulation. These methods include,

1. Semi-structured interviews with port officials regarding their energy transition strategies, governance structure and the measures taken by ports to mitigate negative environmental impacts to the Wadden sea.
2. Semi-structured interviews with energy and ecology experts from initiatives and NGOs regarding the environmental impacts of port activities on the Wadden sea
3. Desk/ Secondary research on policy documents, scientific and academic reports relating to the potential of ports to be the front-runners in the energy transitions and the ways they can reduce negative environmental impacts from port related activities.

First a desk research was conducted that entailed analysis of national and regional policy document on the energy transition and hydrogen strategies of the Netherlands and Germany. Additionally, strategies and concepts on energy transition, sustainability reports by ports and information on the websites of the ports located along the Wadden sea coast were also part of the desk research. These data have made it possible to address relevant questions to the interviewees and aides in having more reliable and valid answers to my research questions.

Secondly, I participated in the Wadden sea forum plenary meeting in which various stakeholders in the Wadden sea region presented their latest research, projects, opinions, and interests concerning the energy transition. Participation in the Wadden sea forum plenary meeting enhanced an in depth understanding of my research context. Furthermore, it provided avenues for me to find potential stakeholders in the Wadden sea region whom I could interview and collect data for my research.

Finally, the focus of this study lies however on deriving qualitative data through semi-structured interviews, that will be used to compare the data to the theoretical literature findings. Therefore, semi-structured interviews have been held with people in several ports who are responsible for planning the port's strategies towards sustainability and energy transition. Semi-structured in-depth interviews were also conducted with organizations that include an environmental initiative; world *wide fund (WWF)*, a NGO that brings together Dutch ports located along the Wadden sea coast; *Waddenzeehavens* and a research institute; New Energy Coalition. The three organizations are actively engaged in creating awareness on the impacts of climate change in the Wadden sea area was consulted.

The semi-structured interviewing allowed both the interviewer and interviewee to introduce and express issues they deem to be important and possibly bring new insights to the research. Follow-up questions about examples made sure a complete understanding of each relationship was achieved. A drawback is that qualitative, semi- structured interviews cost more time and are less suitable to generalize. However, according to Onwuegbuzie and Leech (2010) qualitative data still allow for case-to-case transfer, so suitable lessons can still be drawn from the several ports. The list of interview questions is included in Appendix I

4.3.1 Data collection

4.3.1.1 Document Analysis

A document analysis is executed to determine the landscape level changes and ongoing developments within the energy transition in the ports. The documents have been analyzed to create an understanding on the on the context of the transition under study for the interview analysis and at the one hand to identify the current and the planned developments in the Wadden sea region linked to the energy transition. Furthermore, the document analysis forms the basis for answering sub-question 1.

#	Document Title	Author	Reference
1	The Climate agreement report	The government of The Netherlands	(The government of the Netherlands, 2019)
2	Netherlands Government Strategy on Hydrogen	Ministry of Economic affairs and climate policy	(The Minister of Economic Affairs and Climate Policy, 2020)
3	Hydrogen Strategy for North Germany states	BMVI	(BMVI, 2019)
4	National Hydrogen Strategy	BMWI	(BMWI, 2020)
5	A programmatic approach for Hydrogen innovations in the Netherlands for the 2020-2030 period	TKI New Gas	(Gigler et al., 2020)
6	Infrastructure Outlook 2050. Integrated energy infrastructure in the Netherlands and Germany	Gasunie and TenneT	(Gasunie & TenneT, 2019)
7	European port governance	Patrick Verhoeven	(Verhoeven, 2011)
8	Hafen+ Sustainability report Bremenports sustainability report	Niedersachsen ports Bremenports	(Niedersachsen port, 2017) (Bremenports, 2018)

Table 4. 3 List of Documents Analyzed

4.3.1.2 Semi-structured Interviews

As mentioned before, the interviewees included stakeholders that are involved in planning the ports strategies towards sustainability and energy transition. These have been identified through port websites and have been contacted in advance of the actual interviews in April 2021 by email. In case of non-responding selected interviewees, follow-up emails or phone calls have been made. However, some ports declined to be interviewed (port of Brunsbüttel). The held interviews are shown in the next table.

At the beginning of each interview, questions about data anonymization and data recording have been asked to make sure that data was processed in a correct way.

Interviewee	Function	Organization	Method	Date	Referred to as:
Dr. Matthäus Wuczkowski	Sustainability manager	Niedersachsen Ports	Google meets	12/05/2021	P1
Prof.Dr. Iven Krämmer	Head of port economy, infrastructure, and shipping	Bremenports	Google meets	14/05/2021	P2
Erik Bertholet	Business Manager	Groningen seaports	Google meets	10/06/2021	P3
Ingrid Klinger, **Miralda Van Schot**	Project Manager Project manager	New Energy Coalition	Google meets	29/04/2021	P4, P5
Hans-Ulrich Rosner	Director	World wide fund	Google meets	28/04/2021	P6
Arjen Bosch	Advisory board secretary	Waddenzeehaven	Google meets	14/06/2021	P7

Table 4. 4 The list of interviewees

4.3.2 Data analysis

The interviews were systematically ordered using coding. Coding is assigning certain labels to opinions, responses and suggestions and citations that are relevant for answering the research question and is a way of evaluating and organizing data to understand meanings in a text. The result is the identification and analysis of categories and patterns within and across transcripts. The coding strategy mainly relied on deductive which means that the codes were derived from the theoretical framework. A few codes were inductive, which means that they emerged during the research. Coding categories are listed in Appendix II.

To operationalize the results of the interviews, a SWOT-analysis will be carried out and the responses of the interviewees are categorized as strengths, weakness, opportunities and threats. SWOT-analysis is a strategic planning and analytical tool that is used to evaluate internal and external factors that highlight the strength of a situation or an issue, minimize its weakness, capitalize on its current and future opportunities as well as identifying possible threats.

4.4 Ethics

Ethics are crucial when collecting data and especially when conducting interviews as the information provided by the interviewees is subject to confidentiality arrangement. The interviewees were informed that the data they provide will be treated anonymously and in compliance with the data protection regulations. The interviewees were assured that the information they provide is solely used for the purpose of the research and they will be informed in advance if sections of their data will be quoted in this study. Additionally, a catalogue of the interview questions was shared in advance with the interviewees to specify the scope of the research and enhance the preparedness of the interviewees to provide relevant responses to the questions. The permission to record the interview was requested from the interviewees prior to start of the interviews (all the interviewees accepted recording the interview sessions). The recording was only done for the purpose of transcription and analysis of the responses from the interviewees. The interviewees were informed that they can have access to the transcription of the interview if they demand

5 Results

In this chapter, the results of the document analysis and the semi-structured interviews are presented. Each section is devoted to one of the five sub-questions outlined in Section 1.1. In these sections, the collected data will be presented and analyzed based on the document analysis and the semi-structured interviews. The statements from the interviewees are written in a green font. The fifth sub-question will apply an extensive SWOT analysis on the opportunities and challenges for case ports in the development of a hydrogen economy in the Wadden sea region.

5.1 Sub-question- 1

What are the current developments and planned transformation linked to hydrogen economy developments in the Dutch and German parts of the North Sea?

By applying the transition management framework by Loorbach, (2010) discussed in section 3.2.3, the hydrogen strategies and their timeline of targets provides strategic visions and pathways that guide the transition arena which consists of actors from the various domains in the port governance, functions and characteristic. To find out the current and planned transformation linked to hydrogen economy development in the Dutch and German parts of the North Sea, a document analysis was conducted on the national hydrogen strategy publications of the Netherland and Germany. These documents are presented in section 4.3.1.1

To begin with the Dutch hydrogen strategy, the 2019 Dutch climate agreement publication was analyzed. The findings of this analysis are that, through this agreement a policy agenda was introduced that set the initial targets for the Dutch national hydrogen strategy which are 500 MW of electrolysis capacity by 2025 and 3- 4 GW by 2030. Additionally, pilot projects that enable the use of hydrogen across all the core sectors (electricity, built environment, ports and industry clusters, mobility and agriculture) are part and parcel of these initial targets (ibid). The policy agenda has four pillars: (i) legislation and regulation, (ii) cost reduction and scaling up of green hydrogen, (iii) sustainability of final consumption, (iv) supporting and flanking policy" (The government of the Netherlands, 2019 p 2).

The aim of the policy agenda is to facilitate the production and consumption of hydrogen at a large scale while reducing costs and supporting necessary innovation in the pilot projects (TKI New Gas, 2020).

Following these developments, the Ministry of Economic Affairs and Climate Policy published a national clean hydrogen strategy in 2020 that aims to set up both blue and green hydrogen production and supply chains through a programmatic and adaptive approach (Ministry of Economic Affairs and Climate Policy The Netherlands, 2020). Blue hydrogen is planned to be predominantly used in the short-term and will be instrumental in reaching the 2030 target while green hydrogen is planned to be effectively used from 2030 till 2050 and beyond (ibid).

Since hydrogen technologies and developments spans numerous sector innovations and value chains, the programmatic approach draws a "Multi-year Mission-driven Innovation Programmes" (MMIPs) for the core sectors to coordinate effectively and efficiently in developing green hydrogen-based technologies and functions (Gigler *et al.*, 2020; Ministry of Economic Affairs and Climate Policy the Netherlands, 2020). The Programmatic approach is a long-term strategic arrangement of individual yet interlinked hydrogen projects that aims for a large-scale impact on the national hydrogen targets

Secondly, publication of the German federal ministry of economic affairs and energy [*Nationale Wasserstoff-Strategie-Schlüsselement der Energiewende*] was analyzed and the findings indicate that the German government's hydrogen strategy is closely incorporated with the EU's vision of hydrogen being the backbone of the future energy system. Therefore, Hydrogen in the German strategy is "**positioned as the central component for the decarbonization process in the energiewende**" (BMWI, 2019 p 1).

The government sees hydrogen produced from renewable energy sources as the only sustainable alternative and therefore, aims to ramp-up the market to meet the entire value chain (BMWI, 2020). The entire value chain such as the technologies, production, storage, usage and distribution of hydrogen need to have a net-zero carbon emission impact in the long-term (from 2030 and beyond). However, in the short-term (from 2020 till 2030), hydrogen produced from fossil-fuels and other synthetic fuels in which the CO_2 is captured and stored or utilized in an emission neutral way is to have a crucial role as bridging technology (ibid). Among the goals and ambitions of the strategy are:

- to increase the domestic onshore and offshore renewable energy production capacities and to establish networks for the importation of renewable energy sources,

- to make hydrogen competitive alternative energy carrier for industries, transport, and heating sector by pushing for reductions in hydrogen production and distribution costs through subsidies, tax breaks and funding for hydrogen related investments,
- to develop a domestic market for the production and usage of the hydrogen so as to accelerate the energy transition and to meet the energy demands of 90 -110 TWh of hydrogen by 2030,
- to enhance the existing infrastructure to incorporate networks for the distribution hydrogen and to establish new hydrogen infrastructure,
- to establish international hydrogen networks, markets and cooperation as imports and exports of hydrogen will be important in both the short-and-long-term

Thirdly, the similarity between the national hydrogen strategies of Germany and the Netherlands is that they both aim for accelerating offshore wind farm developments in the North Sea as well as setting up hydrogen economy at the Wadden sea region. Wadden sea region consists of the Southern Denmark province, northern Netherland's provinces of Groningen, Friesland and the northern German states of Bremen, Hamburg, Mecklenburg-Western Pomerania, Lower Saxony and Schleswig-Holstein. All the three regions have also developed their own regional hydrogen strategies that reflect the national hydrogen strategies of their respective countries. This thesis focusses only on the Dutch and German parts of the Wadden sea region and furthermore zooms in to the Dutch ports located in Groningen province, the German ports located in the state of Bremen and Lower Saxony.

The document analysis also involved the hydrogen strategies of the northern Netherlands and the Northern German states. Both sides of the region have developed ambitious hydrogen strategy (BMVI, 2019; Cleijne *et al.*, 2020) and "**are regarded as the leading hydrogen valley in Europe due to their access to assets that are prerequisites for the development of comprehensive green hydrogen economy in their respective countries**" (Netherlands, 2020). Through cross-referencing the reports of (BMVI, 2019; Gasunie and TenneT, 2019; BMWI, 2020; Cleijne *et al.*, 2020; TKI New Gas, 2020); The following assets are found similar between the two sides and include:

1. Proximity and access to offshore (wind) renewable energy from the North Sea,
2. They have a common dense gas infrastructure that can be retrofitted to transmit hydrogen, they share the same electricity grid operator and manager (TenneT) and natural gas operator (Gasunie)
3. Large-scale industrial demand of hydrogen currently and has the potential for a critical mass demand for green hydrogen consumption,

4. Sea ports that function as logistical, industrial and energy hubs such as Groningen seaports, Niedersachsen ports, Bremen ports
5. High capacity for hydrogen storage in salt caverns and other large-scale storage mechanism,
6. Established expertise and experience on the handling of natural gas and (grey) hydrogen (ibid).

To capitalize on these assets, the northern Netherlands have set up a systemic approach to create an integrated hydrogen value chain. "*The systemic approach takes a holistic overview of all the national and regional hydrogen projects, hydrogen value chain (Production, transport, consumption and storage) and the end users in industry, transport, power and building (ibid). The hydrogen strategies of the wadden sea regions not only targets the domestic market but also the enormous industrial hub of Northwestern Europe which includes Benelux, Western Germany and Northern France*" (Ministry of Energy, 2020)

To remain the pioneers in the development of a hydrogen economy in the region (BMVI, 2019) and leading European hydrogen ecosystem in the long-term, the wadden sea region needs to supply of 25% of Northwestern Europe hydrogen demand which translated to green hydrogen production capacity of 100 PJ per annum with 4-6 GW dedicated offshore renewable electricity generation by 2030 (Cleijne *et al.*, 2020; TKI New Gas, 2020).Furthermore, the region plans to exploit these assets and be a pioneer in setting up a hydrogen economy in which their strategic ports are set to become the European roundabout for European-produced and imported green hydrogen (BMVI, 2019; Ministry of Energy, 2020).
To realize these ambitions, both sides of the region have set up a timeline of targets consisting of two phases, phase 1 from 2020 till 2025 and phase 2 from 2025 till 2030 which are summarized in the table below (BMVI, 2019; Gasunie and TenneT, 2019; BMWI, 2020; Cleijne *et al.*, 2020; TKI New Gas, 2020).
:

Table 5. 1 The current development and planned transformation linked to hydrogen economy developments of the Netherlands and Germany and their timelines

Country	Phase 1: 2020 - 2025	Phase 2: 2025- 2030
Northern Netherland targets	- more than 35 projects across the hydrogen value chain are planned that include hydrogen production, storage and distribution infrastructure and demand in end users - 5 to 10 PJ of hydrogen capacity per annum with 2GW of renewable power capacity. - Pipeline network of 169km from Eemshaven – Delfzijl - Emmen and 0.5 PJ storage capacity in salt caverns - Enable sea ports to develop into local hydrogen hubs, import and export of hydrogen and its derivatives - Additionally, the private investments are enhanced through the creation of business cases in these pilot projects while the government's financial commitment and easing regulatory frameworks are needed for timely execution.	- growth to 100PJ/year capacity of which 75 % will be green hydrogen and 25% Blue hydrogen - realize 10 GW of additional dedicated offshore wind. - Investment of EUR 9 billion in cross-border connection of gas infrastructure to spike supply capacity to 400 PJ per annum demand from Northwestern Europe. - Connect 3-4 large scale hydrogen storage caverns - Additionally, public and private investments to bridge investment gaps for accelerating offshore wind development and supporting regulatory frameworks for cross-border energy integration.

Northern German targets	- 500 MW of electrolysis capacity - Setting up hydrogen hubs: convergence of hydrogen provision (production, storage, transportation), critical mass industrial demand and logistics of supply and importation of hydrogen - Convert all state-owned fleet of vehicle and buses to be hydrogen fueled - Enhance sea ports to facilitate imports and export of green hydrogen and hydrogen equipment and facilities in the future. -	- 5- 15 GW of electrolysis capacity - Meet all the suitable conditions for setting up the hydrogen economy - Optimize all the regulatory frameworks and remove the political and financial barriers to hydrogen - Enhance social acceptance through creation of awareness and its relevance on mitigating climate change - Integrating knowledge and education on hydrogen in the academic curriculum

Table 5. 1 The current development and planned transformation linked to hydrogen economy of the Netherlands and Germany and their timelines.

5.2 Sub-question 3

How can these ports facilitate the connection of the hydrogen energy produced in the North Sea to the existing coastal energy infrastructure? How are these developments linked to the ports of the respective countries?

The theoretical framework in section 3.2.2 highlighted the scope for ports to facilitate sustainable energy transitions is highly linked to the functions of the ports. Furthermore, as discussed above in (section 5.1) Germany and the Netherlands hydrogen strategies have explicit offshore wind energy targets to be achieved by 2030 and by 2050. To meet these targets the ports located along the Wadden sea region have proximity advantage to provide their services and can facilitate the rapid deployment of wind turbines to the North Sea offshore wind zones, reception of the energy and integrating the offshore wind energy in port energy consumption mix as well as distribution to the hinterland.

5.2.1 Facilitate offshore wind farms deployment

Depending on the function of the ports, they can be either industrial sites for construction and assemblage of wind turbines or service points for operation and maintenance of turbines. 'Depending on their function, their approaches could be different from each other. If you have got a pure offshore harbor, its approach will be different from the container harbor or the logistic oriented harbor" (P4).
Their proximity to the North Sea offshore wind zones has attracted the wind industry related companies to lease land in port areas for the transshipment and assemblage of the wind turbines. These ports also have the capacity to handle high load (< 400 tonnes), large-scale storage and maneuvering areas which are suitable for the wind construction and assemblages of the turbine components. Furthermore, as logistical hubs, and they add value in providing their expertise and their import and export global networks are essential for outsourcing the wind turbine components (P1; P2; P3).
As service points they act as response ports, to the calls for operational maintenance of wind farms in which they provide operating materials and small-scale components when the installed wind farms need immediate or incidental repair. Secondly, they are supply ports of small- or large-scale tools, instruments and operating equipment for wind farms ports. Thirdly, they provide testing, training and research and development for manufactures, knowledge institutes and governments for the safety and efficiency of the wind farms (P3; P2). Finally, they are contracted also to be handling the dismantling of the wind turbines at the later stages of the decommissioning of the turbines (P2; P3).

5.2.2 Industrial hub with a hydrogen demand

The case ports also serve as industrial hubs in which numerous industries converge at these ports to benefit from the swift importation of raw materials or exportation of finished products (P1; P2; P3). The industries located around these ports have a significant impact on the national and regional markets, for example "the industrial clusters in the port of Delfzijl produces around 18% of the chemical products needed in the Netherlands "(P3). The interviewee from Bremen ports also add on, "we have a steel plant as well, which means iron ore is coming into the port of Bremen. And we have lots of what we call general cargo activities of pipes, forestry products, pulp and paper and so" (P2). Hydrogen as versatile energy carrier is envisioned as a crucial element in decarbonizing heavy industrial sector present at the case ports "we think about our position as a port and as an industrial area, because that's an advantage. Thus, both not only the ports but also the industrial cluster have to go from fossil fuel to green hydrogen for instance, or blue hydrogen. Is it really a chance, so we are adapting the port in order to be able to contribute to this proposition" (P3)? Therefore, the industries located at the ports create the demand for the green/ blue hydrogen that is paramount for the development of a hydrogen economy in the region. The interviewee from Niedersachsen add on "we have the big synergy to offshore and onshore parks. So, they're all here, we have storage capacities. And the soil basically caverns in our area where potentially hydrogen can be stored. We have all the green energy around us, we have all different applications that can use basically, green power. And I think this is the opportunities that we have in general, so we have very good opportunities for energy transition" (P1)

5.2.3 Integrate Hydrogen in coastal energy infrastructure

The case ports are also vital nodes in the North Sea energy infrastructure, and they can also therefore serve as hydrogen hubs. They are receiving points for electric cables, natural gas pipelines from the North Sea as well as energy import terminals, "we are also nationally one of the main entry point distribution and transshipment locations for natural gas, crude oil, coal, chemical and petroleum and also in Europe" (P1). Besides having fossil-fuel powered plants in ports area, the case ports such Groningen Sea ports are receiving points of offshore wind energy "8000 megawatts coming into the port, A third of the total consumption of the Netherlands. So that's energy" (P3). The case ports clearly qualify to be hydrogen hubs as envisioned "the need for a hydrogen hub as a starting point for hydrogen economy planning provides for hydrogen hubs to serve as starting points for establishing a hydrogen economy in North Germany. These provide for the generation, distribution and use of hydrogen to be pooled (geographically), e.g. for the areas of mobility and industry. Regional basic supply of green hydrogen is therefore realized gradually, and this can be extended across the entire region in the medium-term" (BMVI, 2019 page 1). The case ports all have hydrogen related projects, from renewable onshore power, converting electricity to green hydrogen, experimenting on hydrogen application in port related activities, equipment, co-located industries as well as in ships and ferries run by the ports (P1; P2; P3). They also anticipate in the future, importation of hydrogen will be necessary therefore they are setting up the networks and facilities for the importation of energy from international sources as well as the energy infrastructure and storage capacity across multiple energy carriers such as electricity (cables), electrolyzer etc. (P1; P2; P3). These multiple energy carriers can be converted or conditioned and stored on the ports areas or distributed to the hinterland.

5.3 Sub-question 4

Who are the stakeholders in the governance of these ports?

Section 3.2.1 elaborated on the evolution of the ports and provided a general European port governance structure. According to ESPO report by Verhoeven (2011) more than 70 percent of European ports are owned by the state or municipality. In Germany, the Netherlands, 80 percent of the ports are owned by municipalities. Although many ports are mostly owned by municipalities, the governing approaches might differ. In this section the focus lies only on the identification of the stakeholders of the case ports and how they are structured while the governing approaches will be discussion in chapter 6.

In the Netherlands, the national government sees port services are more flexible and efficient if the port operations are operated by the market, which made the national government step out of port operations (Steenderen and Steenderen 2019). For large and medium-sized ports, the landlord model is often used. This makes a port authority a separate legal entity which can conclude contracts and enforce standards (ibid). Within this authority, the port master is the key. The interviewee from Groningen seaports indicated that "in Holland you have privatized ports, but our shareholders are governmental bodies. Groningen seaports the main shareholder is the province of Groningen, and the other shareholders are the municipalities where the ports are located, as we have two ports, Delfzijl it's the municipality of Ames Delta and Eemshaven It's called Hoch land. So those are the shareholders of the Groningen seaports. And we work by reporting to the advisory board which consists of companies so that's not political. So privately run, but publicly owned "(P3).

German ports are usually in the possession of public entities. The federal government of Germany and federal state governments do supply development concepts aimed at the maintenance of ports and its relevant infrastructure. They also follow the landlord model in which the all the land, infrastructure and natural assets such as the rivers and waterways are owned by the local governments while the port services, functions, operations and activities are contracted or leased to private companies.

In Lower saxony, the interviewee from Niedersachsen ports stated that "Basically we are public owned by the federal state of Lower Saxony or the federal state of Niedersachsen in German. So, we are 100% daughter company, but we organize as a limited company. So, we are privately organized but owned by the state of Niedersachsen. So, we work and act as the authority, as well, with our regulations in cooperation with other authorities, with the local authorities, of course, with the environmental authorities, Gewerbeaufsichtamt which is an authority that is focusing on emissions, on work safety, and so on" (P1).

In Bremen, the interviewee from Bremenports explained port's governance structure in detail as "Ministry of Science and Ports is the public interest and the public authority responsible for the infrastructure, the rivers themselves, the seabed, the cable, the land side within the ports, also the access roads, railways and the private companies. Some various private companies are responsible for everything in which real activities where cargo is being handled and so on. These are companies for us, for example the port management company for Bremenports which is much more on the operational level and where they are active, they have like 400 people and they are taking care of most of the things in the ports such as the roads, the railways need to be cleaned up. That's what they do. So, we could call it a housekeeper for the Port Authority to make sure that the port is running 24/7, 365 days a year, taking care of all the infrastructure is their main task. And then we have another unit, which is called the Harbormaster's office, and they are taking care of all, say, for all the shipping activities within the port area. That's their task. Then, of course, you have many, many more public units, like the customs, like the water police, like the veterinary controls, and so on. So, lots of different public units, which also for specific tasks are responsible but the main responsibility lies with the Ministry of Science reports" (P2). The Interviewee from Bremen also indicated that International, European and regional/national regulations and instruments also are part and parcel of the port governance structure," In general, it starts with the European level, European port legislation and some national legislation, which is for general things like how the labor has to be organized and so on. And then, of course, on the local level, we have our own rules and regulations in place. And of course, they have to be in line with international rules and regulations. But what we have done, for example, what you probably have found out that we have very, early decided to go straight for greening the port, getting a clear concept for emission reduction in the ports, which we call reports. And if you're also looking not just to bremensports.de, but

also, green ports you will find lots of lots of measures that we have taken over the last 10 years, for the improvement of overall ports performance in the environmental context. So that's what we have done. We've decided to do so on our own" (P2). Table 5. 3 below outlines an umbrella of various guidelines from International, European and regional/national regulations and instruments that steer the overall governance of the Port located along the wadden sea region.

Function	International	European	Regional
Logistics: **• Shipping** **&** **• Navigation**	IMO: • COLREGs • SOLAS • MARPOL	• Marine Strategy Framework Directive (MSFD)	
Energy **&** **Industry**	• Paris climate agreement	• European climate action • European green deal • Renewable energy directive RED II	
Environment	Espoo Convention • Protocol on Strategic Environmental assessment • Convention on Biological Diversity (CBD)	• Marine Strategy Framework Directive (MSFD) • Habitats and Birds Directive (Natura 2000) • SEA- and EIA-Directives	• OSPAR Convention • International conferences on the protection of the North Sea • Bonn agreement • ICZM Protocol • Trilateral Wadden sea Cooperation

Table 5. 2 multi-level governance setting of the case ports

Sub-question 5

What are the challenges and opportunities for these ports in the developments of a hydrogen economy?

The prerequisite for the development of a hydrogen economy is availability of abundant renewable electricity, interdependent industrial cluster of hydrogen users that create the critical mass demand for blue-green hydrogen economy, supplemented by a well-developed hydrogen transport infrastructure as well as supportive political and social acceptance atmosphere.
The interviewees from the selected ports were asked on the general opportunities and challenges for the ports in the development of a hydrogen economy in the Wadden sea region and the specific or unique opportunities and challenges faced by their respective ports. All the interviewees agreed their ports have similar if not same opportunities and challenges with the other case ports (P1; P2; P3) but there can be slight differences due to the different function the ports serve. To analyze their responses a SWOT-analysis was carried out and their statements are categorized as strengths, weakness, opportunities and threats. SWOT-analysis is a strategic planning and analytical tool that is used to evaluate internal and external factors that highlight the strength of a situation or an issue, minimize its weakness, capitalize on its current and future opportunities as well as identifying possible threats.

5.3.1 Strengths

The strength of the case ports identified in the development of hydrogen economy in the Wadden Sea region relate to the internal factors such as the governance of the ports, their assets and geographical proximity to the North Sea offshore wind farms that are favorable and beneficial for the ports in the development of a hydrogen economy. These act as push factors that stimulate the port authorities in being front runners in the energy transition and in enhancing the development of a hydrogen economy in the wadden sea region.
The strengths of case ports can be seen as push factors that drives the advancement of the energy transition from the current take-off phase to the acceleration phase in the energy transition phases as well as advancing the hydrogen economy from the pre-development phase to take-off phase

The interviewee from Niedersachsen ports acknowledges all the assets that puts them at an advantageous position in the development of a hydrogen economy, "We are at the coast; we have the big synergy to offshore and onshore parks. So,

they're all here, we have storage capacities. And the soil caverns in our area where potentially hydrogen can be stored. We have all the green energy around us, we have all different applications that can use green power basically". (P1).
Furthermore, the interviewee from Bremen identifies infrastructure as their main strength which is crucial for hydrogen importation and distribution to hinterland, "We have, let's say very good infrastructure, which means the accessibility of the ports, from the seaside, the land-based transport and let's say maybe railways or motorways. So that's where we are investing a lot. That's where we already have a very good competitive position. And we are of course trying to improve this competitive position and all these different various aspects" (P2).
All the case ports have a shared perspective on hydrogen being one of the main energy carriers in the future port energy mix next to electricity (P1; P2; P3). This shared perspective stimulates the confidence of both public and private sector in investments in hydrogen projects in the ports. There is also willingness from both the private companies and public authorities that form the governance structures of the ports in facilitation of hydrogen application in their ports (P1; P2; P3).

5.3.2 Weaknesses

The weaknesses of the case ports identified regarding the development of hydrogen economy in the Wadden sea region relate to the internal factors arising from the inability of the ports to adjust to the speed of the energy transition due to dilemmas stemming from the governance of the ports' financial and regulator frameworks and policies that are harmful or weaken the position the ports in the of development of a hydrogen economy in the region. The interviewee from Bremen clarifies the governance dilemma "The plans are wonderful, beautiful plans, lots of things. But like in most ports and especially hydrogen is related to lots of investments at the same time. And it's not totally clear yet if all these investments will be feasible. And that's why it's a tricky situation for the time being. We know that the energy demand or the hydrogen demand will be growing. And then we have this classical problem with the chicken-egg dilemma. So who is going to take the first decision? Who is going to take the first investments? "(P2).
Another challenge shared by the case ports is regulatory frameworks stemming from the public stakeholders in the governance of the ports that are slowing down the expansion of renewable energies, this is elaborated by the interview from Groningen seaports, "And the other limitation is of course that all the investments in the port the life cycle to realize is let's say five years and the energy transition is going so fast that the port cannot adapt and not only in Eemshaven, but all ports cannot adapt to the great challenges in getting more and more gigawatts. They wish to make a fast transition, but governmental incentives and regulations

therefore are not the fastest to happen. So, the ambition is here. But you are not capable in even managing this transition" (P3). The interviewee from also adds to this "in a very fast changing environment, we should also be faster than we are right now, so the rules and regulations that we gave ourselves let's say are not Laws by nature or by physics. So we gave ourselves the laws but still these are hindering a little bit in the fast development and fast changes for the time being" (P2).

These weaknesses contribute to the governance challenge and can be seen as the limiting factors that restrict progression of hydrogen economy from pre-development phase to take-off phase in the transition phases.

5.3.3 Opportunities

The opportunities for the ports are related to external factors such as the wider context energy transition in the national and regional ambitions that offer favorable and beneficial incentives for the ports to enhance and facilitate the energy transition in port activities and operation, in the maritime sector, conduct experiments and innovative research for hydrogen energy applications and to attract "green" industries to port areas.

The interviewee from Groningen seaports elaborates on the energy transition in industries co-located at the ports areas, "we think about our position as a port and as an industrial area, because that's an advantage. Thus, both not only the ports but also the industrial cluster have to go from fossil fuel to green hydrogen for instance, or blue hydrogen. Is it really a chance, so we are adapting the port in order to be able to contribute to this proposition, and also team up of course with companies who can make that happen because the port we are only a facilitator" (P3).

Furthermore, the interviewee from Niedersachsen highlights the need for ports to facilitate the energy transition as their business depends on it, "The opportunity basically is to get carbon emissions down, this is what we are focusing on in general, but basically, we can make our ports more attractive for the industry when they have access to green energy carriers. For example, in the past the industry always followed fossil energy fuels. But in the future, the industry *will* follow green energy. So, if we will have a green energy hub, we can make sure that the industry basically will locate in our port areas. And we will have then basically turnover of energy carriers locally, we will have carbon friendly industries locally and everyone is looking in the future for green power for green hydrogen, and this is where they locate the future. So if we miss this transition we will lose our business" (P1).

The interviewee from Bremen adds on how the ports are also facilitating energy transition and climate neutrality in the maritime sector, "we are going to give rebates to ships which are cleaner. So cleaner means let's say producing less emissions and so on. And that's what we already did a couple of years ago. And for our own fleet, we also have a small fleet which is. some dredging boats and harbor working boats. Of course, if we are let's say investing into new and new activities there, then of course we are building let's say electrical work loads or we have implemented an LNG dredging boat and so on" (P2).

These opportunities act as pull factors that encourage the stakeholders of the ports to facilitate the energy transition as well as the in the development of a hydrogen economy. These pull factors can contribute to the advancement of the energy transition from the current take-off phase to the acceleration phase in the energy transition phases as well as advancing the hydrogen economy from the pre-development phase to take-off phase.

5.3.4 Threats

The threats are external factors such uncertainties regarding whether hydrogen will be the main energy carrier, the cost of hydrogen and the wider environmental context that can be unfavorable or a limitation for the ports in facilitating the development of the hydrogen economy in the Wadden sea. Regarding the uncertainties related to hydrogen economy, the interviewee from Bremen states that, "But we don't exactly know if hydrogen is really the solution is also for, let's say, for international shipping. Most people say, no, hydrogen will not be the solution. It might be ammonia; it might be methane. So different solutions are on the table. No one exactly knows which one will be or, let's say, the number one priority. And that makes it a little bit tricky for all of us in the ports" (P2).

The cost of hydrogen is very high currently and all the interviewees indicated that it is the main threat that is limiting hydrogen production and applications to take-off (P1; P2; P3). The interviewee from Niedersachsen suggests that introducing a cost on carbon emission can make renewable energy competitive "Because now when you compare renewables with fossils, the framework makes the fossils or punishes the renewables, for example. They will lose when you compare them because the framework is not the right framework. So, we need to work on the framework to make renewables more attractive, even if you compare them by costs. So we need to have a cost on carbon emissions" (P1). While the interviewee from Groningen adds "hydrogen is 5 times as expensive as electricity. Yeah, also nowadays I think it's four times as expensive. But it's decreasing, but there's still a long way to go. So you users are not able, you can have a green

ambition and a green attitude, but if it's cost you three times as much, you will never change it "(P3).
Finally, since the ports are located near a world heritage site; the Wadden sea, they are limited to expand towards the sea to accommodate offshore wind industry and other developments linked to hydrogen economy such as construction of cables and pipelines across the Wadden sea, "We are at the edge of world heritance called Wadden sea so we are not allowed to make water related new areas, so we cannot expand. Let's say the wet side of the port. And, Wadden sea is not only in Holland but also in Germany. It ends at Esbjerg our colleague port in Denmark there ends the Wadden sea, so they are able to expand their port also with new docks and new territories and we are not allowed yet. So that's the limitation" (P3).
These threats also contribute the governance challenges and environmental concerns that can be seen as the limiting factors that restrict progression of hydrogen economy from pre-development phase to take-off phase in the transition phases.

	SWOT Analysis	
	Favorable for ports	**Unfavorable for ports**
	Strenghts	**Weaknesses**
Internal Factors	➻ Proximity to offshore wind firms and Capacity to produce renewable energy onshore. ➻ Availability of necessary infrastructure for the importation and distribution of hydrogen ➻ Presence of industrial cluster near ports areas that can create the demand for hydrogen. ➻ Shared perspective on key role of hydrogen in future port energy mix. ➻ Willingness of stakeholders in facilihwtation of hydrogen application in their ports. ➻ Willingness of public authorities to facilitate legislative space for exploration with Hydrogen	➻ Inability of the ports to adjust to the speed of the energy transition ➻ Slow decision-making process ➻ Chicken-egg dilemma associated with the demand and investment on hydrogen ➻ Regulatory frameworks that are slowing down the expansion of renewable energies ➻ Lack of cross-border cooperation between the ports
	Opportunities	**Threats**
External Factors	➻ There is high level of awareness and a shared sense of urgency on the need for an energy transition among the stakeholders ➻ Facilitate the energy transition in port activities and operation ➻ Facilitate the greening of the maritime sector ➻ The potential for sector coupling and attract "green" and hydrogen related industries to port areas ➻ Funds for hydrogen pilot projects and initiatives ➻ Experiments and innovation on hydrogen production and applications that can make the ports pioneers in hydrogen economy	➻ Uncertainties regarding whether hydrogen will be the main energy carrier. ➻ Lack of social acceptance on the expansion of onshore renewable expansion. ➻ Proximity to a world heritage site that limits the potential for ports to expand port areas ➻ The cost of hydrogen that is limiting hydrogen production and applications to take-off.

Table 5. 3 SWOT Analysis

6 Discussion

This section formulates an answer to sub-question 6. The answers formulated for this question are derived from the discussion with the expert interviewees and the interviewees from the case ports. The discussion question is formulated as follows:

In which ways can these ports deal with the potential environmental risks associated with the energy transition and hydrogen economy developments to the Wadden Sea region?

6.1 Scope for ports to facilitate system changes

The case ports, their co-located industries and the maritime vessels that call at the ports are heavily dependent on fossil fuel consumption. There is a mounting pressure from international, European and national levels (landscape level) to transform the energy sector from fossil-based to renewable energy based before 2050. The stakeholders of the governance of the case ports who are considered to be at the regime-level have a shared perspective to transform their ports to be climate neutral. The interviewee from Bremen Ports adds to this that "the only thing we absolutely agree is, that we have to prove ourselves to be climate neutral in a couple of years. That's what we are working on very, very hard and with lots of small and big measures and initiatives" (P2).

Zooming in to the case ports, the scope of the case ports to enable system change is linked to the functions of the ports. They consider themselves as facilitators of the energy transition locally, regionally and nationally as well (P1; P2; P3). The landlord function is the principal governance tool at their disposal to enhance and facilitate the energy transition as they lease land, facilities and basic infrastructure to fIrms and companies. The landlord function is subject to competitive pressure to invest in infrastructure, competition in land-use and financial pressure to ensure feasibility of these investment (Verhoeven & Vanoutrive, 2012) . These pressures are confirmed by the interviewee from Niedersachsen ports

"We make our ports more attractive for the industry when they have access to green energy carriers. So, if we will have a green energy hub, we can make sure that the industry basically will locate in our port areas. We will have then basically turnover of energy carriers locally, we will have carbon carbon friendly industries locally, and everyone is looking in the future for green power, for green hydrogen,

and this is where they will locate the future. So if we miss this transition we will lose our business" (P1). These pressures have drawn ports in a stiff competition to be front runners in the energy transition whereby they aim to attract wind farm industry and other "green" industries to lease land in port areas, setting up reception point for offshore wind power and import terminals for alternative energies such as LNG and hydrogen. All the case ports have also teamed up with public and private investors, knowledge institutes and industrial farms in setting up a hydrogen hub at their respective ports. The stiff competition, among the ports on numerous socio-economic activities exerts immense pressure on the pristine and fragile wadden sea ecosystem. The projects undertaken by the ports such as the hydrogen projects or offshore wind farm installations are uncoordinated between the ports and the interviewees from New Energy Coalition underscores the need for coordination to reduce fragmentation of measures taken by the case ports that can potentially harm the Wadden sea, "Every port has hydrogen project and wants to be the hydrogen hub not knowing what the other ports are doing. So I think that's a little bit weird. It's an uncoordinated development. And when it's coordinated only on national base" (P4),
"I think the challenge will be to coordinate all these activities because we have quite some limited space and we should prevent harm to the Wadden sea" (P5). Therefore, there is the need for coordination between the port activities to mitigate risks discussed in section 3.1 and 3.2.

Zooming out into the context of the Wadden sea area, the current North Sea offshore wind energy governance and planning process is top-down and sectoral approach in nature where the space allocation, planning, implementation and decision-making processes are centrally coordinated from the national governments and there is limited role played by the local and regional governments. The focus of this kind of spatial and energy planning is; where and how ***fast*** can we get to the maximum amount of ***gigawatts*** at the ***lowest economic cost*** as elaborated by the interviewee from Groningen seaports "the energy transition is going so fast that the ports cannot adapt and not only in Eemshaven, but all ports cannot adapt to the great challenges in getting more and more gigawatts" (P3). This top-down and sectoral planning of the energy transition has less focus on the context and local conditions in which major changes in space is happening as the Wind farms, and their associated cabling or pipeline (for hydrogen) infrastructures make fundamental changes to land and seascape. Furthermore, the aim to accelerate the deployment of offshore wind farms in an isolated and stand-alone project leads to difficulties in implementation as there is weak linkages with the local context. The interviewee

from Niedersachsen ports highlights the challenge and difficulties in the rapid development of offshore wind energy as well integration of offshore energy into the coastal energy infrastructure,
"We need far more of this raw material, the raw material is Green Power, and this is the challenge basically, as there are always different interests and wants; one party basically wants to go into the expansion of renewable energies while others see conflicts with nature conservation, as nature conservation have their own focus. The next challenge is basically to the people that are living around here, they don't want to live in a wind Park, you know, the space is limited, and this is quite challenging" (P1).
Therefore, there is a need for an area-based planning approach in which the energy system is integrated in the physical and socio-economic landscape. The interviewee from Groningen seaports highlights the challenges linked to offshore wind farms deployments and elaborates on the complexity of the energy transition as complex web of interrelated actors and networks each with their own interests and access to resources and power, "So, the ambition is here. But you are not capable in even managing this transition, and because if you say, yeah, we will have more offshore wind farms, you also have to talk let's say to fishery and to environmental issues and to a defense area, so there you can address it, but you also have to be able to do that" (P3).

An integrated coastal planning approach highlights the consideration of a geographic area in which activities are carried out, and accounting for different factors which may influence, where when and how you undertake those activities. This calls for decentralized governance of the energy transition in which energy transition can be vehicle for positive local and regional changes which can facilitate local support and ease to reach the "***gigawatts"*** needed. The interactive dialogue between the energy transition and the local conditions is fundamental to ensure that society can accept and endorse these physical and socio-economic changes to the land-and-sea scape bearing in mind the various actors, their interests and environmental impacts as well. The interviewee from Niedersachsen ports emphasize dialogue between all the actors as the way forward," I think dialogue is the best thing for conflict of interests, otherwise you can't solve. We need the energy transition, no doubt. On the other side we lose ecosystems, they create ecosystem services such as clean air, soil and this is an added value we should consider therefore everything needs their space basically" (P1).
To stimulate inter-regional dialogue that also includes other relevant stakeholders from public and environmental initiatives, the Interviewee from New Energy Coalitions suggests that having a common hydrogen project between all

Wadden sea ports will stimulate cross-border cooperation and reduce fragmentation, ""I think it's a very important to have this cross-border cooperation because if you want to make the rules for only on a national level and make all activities on national level, you will not come further. I think it would be very good to have a common port or hydrogen strategy because, then they would be stimulated to talk more to each other because I know that Groningen seaport is not talking to the German harbors or ports or very less for example with Cuxhaven and I think not even to Esbjerg. So we are discussing in the Wadden sea forum with Esbjerg as well. And they have got their own activities and if we need so much hydrogen in the next years , it would be good of course to make plans together but now it's everybody is working for themselves" (P4).

An integrated area-based energy planning includes scanning the regional qualities for energy production, distribution and consumption and makes use of regional advantages to identify local and regional specialization (de Boer & Zuidema, 2013). The ports can complement each other in their pursuit of facilitating the development of hydrogen economy in the Wadden sea region. The case ports have their unique field of specialization and can therefore enhance the hydrogen economy advance to take-off phase if they are willing to cooperate and be complementary to each other. The interviewees from New Energy Coalition also indicate that the case ports "can be very complementarity to each other for instance, not every port has waterways that are deep enough for becoming inport terminals. Not every port has a connection to the offshore wind farms that well that it can import hydrogen via pipelines or it can transmit CO2 going offshore by ship or by pipeline" (P5).

Furthermore, on an inter-regional level, an integrated area-based approach is argued to stimulate spatial diversification (de Boer & Zuidema, 2013). Spatial diversification between the case port is necessary to stimulate cooperation, reduce competition between the ports and uncoordinated endeavors that harm the Wadden sea. The interviewees from New Energy Coalition also stress the need for spatial diversification in the case ports
"We need very different sources, we need various supply sources and a network connecting them and I think of course, they can align their plans better with the other harbors. One thing can be, what is the strong point at this moment of these individual harbors? Do they do a lot of imports? Do they have a large industrial site next nearby? Maybe they only do logistics services"

6.2 Scope for ports to enhance environmental planning

As outlined in section 3.1 the Wadden sea is sensitive area and the potential environmental risks associated with the development of the Hydrogen economy in the region are pollution from ports and maritime vessels, increased traffic of maritime vessels engaged in the deployment of wind farms, continuous dredging and widening of the rivers, channels and estuaries to facilitate the passage of vessels, and the expansion of port areas to accommodate wind industry (P1; P6). The current Wadden sea environmental planning approach is based on centralized instruments, standards and regulations set up by global, European, national and regional institutions. There is also a trilateral national cooperation between the three Wadden sea countries which aims to protect and limit socio-economic activities that are interfering with the natural processes to proceed in undisturbed way. However, the cooperation area is much restricted in a formal sense and is limited only to the Wadden sea area. The case ports are part of the Wadden sea region which includes areas which are beyond the formal cooperation areas such as the offshore areas and land areas, for example the Province of Groningen is not part of the Wadden sea area, but it is part of the Wadden sea region and there is no formal cooperation in the Wadden sea region. The interviewee from World-wide fund stresses this fact that "In the long-term there won't be a protection and well-functioning wadden sea if the energy transition is not inter-linked with what is happening in the surrounding region, we cannot protect the wadden sea in the end, if we are not looking at what happens on the land side and the offshore side and taking care of the activities linked to the ports or with wind farms on land and offshore" (P6). The lack of regional cooperation and coordination highlights the fragmentation on the approaches taken by the case ports in the facilitating environmental upgrading. The need for an area-based environmental/spatial planning approach in which renewable energies are embedded in the physical and local socio-economic landscape. Spatial integration of renewable energies in land-and-seascape requires institutional harmonization which entails the cooperation and coordination between various institutional frameworks that guide different sectors and actors to mitigate environmental risks while enabling synergies between the energy transition and environmental planning (Spijkerboer et al., 2019). There needs to be a shift from centralized governance of the environmental planning based on standards to a more decentralized governance that seeks consensus building (De Roo, 2016).

Zooming in to the case ports, the scope for ports to contribute to environmental planning is nested on the regulatory functions. The regulatory function is also subject to increasing pressure from European and national landscape-level to actively implement alternative solutions for maritime sector, reduce pollution and negative externalities and facilitate sustainable transitions. At the local and regional level, the regulatory function also doubles as a community manager function whereby the port authority not only enforces regulations and environmental standards but also brings together the networks and private stakeholders to enhance performance as well as enhancing collaboration and positive externalities for the local community. The Niedersachsen and Bremenports plan to phasing-out fossil-fueled power plants operated by the port. They are simultaneous investing in onshore renewable power generation as they phase out the coal powered plants (P1; P2).

The case ports are closely monitoring the efficient use of energy and infrastructure while they shift to sustainable renewable energy sources to mitigate pollution and negative externalities to the environment and neighbor communities. All the case ports are currently aiming for electrification of port-related operations and co-located industries (P1; P2; P3).

Finally, the case port also aims to provide alternative solution for maritime industry such as rebates and incentives for switching to sustainable fuels. The case ports are all participants of the Environmental shipping Index which is a platform that identifies cleaner ships (produce less air emission than the required standard) and rewards them by giving them discounts on the port fees (P1; P2; P3). They are also participating in environmental initiatives such as EcoPorts which aims to improve environmental management by sharing of knowledge and cooperation between ports and raising awareness on environmental protection (EcoPorts n.d).

7 Conclusion, Recommendation and Reflection

This section formulates an answer to the main research question, as all the sub-questions have been answered. The main research question was formulated as follows:

> What do the prospects of hydrogen economy and spatial developments in the North Sea linked to the energy transition mean for the governance and environmental consequences for the Dutch and German ports located along the Wadden Sea coast?

The energy transition is a cornerstone pillar in the National strategic visions of the Netherlands and Germany towards meeting the targets of Paris climate agreements and it entails a transition from the dependency on fossil fuels to renewable energy. The strategies of both countries include ramping up the production of renewable electricity from offshore wind farms in the North Sea to meet the high demand of renewable electricity and storing or converting the excess power to green hydrogen or other suitable energy carriers. The studied ports are integral in facilitating the assemblage, storage, transportation and installation of the offshore wind farms in the North Sea. These ports offer suitable locations for the development of a hydrogen hub, referring to the convergence of hydrogen provision (production, storage and distribution), critical industrial mass demand of hydrogen and the logistics of exportation and importation of hydrogen. Therefore, the prospects of hydrogen economy and spatial developments in the North Sea translate to opportunities of being front runner in the energy transition and the challenges of integrating the renewable energies in the physical and socio-economic landscape. This research focuses on what kind of governance or who are involved in the governance of the energy transition and environmental planning and how to approach these challenges and opportunities.

7.1.1 Approach

Drawing from the insights of socio-technical systems in transition theory by Van Der Brugge, Rotmans and Loorbach, (2005), ports authorities are placed at the Meso/regime level as they can facilitate or enable the upscaling of niche developments such as hydrogen as an alternative energy carrier. However, the research follows de Boer and Zuidema, (2013) critic of that niches should not be isolated from their local contexts and therefore proposes to re-frame niche development as also areas-based niche developments. Area-based planning entails embedding renewable energies in the physical and socio-economic landscape.

The results of the interviews conducted show the fragmentation of measures and approaches taken by the ports and the absence of regional and inter-regional cooperation between the case ports and these proves to be a challenge for the case ports in contributing to environmental upgrading of the Wadden sea. Spatial integration of renewable energies in physical land-and-seascape requires institutional harmonization which entails the cooperation and coordination between various institutional frameworks that guide different sectors and actors to mitigate environmental risks while enabling synergies between the energy transition and environmental planning (Spijkerboer et al., 2019). Institutional harmonization in the wadden sea region entails cross-border cooperation between institutions from different jurisdictional borders and therefore also calls for alignment of regulatory frameworks across the wadden sea region.

Area-based planning approach stimulates finding regional specialization and as the case ports have their unique field of specialization, they can therefore enhance hydrogen economy to take-off phase if they are willing to cooperate and be complementary to each other. Additionally, on an inter-regional level area-based planning approaches stimulate spatial diversification between the case port is necessary to stimulate cooperation, reduce competition between the ports and uncoordinated endeavors that harm the Wadden sea.

Considering transition management cycles by Loorbach, 2010, the port authorities strategic and the tactical activities are crucial in operationalizing the long-term hydrogen visions and strategies of their respective nations into short-term plans, projects and scenarios. Embedding these projects and plans in the Wadden sea region context requires regional specialization and spatial diversification therefore there is the need for:

- Coordination of activities and measures between the ports to enhance complementarity between the ports,
- Common programs and agenda setting to align the different ports interests, plans and minimize diverging and conflicting interest that put pressure on the wadden sea,
- Cross-border cooperation between the ports to facilitate sharing of information, exchanging knowledge and abatement of environmental risks,
- Working together with nature protection organizations and initiatives.

7.1.2 Governance

Zooming in to the port governance itself, following the report of the Verhoeven & Vanoutrive, (2012) the scope for port to enable system change is linked to the functions of the ports: landlords, regulator, operators and community managers. The landlord function doubles as operator function also and is the principal governance tool at their disposal to enhance and facilitate the energy transition as they lease land, facilities and basic infrastructure to farms and companies. As landlords the case ports want to be front runners in the energy transition whereby, they aim to attract wind farms industry and other "green" industries to lease land in port areas, setting up reception point for offshore wind power and import terminals for alternative energies such as LNG and hydrogen.

The regulatory function also doubles as a community manager function whereby the port authority not only enforces regulations and environmental standards but also brings together the networks and private stakeholders to enhance performance as well as enhancing collaboration and positive externalities for the local community. As regulators, the case ports are phasing-out coal fired power plants located at the ports while simultaneously investing in onshore renewable energy. They are also taking measures to reduce carbon emission at ports by electrification of port-related operations and co-located industries. They are also providing alternative solution for maritime industry such as rebates and incentives for switching to sustainable fuels.

Zooming out into the context of the Wadden sea, the North Sea offshore wind energy governance and planning process is top-down and sectoral approach in nature whereby the planning, implementation and decision-making processes are centrally coordinated from the national governments and there is limited role played by the local and regional governments. Spatial integration of renewable energies requires local(municipalities) and regional (provinces and *Bundesländer*) actors such as port authorities to have a crucial role in delivering public policies that can unlock the potential for area-based planning.

7.2 Recommendations

The recommendation provided below augment a planning-oriented action from command control planning to a shared governance, in which a hybrid governance that is made up of both top-down centralized governance and bottom-up decentralized is necessary to navigate the governance challenges posed by the energy transition and environmental planning.

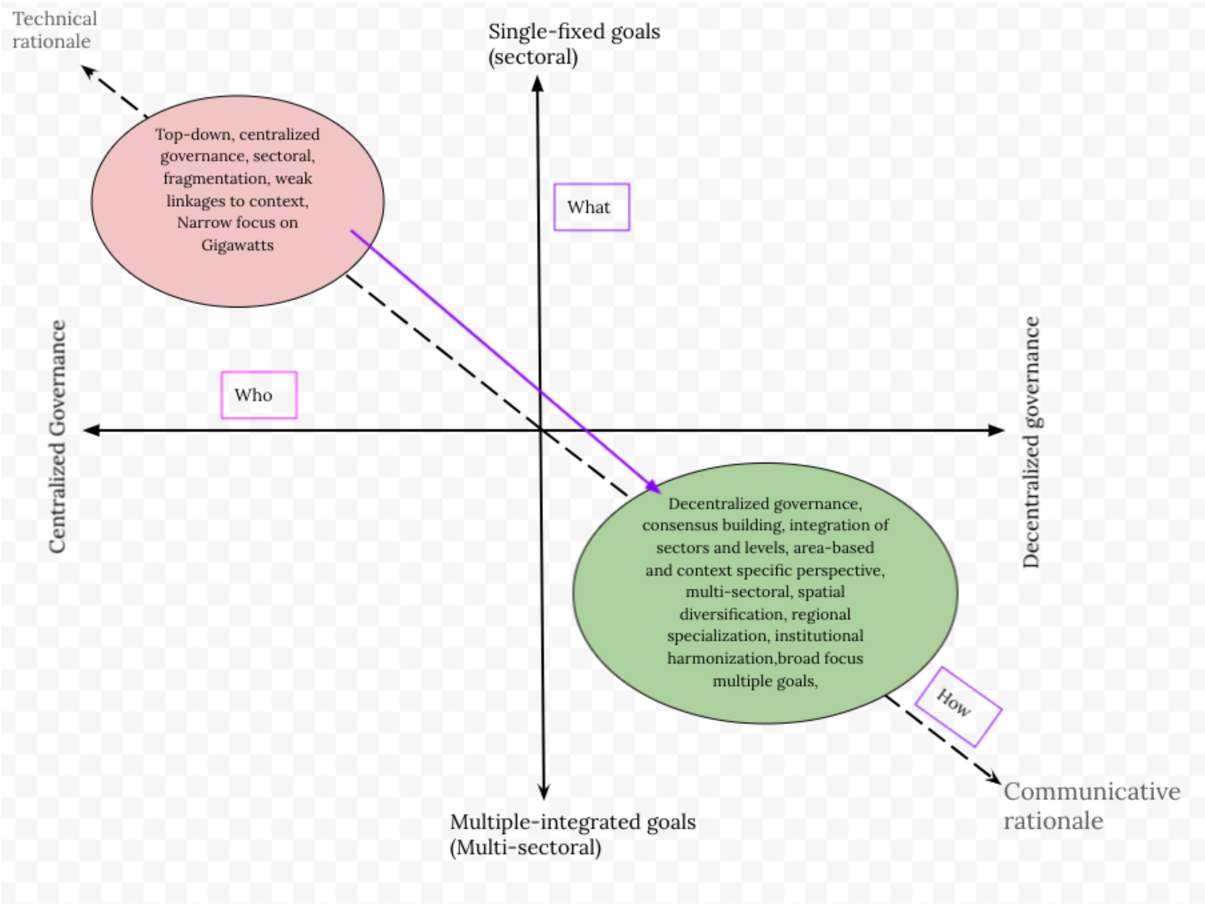

Figure 7. 1 Framework of recommendation (after, De Roo, 2016)

1. **The who question: shift from centralized towards decentralized governance**

The current North Sea offshore wind energy governance and planning process is top-down and sectoral approach in nature where the space allocation, planning, implementation and decision-making processes are centrally coordinated from the national governments and there is limited role played by the local and regional governments. The focus of this kind of spatial and energy planning is; where and how ***fast*** can we get to the maximum amount of ***gigawatts*** at the ***lowest economic cost***

A decentralized governance of the energy transition in which local citizens, municipalities and provinces and *Bundesländer* actors have a crucial role in delivering public policies that can unlock the potential for reaping multiple benefits and goals that are area and context specific whereby the energy transition can be vehicle for positive local and regional changes which can facilitate local support and ease to reach the "***gigawatts"*** needed (de Boer and Zuidema, 2013).

Spatial integration of renewable energies in land-and-seascape requires institutional harmonization which entails the cooperation and coordination between various institutional frameworks that guide different sectors and actors to mitigate environmental risks while enabling synergies between the energy transition and environmental planning (Spijkerboer et al., 2019). There needs to be a shift from centralized governance of the environmental planning based on standards to a more decentralized governance that seeks consensus building (De Roo, 2016).

2. **The What question: Shift focus from single fixed targets towards multiple integrated goals**

The current focus of the ports is on fixed technical targets, sectoral approach dominated by offshore wind industry and the goals are mainly expansion of the offshore wind farms, and related infrastructures. There are limited linkages with other sectors i.e. nature, maritime transport and weak linkages with the physical landscape and socio-ecological landscape. As the port authorities aim to be front runners in the energy transition, the case ports are actively using their functions of; landlords, operators, regulators and community managers, to facilitate and enable:

- Enhancing synergies between the energy transition and nature protection
- Creative and innovative way of embedding renewable energies in physical land-and seascape
- Connection of renewable energy production to other functions, sectors and socio-economic landscape to create regional spin-offs and local benefits,
- Phasing-out fossil-fueled power plants operated by the port and investing in onshore renewable power generation,
- Efficient use of energy, infrastructure and sustainable use of resources to mitigate pollution and negative externalities to the environment and neighbor communities,
- The electrification of port-related operations and co-located industries,
- The rapid development of offshore wind energy as well integration of offshore energy into the coastal energy infrastructure,

- Provide alternative solution for maritime industry as well as rebates and incentives for switching to sustainable fuels,

3. **The How question: Shift from Technical approach towards communicative approach**

The port authorities strategic and the tactical activities are crucial in operationalizing the long-term hydrogen visions and strategies of their respective nations into short-term plans, projects and scenarios. Embedding these projects and plans in the Wadden sea region context requires regional specialization and spatial diversification. Therefore there is the need for:

- Common programs and agenda setting to align the different ports interests, plans and minimize diverging and conflicting interest that put pressure on the wadden sea,
- Coordination of activities and measures between the ports to enhance complementarity between the ports,
- Cross-border cooperation between the ports to facilitate sharing of information, exchanging knowledge and abatement of environmental risks,
- Investing in reflexive activities search as learning processes that can enhance a broad social acceptance
- Working together with nature protection organizations and initiatives.
- Institutional harmonization in the wadden sea region entails cross-border cooperation between institutions from different jurisdictional borders and therefore also calls for alignment of regulatory frameworks across the wadden sea region.

7.3 Reflection

The results of this research have mostly met the research objectives that were outlined in Section 1.2. A better understanding of the current developments and the environmental concerns linked to the energy transition has been achieved. Furthermore, identifying the current position of the energy transition and hydrogen economy development in the transition phases, and the actors involved in the energy transition and how they are interlinked has been achieved. This has resulted in the development of a set of recommendations for stakeholders who are involved in the governance of the energy transition and hydrogen economy development in the ports located along the wadden sea coast.

The results of this research also has identified the current governance approach of the spatial developments linked to the energy transition in the North sea and the environmental planning of the Wadden sea and has proposed a shift from the top-down, centralized, sectoral and technical approach to a decentralized, integrated, area-based with context specific approach that aims for consensus building. The recommendation contributes to the navigating the complexities of managing the energy transition in the Wadden sea region as well as challenges of integrating the renewable energies in physical and socio-economic landscape. Therefore it can be fairly argued that this research has successfully achieved its goals which make it relevant for society, academia and planning practitioners as outlined in Section 1.4. However, the generalization of the results to the whole Wadden sea is insufficient as some difficulties arose during the data collection phase of this research, and these will be highlighted here.

The most present challenge was the global pandemic of SARS-Covid19 that has caused challenges in conducting interviews. First, the interviews had to be conducted online which put high dependence on the technical performance of the platforms used to conduct the interviews. Technical complication arose during some of the interviews that had significant impact on the quality of the responses from the interviewees and the time allocated for the interview. However, the interviewees were very helpful and willing to be contacted for further inquiries that were not answered during the interviews.

Secondly, due to the absence of the presence, the interactions with an interviewee with respect to reaction, response and body expressions was limited. However, with the permission to record the interview from interviewees, the recordings were reviewed several times and confirmed the content of the answers was sufficient to analyse them in the sense of the research.

Thirdly, availability of some crucial stakeholders in the spatial developments in the North Sea was highly affected by COVID-19 pandemic. These included stakeholders from offshore wind farm sector and Transmission Service Operators (TSOs).
Fourthly, due to limited time allocated for this research, all the ports located along the wadden sea coast that meet the criteria set by this research could not be interviewed. This has implication on the generalizability of the results of this research. To compensate for this, additional interviews were conducted with experts from various sectors (research and energy institutes, nature and cooperation initiatives). These experts are very active in Wadden sea area and region, and their responses represent the broader sense of the study area.
Lastly, concerning the quality of the interviews, I have little experience with conducting interviews and especially none with online interviews, therefore I still have much to learn and improve on how to conduct interviews.

Using the lenses of transition theory and management has proven to be helpful in understand how the stakeholders in the ports can approach the governance challenge of the energy transition as well as the environmental risks linked to the energy transition. However, in retrospect other approaches could be relevant in finding answers to the research questions. Marine spatial planning by (Douvere, 2008; Ehler & Douvere, 2009; Gusatu et al., 2020), Ecological modernization (Jänicke, 2008; Laes et al., 2014; Warner, 2010) and Integrated coastal zone management by Karrasch, L., Klenke, T., & Woltjer, J. (2014) could be such alternative frame of reference to study the current developments linked to the energy transition in the wadden sea region and the environmental risks linked to such developments to the wadden sea.

References

Allmendinger, P. (2017). *Planning Theory*.

Baer, J., & Nehls, G. (2019). Wadden Sea Quality Status Report on Energy. *Wadden Sea Ecosystem*, *9*(2017).

Bahlke, C. (2019). *Wadden Sea Quality Status Report, Common Wadden Sea Secretariat*. *25*, 597.

Barth, F., Vanhoudt, W., Londo, M., Jansen, J. C., Veum, K., & Castro, J. (2015). *Technical Report on the Definition of 'CertifHy Green' Hydrogen*. *D2.4*, 5.

BFN, F. A. for N. C. (2013). *Konzept für den Schutz der Schweinswale vor Schallbelastungen bei der Errichtung von Offshore-Windparks in der deutschen Nordsee (Schallschutzkonzept) (Concept for the protection of harbour porpoises against noise pollution during the construction of offs*. 33.

Bleischwitz, R., & Bader, N. (2010). Policies for the transition towards a hydrogen economy: The EU case. *Energy Policy*, *38*(10), 5388–5398. https://doi.org/10.1016/j.enpol.2009.03.041

BMVI. (2019). Hydrogen Strategy for North germany. In *Ministries of Economy and Transport of the North German Coastal States Bremen,* (Issue 9).

BMWI, (Federal Ministry for Economic Affairs and Energy). (2019). *Our energy transition for an energy supply that is secure, clean, and affordable*. 2019. https://www.bmwi.de/Redaktion/EN/Dossier/energy-transition.html

BMWI, (Federal Ministry for Economic Affairs and Energy). (2020). National Hydrogen Strategy. *Federal Ministry for Economic Affairs and Energy Public Relations Division 11019 Berlin Www.Bmwi.De*, 32.

Bosman, R., Loorbach, D., Rotmans, J., & van Raak, R. (2018). Carbon lock-out: Leading the fossil port of rotterdam into transition. *Sustainability (Switzerland)*, *10*(7). https://doi.org/10.3390/su10072558

Brett, V., & Roe, M. (2010). The potential for the clustering of the maritime transport sector in the greater Dublin region. *Maritime Policy and Management*, *37*(1), 1–16. https://doi.org/10.1080/03088830903461126

CWSS. (2010). Wadden Sea Plan 2010. Eleventh Trilateral Governmental Conference on the Protection of the Wadden Sea. March, 104

.

Damman, S., & Steen, M. (2021). A socio-technical perspective on the scope for ports to enable energy transition. Transportation Research Part D: Transport and Environment, 91(January), 102691. https://doi.org/10.1016/j.trd.2020.102691.

De Boer, J., & Zuidema, C. (2013). Towards An Integrated Energy landscape. July, 1–16.

De Roo, G. (2016). Environmental Planning in the Netherlands: Too Good to be True From Command-and-Control Planning to Shared Governance.

De Roo, G. (2017). Understanding fuzziness in planning- Environmental planning in the Netherlands: too good to be true: from command- and-control planning to shared governance. Chapter 8, 109–122.

DNV GL. (2020a). Energy Transition Outlook 2020 - A global and regional forecast to 2050. Dnv Gl Energy Transition Outlook, 306.

DNV GL. (2020b). Ports : Green gateways to Europe, 10 transitions to turn ports into decarbonization hubs(1). 44(2), 264–266.

Dolch, T., Folmer, E. O., & Frederiksen, M. S. (2017). Wadden Sea Quality Status Report - East Atlantic Flyway. *Wadden Sea Quality Status Report 2017*, *9*, 146–147.

Douvere, F. (2008). The importance of marine spatial planning in advancing ecosystem-based sea use management. Marine Policy, 32(5), 762–771. https://doi.org/10.1016/j.marpol.2008.03.021

Ehler, C., & Douvere, F. (2009). Marine spatial planning: a step-by-step approach, IOC Manuals and Guides 53. 99.

Energiewende, A. (2019). European Energy Transition 2030 : The Big Picture Transition 2030 : The Big Picture.

European Commission. (2015). Trans-European Transport Network. In Security and Defence Quarterly (Vol. 7, Issue 2). https://doi.org/10.5604/23008741.1189296

Fox, A. D., & Petersen, I. K. (2019). *Offshore wind farms and their effects on birds*. *113*(September), 86–101.

Gasunie, & TenneT. (2019). Infrastructure Outlook 2050. Integrated energy infrastructure in the Netherlands and Germany. 1–62.

Geels, F. W. (2011). Environmental Innovation and Societal Transitions The multi-level perspective on sustainability transitions : Responses to seven criticisms. Environmental Innovation and Societal Transitions, 1(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.00

Gigler, J., Weeda, M., Remco, H., & De Boer, J. (2020). Hydrogen for the energy transition, A programmatic approach for Hydrogen innovations in the Netherlands for the 2020-2030 period.

Gusatu, L. F., Yamu, C., Zuidema, C., & Faaij, A. (2020). A spatial analysis of the potentials for offshore wind farm locations in the North Sea region: Challenges and opportunities. *ISPRS International Journal of Geo-Information*, *9*(2). https://doi.org/10.3390/ijgi9020096

Howes, J. (2004). The future of the North Sea. In *Journal of Offshore Technology* (Vol. 12, Issue 2).

Hydrogen Council. (2017). How hydrogen empowers the energy transition. *Https://Hydrogencouncil.Com/Wp-Content/Uploads/2017/06/Hydrogen-Council-Vision-Document.Pdf.*, *Accessed September 17*, *2020*, 1–28.

ICES. (2014). ICES Report of the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT). *International Council for the Exploration of the Sea*, *April*, 17–20.

ICES. (2016). *Effects of Extraction of Marine Sediments on the Marine Ecosystem. ICES Cooperative Research Report No. 247*. International Council for the Exploration of the Sea.

Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas, 1 (2005).

Interreg. (n.d.). *Concepts for Harbour Logistics Getting offshore wind SMEs involved in developing harbor logistics*. North Sea Region.

Jänicke, M. (2008). Ecological modernisation: new perspectives. *Journal of Cleaner Production*, *16*(5), 557–565. https://doi.org/10.1016/j.jclepro.2007.02.011

Kemp, R. (2010). The Dutch energy transition approach. *International Economics and Economic Policy*, *7*(2), 291–316. https://doi.org/10.1007/s10368-010-0163-y

Koschinski, S., & Lüdemann, K. (2013). Development of Noise Mitigation Measures in Offshore Wind Farm Construction 2013. *Report Commissioned by the Federal Agency for Nature Conservation (Germany)*, *February*, 102 pp.

Laes, E., Gorissen, L., & Nevens, F. (2014). *A Comparison of Energy Transition Governance in Germany, The Netherlands and the United Kingdom*. *ii*, 1129–1152. https://doi.org/10.3390/su6031129

Loorbach, D. (2010). Transition management for sustainable development: A prescriptive, complexity-based governance framework. *Governance*, *23*(1), 161–183. https://doi.org/10.1111/j.1468-0491.2009.01471.x

Loorbach, D., & Raak, R. Van. (2006). Transition Management : toward a prescriptive model for multi- level governance systems. 1–17.

Mangi, S. C. (2013). The impact of offshore wind farms on marine ecosystems: A review taking an ecosystem services perspective. Proceedings of the IEEE, 101(4), 999–1009. https://doi.org/10.1109/JPROC.2012.2232251

Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. Policy Sciences, 42(4), 323–340. https://doi.org/10.1007/s11077-009-9097-z

OSPAR Commission. (2017a). Dumping and Placement of Dredged Material. 2007, 2007–2008.

OSPAR Commission. (2017b). Summary of Trends in Discharges , Spills and Emissions from Offshore Oil and Gas Installations Summary of Trends in Discharges , Spills and Emissions.

Pettit, S. J., & Beresford, A. K. C. (2009). Port development: From gateways to logistics hubs. *Maritime Policy and Management*, *36*(3), 253–267. https://doi.org/10.1080/03088830902861144

Poulsen, R. T., Ponte, S., & Sornn-Friese, H. (2018). Environmental upgrading in global value chains: The potential and limitations of ports in the greening of maritime transport. Geoforum, 89(July 2017), 83–95. https://doi.org/10.1016/j.geoforum.2018.01.011

Robinson, R. (2002). Ports as elements in value-driven chain systems: The new paradigm. Maritime Policy and Management, 29(3), 241–255. https://doi.org/10.1080/03088830210132623

Rösner, H.-U. (2012). Energy Production and Nature Conservation in the Wadden Sea Region and the Wadden Sea : Future Perspectives Energy Production and Nature Conservation in the Wadden Sea Region and the Wadden Sea : Future Perspectives Den- Netherlands Den-. August.

Schultze, M., & Nehls, G. (2017). Extraction and dredging. Wadden Sea Quality Status, 9(February).

Seanergy. (2012). Delivering offshore electricity to the EU. May, 1–80.

Spijkerboer, R. C., Zuidema, C., Busscher, T., & Arts, J. (2019). Institutional harmonization for spatial integration of renewable energy: Developing an analytical approach. Journal of Cleaner Production, 209, 1593–1603. https://doi.org/10.1016/j.jclepro.2018.11.008

TenneT. (2019). Tennet Offshore Wind - Connecting Wind Energy The Offshore Grid In The Netherlands. TenneT.

The government of the Netherlands. (2019). Climate Agreement | Report | Government.nl. June, 1–247.

The Minister of Economic Affairs and Climate Policy. (2020). Netherlands Government Strategy on Hydrogen. *Report*, *387*, 1–14.

UNCTAD. (2018). Reveiw of Maritime Transport. In United Nations Conference on Trade and Development.

Van Der Brugge, R., Rotmans, J., & Loorbach, D. (2005). The transition in Dutch water management. Regional Environmental Change, 5(4), 164–176. https://doi.org/10.1007/s10113-004-0086-7

Verbong, G., & Geels, F. (2007). The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960-2004). Energy Policy, 35(2), 1025–1037. https://doi.org/10.1016/j.enpol.2006.02.010

Verhoeven, P. (2011). European port governance. Report of an Enquiry into the Current Governance of European Seaports, 110.

Verhoeven, P., & Vanoutrive, T. (2012). A quantitative analysis of European port governance. Maritime Economics and Logistics, 14(2), 178–203. https://doi.org/10.1057/mel.2012.6

Wan, Z., Zhu, M., Chen, S., & Sperling, D. (2016). Pollution: Three steps to a green shipping industry. *Nature*, *530*(7590), 275–277. https://doi.org/10.1038/530275a

Wang, A., van der Leun, K., Peters, D., & Buseman, M. (2020). European Hydrogen Backbone. July, 24.

Warner, R. (2010). Ecological modernisation theory: Towards a critical ecopolitics of change? Environmental Politics, 19(4), 538–556. https://doi.org/10.1080/09644016.2010.489710

WEC. (2017). BRINGING NORTH SEA ENERGY ASHORE EFFICIENTLY, World Energy Council The Netherlands. World Energy Council.

WSF. (2020). Round Table “Shipping Safety” -Trilateral Stakeholder Analysis. December.

WSF, W. S. F. (n.d.). Planning Portal for the Wadden Sea Region. Retrieved March 14,2021,fromhttps://www.waddenseaforum.org/topics/instruments/planning-portal

WWF. (1991). The Common Future of the Wadden Sea: A report by the World Wide Fund for Nature. 1–64.

Yin, R. (1994): Case Study Research: Design and Methods. Thousand Oaks: SAGE.

Appendix I

Interview Questions for ports.

1. Could you tell me something about yourself, your professional background and your current responsibilities at the Port of **[name of port]**?

2. Could you tell me more about how the port is managed?
   2a. Who are the stakeholders in the governance of the port?

3. What are the main port operations and activities?
   3a. Does the port also function as an industrial hub and/or energy hub?

4. Are there impacts of the energy transition on the port operations and functions?
   4a. Do you have strategies / policies / concepts to cope with the energy transition?
   4b. How different is the port **[name of port]** approaching the energy transition as a port located in the wadden sea region?

5. Are you aware of the national and regional hydrogen strategies and are these strategies relevant for you as a port?
   5a. What are the current developments and planned transformation (*long-term plans, strategies*) linked to hydrogen economy developments in the port of **[name of port]**?
   5b. Are there institutional arrangements / organization or a management structure that oversees these activities?
   5c. Stimulate decarbonization in the co-located industries and maritime sector?
6. What are the opportunities and challenges for the port in the developments of a hydrogen economy?

7. Is the port of **[name of port]** in cooperation with other ports in regard to reducing environmental risks to the Wadden sea?
   8a. Does the port share information or consult other ports in their approach to mitigate the impacts of climate change?

8b. Does the port have joint projects with other ports in the Wadden sea such as Hydrogen projects or cross-border energy integration?
8c. What are the barriers and challenges for a common port strategy for the ports located in the wadden sea coast?

9. Is the port of **[name of port]** in cooperation/ share information / consult with local or international environmental initiatives?
   9a. Does the port include the interest of the local community in the planning and decision-making processes at the port? How?

10. How can the port facilitate the development of (offshore) renewable energy in the North Sea and to the (onshore) existing coastal energy infrastructure?

11. In which ways can the ports deal with the potential environmental risks associated with hydrogen economy developments to the Wadden Sea? Do you know these risks? Do you have information / studies/ reports about the risks associated?

12. Is there anything that you would like to ask me, or any last points you would like to add?

Are there specific material/ documents or information you can suggest for me that can be useful for my research?

Appendix II

Coding categories for the interviews

1. Governance
    - International & European
    - National
    - Regional
    - Local
    - Private actors & networks
    - NGOs, environmental initiatives
2. Port functions
    - Activities
    - Operations
    - Services
3. Impact of energy transition and hydrogen strategies on port functions
    - Strategies to cope with the energy transition

4. Opportunities and challenges for the ports in the development of a hydrogen economy

5. Cooperation
    - With other Wadden sea ports
    - With NGOs, Environmental initiatives
    - Barriers to cooperation

6. Facilitating energy transition
7. Environmental risks
    - Awareness
    - Attitude about responsibility
    - Approach taken
    - Challenges
8. Desired Improvements
    - What
    - Who
    - How