The Route Towards Reaching Net-Zero for European Ports

A comparative study between the two largest ports in Europe; the Port of Rotterdam and the Port of Hamburg

ERASMUS UNIVERSITY ROTTERDAM
Erasmus School of Economics
Bachelor Thesis for Urban, Port & Transport Economics

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Date Final Version: 24 July 2024

Table of Contents

1. Introduction

1.1 Context and Relevance of the Research

Since the Paris Agreement entered into force in 2016, 159 nations worldwide committed to tackling climate change (The United Nations, n.d.). One of the parties to the Paris Agreement is the European Union. Through this, it has committed to the Net Zero Plan which forms an element of the agreement. The objective of reducing greenhouse gas (GHG) emissions to zero can therefore be regarded as one of the current main goals of the Union. The seriousness of achieving this ambitious reduction in GHGs is emphasized by the fact that the Union has even written this goal into law (Art. 2, Regulation (EU) 2021/1119). As one of the larger GHG-producing sectors, the port industry was no exception to the rules provided and thus has been impacted by the relatively quick need to shift business operations. Among many others, the biggest ports of Europe, have set up strategies to effectively work towards reaching the goal of Net Zero.

Where the previously mentioned legislation, the European Climate Law, voices the need and ambition of the EU to set up frameworks for and in the Member States to reach Net Zero goals by 2050, this is notably a regulation aimed at affecting the Member States as a whole (Art 5(1), Regulation (EU) 2021/1119). The EU does have legislation that has a more direct effect, namely the Corporate Sustainability Reporting Directive (Directive (EU) 2022/2464). This Directive is set up 'to ensure that all regions, Union citizens, and Union businesses participate in a socially just transition to a sustainable economic system whereby no person and no place is left behind' (Preamble (1), Directive (EU) 2022/2464).

Next to this directive, which outlines reporting requirements for businesses, the EU has also developed a positive enforcement system through EU taxonomy. It establishes four overreaching conditions that economic activity has to meet to qualify as environmentally sustainable (Art. 3, Regulation (EU) 2020/852). It is aimed at aiding the scale-up of sustainable investment. To guide businesses further in this, a particular navigator website was set up to help with understanding EU taxonomy (EU Taxonomy Navigator).

It must be noted, however, that while there is a legal framework that stresses the overreaching goals and wishes of nations, working on creating a sustainable port is not guided solely by the need to follow the rules. There are also many reasons why a port itself would wish to take into account certain stakeholders and work on eliminating negative external effects. One of the reasons a port might, for its own benefit, commit to taking responsibility for sustainability aspects is that it is regarded as important by others and thus creates a stable reputation

regarding aspects that could increase short-term and long-term profit expectations (Story & Nevis, 2015).

When looking at the Port of Rotterdam specifically, a case study by De Langen showed that one important aspect of the port authority's structure enables them to quickly implement and execute the needed sustainable transformation (De Langen, 2023). This is because the Port of Rotterdam is partly owned by state-owned shareholders, making the public interest and thus the sustainability of the port the key motive for these shareholders (De Langen, 2023). In contrast to when a port is owned by profit-driven companies, this is said to have sped up the process of creating a more sustainable port.

One of the aspects the Port of Hamburg is well known for is the smart energy grid that they have implemented, which has been evaluated in a case study by Bouchard et al (2023). This smart energy grid has allowed for the move toward a complete energy transition to 100% renewable energy sources (Bouchard, et al, 2023). The case study found that the smart energy grid not only makes great steps toward becoming a sustainable port but has also resulted in a reduction of around 32% regarding the costs previously made for energy-driven technologies (Bouchard et al, 2023).

1.2 Goals and Methods of the Research

With only about 25 years to go until the Net Zero by 2050, goals need to be reached under European legislation. The strategy which ports have chosen to achieve this has become more and more important. As the types of investments required for each port to effectively reach Net Zero emission are different, due to the different nature of economic activity, it leaves an interesting opportunity to research how the Rotterdam Port Authority and the Hamburg Port Authority have shown to adapt and will adapt in the future. This results in the focus of this research being centered around the following research question:

“How do the two largest ports in Europe differ in their strategy to approach Net Zero goals, mainly focusing on the differences in investments into green energy sources and the renewed use of raw materials ?’

To successfully answer the research question, this thesis will be separated into three main parts. Firstly there will be an extensive literature review of how ports have incorporated social responsibility into their strategies, after which there will be a short overview of standing European legislation as well as EU taxonomy and the effect these rules and regulations have on ports. It aims to shed light on the adaptations ports have to make following the set-up legislation

and evaluate how this has taken form in practice. After this, papers will be evaluated regarding the effective investments ports have made into reaching Net Zero. The paper solely focuses on efforts that have been shown by the Port Authorities, which means that projects initiated solely by private companies are not regarded in the thesis. In this thesis, there is thus a clear line between the Port Authority, which manages the port activities, and the Port of Rotterdam or Port of Hamburg that refers to the location of the port.

An overview of case studies published regarding the Rotterdam Port Authority and the Hamburg Port Authority will be presented in the second part of the research. This aims to illustrate the current and past efforts in reaching a Net Zero port and their effectiveness, as well as evaluations of scholars on which areas could still be improved.

The third and final part of this research will consist of an evaluation of the investments made by the ports to reach Net Zero goals, what the main focus of the ports is, and in which sector these investments lie. First, there will be extensive research into the Rotterdam Port Authority, followed by research into the Hamburg Port Authority. The research concludes with a comparative analysis of the differences present in the two ports and an analysis where these differences might stem from.

2. Literature Review

2.1 Port Contributions to SDGs

The sustainability strategy has been embedded into almost all companies, as both internally and externally it is seen as essential to ensure the stability and the projected profits for businesses (Story & Nevis, 2015). The risks of a changing climate and impending strict legal regulations make it so that port authorities intrinsically have a strong reason to anticipate these risks. Companies thus have their reasons for taking action, next to the legal ramifications.

Corporate responsibility is present in all sectors but in the last couple of decades, the emphasis on ports has increased tremendously (Acciaro, 2015). Adopting green practices in the port not only leads to improved conditions for the environment, but the label of being a green port also creates a better image among stakeholders (Acciaro, 2015). The concept of a green port is linked to improving the conditions based on social, environmental, and economic actions (Acciaro, 2015). However, it is also closely linked to corporate responsibility, which highlights the social impact and economic viability of a port even more (Vanelslander, 2016). Successful implementation of corporate responsibility in the strategy of the port is observed to lead to competitive advantages as the supply chain is regarded to be more stable (Acciaro, 2015).

Therefore it is said that acting on corporate responsibility is one of the main competing points between ports (Acciaro, 2015). This shows that if a port wishes to become or remain an important player in the competitive field, it cannot deny the need to take sustainable action and thus does this for its benefit.

Further research shows that ports have taken steps to include economic growth with the development of limiting the negative externalities and enhancing the positive externalities (Jansen, Van Tulder, & Afrianto, 2018). Communication and active participation with stakeholders are observed to be a necessity for implementing sustainability strategies in a port's long-term plans (Jansen, Van Tulder & Afrianto, 2018). Collaboration with other actors close to the port is therefore crucial to the successful implementation of such a strategy and, with that, partnerships are seen to be key aspects of successful sustainable growth (Jansen, Van Tulder & Afrianto, 2018). The place where a port can make a difference in the environmental and societal negative externalities is local. The partnerships with local stakeholders thus enhance the ability of the port to successfully do this as they offer exclusive insights into the local nature and the conditions surrounding the port (Jansen, Van Tulder & Afrianto, 2018).

The drivers of corporate responsibility can be based on four main perspectives that all include the partnership with stakeholders in order to make them work (Ashrafi, et al, 2020). The first would be the governmental perspective where voluntary initiatives have been identified both on a national level as well as on a regional level (Ashrafi, et al, 2020). Secondly, there is the societal perspective, where the social license to operate pushes ports to take further actions than what is necessary under compliance (Ashrafi, et al, 2020). Thirdly there is the market perspective, which shows that taking the responsibility to improve the sustainability image of a port is good for the competitive placement of the port (Ashrafi, et al, 2020). Lastly from the organizational perspective, the push to incorporate actions to lower carbon emissions often stems from the viewpoint of lower costs and more stability in the future (Ashrafi, et al, 2020).

This overview illustrates that port authorities do not only act based on compliance with regulations but that they also have an intrinsic motivation to do so. The literary analysis has shown that incorporating stakeholders into the actions that are taken to reduce the negative external effects yields the best results. The undertaken projects often stem from perspectives put forward all around the port. However, to reflect the minimum expectations of society, legislation is also put in place. This nudges those ports that show a lower intrinsic level of commitment in the right direction as well as establishes minimum guidelines on what should be

expected of the ports. The legal framework that the EU has set up will be discussed in section 2.2.

2.2 EU Legal Framework

2.2.1 EU Taxonomy

After the adaptation of the new global sustainable development framework of the UN General Assembly in 2015, the EU needed to take action to fulfill the commitments made by the Member States (Preamble (2), Regulation 2020/852). One of the ways this was done was by implementing the Regulation on the establishment of a framework to facilitate sustainable investment (Preamble (2), Regulation 2020/852). By creating a unified classification system for sustainable activities, the Union aims to give some clear guidance on activities that qualify as contributing to environmental objectives and help inform investors about the investments that fund environmentally sustainable economic activities (Preamble (6), Regulation 2020/852).

Article 3 of this Regulation clarifies the four criteria that are established to officially categorize an economic activity as environmentally sustainable (Regulation 2020/852). When an activity contributes substantially to one or more of the environmental objectives set out in the Regulation, and it does not significantly harm any of these environmental objectives, it is carried out in compliance with the minimum safeguards laid down in the Regulation and it complies with the technical screening criteria, then it can be called an environmentally sustainable economic activity (Art 3, Regulation 2020/852).

The EU has aimed to give the financial and non-financial institutions in the Union a common definition of economic activities that can be considered environmentally sustainable. With the 2050 Net Zero targets coming closer and closer, it was deemed necessary to streamline a common language (Preamble (14), Regulation 2020/852). The Regulation gives some clear guidelines for ports as well and can aid tremendously in the process of creating new projects.

2.2.2 Corporate Sustainability Reporting Directive

The EU Taxonomy as described above builds on the Corporate Sustainability Reporting Directive (CSRD). This directive has been amended, and thus a new version has been adopted in 2022 (Directive (EU) 2022/2464). In this Directive it is mentioned that if undertakings carried out better sustainability reporting, the group of ultimate beneficiaries would grow, meaning that both investors would have a better understanding of the long-term risks and opportunities in terms of sustainability, as well as civil society actors getting a clearer view on which undertakings to account for their impact on the environment (Preamble (9), Directive (EU) 2022/2464). This

Directive thus aims to aid the growing market for sustainability information by sharpening the reporting duties of businesses to increase the level of disaggregated data on the matter (preamble (10), Directive (EU) 2022/2462). This new Directive is set up as an amendment directive, meaning that its articles contain amendments to previous directives on the topic of sustainability reporting.

This also affects the port authorities, as they must also comply with all of the requirements that are laid out in this directive. While the list of amendments made to the reporting duties, as well as the already existing reporting requirements, is too long to fully include, it is evident that the burden of reporting on the matter is growing. Therefore underlining that not only the burden to correctly report and categorize all of the activities is becoming larger, the need to adapt the business model and the investment activities towards those that are more sustainable is also becoming more and more pressing.

2.3 Sustainable Economic Activity

Ports have always played an important role in the economic development of countries (Alamoush, Olcer & Ballini, 2020). While maritime transport is deemed to be one of the more efficient modes of transport in terms of emissions per unit of cargo, due to increasing demand and large numbers it is regarded as one of the main sectors of CO_2 emissions (Alamoush, Olcer & Ballini, 2020). The need for decarbonization in the maritime sector and the ports is a top priority and thus has also been seen as a factor that will continue to influence all major investment strategies for the coming years (Alamoush, Olcer & Ballini, 2020). The impact ports have on the sector as a whole can be seen as crucial, which is why Alamoush, Olcer & Ballini (2020) have decided to analyze the status of port incentives and the need for general schemes. They concluded that the effectiveness of the sector as a whole could be increased if the incentives ports give are united through international programs and harmonized instead of created on a national level (Alamoush, Olcer & Ballini, 2020). This can be related to the same need that was seen that triggered the EU Taxonomy to be created, as this was also said to be able to benefit from an overreaching system, definition, and course of action to streamline and quicken the pace at which a port and its business can adopt a greener model.

One of the effects that was seen following the implementation of EU Taxonomy, is that it increased the transparency of sustainable investments, mainly due to the standardized classification methods (Schütze, 2020). However, the EU Taxonomy was found by Schütze (2020) to categorize both traditionally green economic activity and those activities in an emission-intensive sector that can be labeled as sustainable. Therefore it was stated that the threshold for

these transition activities was a key component in the effectiveness of EU Taxonomy and that these thresholds needed not to be too low (Schütze, 2020). A too-low threshold could result in carbon lock-in effects, meaning that those emission-intensive technologies would remain present in the economy and that there would be little incentive to change these practices as they were considered 'sustainable' already (Schütze, 2020). Schütze (2020) therefore concluded different sectors in would need different criteria and different thresholds to specifically meet the challenges faced in the sectors.

A more recent study has looked at the effects of the EU Taxonomy, by comparing those companies that were eligible under the Taxonomy regime and those that were not (Schinas, 2023). The main focus was on the type of investments that were made and if there was an increasing amount of sustainable investment in the case that there was eligible (Schinas, 2023). It was concluded that those companies that faced clarity about their EU Taxonomy eligibility, thus operating in sectors that were considered to have a high level of certainty, showed an increasing amount of investments to become more and more sustainable (Schinas, 2023). However, a similar trend was observed by those companies facing more uncertainty regarding the EU Taxonomy (Schinas, 2023). This suggests that other forms of regulations also push companies to become more sustainable (Schinas, 2023). An example of this can be the previously described CSRD, as this already places a burden on companies to create a strategy regarding sustainability.

To further illustrate the current importance of the way that sustainability planning is implemented, the specific case of the port of Piraeus will be evaluated following the paper of Konstantinos (2023). For European ports such as the Port of Piraeus, to effectively achieve Net Zero, it was stated that improving air quality, lowering energy consumption, and fighting climate change, thus reducing CO2 emissions, are a top priority (European Seaports Organization, 2019). For the port of Piraeus, Konstantinos (2023) made some recommendations regarding the investments that would be smart from a competitive point of view. They defined these types of actions as having a good cost-to-effect ratio, meaning that investments with a balanced cost and benefits, in terms of energy consumption or GHG emissions reductions, are categorized as advisable (Konstantinos, 2023). It is found that investing in hybrid or fully electric vehicles on site is seen as a quick win investment. (Konstantinos, 2023). Next to that, investments that lead to a high level of decarbonization, which should extend to long-term infrastructural changes, are good for the competitive advantage of a port, examples include investing in solar energy or investing in Bio Liquefied Natural Gas fueling stations (Konstantinos, 2023). With these actions being tailored to the port of Piraeus, they might not apply to all other ports, but the main

consensus, namely choosing sustainable investments that help reach Net Zero by 2050, is broadly advisable.

This literature review reflects that ports overall do not only act based on the legal framework that is provided. This legal framework aims to put the minimum expectations and actions onto paper and therefore forces ports to at least comply with this. The ports however often take steps beyond what is necessary based on compliance and work together with the relevant stakeholders to do so, due to intrinsic motivation. Following the development of the legal framework, more clarity and transparency were brought to the market, as there is now an overreaching benchmark to classify the actions taken.

3. Methodology & Data

3.1 Research Methodology

Firstly, an overview will be given of the previously picked up initiatives by both the Rotterdam Port Authority and the Hamburg Port Authority. This will be done following a case study analysis for both of the ports. The aim is to relate the level of activity undertaken by the Port Authority, as is seen in the conceptual framework presented in the previous section to what is practically undertaken. Both for Rotterdam and for Hamburg multiple case studies will be the base of this analysis.

The research itself will base itself on the collected data and aims to show an overview of those investments that have been made by the Rotterdam Port Authority and the Hamburg Port Authority to reach the goal of Net Zero. The overall research will be divided into three main parts, firstly there will be an analysis based on the information regarding the Rotterdam Port Authority, and following this a similar analysis of the Hamburg Port Authority will be made. Lastly, the conclusion and main points of interest for both of the ports will be compared based on the project sectors, the project pipelines, and the project partners, This will ultimately lead to an answer to the main research question.

The analysis of the investment made by the ports will follow a similar approach for both the Rotterdam Port Authority and the Hamburg Port Authority. It will first outline the main strategy communicated by the Port Authority and the goals that were set in order to reach Net Zero. This will show which sectors should have been the main points of attention and the types of projects that would be the main focus. Following this, an analysis of the collected data will be presented, which will show the partners the Port Authority collaborated with, the sectors that have been

targeted, and the number of projects in the pipeline including their respective stages. The sectors targeted by the projects undertaken by the Port Authority will be separated into being focused on the Energy Renewal and Renewed use of Raw Materials. These will be further specified into the sectors of; Waste Heat, Wind Energy, Hydrogen, Solar Energy, Shore Energy, Electricity, Recycling, and Efficiency. Following these main units of analysis for both ports, the research can conclude with a comparative study of the main differences.

3.2 Data Collection

This research will be based on a collection of investments made by the Hamburg Port Authority as well as the Rotterdam Port Authority that are aimed at reducing the amount of CO_2 emissions emitted by port activities as well as those investments that are explicitly aimed at reaching the goal of Net Zero. A dataset is constructed with those projects that are managed by the Port Authority of both Rotterdam and Hamburg, which will not have an earlier starting date than 2020 as this is when the EU Taxonomy was first presented. This dataset contains information on the project, the sector that is affected by the project, the status of the project, notable partners on the project, the year of start, and the projected year of finish of the project. The dataset will only consist of those projects that are categorized under EU Taxonomy as sustainable economic activity

The information that is used as the data is gathered from public sources. For the port of Rotterdam, the website of the Port Authority is consulted, this includes a detailed overview of those projects that are currently in progress, as well as those that have been finished and are now operational, those that are in the phase of preparations, and those that are still in the earlier orientational phase. The website of the Hamburg Port Authority also contains a dedicated section to those investments that aid the energy transition and their ambition of reaching Net Zero already in 2040. This will be an important source for the dataset. The website of Hamburg includes extensive documentation on the projects, their timelines, partners, and sectors that line up with the available data presented by the Rotterdam Port Authority.

3.3 The Dataset

After construction, the dataset contains 38 entries for the Port of Rotterdam and the Port of Hamburg. These entries were selected and can be categorized as can be seen in Table 1 below.[1]

[1] Port of Rotterdam: https://www.portofrotterdam.com/nl/haven-van-de-toekomst/energietransitie/lopende-projecten
Port of Hamburg:
https://cdn.sanity.io/files/sxgebz2d/production/61cf7b32a2eabf799b5a9bd72643e5f0cbb4697e.pdf &
https://www.hamburg-port-authority.de/de/hpa-360/smartport/its-projekte#c8537

This table shows the main sectors which are targeted by the Port Authorities and are activities that can be seen as fitting within the guidelines of EU Taxonomy. It must be noted that while more projects are present on the website of the Port Authorities, we have specifically looked at those projects that are set up to aid the transition towards a Net Zero port and are set up with the involvement of the Port Authorities. This means that projects that happen in the port area but are set up solely by private parties without the involvement of the port Authority are not regarded in Table 1.

Table 1

General information on the dataset

	Port of Rotterdam	Port of Hamburg
Energy Renewal	25	11
Renewed Raw Materials	2	0
Total	27	11

Table Notes: The information in the tables is descriptive of the amount of entries in the dataset for both the Port of Rotterdam and the Port of Hamburg

Notably, this table shows the division of sectors that both of the Port Authorities focus on in their developments. It indicates that Energy Renewal is the most popular sector. This means that developments initiated solely by a private company without the involvement of the Port Authority are not regarded in the dataset. The full dataset can be consulted in Annex 1.

4. Case Study Review

Different studies have already been conducted regarding steps that have been taken in the Port of Rotterdam and the Port of Hamburg in order to reach Net Zero by 2050. Scholars have voiced opinions on the effectiveness and the different focus areas throughout this time. As this thesis aims to create an overview of the current projects being undertaken to reach Net Zero in both of the ports, it is thus important to also review the opinion regarding previous steps.

4.1 Case Study Review for the Port of Rotterdam

The Port of Rotterdam as a gateway is known to be a large emitter of CO2 and with that has faced major challenges in the need to reform its structure and methods into a more sustainable port. Already before the Paris Agreement was signed, the Port Authority felt the need to develop a sustainability strategy due to increasing societal and economic pressure (Bosman, et al, 2018). To achieve this, many different actions have been taken in the past, which will be further

discussed in this section. This section will regard actions taken by the Rotterdam Port Authority within the bounds of the Port of Rotterdam.

One of the ways that the Rotterdam Port Authority has approached the task of becoming a more sustainable port is through transition management. Bosman has evaluated how this has been done and what the effectiveness of this was in 2018. In this article, the Port Authority was followed to perceive the transitional phases and understand the destabilization of the older regime and the main actors in the transition of energy-intensive industries (Bosman et al, 2018). The narrative that was shared actively in public was that there should be space for the new direction of the transition (Bosman et al, 2018). Next to the narrative, a change was also observed in the organizational structure and investments. This shows that there has been an increased focus on funding innovation to help the energy transition. Lastly, in order to make more ground on the transition, changes were made in the way the Port Authority dealt with partnerships and practices. Regarding traditional industries in the port, communication on the matter was prioritized with stakeholders, as well as engaging with new partners (Bosman et al, 2018). To manage the transition we thus can observe two different movements happening within the port authority, firstly one focused on the old industries that are present in the port and encouraging reform, next to that we see one focused on new investments, projects, and viewpoints on the transition (Bosman et al, 2018).

De Langen (2023) took a closer look at the structure of the Port of Rotterdam and found the special structure of the shareholders of the Port made it so that it could easier move its focus towards a more sustainable viewpoint. He found that this was not a coincidence, as the shares are partly in the hands of the Dutch National government and the Municipality of Rotterdam (De Langen, 2023). These shareholders play a role in the development of the strategy of the Port Authority. Because such a substantial part of the Port Authority strategy is formed by the approval of the public institutions, this makes it so that public interests are also included in the discussion and the decision process (De Langen, 2023). One of the main points of public interest to be identified over the years is sustainability and the reduction of CO_2 emissions (De Langen, 2023). This is thus also present in the individual strategies of the Municipality of Rotterdam and the National government of the Netherlands, which allows them to prioritize the course towards a sustainable port in their decision-making (De Langen, 2023). This is in contrast with what is expected of a regular shareholder, as these are often known to prioritize the growth of a company and the growth of the value of shares. All in all, de Langen (2023) has thus shown with his research into the Port of Rotterdam that the implementation of the sustainability

strategy was prioritized due to the shareholders' interests in the public interest and with that the interest in limiting the CO2 emissions.

Following the previous two case studies that were discussed, the intention of the Rotterdam Port Authority seems to be very present. Gianoli and Bravo have looked into the process of decarbonization of the industrial processes in the Port of Rotterdam and have couple this to the Carbon Tax (2020). It has been stated that due to the nature of the products traded in the Port of Rotterdam, the demand for these products is rather sensitive to an increase in prices due to a possible carbon tax (Gianoli & Bravo, 2020). Due to this, the authors of this case study assume that with certain measures around the corner, steps have been taken by the Port Authority to limit the risk of reallocation, either in the form of improving the competitive position of the Port itself or in the form of low reliance on CO_2 emissions (Gianoli & Bravo, 2020). The solutions of green hydrogen and electrification seem to be the main way to lower the high carbon emissions of port industries and ensure Net Zero emissions throughout the port's activities (Gianoli & Bravo, 2020). While there are still barriers present for these technologies, it is said that if the market presents itself to be interested in this technologies in this field can be scaled up (Gianoli & Bravo, 2020). The scale of the operations in the Port of Rotterdam, if stimulated in the right way, could make them the real front runner in the area of large investments into green hydrogen and electrification and thus the implementation of these new, low carbon emitting, technologies (Gianoli & Bravo, 2020).

The potential effectiveness of the use of hydrogen in the Port of Rotterdam has been highlighted by Gianoli & Bravo. In a case study Van den Boomen looked at the potential of expanding the current strategy for hydrogen in the Port of Rotterdam (2021). The focus on hydrogen is seen as critical in the global sustainability transition and therefore necessary for the Port of Rotterdam to maintain its position as one of the leading seaports in the world (Van den Boomen et al, 2021). Changes in the energy sector are often costly as well as being highly reliant on the demand for hydrogen in this case (Van den Boomen, et al, 2021). Because the price of hydrogen is seen as highly variable, it is difficult to determine the pricing of when such an investment would become relevant for companies (Van den Boomen, et al, 2021). However, as mentioned previously, to maintain the competitive position of the port, it must prioritize the development of technologies that will fit with the future industry and the sustainability aims of the business sector (Van den Boomen, et al, 2021). For this purpose, hydrogen is seen as a leading form of green energy (Van den Boomen, et al, 2021). At this point, it is already observed that the question is not whether the plans to incorporate hydrogen will be implemented, but when the plans can be expanded

(Van den Boomen, et al, 2021). Thus further highlighting the importance of the incorporation of this form of green energy in the decarbonization of the port and its competitive position.

A combination of the above case studies shows that the Rotterdam Port Authority has made a public commitment to creating a sustainable port. The Port Authority has an active strategy of not only reshaping the standing industry but also incentivizing new technologies. Next to that, the structure of the shareholders makes it so that the strategy development is focused on including the public interests and thus the sustainability of the port. It has been stated that the inclusion of more hydrogen and electrification technologies is essential to the position of the port. In Chapter 5, the current projects of the Rotterdam Port Authority will show if it is currently the case that the focus lies on these developments.

4.2 Case Study Review for the Port of Hamburg

Next to the Port of Rotterdam, the Port of Hamburg is one of the biggest ports in Europe. While we have seen in the previous sections that the structure of the Port Authority in Rotterdam is very beneficial to the adaptation to a new more sustainable port, the Hamburg Port Authority has its challenges. These challenges do not perfectly align with those presented previously. Both of the ports have different points of orientation, which is why this part of the research will focus on the structure of and the steps taken in the Port of Hamburg to create a port that can reach the Net Zero goals. This section will regard actions taken by the Hamburg Port Authority within the bounds of the Port of Hamburg.

Hamburg Port Authority is one of the earliest in Europe that started to actively pursue energy management strategies (Acciaro, Ghiara, Cusano, 2014). Over time, this has become increasingly important, and renewable energy has played a big role in the transition process toward Net Zero ports. The Port of Hamburg is governed by the City of Hamburg, as this is the sole shareholder (Acciaro, Ghiara, Cusano, 2014). In a case study of the Port of Hamburg, it is evaluated how the strategy regarding energy supply and protecting the environment was shaped by the Port Authority (Acciaro, Ghiara, Cusano, 2014). It is seen that the Hamburg Port Authority was a pioneer in starting the transition to renewable energy supply, mainly in the form of wind energy (Acciaro, Ghiara, Cusano, 2014). One of the aspects that was considered to be instrumental in the fact that the Port of Hamburg was able to make this transition so early on, is that with the close links to the City of Hamburg, it was able to cooperate with the City's own energy company, Hamburg Energy, in the exploitation of renewable energy (Acciaro, Ghiara, Cusano, 2014). Already in 2014, the Hamburg Port Authority started to focus on lowering emissions and providing incentives as a source of increased revenues (Acciaro, Ghiara, Cusano,

2014). Due to the close relations between the Port Authority and the City, we see that very early on emphasis is placed on the sustainability strategy (Acciaro, Ghiara, Cusano, 2014). Energy management is thus fully embedded in the city's sustainability goals (Acciaro, Ghiara, Cusano, 2014).

When we move closer to the current situation, we observe that renewed energy is still the main focus of the Hamburg Port Authority. Through Shore Side Electricity the Hamburg Port Authority is trying to minimize CO_2 emissions by optimizing the supply points toward the vessels that are able to receive Shore Side Electricity (Yu et al, 2023). In the evaluation of the plan of the Hamburg Port Authority to create five supply points for Shore Side Electricity the environmental benefits were set off to the costs of placing these supply points (Yu et al, 2023). What is noted specifically is the rather high initial costs, which make it a difficult investment (Yu et al, 2023). While the benefits for the environment are also high, there needs to be enough demand to make sure the investment does not go to waste (Yu et al, 2023). It is noted that purely looking at the trade between allocation and the environmental benefit would lead to efficiency when seven supply points are created (Yu et al, 2023). The current plan of the Hamburg Port Authority is to create 5 supply points. To start with, its benefits are evident and should be considered by other ports as well (Yu et al, 2023). Next to that, it is also noted that the allocation is not optimal and thus that there might be a loss of efficiency (Yu et al, 2023). This case study highlights the fact that the Hamburg Port Authority is ahead of other ports when it comes to green energy supply, which aligns with the previous case study as the focus was shifted early on.

Next to providing renewable energy, another case study shows that there is also a lot of focus on how energy is best provided in Hamburg (Bouchard, 2023). To manage the large amounts of energy that can now be provided to reduce the reliance on older technologies and the use of large CO_2-emitting systems, a smart system has to be set in place (Bouchard, 2023). It is identified by Bouchard that both the energy supply and the energy demand need to be evaluated to be able to set up this system (Bouchard, 2023). Once again it is highlighted that the Hamburg Port Authority already has a steady income from renewable energy mainly based on wind energy, while biomass and hydropower are also becoming more prominent (Bouchard, 2023). The research in the case study of Hamburg finds that the Hamburg Port Authority can supply a sufficient amount of renewable energy to be categorized as reliable and as a result, the opportunity to extend this and create a reliable system for the city as well could arise. This takes away a part of the risk of overproduction of renewable energy and thus creates a more stable market and energy grid for the encouraged production of renewable energy.

The three papers discussed above show that in the Port of Hamburg there is already a rather well-established system of renewable energy. As such, the main focus is not so much on projects that look at the creation of renewable energy and actively working to establish a good innovative system, but more on how to make sure everything is implemented in such a way that it is efficient and provides a stable source for the future. This can be contrasted with what we see in Rotterdam, where the focus is chiefly on innovating new technologies and setting up systems to provide renewable energy. Chapter 5 will provide a practical view of how this works in practice by analyzing the different projects present under the supervision of the ports.

5. Research and Results

This section builds up to a comparative analysis of project management by the Rotterdam Port Authority and the Hamburg Port Authority. To achieve this, the sections concerning both ports will follow a similar setup. This means that to start with, the annual report and the sustainability strategy for both of the ports will be analyzed. Here, the goals and ambitions the port has set for its Net Zero goals are explored. Subsequently, the research zooms in on the actual projects that have been initiated since 2020 and compares the findings for the Port of Rotterdam and the Port of Hamburg.

5.1 Investments and Projects in the Port of Rotterdam

5.1.1 The Annual Report and the Sustainability Strategy

In its most recent Annual Report, the Rotterdam Port Authority has used the slogan; ‘Connecting the world. Building tomorrow's sustainable port’ (Port of Rotterdam, 2023 pg.1). The ambitions to create a sustainable port are highlighted and with 2050 nearing, the executive board states that speed is essential in tackling the sustainability goals (Port of Rotterdam 2023, pg. 6). To stimulate the necessary innovations, the Port Authority not only mentions the needs for active management, they also ensure the continuous offering of incentives to their clients’ initiatives. (Port of Rotterdam 2023, pg. 6).

The Port Authority outlines the ambition to become a climate-neutral port as soon as possible in the Annual Report as well (Port of Rotterdam, 2023, pg. 30). One of the key elements that are discussed to enable the transition of the port is the need to transfer to reliance on green rather than grey energy. (Port of Rotterdam, 2023, pg. 34). The main goal that is communicated, is that the Port Authority wishes to create an environment for private parties to switch to a more sustainable production process, or for those companies that have a sustainable outlook and wish to use the area of the Port of Rotterdam as their location (Port of Rotterdam, 2023, pg. 34).

However, with this, the locational struggle is also noted (Port of Rotterdam, 2023, Pg. 6). The strategy to achieve CO_2 neutrality in 2050 is based on four pillars. All of these pillars are acknowledged to have their own pace and their priority, but they are closely intertwined and thus it often happens that a project can be categorized into more than one of the pillars (Port of Rotterdam, 2023, pg. 35). The pillars are divided as follows; pillar one looks at infrastructure improvements; pillar two focusses on the transformation of the energy systems; pillar three contains those projects that provide sustainable alternatives to fossil fuels and raw material; pillar four focusses on the logistics and transport efficiency (Port of Rotterdam, 2023, pg 36-38). When we look more specifically at some of the goals, projects linked to residual heat, carbon capture and storage, the reuse of waste products offshore energy, and hydrogen are presented (Port of Rotterdam A, 2021).

All in all, this illustrates that the Rotterdam Port Authority is focusing on many different aspects to ensure the port can operate on Net Zero emissions in 2050. The analysis of the dataset will show if the current projects are representative of this aim and how active the Port Authority is in achieving these goals.

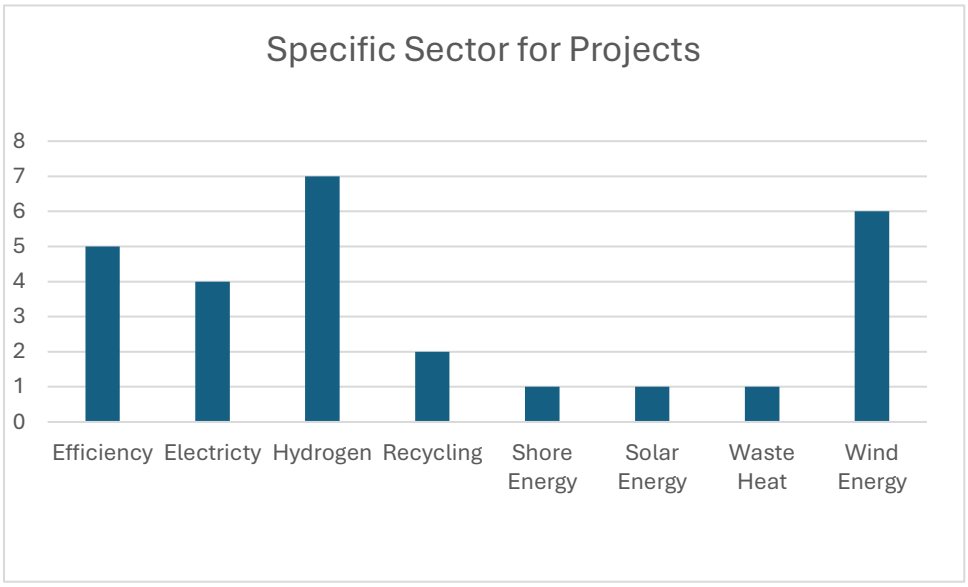
5.1.2 Results for the Rotterdam Port Authority

The analysis for both of the Ports is focused on the steps taken related to energy renewal and the renewed use of raw materials and their effects on reaching Net Zero. As we observe in Table 1, this resulted in 27 projects being cataloged for the Rotterdam Port Authority. Graph 1 provides a closer look at the different sectors that are being targeted. In the previous section, it was noted that the Rotterdam Port Authority has an ambition to transition the many different sectors simultaneously.

As can be observed in Graph 1, there is a focus on many different sectors in the Port of Rotterdam. This aligns with the views we have seen when looking at the sustainability strategy, where projects over the full spectrum of the port's activities are considered to be essential factors in reaching the goal of Net Zero.

Graph 1

Specific Sectors for Projects in the Port of Rotterdam



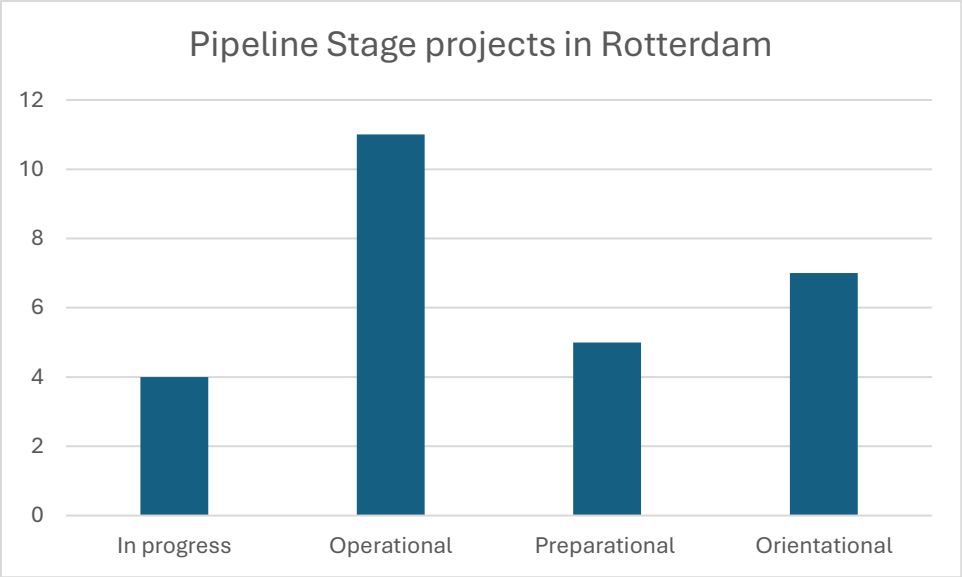
Graph notes: The left side of the graph shows the amount of projects that are classified into the specific sectors mentioned. There is differentiation into different sources for energy provision, as well as projects classified into electrification of processes, hydrogen-oriented projects, projects focused on the recycling of raw materials, and projects that focus on the efficient use of the innovations.

The amount of projects combined with the differentiation in sectors illustrates that the Port Authority has taken action in the entirety of the port. Green energy provision is one of the greater goals of the port. There is notably a lot of activity in the hydrogen sector and the wind energy sector. These sectors are prominent in the Port of Rotterdam for a reason. Regarding hydrogen, the Rotterdam Port Authority has shared its aim to be the hydrogen hub in Europe, as it believes it to be the key way of green energy provision in the energy transition (Port of Rotterdam (B), n.d.). As for the wind energy sector, this is one of the more well-known ways to produce green energy, and when looking at the Rotterdam Port Authority, the coalition that has established itself in building these offshore wind energy clusters has the benefit of specialized knowledge (Port of Rotterdam (C), n.d.). Lastly, an interesting observation from Graph 1 is that many projects focused on efficiency. These types of projects do not look at the construction of plants but concentrate on the efficient use of the power that is generated. Examples of the entries in this field include HYXchange, an exchange platform for the generated hydrogen, and the Exchange platform Distro. This shows that the Port Authority is not only working on supplying newly generated energy sources or use of raw materials but is also focusing on the following steps in the distribution of the supply and the practical use of these innovations.

While the Port Authority has been working towards reaching the goal, 2050 is still some time away. However, as was mentioned in the Annual Report of the Port of Rotterdam, setting up a new construction project or collaborative investments into green energy provision takes a lot of time. This is why the pipeline stages of the current projects in the port of Rotterdam give an interesting insight into how far the Port Authority is looking into the future and working towards new projects that can be connected to those currently being developed or further lower the CO_2 emissions. Graph 2 shows this information with a four-stage division; orientational, preparational, in progress, or operational.

Graph 2

Progress of the projects in the Port of Rotterdam



Graph notes: The left side of the graph shows the amount of projects that are categorized in each one of the four stages. Projects in progress are those projects that are currently being constructed or set up. Operational projects are those projects of which the construction is finished and it is up and running. Projects in the Preparatory phase are those projects for which construction has not yet started, but to have a concrete outlook on when it will start. Those projects that are considered orientational do not yet have a plan to start construction in place at the moment.

What can easily be seen from Graph 2, is that the amount of projects that have already been finished and are now in progress is relatively similar to the amount of projects that are in a preparational phase. One extra project that is currently in the preparational phase shows that the Rotterdam Port Authority has not yet stopped its initiatives and acts accordingly to what has been mentioned previously in the Annual Report. Next to that, the relatively high amount of projects that are still in the orientation phase can be explained by the fact that all these projects

are taken up with partners, which typically comes with a rather long timeline before the investment decision is concluded and the actual construction or setup of the project can start. The fact that there is a relatively large amount of projects currently operational also shows that the Rotterdam Port Authority has been effective in promoting and actualizing the reduction of CO_2 emission reduction initiatives.

As stated previously, the Rotterdam Port Authority collaborates with many partners on the projects in the port. Due to the landlord function of the Port Authority, this seems like a logical approach, as many of the actual activities in the port are not carried out by the Authority. It is therefore interesting to analyze to what extent these projects are a collaborative effort with private or public partners. The shares of each type of partnership can be observed in Table 2.

Table 2

Partners of the projects in the Port of Rotterdam

	Amount
Private Sector	21
Public Sector	6
Total	27

Table Notes: A project is classified as being set up with public sector partners if the partner is a province, a municipality, or the national government or if the partner is fully owned by one of these parties. All other partners are classified as private-sector partners.

The division as displayed in Table 2 shows that a large share of the projects are partnered with parties in the private sector. This is no surprise when we look at the landlord function of the Rotterdam Port Authority. This means that private parties often are in charge of the actual activities that take place in the port. In the Annual report, the Port Authority also mentioned that it wished to continue to incentivize its clients' innovations (Port of Rotterdam, 2023). Table 2 shows that the Port Authority has succeeded in creating a positive environment in the port concerning attracting useful projects. The projects that are partnered with the public sector typically are those projects that have a direct impact on those partnered with it, like the Warmtelinq partnered with the province of Zuid-Holland. An interesting element regarding this matter is that three out of the six projects partnered with the public sector are projects with Gasunie N.V., a private company fully owned by the Dutch state, thus being classified as public for this thesis.

All in all, the three figures presented in this section illustrate that the Rotterdam Port Authority does not make empty promises as they are active in its pursuit of new projects as well as continues building on previous projects. In the Annual report and the Sustainability Strategy, we can observe that the Port Authority has noted the importance of collaborating with its clients as well as making sure that there are sufficient projects in the pipeline across a wide variety of sectors present in the port. When we compare this to what the figures show us it can thus be concluded that the Port Authority focuses its projects in many different sectors, chiefly partners with its clients in the private sector, but also with the public sector, and is completing current projects as well as having many in their preparatory stage. Based on the insights given by the dataset, we can thus conclude that the Rotterdam Port Authority takes the Net Zero goals seriously and is working actively to reach them.

5.2 Investments and Projects in the Port of Hamburg

5.2.1 The Annual Report and the Sustainability Strategy

The Hamburg Port Authority has clear ambitions, and with that also a clear plan. Next to the annual report, the Port Authority has published a detailed development plan. This plan includes all the steps that the Port Authority intends to take to reach the goal of a Net Zero port in 2040 (Port of Hamburg (B), 2023). In its Sustainability strategy, the Hamburg Port Authority refers to the COVID-19 pandemic and the war in Ukraine to emphasize that creating a reliable port of the future that is resilient to challenges that might come ahead is a clear goal (Port of Hamburg (B), 2023, pg 2). Following the views of the Port Authority, one of the main ways this is done is through creating a port that has reached Net Zero emission in 2040 (Port of Hamburg (B), 2023, pg. 4). The focus is stated to be on combining economic success with carbon neutrality and environmental sustainability (Port of Hamburg (B), 2023. pg. 12).

The transition to new energy sources is the main way that the Hamburg Port Authority aims to achieve Net Zero carbon emissions in 2040 (Port of Hamburg (B), 2023, pg. 13). The two specific measures that are mentioned in the development plan are actualizing a large reduction in emission through the providing shore power for container, inland and cruise ships. When we link this goal to what we can observe in the operational implementation of the plan we see that this measure will mainly look at the expansion of the current shore power plants that are already installed and the construction of this technology at new locations in the port (Port of Hamburg (A), 2023, pg. 32). The second measure that is mentioned is the fact that the Hamburg Port Authority will start working on the development of the port to become a hydrogen hub in Europe (Port of Hamburg (B), pg. 14). The way that this is aimed to be implemented is through increased

investments into this sector, this includes the construction of an electrolysis plant as well as link with customers for green hydrogen (Port of Hamburg (B), pg. 35).

In the Annual Report of the HHLA, the executive branch of the Port of Hamburg, we see that there is an acknowledgment of the progress that has already been made with the sustainability efforts and the ambition to continue this line (HHLA Annual Report, 2023, pg. 9). The transformation of the port is based on four pillars in their eyes; making the port fit for the world of tomorrow, making investments that will result towards sustainable growth, exploiting additional growth areas and aligning the organization with these goals (HHLA Annual Report, 2023, pg. 50).

These guidelines can directly be linked back to what is seen in the strategy document, which thus shows that at least on paper there is a clear consensus between the steps that have to be taken to reach a Net Zero port in 2040. The following section will take a deep dive into the projects that are in the works and assesses if this alignment is also reached regarding practical application.

5.2.2 Results for the Port of Hamburg

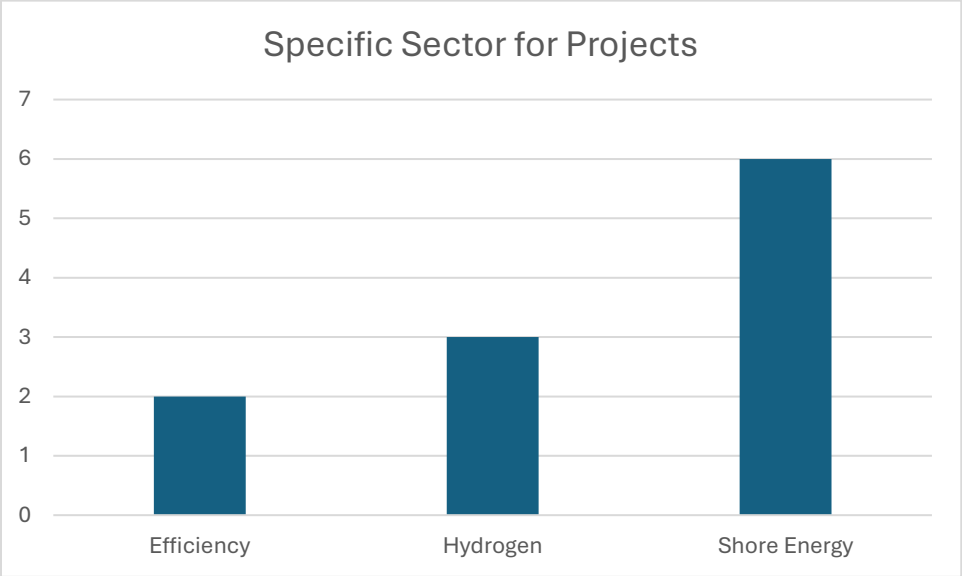
As stated in section 4, for the Port of Hamburg eleven projects have been collected that can be categorized in either the sector of energy renewal or the renewed use of raw materials. All of these projects have been selected because the Port Authority mentioned them to be set up with the intent of reaching Net Zero. Graph 3 provides an overview of the different sectors that are transitioning to become more sustainable due to the projects. From the previous section, as well as the case studies presented in Section 3, we have already seen that the Hamburg Port Authority has been actively transitioning to become more sustainable for a while now and that select groups of sectors are still being targeted.

Graph 3 shows that there is a rather large focus on Shore Energy. This can be explained by the fact that already since 2016 the Port Authority has been developing and innovating Shore Energy, which has thus turned into a very efficient and green supply of energy for the port (Port of Hamburg, 2023). Next to that, following the Sustainability Report and its practical operation we can also see that the Hydrogen Sector has more recently also picked up the interest, as it can be seen that similarly to in the Port of Rotterdam, the Hamburg has also noted that hydrogen is turning into one of the crucial industries to effectively speed up the decarbonization of the port and that it will be a key factor for the future in the port industry as well (Port of Hamburg (A), 2023). This thus explains why the hydrogen sector is also on the rise. In line with what we have seen in previous sections, the third and last sector that the Hamburg Port Authority focuses on is

the efficiency of the implementation of earlier innovations and the ease with which the main activities can be practically used to lower CO2 emissions and reach Net Zero.

Graph 3

Specific Sectors for Projects in the Port of Hamburg

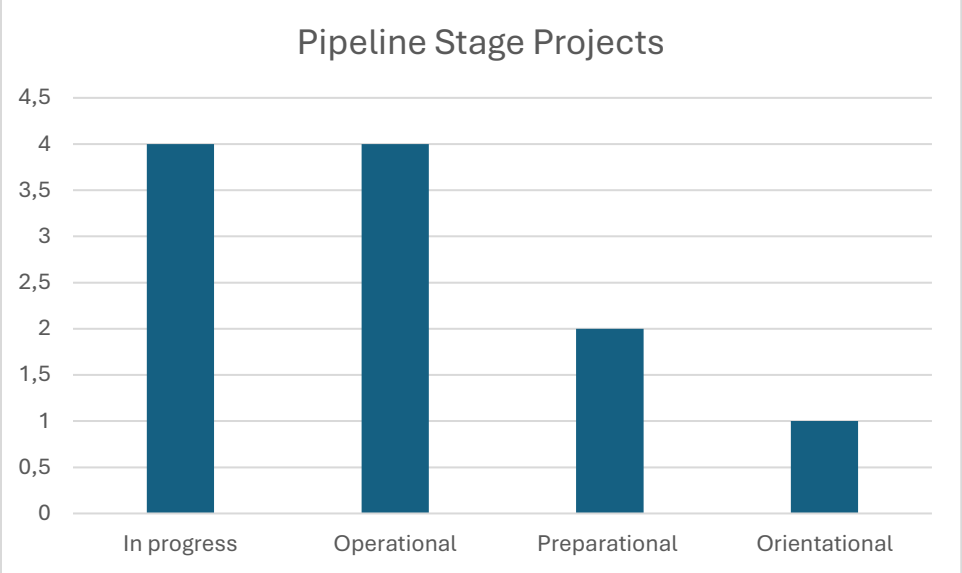


Graph notes: The left side of the graph shows the amount of projects that are classified into the specific sectors mentioned. There is differentiation into different sources for energy provision, hydrogen-oriented projects, and projects that focus on the efficient use of the innovations.

The Hamburg Port Authority has proclaimed to be even more ambitious than what the Paris Agreement states and wishes to be fully Net Zero by 2040. While there have been continuous investments to reach this goal over a long period, it is also the case that this has not been reached yet. To reach this, more projects will have to be concluded. Graph 4 displays the pipeline analysis of the project currently in present in the Port of Hamburg. Similarly, as to Graph 2, the information will be shown in the preparational, operational, orientational, and in-progress stages.

Graph 4

Progress of the projects in the Port of Hamburg



Graph notes: The left side of the graph shows the amount of projects that are categorized in each one of the four stages. Projects in progress are those projects that are currently being constructed or set up. Operational projects are those projects of which the construction is finished and it is up and running. Projects in the Preparatory phase are those projects for which construction has not yet started, but to have a concrete outlook on when it will start. Those projects that are considered orientational do not yet have a plan to start construction in place at the moment.

Graph 4 shows a notably lower amount of projects currently are in the preparing and orienting phase than in progress or operational, which can be explained by the fact that Hamburg has such a long history of creating a more sustainable port and thus has many projects already concluded before 2020 and thus outside of the scope of this thesis. None of the projects that are related to the hydrogen industry are currently operational, which further underlines that the Port Authority only rather recently has included this sector and expanded the green energy innovations past solutions such as wind and shore energy. Regarding the Shore Energy projects, except for the expansion project, all are expected to be finished in 2025, making it so that all corners of the Port of Hamburg will be supplied with Shore Energy. Graph 4 shows that the Hamburg Port Authority is currently actively working hard to construct all the Green energy power supply points and further expand into the Hydrogen sector.

The Port of Hamburg can be categorized as a public sector port, as it owned as well as actively operates under the public sector (Port of Hamburg, nd). While there are private parties, such as Air Products active in the port, all of the main activities are under the umbrella of different public parties. This is a contrast with the governance of the Port of Rotterdam and this makes it

interesting to see how many of the projects are partnered with public institutions, that are shown in Table 3.

Table 3

Partners of the projects in the Port of Hamburg

	Amount
Private Sector	2
Public Sector	9
Total	11

Table Notes: A project is classified as being set up with public sector partners if the partner is a province, a municipality, or the national government or if the partner is fully owned by one of these parties. All other partners are classified as private-sector partners.

As can be expected, the majority of the projects in the Port of Hamburg are set up with the public sector. This is in line with the operations of a public sector port, as these would be mostly executed by the public sector. When taking a closer look into the dataset it can be seen that all of the projects that are focused on Shore Energy, currently the most popular sector as displayed in Graph 3, are set up in partnership with the Federal Government. This shows that the Hamburg Port Authority has effectively taken the necessary steps to reach its goal of Net Zero with rather little interference from the private sector. It has developed the green energy provision fitting to the needs of the Port of Hamburg mainly with the contributions of the Federal Government. The projects that have been set up with the private sector are split between the other three sectors that we have seen in Graph 3.

From this section, it can be concluded that the Hamburg Port Authority has a clear focus and ambition that guides the road to reaching Net Zero emissions. When we look at the Development Plan and the Annual report, we see that three concrete measures have been identified that need to be implemented to reach the 2040 goals. The investments that are considered to be necessary for the hydrogen sector, as well as the shore energy sector, are seen in practice as well, as illustrated by Graph 3. Next to the projects being targeted into these sectors, we also see that the division between projects in the pipeline is about equal and thus shows a good spread of projects still to be implemented. Lastly, the large collaboration with the public sector also seems to be fitting for the governance of the port. All in all, we thus see that the dataset aligns with the clear goal and plan that is communicated by the Hamburg Port Authority.

5.3 Comparative Analysis

In the previous two sections, the Port of Hamburg and the Port of Rotterdam have been analyzed based on the dataset that was constructed. This analysis has been based on three topics the sectors, the pipeline, and the partners. In the following section, the views that have been presented in 5.1 and 5.2 will be combined in order to compare the Port of Rotterdam and the Port of Hamburg. One important note for this comparison is that there are great differences and in order to look at these differences it is important to understand that these Port Authorities do not operate in the same way. The Port of Rotterdam was identified as a landlord port and the Port of Hamburg was identified as a public-sector port, this makes it so that the choices that would best fit the ports are different.

Table 4 shows a comparison of the different sectors that have been targeted by the projects that are initiated by the Rotterdam and Hamburg Port Authorities. This shows a clear overview of the priority sectors and the differences between these priorities

Table 4

Specific Sectors for the Projects

	Port of Rotterdam	Port of Hamburg
Efficiency	5	2
Electricity	4	0
Hydrogen	7	3
Recycling	2	0
Shore Energy	1	6
Solar Energy	1	0
Waste Heat	1	0
Wind Energy	6	0
Total	27	11

Table Notes: The information in the table is descriptive of the number of entries in the dataset for both the Port of Rotterdam and the Port of Hamburg. The differentiation of the categories is similar as those that can be observed in Graph 1 and Graph 3.

Next to the differences in the number of projects that are present in the ports, it is clear that both of the ports focus and want to focus on Hydrogen. As stated in the previous section both of the Port Authorities aim to become a hydrogen hub in Europe and they both underwrite the necessity of Hydrogen for the energy transition and lowering the carbon emissions. When looking at the Port of Rotterdam we see that next to focusing on developing the hydrogen sector,

we can also observe the act of diversification. Multiple different green energy sources are being developed in order to create a stable supply. Specialization seems to be the aim of the Hamburg Port Authority, as there are only two main energy provision sectors that are being actively developed to lower carbon emissions. While the approaches that have been chosen are thus different, both of the ports seem to have found a fitting strategy that complements the activities present in the port and the demand for the sectors that are being developed.

The second topic to be discussed is the differences in projects in the pipeline. Table 5 outlines the division between the number of projects in progress, operational, preparational, and orientational. This difference provides insight into the planning and the actual construction that is happening in the ports and hence showing how actively the ports are thinking ahead.

Table 5

Pipeline Stages for the Projects

	Port of Rotterdam	Port of Hamburg
In progress	4	4
Operational	11	4
Preparational	5	2
Orientational	7	1
Total	27	11

Table Notes: The information in the table is descriptive of the number of entries in the dataset for both the Port of Rotterdam and the Port of Hamburg. The differentiation of the categories is similar to those that can be observed in Graph 2 and Graph 4.

Table 5 shows that both ports are not staggering in creating new projects and that combined with actually having developed the initiative to lower the carbon emissions there is an active look into the future as well. The Rotterdam Port Authority has a rather little share of the projects in the actual construction phase. This however is in line with the statements in the Annual Report that highlight the longevity of creating such projects and making the actual investment decisions. Next to that, it also highlights that it is necessary to have a rather large share of projects in the preparational and orientational phase because after the actual progress is made, there still needs to be a look into the future. On the other hand, the view created by the Hamburg Port Authority's projects fits with their ambition of specializing in the industry of shore energy and hydrogen energy. Because of this specialization, the next steps can only happen once the previous projects have been concluded and thus it is to be expected that Table 5 shows a rather even division.

The last topics to be compared are the project partners and their backgrounds. Table 6 gives the overview that combines the views of Table 2 and Table 3 and thus highlights the contrast that is created by comparing Hamburg and Rotterdam.

Table 6

Partners of the projects

	Port of Rotterdam	Port of Hamburg
Private Sector	21	2
Public Sector	6	9
Total	27	11

Table Notes: The information in the table is descriptive of the number of entries in the dataset for both the Port of Rotterdam and the Port of Hamburg. The differentiation of the categories is similar to those that can be observed in Table 2 and Table 3.

A clear contrast can be found between the majority of the partners of the Rotterdam Port Authority and the Hamburg Port Authority. Table 6 shows that the governance of a port is very much of an influence on the partners and thus the strategy that is chosen to reach Net Zero in 2050. In Rotterdam, we can see that many private partners, which are often the clients of the Port Authority, are contributing to and collaborating on the initiatives that are put forward. On the other hand, in Hamburg, we note that the majority of the projects are taken up in partnership with other public parties. This aligns with the categorization of the port as a public-sector port. These views thus show that the strategy differs and that the actualization differs, however, this is also in line with the nature of the port and thus of the activities that need to be transitioned by the port. The note must also be made that the projects that are started and executed solely by private partners without interference from the Port Authority are not regarded in this thesis and thus the view of Table 6 has considered only those actions taken by the Port Authorities.

All in all, there are some clear differences between the strategies that the Rotterdam and Hamburg Port Authority have chosen to reach Net Zero by 2050, with the strategy of the Hamburg Port Authority aiming to reach this goal already by 2040. The differences can be observed over all three of the topics that have been discussed. Not only do the total amount of projects vastly differ, but also the partnering sectors, the industries targeted, and the pipeline division are very different. Nevertheless, this does not imply any issue for either port. We can see that both of the Ports chose a different road, where the Hamburg Port Authority has a very clear and concise plan and focuses on specializing in two main ways of green energy provision, while the Rotterdam Port Authority leans more towards a combination of specializing in hydrogen, but

also diversifying towards other green energy sources. The most pressing goals for both of the ports are colored by the activities that take place in the ports and therefore both fit well.

6. Conclusion and Discussion

Since the Paris Agreement was reached, achieving Net Zero goals has been a hot topic, not only in academia but also among businesses and consumers. The first part of this thesis has shown that although there is a strong legal framework in place in the EU, companies, more specifically ports, also have an intrinsic motivation to become more sustainable and lower their carbon emissions. Not only did many ports adopt a sustainability strategy, but it became essential to have one, as it ensured its clients that the port is focused on its stability and its stakeholders. The literature review has shown that the implementation of EU taxonomy has led to positive actions like increased transparency and an even higher amount of investments to put the sustainability strategy into practice.

When looking specifically at the Port Authority for Rotterdam and Hamburg through the case studies in the second part of the thesis, it can be concluded that both hold an active stance in forward-thinking regarding reducing their CO_2 emissions. The Port of Rotterdam's structure and the active participation of the government allow it to change policy to include the public interest quicker than when it would have been fully privately owned, concerning the discussion of shareholders. Its structure is presumed to be incentivizing the development of new technologies as well as focusing on a specialization towards the hydrogen sector. We observe that the Hamburg Port Authority has focused on specializing in Shore Energy to set up a reliable green energy system in the port. As one of the first ports to focus on green development, this currently is a well-established sector and the focus moving forward is observed to be on using this efficiently and expanding the current system.

The third part of this thesis is based on the constructed dataset on projects currently present in the Port of Rotterdam and the Port of Hamburg that focus on reaching Net Zero by 2050. This was constructed to answer the main research question:

'How do the two largest ports in Europe differ in their strategy to approach Net Zero goals, mainly focusing on the differences in investments into green energy sources and the renewed use of raw materials ?'

Interestingly, the results of the research showed many aspects that align with what was found in the case studies. It was observed that the Rotterdam Port Authority aims to specialize the port in

the hydrogen sector and that there is a lot of collaboration with private parties, thus incentivizing them to participate in the energy transition. The results also confirmed the conclusions for Hamburg Port Authority based on the case studies. It is outlined that the Shore Energy Sector is one of the main topics in the transition for the Hamburg Port Authority and that there is a rising interest in hydrogen.

The subjects that were present in the research did not include the actual amounts of CO_2 emissions that would be compensated or reduced due to the projects and it did also not include the costs of each project. This is because, while the data was traceable for some of the projects in the database, there were not sufficient public sources to find this information for all projects. Therefore, the choice was made to exclude these aspects to make a valid comparison between the Rotterdam and Hamburg Port Authorities. Nonetheless, research including these missing topics would be an interesting addition that would provide a more complete overview of the current situation.

Next to that, it must me noted that this thesis solely focuses on a small subset of the total amount of projects being performed within the premises of a port. Different categories such as infrastructure and digitalization are not regarded in this thesis, while projects focused on these sectors could also have a substantial influence on reaching Net Zero by 2050. To be able to draw a conclusion based on the full effort of the Port Authorities, further research into this field would be advisable.

With that being said, the focus of this research is on the topics of active energy transition and the renewed use of raw materials projects that are set up to reach the goal of Net Zero by 2050, in the case of the Port of Hamburg even 2040. What can be concluded from the research, is that both of the ports discussed have chosen different strategies to reach this goal. This different strategies leads to not only a large difference in the number of projects currently in the pipeline but also the partners and the topics that are prioritized.

These differences can however be ascribed to the inherent difference in the port structure making the chosen strategies a good fit for each of the ports. The research has shown that the Rotterdam Port Authority focuses more on partnering with private companies, while Hamburg focuses on public partners. Next to that, both of the ports have a focus on developing in the hydrogen sector, but we note that the Rotterdam Port Authority diversifies around this focus, and the Hamburg Port Authority is leaning toward specialization in this sector, after having specialized in Shore Energy. Lastly, the Hamburg Port Authority has a rather even division of projects in the four pipeline stages, while in the Port of Rotterdam, there are a lower number of

projects currently in progress and more either already operational or being planned for the future. Although there are big differences, both of the ports are well on their way to reach their goals. They both take a proactive stance on the transition and work not only based on what is necessary in terms of legal compliance but also take the extra steps and take their responsibility.

7. Annex 1: The Dataset

Name of the project	Responsible Authority	Main partner 1	Partner Sector	Start	(expected) Finish	Targeted sector	Specific type	Pipeline Stage
Net op Zee Ijmuiden Ver Beta	Port of Rotterdam	TenneT	Private	2024	2029	Energy Renewal	Wind energy	Preparational
Net op Zee Nederwiek 2	Port of Rotterdam	TenneT	Private	Undecided	Undecided	Energy Renewal	Wind energy	Orientational
Net op zee Ijmuiden Ver Gamma	Port of Rotterdam	TenneT	Private	2024	2029	Energy Renewal	Wind energy	Preparational
Offshore net Zuidhollandse Kust	Port of Rotterdam	TenneT	Private	2022	2023	Energy Renewal	Wind Energy	Operational
Warmteling	Port of Rotterdam	Gasunie	Public	2022	2027	Energy Renewal	Waste heat	In progress
Windpark Maasvlakte 2	Port of Rotterdam	Eneco	Public	2022	2022	Energy Renewal	Wind energy	Operational
HyNetwork	Port of Rotterdam	HyNetwork Services	Private	2020	2025	Energy Renewal	Hydrogen	In progress
Delta Rhine Corridor	Port of Rotterdam	Gasunie	Public	2032	2035	Energy Renewal	Hydrogen	Orientational
Uitbreiding Sif	Port of Rotterdam	Sif Group	Private	2020	2021	Energy Renewal	Wind energy	Operational
New Energy Taskforce	Port of Rotterdam	Tennet	Private	2023		Energy Renewal	Efficiency	Operational
Walstroom	Port of Rotterdam	Gemeente Rotterdam	Public	2023	2024	Energy Renewal	Shore Energy	In progress
Zon op de slufter	Port of Rotterdam	Rijksoverheid	Public	undecided	undecided	Energy Renewal	Solar energy	Orientational

Waterstof Taxi	Port of Rotterdam	Watertaxi	Private	2020	2022	Energy Renewal	Hydrogen	Operational
TRE	Port of Rotterdam	Truckparkings Rotterdam Exploitatie	Private	2022	2024	Energy Renewal	Electricty	Operational
Exchange platform renewable energy	Port of Rotterdam	Distro Energy	Private		2023	Energy Renewal	Efficiency	Operational
H2Maasvlakte	Port of Rotterdam	Uniper	Private	2025	2030	Energy Renewal	Hydrogen	Preparational
Load pocket Amalia haven	Port of Rotterdam	Tennet	Private	2023	2027	Energy Renewal	Electricty	Preparational
HYXchange	Port of Rotterdam	Gasunie	Public	2020	2022	Energy Renewal	Efficiency	Operational
TES Battery recycling	Port of Rotterdam	TES	Private	2021	2023	Renewed raw materials	Recycling	Operational
Load pocket Europort	Port of Rotterdam	Tennet	Private	Undecided	Undecided	Energy Renewal	Electricty	Orientational
Xclye, plastic recycling	Port of Rotterdam	Xclycle	Private	2022	2024	Renewed raw materials	Recycling	In progress
Ampliphy from VTTI	Port of Rotterdam	VTTI	Private	2022	2028	Energy Renewal	Hydrogen	Preparational
Fieldlab electrification	Port of Rotterdam		Private		2021	Energy Renewal	Efficiency	Operational
Air products hydrogen tanking	Port of Rotterdam	Air Products	Private	2022	2023	Energy Renewal	Hydrogen	Operational
SPERAHydrogen	Port of Rotterdam	Chane	Private	Undecided	Undecided	Energy Renewal	Hydrogen	Orientational
Advario	Port of Rotterdam	Advario	Private	2025	Undecided	Energy Renewal	Efficiency	Orientational
Loadpocket Simonshaven	Port of Rotterdam	Tennet	Private	undecided	undecided	Energy Renewal	Electricty	Orientational

Green4 Transport	Port of Hamburg	Scannia	Private	2020	2022	Energy Renewal	efficiency	Operational
Mozart	Port of Hamburg		Public	2020	2021	Energy Renewal	efficiency	Operational
Shore power Burchardkai	Port of Hamburg	Federal Government	Public	2020	2023	Energy Renewal	Shore Energy	Operational
Shore power Eurogate	Port of Hamburg	Federal Government	Public	2020	2023	Energy Renewal	Shore Energy	Operational
Shore power Tollerort	Port of Hamburg	Federal Government	Public	2020	2023	Energy Renewal	Shore Energy	In progress
Shore power Steinwerder	Port of Hamburg	Federal Government	Public	2020	2024	Energy Renewal	Shore Energy	In progress
Shore power Hafencity	Port of Hamburg	Federal Government	Public	2020	2025	Energy Renewal	Shore Energy	In progress
Shore power Altenwerder expansions	Port of Hamburg	Federal Government	Public	Undecided	Undecided	Energy Renewal	Shore Energy	Orientational
Moorburg	Port of Hamburg	Hamburger Energiewerke	Public	2026	2030	Energy Renewal	Hydrogen	Preparational
HH-Win hydrogen Net	Port of Hamburg	Gasnetz Hamburg	Public	2024	2030	Energy Renewal	Hydrogen	Preparational
Amonia to Hydrogen cvonversion plant	Port of Hamburg	Air Products	Private	2022	2026	Energy Renewal	Hydrogen	In progress

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