FROM TENDERS TO TURBINES: the limits and potentials of forecasting offshore wind farm development in Denmark using temporal indicators in public project timelines

IN COLLABORATION WITH

PORT OF AALBORG

gate to great

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"See you Monday."

That’s what we’d say to each other on Fridays, not because we were going anywhere, but because we worked opposite shifts all weekend. Living together, studying together, writing a thesis together… and yet, often just passing each other by. Still, we made it work. Not perfectly, but with care, effort and commitment.

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Abstract

This study investigates whether early-stage administrative indicators, specifically government tenders and permitting activity can be used to anticipate the development of offshore wind projects in Denmark. The research was motivated by an initial meeting with the Port of Aalborg, where representatives noted the absence of an in-house data science department but expressed interest in exploring whether offshore wind development could be tracked using publicly available data, particularly to understand if storage needs for turbine components could be anticipated ahead of construction.

To address this challenge, a qualitative case study approach was used, examining six Danish offshore wind projects. Public data on project milestones were manually collected and structured into a three-part temporal model: Tender to Permit (T2P), Permit to Construction (P2C), and Construction to Operation (C2O). Scenario planning and Flyvbjerg's theory of megaprojects were applied to interpret the behavior of these indicators under different political and institutional conditions.

Findings show that government tenders are reliable indicators of intent but are frequently disrupted by regulatory delays, legal appeals or strategic overpromising. Permitting activity, while less consistent in timing, proved to be a stronger predictor of actual project execution. The T2P phase exhibited the highest variability, making it a critical risk period for infrastructure planners. Once permits are secured, P2C and C2O intervals follow more stable and actionable timelines.

The study concludes that forecasting in offshore wind development is less about observing data points and more about interpreting how administrative indicators behave within broader institutional contexts. A scenario-based framework is recommended for ports and infrastructure planners to adapt logistics readiness based on signal strength and political momentum. The temporal model and case-based analysis offer practical tools for identifying early project risks and improving decision-making under uncertainty.

Keywords: offshore wind, forecasting, tenders, permits, scenario planning, Port of Aalborg, storage, megaprojects

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1 Introduction

In the offshore wind industry, announcements are easy. Execution is not. Every few months, new gigawatts are promised, maps are redrawn and bold political targets are declared. But for infrastructure actors like the Port of Aalborg, who must turn these ambitions into physical logistics, the real question is not *what* is being planned, but it's *when* it will actually happen. This thesis asks whether the future of offshore wind can be forecasted with any degree of confidence. Not by relying on speculative policy goals or after the fact updates, but by analyzing early, formal indicators embedded in the development process, more particularly government tenders and permitting activity. These are not PR headlines. They are timestamped, project-specific and legally binding steps in the offshore wind lifecycle. In theory, they should provide a strategic edge to planners trying to anticipate demand before it arrives. But theory rarely survives contact with politics, legal systems or public resistance.

To explore these questions, we looked at how offshore wind projects unfold. Using project timelines, permitting records and scenario analysis to understand what early indicators can (and cannot) tell us. Rather than building a new theory, we worked with what's already visible: official milestones, public data and the patterns hidden between them. The goal is not just academic insight, but actionable intelligence, helping infrastructure planners move from reactive logistics to proactive readiness.

1.1 Research questions and problem statement

As Europe accelerates its transition to green energy, ports are becoming essential logistical centers for the development of offshore wind projects, playing a key role in storing, preparing, and transporting turbines, blades and other components within tight and often unpredictable timelines. For the Port of Aalborg, this shift presents not only a strategic opportunity but also a planning challenge: how can a port without a formal data analytics department anticipate offshore wind activity early enough to align infrastructure and capacity decisions with actual project needs?

This thesis was developed in collaboration with the Port of Aalborg, which has expressed growing interest in exploring how publicly available data might be used to improve logistical forecasting. At present, the port relies primarily on direct communication with developers and broad policy targets. However, it offers little visibility into when specific offshore projects will actually begin to require space, labor or logistics support.

The central problem is that while wind farms are often discussed in ambitious terms with megawatt targets and political endorsements, their development is shaped by administrative indicators that are less visible, less standardized and often unpredictable. From a planning perspective, this uncertainty introduces a significant risk: the port may overcommit resources to projects that are delayed or never realized or miss critical readiness windows for those that advance unexpectedly.

What is missing is a structured method for identifying which early-stage indicators actually reflect momentum and how consistently they can be used to anticipate actual activity. This gap sits at the intersection of data interpretation, infrastructure readiness and institutional trust. Addressing this issue could strengthen the port's ability to prepare for future developments and provide a useful approach for other infrastructure actors facing similar changes.

This ambition is expressed through the following research questions:

RQ1:

To what extent can the development of offshore wind projects in Denmark be forecasted using early administrative indicators such as government tenders and permitting activity?

> 1.1. Which early-stage indicators are most reliable and publicly traceable for forecasting offshore wind project development?
>
> 1.2. How do the durations and variability of key development phases (e.g. tender to permit, permit to construction) affect the forecasting of project timelines?
>
> 1.3. How do political, regulatory and stakeholder dynamics influence the reliability of these early indicators under different future scenarios?

RQ2:

How can infrastructure planners, such as the Port of Aalborg, use these indicators to improve forecasting and scenario-based planning?

> 2.1. How do scenario planning and temporal signal modeling help ports anticipate storage needs and adapt to uncertainty?
>
> 2.2. How do external factors (e.g., legal appeals, public opposition, market conditions) disrupt the predictive value of otherwise strong indicators?

Terminology clarification:

This thesis uses the term *indicator* to refer to early-stage, project-specific events such as government tenders and permitting activity that can be tracked to anticipate offshore wind development. These indicators are considered observable, legally documented steps in the project lifecycle and serve as inputs for forecasting and strategic planning. In some sections, the term *signal* is used descriptively to highlight how indicators may function as early warnings or directional clues. However, in all analytical contexts, the two terms are used interchangeably, with *indicator* preferred for consistency and clarity.

Similarly, while *forecasting* is used throughout this thesis to describe the structured, data-informed estimation of future developments, related terms such as *predictable* or *prediction* may occasionally appear in descriptive contexts. These are used to refer to the observed behavior of certain project phases such as a “predictable interval” between permitting and construction rather than to suggest an informal or intuitive forecasting method. In all methodological and analytical contexts, however, *forecasting* is preferred to emphasize the systematic, indicator-based approach applied in this study. This distinction is particularly relevant in the context of infrastructure planning, where decisions must rest on observable signals rather than speculative assumptions. Forecasting in this study is not about achieving precise certainty but about constructing plausible development trajectories based on milestone timing, such as the intervals between tenders, permits and construction starts.

2 Theoretical background

Forecasting the development of new wind farms is a complex challenge that requires insights from multiple disciplines, particularly business intelligence, logistics and data science. This theoretical background explores existing research on predictive analytics, wind farm development processes and stakeholder decision making, providing a foundation for understanding how data-driven approaches can be applied in this context.

A comprehensive understanding of the industry landscape, including the roles of wind farm developers, original equipment manufacturers (OEMs) and ports, is crucial for identifying the factors that drive new wind farm projects. Equally important is a thorough knowledge of the wind farm lifecycle, as it reveals key events and indicators that indicate when and where a new project is likely to emerge. These signals can range from government tenders and environmental approvals to shifts in supply chain activities and job postings from major industry players. Recognizing these patterns is critical for anticipating future developments and enabling data-driven business strategies.

This theoretical background will examine the key industry players and the full lifecycle of wind farm projects. Rather than developing a predictive or forecasting model, the goal is to explore how existing methods and observable indicators can support practical forecasting and strategic interpretation in offshore wind development, ultimately allowing ports to refine their business strategies and proactively target future customers in the wind energy sector.

2.1 The wind farm development process: from conception to commissioning

Developing a wind farm is a structured, multi-phase process that moves from early planning to full operation. According to the American Wind Energy Association (AWEA), the process typically begins with high-level project planning and moves through stages such as site identification, permitting, financing, construction and commissioning. For the purpose of this research, understanding this process is essential because each phase contains key events such as government tenders and permit approvals that can serve as early indicators of future development activity.

One of the first formal signals in the development process is the publication of a government tender, which shows the formal intent to open a site for offshore wind development (European Commission, 2020). Once awarded, the developer begins preparing for the project, starting with the permitting phase, which includes regulatory approvals such as environmental impact (European Commission, 2023).

After tenders and permits, the next steps include arranging financing and planning the supply chain. This involves working with equipment suppliers and port operators. At this stage, logistics planning also begins, covering how and when components will be stored, transported and installed. These decisions rely heavily on knowing the project timeline in advance, which is why the timing and reliability of tenders and permits matter so much.

Construction then follows, involving turbine foundation installation, cable laying and grid connection. The project ends with commissioning, when the wind farm begins producing electricity and enters the operational phase. While later stages, such as maintenance and repowering are important from an engineering perspective, they are outside the scope of this research, which focuses on the earlier stages where observable development indicators can be seen.

In conclusion, tenders and permits are the most visible and relevant indicators of progress in the offshore wind project lifecycle. The **Figure 1** shows the visual timeline of windfarm development.

Figure 1. Danish offshore windfarm development

Note. Adapted from *Timeline of an Offshore Wind Farm*, by Caledonia Offshore Wind Farm.

2.2 Planning vs. reality in wind farm projects

Although offshore wind development is often discussed in terms of energy policy, technical innovation or environmental planning. But at their core, they are also large infrastructure projects. This means they face many of the same challenges, risks and complexities that are common to other megaprojects, such as bridges, airports or metro systems. Looking at offshore wind from this angle helps explain why early signs of progress can be unreliable, why plans need to stay flexible and why delays happen so often.

In his work, Flyvbjerg (2014) highlights how megaprojects, usually those costing more than one billion dollars and taking several years to complete, frequently experience significant delays and go over budget. He argues that these issues are not primarily the result of technical issues.

He explains that project developers often underestimate the complexity of large-scale developments in a way that they overemphasize the level of certainty in planning and outcomes and assume that coordination will proceed smoothly. These tendencies are often seen in both public and private sector projects but are particularly emphasized in politically driven and publicly funded infrastructure initiatives. And offshore wind farms in Denmark show several of these characteristics.

By applying Flyvbjerg's framework, this thesis views offshore wind not just as a product of energy transition but as a process embedded in megaproject dynamics. This perspective helps explain why early signals such as government tenders do not always lead to construction and why permitting delays can undermine otherwise well-planned projects. It also supports the need for forecasting approaches that are not deterministic but adaptive, capable of accounting for institutional friction and planning complexity.

Seeing wind farm development as a type of megaproject changes the focus from only making technical forecasts to also considering broader strategic factors. It encourages tracking key signals by acknowledging that uncertainty is not necessarily a planning mistake but a normal part of delivering large and complex infrastructure.

2.3 Scenario planning framework

Scenario planning is a strategic tool used to explore and prepare for multiple expected futures under conditions of uncertainty (Schoemaker, 1995). Originally developed in military and energy contexts during the Cold War the method has since evolved into a widely adopted approach in business and public policy to support long-term thinking. Unlike traditional forecasting methods, which usually use past data or probabilistic models, scenario planning takes a different approach that focuses on understanding how various external drivers and uncertainties might shape future developments in different directions. As emphasized by Schoemaker (1995), scenario planning does not seek to predict a single most likely outcome but create a few well-structured and realistic scenarios that illustrate how the future might unfold under different assumptions. These scenarios help organizations to consider a broader range of possibilities, detect early warning signals and test the resilience of strategies in diverse situations. This approach helps improve flexibility, supports better adaptation and improves the quality of long-term decisions.

Scenario planning is helpful in fields like offshore wind where projects take many years to develop which require large investments and involve many different stakeholders. The development process often includes many important steps such as government tenders, environmental permitting and large-scale infrastructure coordination. These steps depend heavily on political decisions, clear regulations and market conditions, all of which are subject to change and hard to predict. In this context, where accurate forecasting is difficult and planning must occur well in advance, scenario planning offers a structured way to consider how different external factors might influence future outcomes. Rather than offering a final forecast, the method helps stakeholders to assess a range of possible developments, such as faster or slower permitting, shifts in government policy or problems in the supply chain and develop strategies that can still work under different future conditions.

A core principle of effective scenario planning, as described by Schoemaker (1995), is the difference between things that are almost certain to happen and things that are harder to predict but still important. The first group, often called predetermined elements, includes trends or conditions that are very likely to continue no matter how the future turns out. In offshore wind development, this might include national climate goals, current European Union policies or grid systems that have already been approved. The second group, known as critical uncertainties, includes factors that are more unpredictable but can strongly influence outcomes. Examples might be how often governments announce tenders, how open those announcements are or how fast permits are processed. Scenarios are built by combining different versions of these uncertain factors into clear and believable stories that show how future situations could develop in different ways (Schoemaker,1995).

Schoemaker (1995) suggests a structured ten-step method that can be adjusted to fit different strategic questions. The process starts by identifying the main issue or decision the scenarios are meant to support. After that, it involves listing key factors in the immediate setting along with broader external influences that could affect the issue. These factors are then assessed based on how important they are and how uncertain they appear to be. The ones that are both highly important and highly uncertain form the basis of the scenario framework. From there, different versions of how these uncertainties might develop are used to build each scenario. Each scenario is kept logically consistent and explored for its possible effects on strategy. To help track how the future is unfolding, specific signals or signs are chosen that may show which scenario is becoming more likely. Each scenario is made internally consistent and adjusted if needed before being used to support actual decision making. The strength of this framework comes not just from the details of each scenario but from how it helps organizations plan, adjust their strategies and respond thoughtfully to future changes.

A practical example of this theoretical framework is found in the work of Amer M., Jetter A.J., Daim T. U. (2013), who developed national wind energy scenarios using Fuzzy Cognitive Maps (FCMs). Their study demonstrates how scenario planning can be translated into a structured modeling technique that incorporates expert knowledge and maps causal relationships among policy, market, technological and environmental drivers. By using FCMs, the authors were able to test different possible futures based on changes in these factors. This method follows Schoemaker's idea of focusing on key uncertainties and building outcomes that make sense within each scenario. The modeling also helped stakeholders see how different elements could influence each other in ways that are hard to capture with simple forecasting methods.

The study by Amer, Jetter and Daim (2013) highlights the usefulness of scenario planning in settings that are complex and uncertain such as the renewable energy sector. By combining group-based model building with structured simulation, their approach goes beyond general storytelling and offers a more concrete way to support strategic thinking. This example shows how scenario planning can guide long-term decisions about energy policy and infrastructure, especially when many different actors are involved and systems are closely connected. It shows that scenario methods can help not just with imagining possible futures but also with building a strong and flexible approach to planning in fields that are going through major changes and dealing with long-term uncertainty.

2.4 Offshore wind energy overview

The wind energy industry has experienced rapid growth in the last three decades with the technological advancements, government policies and an increasing global push for cleaner energy. Offshore wind has become an important part of this progress that depends on good port logistics, efficient infrastructure and strong government incentives to support the expansion. The increasing demand for renewable energy has pushed both governments and private companies to scale up their efforts in wind farm development. However, offshore wind's growth also presents logistical and operational challenges that require innovative solutions (DTU Wind Energy Report; BCG Report).

The wind energy sector has expanded significantly worldwide, particularly in offshore wind projects. According to the BCG Report, offshore wind capacity reached 41 GW by 2021 and is projected to grow by an additional 200+ GW by 2030. Europe is expected to account for 60% of this growth, followed by Asia (20%) and North America (15%). Europe remains the global leader in offshore wind deployment due to strong policy support and extensive industry experience. However, Asian markets such as China are rapidly expanding their offshore wind capacity with large-scale installations. North America is still in the early stages but is expected to grow quickly as new government policies encourage more investment (BCG Report, 2022).

2.4.1 Permit activity

Permitting activity plays a central role in the development of offshore wind projects, providing insight into the regulatory progress and overall maturity of a given initiative. Permits are formal regulatory approvals that must be secured before a project can proceed to construction, and as such, they represent a critical milestone in the development lifecycle. Within the context of this research, permitting activity serves as a complementary signal to tenders, offering insight into the legal and environmental readiness of a project. While tenders reflect policy intent and public commitment, permits indicate that a project has met essential regulatory conditions, marking a transition from planning to implementation.

Permitting processes in the offshore wind sector are structured, multi-phase procedures designed to make sure that proposed developments comply with national and EU regulations, environmental standards and spatial planning approaches. In Denmark, the permitting process is managed primarily by the Danish Energy Agency (Energistyrelsen), with coordination from other entities such as Energinet and the Danish Maritime Authority (Danish Energy Agency, 2023). One of the core components of the permitting process is the Environmental Impact Assessment (EIA), which evaluates the potential effects of a project on marine biodiversity, coastal landscapes, fisheries and other environmental factors. The EIA process typically includes a preliminary assessment, submission of a comprehensive report, a period for public consultation and final approval by regulatory authorities (European Commission, 2022).

Beyond the EIA, developers are required to obtain additional permits that relate to seabed usage, grid connectivity and construction licensing. For instance, seabed leases are granted to regulate the spatial occupation of marine areas, while grid connection permits ensure that new wind farms are technically and legally integrated into the national transmission system (Energinet, 2023). These permit types are often reviewed by different regulatory bodies and may follow different timelines however, their approval generally signals that the project is entering an advanced stage of development.

2.4.2 Role of ports in wind farm logistics

Ports play an essential role in the logistics of wind farms by supporting the storage, assembly, and transportation of turbine components. According to the BCG Report, ports help reduce project lead times and optimize logistical efficiency by providing dedicated facilities for preassembly, maintenance and component storage.

Several Danish ports have emerged as key enablers of offshore wind development, including Esbjerg, Rønne, Grenaa and Odense (CIP Foundation, 2024). Among them, the Port of Esbjerg stands out as a major logistics and installation hub for offshore wind projects in the North Sea. With over 1,000,000 m^2 of dedicated storage and pre-assembly space, Esbjerg has supported large-scale wind farms such as Horns Rev 1, 2 and 3. However, increasing turbine sizes and installation requirements necessitate continued investment in quay capacity, deep water berths and specialized transport vessels (CIP Foundation, 2024).

Despite its strengths, Danish ports face growing competition from ports such as Eemshaven (Netherlands) and Cuxhaven (Germany), which are rapidly expanding their offshore wind capabilities. Without further investments in port upgrades, logistics space and workforce development, Denmark risks losing its strategic advantage in offshore wind logistics (CIP Foundation, 2024).

2.4.3 Key industry stakeholders & their roles

The offshore wind industry consists of two primary stakeholder groups: original equipment manufacturers (OEMs) and developers, each with distinct roles in the sector.

OEMs, such as Siemens Gamesa and Vestas, are responsible for designing, manufacturing and innovating wind turbine components. These companies invest heavily in research and development to improve turbine efficiency, durability and size, ensuring that wind energy remains a cost-effective and sustainable energy solution. Larger turbines with higher capacities allow wind farms to generate more power, improving overall efficiency. The technological advancements introduced by OEMs significantly influence the cost and performance of wind farms (BCG Report, 2022).

Developers, including Ørsted, RWE, Vattenfall and EnBW, focus on planning, financing, constructing and operating wind farms. They work closely with OEMs to integrate the latest turbine technologies into their projects and manage long-term operational strategies to maximize efficiency and profitability. Developers must also navigate complex permitting processes, secure financing and coordinate with multiple stakeholders to ensure projects progress according to plan (BCG Report, 2022).

As the wind energy sector continues to expand, developers are increasingly outsourcing logistics and maintenance operations to specialized service providers. This outsourcing trend lets developers streamline operations, enhance cost efficiency and maintain high performance standards across wind farms (BCG Report, 2022).

2.5 Application of data-driven indicators in the wind energy sector

Data-driven indicators are important tools in the wind energy sector. They support decision making throughout the planning and operation of wind farms by using large sets of data to improve performance, reliability and financial outcomes.

One common use of these indicators is in predicting wind power output. Reliable forecasts are needed to help manage how wind energy is connected to the electricity grid and to keep energy supply steady. Recent developments in data-based prediction models have improved their accuracy by including both turbine performance and detailed weather information. This has helped make wind energy more dependable for grid systems (Liu et al., 2023).

These methods are also applied to study turbine behavior more closely. By examining data from turbine operations, it is possible to track performance and detect technical issues early. This can lower maintenance expenses and make daily operations more effective (Moss et al., 2024). Predictive maintenance is another area where data plays an important role. By analyzing how turbines are performing, potential problems can be found early and repairs can be planned before equipment fails. This helps reduce downtime and supports higher returns. Chatterje and Dethlefs (2022) explored this topic in their review of artificial intelligence in turbine maintenance.

These indicators also assist in planning wind farm layouts. Using predictive models, developers can choose better turbine locations and apply methods like wake steering to increase energy output. This helps improve both technical results and financial planning (Bempedelis et al., 2024).

Data-driven indicators help wind energy projects operate more effectively by offering useful information that supports better planning, lowers costs and contributes to long-term project success.

2.6 Data-driven approaches for forecasting wind farm development

Accurate forecasting plays a key role in the renewable energy sector, as wind and solar power generation are directly influenced by changing weather conditions. Unlike traditional energy sources, renewable energy is not always available at a steady rate, so accurate predictions help with planning and management (Teixeira et al., 2024).

Forecasting in this field uses a variety of methods, including statistical techniques, machine learning and combinations of both. These models rely on past data, weather information and computational methods to improve prediction results (Benti et al., 2023). While much of the existing research focuses on predicting how much energy will be produced, similar approaches can help estimate other future developments, such as where new projects will be built, how investment is changing and how infrastructure is likely to grow.

This section reviews important studies that contribute to the knowledge of forecasting in renewable energy. It focuses on how forecasting supports decision-making and business planning in this sector.

2.6.1 Forecasting methods

Renewable energy forecasting supports the effective integration of wind and solar power into modern energy systems. Unlike fossil fuel-based generation, renewable energy output is variable and sensitive to environmental conditions, making accurate forecasting essential for grid stability, market operations and infrastructure readiness.

Over time, forecasting techniques have evolved from traditional statistical models to advanced machine learning methods. Algorithms such as artificial neural networks (ANNs), support vector machines (SVMs) and deep learning models like long short-term memory (LSTM) networks have shown improved performance in predicting short-term energy production based on historical and weather-related data (Unsal et al., 2024). These models are particularly useful in operational contexts that require real-time adjustment of grid input or market pricing.

However, in the context of offshore wind development, especially at the infrastructure planning level, a different kind of forecasting becomes relevant. Rather than predicting energy output, this thesis explores whether early project signals, such as government tenders and permitting activity, can act as leading indicators of offshore wind project progression. These indicators are less about real-time operations and more about anticipating future demand for port facilities, grid extensions and construction readiness.

Teixeira et al. (2024) provide a broad review of forecasting approaches and highlight the importance of input selection, time horizons and model applicability. While their focus remains on energy output forecasting, their framework supports this thesis by showing how clear, timely inputs, whether environmental, regulatory or procedural can improve predictive capacity. In this sense, the logic of renewable energy forecasting extends beyond electricity models to encompass project-based signals and development timelines.

By grounding forecasting in early, traceable events such as tenders and permits, this thesis builds on the broader forecasting literature while tailoring its application to long-term infrastructure strategy. Rather than relying on real-time energy predictions, the focus here is on actionable foresight for stakeholders who must allocate resources well before turbines begin generating power.

2.6.2 Government policy and regulatory analysis

Government policies are one of the strongest showcases of wind energy development, as regulatory frameworks dictate investment feasibility, project approvals and market stability. Policy initiatives such as tenders, subsidies, tax credits, carbon pricing mechanisms and regulatory reforms influence investment decisions and determine the pace of wind farm deployment (Danish Energy Agency, 2017). However, policy environments are dynamic, requiring systematic approaches to analyze historical trends and forecast future regulatory shifts.

Ma & Wang (2024) demonstrate how advanced Natural Language Processing (NLP) techniques, such as Latent Dirichlet Allocation (LDA) topic modeling, can be used to analyze and track policy evolution over time. Their study applies machine learning to 40 years of China's renewable energy legislation, identifying key policy shifts from early-stage development incentives (such as feed-in tariffs and government backed investment funds) to later regulations focused on market stability, competitive bidding processes and supply chain integration. These findings reinforce the idea that policy-driven forecasting models can help stakeholders anticipate future regulatory trends and adjust investment strategies accordingly. This data-driven approach provides empirical evidence that policy trends can be systematically analyzed to forecast future regulatory environments and their impact on wind energy expansion. For instance, they found that in China, early renewable energy policies focused on promoting growth through subsidies and government-backed projects, but over time, the focus shifted to regulatory monitoring, market reform and sustainable development planning. This shift mirrors trends observed in other major wind energy markets, such as Europe and the United States, where policymakers have transitioned from fixed subsidy schemes to competitive auctions and regulatory mandates.

2.6.3 Investment and financial forecasting

By analyzing financial trends, investment forecasting helps anticipate when and where new wind farms will be built, as economic factors shape infrastructure growth in the renewable energy sector (International Energy Agency, 2023). Accurate financial forecasting helps investors, policymakers and industry stakeholders identify regions with high potential for wind energy projects, ensuring capital is allocated efficiently and minimizing investment risks.

The paper Development of a Machine Learning Assessment Method for Renewable Energy Investment Decision Making by Izanloo et al. (2022) demonstrates how machine learning models can effectively assess investment attractiveness for renewable energy projects, including wind farms. Their research employs Artificial Neural Networks (ANNs), Logistic Regression, Decision Trees and Support Vector Machines (SVMs) to analyze key economic and financial indicators, achieving an impressive 94% prediction accuracy in classifying investment risks across different countries. The model combines financial and economic indicators, including:

- GDP growth.
- Electricity demand.
- Government incentives.
- Carbon emissions and renewable energy targets.

The findings highlight that machine learning forecasting may successfully evaluate nations according to their financial viability for renewable energy projects. The algorithm identifies economic trends and assesses market circumstances, providing insights that might help investors choose low risk, high reward sites for renewable energy projects, such as wind farm development.

Additionally, the study highlights the importance of integrating multiple economic variables into predictive models to enhance forecasting accuracy. Their results emphasize that AI-based forecasting methods outperform traditional statistical models in investment decision making, as they can process large datasets, detect complex relationships and adapt to market fluctuations.

It also provides a strong foundation for applying machine learning techniques to financial forecasting in wind energy development. By using AI-driven risk assessment, investors, policymakers and developers can make informed decisions about where to allocate resources, ensuring that wind energy projects are carried out in financially viable markets.

2.6.4 Supply chain readiness and logistics forecasting

The expansion of wind energy requires a complex network of suppliers, manufacturers, transport systems and specialized infrastructure, all of which must operate efficiently to meet growing global demand. A well-structured and strong supply chain guarantees that important components such as wind turbine blades, nacelles, towers and foundations are available at the right time and in the right locations, saving delays and reducing costs.

Studies such as Mogre et al. (2016) demonstrate how Decision-Support Systems (DSS) can be employed to assess and mitigate supply chain risks in offshore wind logistics. Their research introduces a matrix-based decision tree model that quantifies risks associated with component shortages, supplier failures, port congestion and transportation bottlenecks. By integrating structured risk forecasting into logistics planning, their approach allows a more predictive assessment of wind farm development timelines, allowing stakeholders to proactively identify and address potential supply chain disruptions before they escalate into major delays.

In wind energy expansion, supply chain bottlenecks such as turbine component shortages, limited vessel availability and supplier delays can cause significant setbacks in project execution. These interruptions affect not only construction timelines but also cost structures, as delays often lead to higher storage costs, penalty fees and missed energy production objectives. Mogre et al. (2016) emphasize that applying data driven risk mitigation models to logistics planning improves the ability to estimate wind energy infrastructure growth by adding supply chain constraints into predictive analytics. This aligns with broader trends in business intelligence and data science, where machine learning, optimization algorithms and real time data analytics are increasingly used to improve supply chain efficiency in renewable energy.

2.6.5 Geospatial analysis

Geospatial analysis refers to the use of geographic data, spatial statistics and mapping technologies to interpret patterns and relationships across physical space (Mahavidanage, 2011). In wind energy development, it plays a crucial role in evaluating factors such as land availability, environmental constraints, infrastructure access and wind resource potential. Tools like Geographic Information Systems (GIS), remote sensing and spatial modeling help integrate these datasets to support informed site selection.

A study by Tobin, J., Morrison, G., & Wanner, N. (2023) illustrates how GIS-based models, combined with logistic regression, can effectively predict wind farm site suitability by analyzing spatial variables such as wind speed, land use restrictions and proximity to power grids. These models provide a data-driven foundation for identifying promising locations.

However, while such tools offer valuable guidance, especially in early-stage planning, they often cannot account for the full complexity of wind farm development—particularly in offshore contexts. For example, issues related to seabed conditions, ecological impact assessments and regulatory approvals may emerge only after detailed investigations, potentially delaying or altering the project despite earlier geospatial evaluations. This unpredictability means that even after securing tenders or preliminary permits, additional excavation or compliance checks may uncover constraints that were not initially visible.

Therefore, although geospatial analysis enhances strategic planning and forecasting by identifying technically suitable sites, it must be viewed as one component within a broader framework that considers technological, economic and policy factors. For offshore wind projects in particular, the influence of location remains critical, but must be approached with an understanding of both its predictive power and its limitations.

Table 1. Forecasting types

Forecasting Type	Article	Authors	Prediction	Method used
Energy production forecasting	Advancing Renewable Energy Forecasting: A Comprehensive Review of Renewable Energy Forecasting Methods	Teixeira et al. (2024)	Forecasting wind and solar power generation based on weather and operational data	Machine learning (ANNs, SVMs, LSTM), statistical modeling
Investment and financial forecasting	Development of a Machine Learning Assessment Method for Renewable Energy Investment Decision Making	Izanloo et al. (2022)	Identifying economically viable countries/regions for renewable energy investments	Machine learning (ANNs, SVM, Decision Trees, Logistic Regression)
Supply chain and logistics forecasting	Decision-Support Systems for Risk Mitigation in Offshore Wind Supply Chains	Mogre et al. (2016)	Predicting delays and risks in offshore wind logistics due to supply chain issues	Decision-support systems, matrix-based decision trees, risk quantification
Policy and regulatory forecasting	Tracking Renewable Energy Policy Shifts Using NLP: A Case Study of China's Wind Sector	Ma & Wang (2024)	Forecasting policy shifts and their impact on wind energy market dynamics	Natural Language Processing (LDA Topic Modeling)
Geospatial site selection forecasting	GIS-based Logistic Regression Models for Wind Farm Site Suitability	Tobin et al. (2023)	Identifying suitable wind farm sites based on spatial, technical and regulatory factors	GIS modeling, logistic regression, spatial analysis

2.7 Project timelines as forecasting data

Temporal data refers to any data that is indexed in time order. In the context of offshore wind development, this includes observable events such as the publication of tenders, granting of permits and the start of construction. These events are not only critical project milestones, but they are also signals that appear in a specific sequence and are separated by variable time intervals.

This approach draws from concepts used in time series analysis, which is the study of data points collected or recorded at specific time intervals. As explained by OpenStax (2023), time series analysis helps uncover trends, seasonal patterns and potential future events based on the temporal structure of historical data. In our case, the key interest lies not in predicting the value of a variable at a future time, but in understanding the timing and order of development indicators across multiple projects. For instance, delays between a tender award and permit approval may signal administrative friction, while short lead times between permit and construction could indicate effective stakeholder coordination. These types of relationships, though not numerical, still exhibit temporal structure and can support decision making for ports and logistics providers who rely on anticipating future demand.

By organizing indicators data as time ordered sequences, this thesis applies a temporal logic to project forecasting. This structure allows scenario planning to move beyond static snapshots of project status and instead consider how timing variation impacts reliability, predictability and logistical planning. In that sense, the use of temporal data serves as a bridge between qualitative scenario narratives and structured forecasting logic.

3 Methodology

3.1 Research design

This thesis uses a qualitative and exploratory research method to examine whether early indicators such as government tender announcements and permitting activity can help to anticipate offshore wind farm development in Denmark. The goal is not to build forecasting models or make precise predictions but to create a structured approach that supports business intelligence and strategic planning. This approach is designed to help stakeholders such as the Port of Aalborg better understand how early project developments might shift into future logistics demands.

The research is grounded in a pragmatic approach that focuses on how the findings can be applied in real-world settings. Data was manually collected from a range of open and public sources, including official government announcements, developer press releases, newspaper articles and industry platforms. Additional insights were gathered through informal discussions with industry professionals during the Copenhagen Wind Conference 2025. These conversations with developers, OEM representatives and port logistics experts helped confirm which indicators are viewed as useful and revealed that some such as job advertisements or postponements are generally unreliable or difficult to verify.

Based on this mix of sources six offshore wind projects in Denmark were selected to build project timelines. Each project milestone was constructed using publicly available information to identify key milestone dates such as tender publication and approval, permit approval, construction start and full commissioning. Although the number of projects is small, this sample made it possible to track how early indicators show up over time, how close they are to each other and whether clear patterns or disruptions are visible.

The use of project milestones such as tender awards, permit approvals and construction starts forms a structured basis for interpreting the offshore wind activity. These events serve both as markers and as time-based information, helping to estimate project movement in uncertain conditions. This approach supports the use of scenario planning, which allows for exploring how expectations about project progress may change under different political, legal or economic conditions.

The use of project timelines combined with manually gathered, real-world project timelines provides structured scenario analysis to build a flexible but grounded logic for strategic interpretation. While this study does not offer precise predictions, it provides a way to follow project progress and consider its relevance for long-term planning in a fast-changing industry where timing is a key factor.

3.2 Data collection

3.2.1 Government tender tracking data

This thesis uses government tender announcement data as a primary indicator that can identify upcoming offshore wind projects. These official documents provide the earliest and most reliable indicators of planned developments as they represent formal assurance by authorities to construct new wind farms.

To collect this data, a multi-source strategy was applied. Although tender announcements are theoretically available through institutional platforms, such as the EU Supply portal and national energy agency databases, practical access was often inconsistent. Important information such as publication and award dates, was hidden in lengthy documentation or scattered across different web pages.

To address these challenges data collection relied on retrieving data from the following sources:

(a) Developer press releases (e.g., Ørsted, Vattenfall, RWE)

(b) Energy sector government pages and platforms such as ens.dk

(c) Public construction updates and milestone announcements from governmental, media and corporate sources

For each wind farm project, the key dates gathered included the tender publication date, tender award date, construction start date and when the project became operational. Each data point was manually cross-checked across multiple sources to ensure consistency and reduce the risk of error. For example, if a tender award date appeared in both a developer's press release and an industry news outlet, this was taken as confirmation.

Tender data provided a solid chronological foundation for mapping project development, serving as a foundation for tracking the shift from planning to execution. The decision to focus on tenders comes from their nature as legally binding procedures with fixed schedules, unlike informal market rumors or speculative announcements. While additional indicators are explored later in the study, government tenders remain the most consistent and verifiable input for determining when and where offshore wind activity is expected.

3.2.2 Permitting activity tracking

Permitting activity is used as another indicator in this study, complementing the analysis of government tenders. While government tenders mark the formal start of development, permit approvals serve as confirmation that a project has passed the necessary legal and environmental checks and is ready to proceed to construction.

The primary goal of this data collection was to identify the permit approval date for each project. This milestone was used to calculate the time from the original tender and the moment at which a project received regulatory clearance.

The initial approach was to gather this information from official institutional sources, primarily the Danish Energy Agency (Energistyrelsen) and relevant EU procurement platforms. While these sources publish regulatory information, the data is often not available in a structured format. Timeline details are scattered across project-specific pages and environmental assessment documents and in many cases dates for permit approvals had to be manually extracted from detailed reports as well as from previously mentioned sources such as industry outlets, developer updates and other public announcements.

By focusing specifically on approval dates the research was able to make clearer project timelines and assess how long it typically takes for offshore wind projects in Denmark to move from tender to regulatory clearance. This information was beneficial in creating realistic development scenarios and evaluating the operational effects for the Port of Aalborg.

3.2.3 Hiring patterns

This research initially considered that hiring could be a potential early indicator for wind farm development. The assumption was that large-scale projects would require significant workforce preparation, potentially observable through job postings or recruitment announcements. To verify this, informal conversations were held with industry professionals during events such as WindEurope 2024 in Copenhagen.

Discussions included stakeholders from development firms, OEMs and ports. A common takeaway was that hiring in the offshore wind sector is often highly flexible, with many companies relying on subcontractors, internal reallocation or seasonal labor. Often, recruitment for positions starts just one to three months before construction begins, especially when schedules are tight due to permitting setbacks or limited weather windows. Additionally, such hiring activity is rarely documented in publicly accessible databases or clearly linked to individual projects, making them difficult to monitor accurately.

Due to this short lead time, lack of transparency and the inconsistent nature of data, workforce-related indicators were excluded from the final list of validated signals. While the consultations with professionals helped with a better understanding of industry operations, they did not offer predictive value aligned with the objective of this research. This decision supports methodological transparency and helps clarify why only certain data sources were prioritized.

3.2.4 Project delays

While this thesis does not treat project delays as a standalone forecasting indicator, it acknowledges the importance in shaping project timelines. In practice, even after a project has been awarded through a public tender, a number of unforeseen factors may cause significant delays. These include challenges related to permitting, supply chain disruptions, financing difficulties, or shifting regulatory environments. Instead of trying to model and predict delays, the research reviews publicly available cases of postponed offshore wind projects to identify recurring patterns and gain an understanding of the reasons. These were sourced from news articles, developer announcements and financial reports and used to assess whether any factors tend to lead up to changes. In some cases, stakeholder discussions also offered informal insights into typical causes of delays, such as bottlenecks in government changes or extended environmental permitting processes.

The purpose is to highlight that tender announcements alone do not always lead to projects being carried out on time. For the Port of Aalborg and similar logistics providers, this means that even confirmed projects may require flexible planning, especially when it comes to storage capacity and scheduling. Therefore, delays are considered a qualitative factor in this study, used as a caution when interpreting more reliable indicators such as tenders or progress in permitting.

3.3 Scenario development

Scenario planning was selected as the main analytical approach in this research due to the uncertainty surrounding offshore wind project timelines and the limited availability of structured data. The method was appropriate for addressing the main research question, which concerns how the Port of Aalborg can prepare strategically for future offshore wind developments despite incomplete or inconsistent data.

The scenario development is followed by a structured step by step process. First, key variables that influence project development were identified through a combination of publicly available data and informal input from industry professionals. Among various potential indicators, government tenders and permitting activity were selected as the most relevant and reliable. These two indicators represent formal and regulated steps in the offshore wind development cycle.

Historical project data was analyzed to determine average timelines between tender publication and permit approval. These insights allowed the study to establish realistic assumptions for the development pace of offshore wind projects. Based on this, three future scenarios were created: one scenario assumed increased activity, another assumed limited activity and a third represented an ongoing nature of current trends. The logic behind these scenarios was created from the observed patterns in the data and supported by expert reasoning shared during industry conversations.

The scenarios were not intended to predict exact outcomes but to structure the analysis around possible outcomes. Each scenario provides a framework to evaluate how different offshore wind activities would affect logistical needs and strategic options for the Port of Aalborg.

3.4 Integrating megaprojects theory

This thesis applies scenario planning as the main method to explore how offshore wind development in Denmark can be forecast using early signals. Scenario planning is useful in settings with high uncertainty because it supports the development of several possible future directions instead of relying on single track predictions. It offers a way to examine how political, regulatory and economic changes may affect the reliability of these signals over time.

To strengthen this approach, the thesis also draws on ideas from Bent Flyvbjerg's theory of megaprojects as a supporting analytical framework. Offshore wind projects in Denmark show many of the features that Flyvbjerg (2014) links with large-scale infrastructure. These include long planning periods, high financial costs, complex approval processes and involvement from multiple actors. These characteristics mean that delays are not only caused by technical issues but also by risks linked to behavior and institutions, which make clear forecasting more difficult.

While Flyvbjerg does not explicitly name the phenomena we identify, his descriptions strongly resonate with issues encountered in the research study.
Based on the readings, the study derived and adapted the following concepts to better suit the specific dynamics of the case:

1. **Optimism-driven delay**: Informed by Flyvbjerg's discussion of extensive cost and schedule underestimation, which he links to overconfidence and inadequate risk assessment, this term is used to capture how overly optimistic planning contributed to repeated postponements in the project.
2. **Systemic lock-in**: Inspired by Flyvbjerg's observations on early overcommitment and the difficulty of course correction in megaprojects, the term is used to describe how institutional and procedural inertia limited flexibility even in the face of emerging problems.
3. **Strategic signalling**: Drawing on Flyvbjerg's critique of the "break-fix model" and the examples of project promoters presenting selectively favourable information, this term was introduced to capture the deliberate shaping of external perceptions to secure project legitimacy or funding.

These adapted concepts are not direct quotations or formal terminology used by Flyvbjerg, but rather our interpretive extensions based on the patterns and mechanisms he describes. They serve as tools to make sense of the specific issues at play in our case.

This combined approach shows that no single method is enough to explain how large infrastructure projects develop. Scenario planning helps outline possible future directions while Flyvbjerg's megaprojects theory helps explain why indicators sometimes lead to delays or produce outcomes that differ from what was expected. Together, they offer a more detailed and realistic way to examine offshore wind development and assess how early signals might be used to plan for future activity.

3.5 Limitations

Although the necessary data for tenders and permit approvals was eventually retrievable, the process revealed a significant issue: publicly available data is not always practically accessible. Key dates and project milestones were frequently found within unstructured or fragmented documents, requiring considerable manual effort to extract. This highlights a broader challenge, which is the lack of standardized data publication across official platforms.

A related limitation involves the general accessibility and completeness of sources. The study relies on publicly available sources such as government tender platforms, company announcements and annual reports. While these sources provide valuable information, they do not always show thorough internal processes or operational realities. There is often a delay between real-time developments and public disclosure, which limits the ability to trace when certain signals actually happen within a project timeline. Moreover, information made publicly available, particularly about project completion delays or any changes to schedules, is often incomplete without giving details about the reasons. Many relevant indicators, such as call schedules, supplier contracts or tender timelines are either not published or provide limited resources. As a result, while public data provides a necessary foundation for this research, its limitations require careful interpretation and should be complemented by interviews to provide more accurate information.

The scattered nature of public data also creates challenges. Many potentially useful indicators, such as call schedules, supplier names, or financial commitments, are either confidential or inconsistently disclosed. This requires a focused emphasis on only the most verifiable and consistently available indicators, such as tenders and permitting activity.

The use of scenario planning in the analysis introduces another constraint. While the method is useful for exploring possible futures, it heavily relies on assumptions and judgment. The created scenarios are not forecasts, but rather representations of what may happen under certain conditions. Their purpose is to support strategic thinking, not to produce definitive outcomes.

Finally, the analysis of project delays was qualitative in nature. Since delay data was not tracked systematically, the findings related to postponements are based more on public disclosures than on comprehensive datasets.

Despite these limitations, the research remains transparent in its approach and careful in its interpretation. The combination of reliable public data, structured scenario logic and insights from professionals allows the study to offer practical value for the strategic planning of ports.

4 Analysis and findings

4.1 Indicator selection

This research explores whether offshore wind project development in Denmark can be forcasted using early and visible indicators. The main hypothesis is that specific administrative tasks, such as government tenders or permitting approvals, can serve as reliable indicators of future project activity. Identifying which indicators are both reliable and easy to track is essential to building a forecasting method that can support long-term infrastructure planning.

To evaluate potential indicators, four were selected at the beginning of the study. These included government tenders, permitting activity, job postings and project postponements. These were assessed using four criteria: (1) public availability, (2) traceability to individual projects, (3) timing within the project lifecycle and (4) usability for forecasting purposes. This criterion was selected to assure that indicators were not only theoretically relevant but also practically actionable.

Indicators categorized as "strong," "moderate," or "weak" based on their consistency, observability and relevance to early-stage planning. "Strong" indicators appeared early in the development process, could be linked to specific projects and were published through official and publicly accessible channels. "Moderate indicators" showed some uncertainty in timing or traceability. "Weak" indicators were either difficult to access or appeared too late to support advance planning.

As a result of this evaluation, two indicators were selected for deeper analysis such as government tenders and permitting activity. These indicators are part of formal administrative processes, include clear time records, tied to individual projects and are consistently documented by regulatory authorities such as the Danish Energy Agency. These are issued through formal legal processes, carry official timestamps, are specific to individual projects and are consistently documented by regulatory authorities such as the Danish Energy Agency. Tenders represent the initial government commitment to offshore development and often come before commercial involvement. Permits, particularly environmental and construction-related, signal that a project is moving toward implementation. This allows for a structured analysis of project timing and progression. Other potential indicators were ruled out due to issues with accuracy or accessibility. Job postings, while potentially reflective of hiring needs are rarely tied to specific projects and tend to appear later in the development phase. In practice, companies rely heavily on subcontractors and internal reallocations, making hiring data too scattered to interpret clearly. Turbine shipments, while physically significant, are difficult to track through public sources. Even when visible, they are not necessarily tied to a specific project or phase either.

Project postponements were not included as core indicators in the timeline analysis, as they typically represent downstream outcomes rather than early-stage indicator. Unlike tenders or permits, which are formal, timestamped milestones, postponements are often triggered by a combination of permitting challenges, political uncertainty or environmental objections and are less consistently documented across projects. However, they were kept for analysis, as they help reveal structural vulnerabilities in the development process.

The analysis focuses on tenders and permits as the most structurally consistent and operationally relevant indicators. These indicators are grounded in formal procedures that can be easily tracked and occur early enough in the project lifecycle to support forecasting efforts. **Table 2** summarizes the evaluation of each considered indicator using the four criteria. This structured comparison explains the selection of tenders and permits as the primary focus of the analysis.

Table 2. Summary of indicator evaluation

Indicator	Publicly available	Project specific	Early enough?	Usability for forecasting	Included?	Notes
Government tenders	Yes	Yes	Yes	Strong	Yes	Published by DEA
Permitting activity	Yes	Yes	Variable	Moderate-strong	Yes	Timing varies
Job postings	Partially	No	No	Weak	No	Often too late and not linked to projects
Project postponements	Yes	Yes	No	(valuable insight)	Yes	Useful for risk awareness, not forecasting

4.2 Analysis of key indicators

This section focuses on the two main indicators identified as the most reliable for anticipating the development of offshore wind projects in Denmark: government tender announcements and permitting activity. These indicators are documented through official channels, associated with identifiable projects and recorded with specific dates.

4.2.1 Government tenders

Government tenders are formal invitations issued by authorities such as the Danish Energy Agency (DEA) or through broader European mechanisms like the *Clean Energy for EU Islands* initiative. These tenders initiate the development of offshore wind farms and follow a structured legal framework, primarily outlined in the Renewable Energy Act (RE Act). This includes mechanisms like Contracts for Difference (CfD), along with specific technical, financial and procedural requirements for participation (§37a RE Act).

Because tenders are embedded in a regulated and transparent process, they are among the most reliable and consistently documented indicators of future offshore wind activity. Each tender is tied to a specific project and includes detailed information such as planned capacity, geographic location, deadlines and bid evaluation criteria. These characteristics make tenders a strong starting point for strategic planning, timeline modeling and risk assessment.

From a forecasting perspective, tenders serve as early indicators of governmental commitment. They are typically issued well before the commercial or construction phases begin and their timelines include several formal stages. These usually involve prequalification checks based on the applicant's technical and financial capacity, submission of bids, negotiation phases and final concession awards. Each step is documented and published with official timestamps, offering a valuable trail of data for project tracking and comparative analysis.

While tenders alone cannot predict exactly when a wind farm will be built or operational, they are often the first actionable milestone in a project's lifecycle. Their consistency and availability make them particularly useful for building probabilistic forecasting models and for monitoring market readiness at a national level. When viewed alongside permitting and construction milestones, tenders help understand the likely pacing and progression of offshore wind development in Denmark.

4.2.2 Permits

Permits indicate that an offshore wind project has advanced through key regulatory checkpoints necessary for development. Although the permitting process is less standardized than the tendering process and involves a broader range of authorities, it plays a decisive role in project progression. In Denmark, permits, especially those related to environmental and construction phases, are typically issued one to three years after the initial tender award, serving as strong confirmation that a project is advancing toward physical implementation (Clean Energy for EU Islands; RE Act §22).

Under Danish law, developers must first obtain a license to carry out preliminary investigations in the designated offshore area. This license is issued either as part of the tendering process or under the open-door procedure, depending on the project type. The *Danish Energy Agency* (DEA) and the *Danish Environmental Protection Agency* (DEPA) jointly oversee a sequence of environmental assessments, including a Strategic Environmental Assessment (SEA) and an Environmental Impact Assessment (EIA), followed by public consultations (Clean Energy for EU Islands; SEA and EIA Act). Only after these steps are satisfactorily completed can a developer proceed to apply for further construction-related licenses.

From a modeling perspective, the time between a tender award and permit approval provides valuable insight into both administrative efficiency and project risk. For example, in recent Danish projects, this interval has ranged from under two years to nearly four. Such variation suggests that permitting is a major source of uncertainty in development timelines. Extended delays can signal complex environmental conditions, evolving policy environments, or coordination challenges between national and local stakeholders.

Figure 2. Steps in the Danish offshore wind permitting process.

Note. Adapted from European Commission

4.2.3 Real-world patterns from Danish projects

To assess the behavior of key development indicators, a structured timeline was compiled for six Danish offshore wind farms: Thor, Kriegers Flak, Vesterhav Syd, Anholt, Horns Rev 3 and Vesterhav Nord, as shown in **Table 3.** These projects were selected based on data availability and their varying development outcomes. Each timeline includes five milestones such as tender publication, tender award, permit approval, construction start and commissioning, allowing for a comparative analysis of how these signals correspond to real-world project execution.

While all projects follow the same basic structure, the duration between each phase varies. The period between tender award and permit approval shows the greatest inconsistency. For example, Thor experienced a 34-month delay between award and permitting, whereas Horns Rev 3 moved through this phase in only 16 months. Vesterhav Nord and Syd each required close to four years to secure permits, which is significantly longer than average for such projects.

In contrast, the time between permit approval and construction start is generally more stable. Across the projects analyzed, the average duration for this phase is 25.7 months, with a median of 25 months and a standard deviation of 8.4 months. This indicates a moderately predictable interval once permits are granted. Similarly, the construction-to-commissioning phase has the lowest variation, with a standard deviation of 4.6 months, reinforcing that once construction begins, projects usually proceed on a steady timeline. The variability across phases is further illustrated in **Table 4**, which highlights the average, median and standard deviation for key intervals.

The tender-to-permit phase stands out as the least reliable, with a standard deviation of 19.4 months, confirming that this stage is a key source of timeline uncertainty. Overall, the total project duration from tender to commissioning averages 73.5 months, but varies significantly between projects, with a standard deviation of 18.4 months.

Table 3. Windfarms table comparison

Project name	Tender published	Tender awarded	Permit granted	Construction start	Commissionin g	Developer
Anholt	Apr 2009	Jul 2010	—	Jan 2012	Sep 2013	Ørsted
Horns Rev 3	2013	Feb 2015	Jun 2016	Oct 2017	Aug 2019	Vattenfall
Kriegers Flak	2016	Nov 2016	2018	May 2020	Sep 2021	Vattenfall
Vesterhav Nord	Sep 2016	Sep 2016	Dec 2020	2022	Feb 2024	Vattenfall
Vesterhav Syd	Sep 2016	Sep 2016	Dec 2020	Jul 2023	Nov 2023	Vattenfall
Thor	Sep 2020	Dec 2021	Oct 2024	Spring 2025	End of 2027	RWE

Note. For timeline calculations, general seasonal terms (e.g., "Spring 2025") were standardized to the middle month of the season (e.g., April for Spring). Month-based durations were calculated using full calendar months, with both start and end months included.

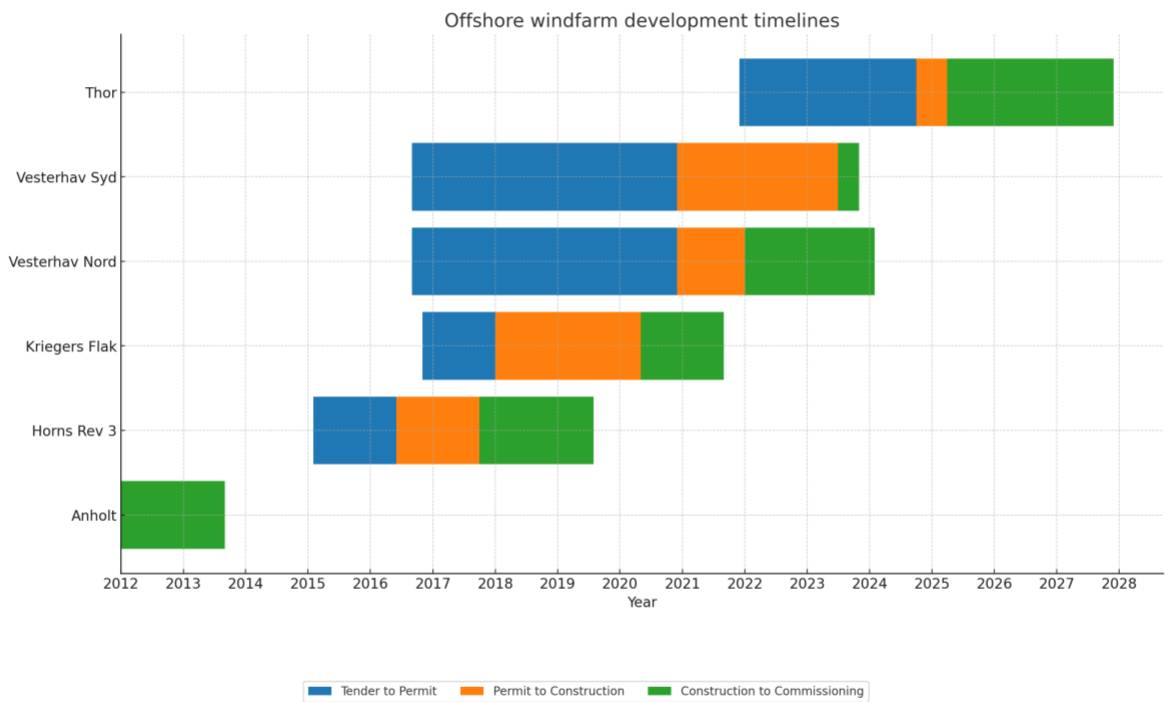
Table 4. Summary statistics for development intervals (in months):

Interval	Average	Median	Std. dev
T2P	33.2	34	19.4
P2C	25.7	25	8.4
C2O	17	17	4.6
Total duration	73.5	74	18.4

Note. T2P = Tender to Permit; P2C = Permit to Construction; C2O = Construction to Operation. Summary statistics are based on all six projects.

Figure 3 illustrates these timelines in a Gantt-style format, visually segmenting each project into three key phases: tender to permit, permit to construction and construction to commissioning. This visualization supports the patterns observed in **Table 2**, particularly the lengthy permitting durations seen in recent projects like Thor and Vesterhav Nord and Syd. In contrast, Anholt stands out not because of a notably short permitting process, but due to missing data on the exact permit approval date. However, given that its tender was awarded in July 2010 and construction began in January 2012, we can infer that the permitting and pre-construction phase lasted approximately 18 months, which is a significantly shorter period than in later projects. This suggests that earlier offshore wind developments may have faced fewer procedural obstacles or benefited from a less complex regulatory environment. The visual timeline also highlights overlaps and sequencing trends across projects, helping to contextualize regulatory efficiency and project pacing in the broader development pipeline.

Figure 3. Gantt-style timeline



4.3 Temporal indicator features: capturing project signals over time

While the Gantt-style timeline in the previous section revealed significant irregularities in offshore wind development, this section reframes those same intervals into a structured, repeatable model for analysis. Specifically, it introduces three temporal features that quantify the lag between key project milestones:

- **T2P (Tender → Permit):** the number of years from tender award to first permit approval

- **P2C (Permit → Construction):** the years from permit approval to construction start

- **C2O (Construction → Operation):** the years from construction start to commissioning

These intervals capture the most influential phases in the offshore wind lifecycle and provide a clean basis for classifying project trajectories, estimating risk and flagging when infrastructure readiness (such as port logistics) should begin. **Table 5** summarizes these intervals across five Danish offshore wind projects.

Table 5. Project timeline intervals

Project	T2P(years)	P2C(years)	C2C(years)
Horns Rev 3	1	1	2
Kriegers Flak	2	2	1
Vesterhav Nord	4	2	2
Vesterhav Syd	4	3	0
Thor	3	1	2

Note. T2P = Tender to Permit; P2C = Permit to Construction; C2O = Construction to Operation. Summary statistics are based on all six projects.

The most striking feature across this dataset is the high variability in T2P, ranging from 1 year (Horns Rev 3) to 4 years (Vesterhav projects). This stage consistently emerged as the most unpredictable and delay prone phase, often shaped not by technical barriers but by regulatory bottlenecks, legal appeals or stakeholder opposition. In contrast, P2C and C2O phases were generally more stable with values clustering around 1-2 years. This suggests that once permits are secured, development momentum tends to hold, making this a more reliable planning threshold for ports. There were also unusual cases. For example, Vesterhav Syd showed a C2O duration of zero, which may indicate that commissioning took place immediately after construction began or that the reported dates overlap. Such outliers highlight the need for consistent and high-quality milestone data, especially when using these variables for future modeling. From a strategic perspective, this logic allows infrastructure actors like the Port of Aalborg to adopt simple trigger points to guide planning. For instance, if a project shows a T2P duration exceeding 36 months with no permit in sight, the port could flag it as "high uncertainty" pausing resource allocation. In contrast, a project with approved permits and a short P2C period could be treated as a planning priority, as construction is likely to begin soon. This allows public data to support practical decision-making, even in the absence of detailed forecasting models. More broadly, these elements provide a basic approach that could support future forecasting efforts. They are straightforward, linked to specific projects and can be gathered from existing public data, which makes them suitable for use in methods such as classification systems or machine learning models. For example, past T2P durations could help identify where permitting delays are more likely to occur based on location or the agency responsible. Although this thesis does not apply these types of models, it demonstrates that even simple time-based indicators can help bring greater structure to how offshore wind project readiness is evaluated and planned. Overall, the T2P-P2C-C2O model is not just an observation, it is a starting point for building a data-informed decision logic around offshore wind infrastructure. For the Port of Aalborg and others like it, this offers a way to move from reacting to published milestones toward proactively interpreting what they might mean.

4.4 Applying Flyvbjerg's theory

While the scenario planning framework captures how external policy and regulatory environments shape offshore wind development, Flyvbjerg's theory helps explain why early indicators fail or mislead through rooted behavioral and institutional patterns. By applying the adapted disruption typology, optimism-driven delay, strategic signaling and systemic lock-in, we can better understand what kind of risk each project encountered, even when formal indicators like tenders and permits were present. This section does not repeat the timeline or policy details from the scenario mapping. Instead, it categorizes the underlying character of the disruption observed in each case, offering a second layer of interpretation that builds on Flyvbjerg's insights into megaproject fragility.

Thor - optimism-driven delay

Thor experienced no major public opposition or legal appeals and the tender and permit phases followed a transparent process. Yet the 34-month gap between tender award in 2021 and final permit approval in October 2024 indicates a longer than expected process (Reuters, 2024). This reflects a classic case of optimism bias, an assumption that coordination and approvals would proceed more smoothly than they did. The disruption was not caused by resistance or policy failure, but by the gap between formal milestones and actual administrative capacity.

Vesterhav Nord and Syd - systemic lock-in

Vesterhav Nord and Syd are examples of systemic lock-in. Although permits were granted in 2016, both projects were delayed after environmental organizations and local citizens successfully challenged the permits, leading to their annulment in 2018. The Danish Environmental and Food Appeals Board ruled that the Environmental Impact Assessment (EIA) was insufficient, forcing the Danish Energy Agency (DEA) to restart the process (Danish Energy Agency, 2021; 4C Offshore, 2020). Despite these regulatory failures, the projects remained on Denmark's official project list, illustrating political and institutional commitment despite overpowering unresolved risks and issues, an example of Flyvbjerg's lock-in effect.

Anholt - Strategic signaling

The Anholt project was launched in 2009 as part of Denmark's early offshore wind ambitions. It was politically framed as a landmark project, but the tender conditions were so compressed and specific that only one bidder, DONG Energy, applied (Maritimedanmark.dk, 2009). This suggests a case of strategic signaling, where the tender served to reinforce policy ambition rather than reflect market readiness. Although the project succeeded technically, the weak competition raises questions about the practical intent of the signal.

Horns Rev 3 - Minimal disruption

Horns Rev 3 is an outlier. It moved steadily from tender award in 2015 to full commissioning in 2019 with minimal delays. The Danish Energy Agency published the final tender material in late 2014 and no significant legal or regulatory barriers were reported (Offshore Energy, 2016). While there were some weather-related challenges during substation installation (WindFair.net, 2016), the process stayed largely on schedule. This confirms that when political alignment, technical capacity and institutional coordination are in place, early signals can be strong predictors of success.

Hesselø - Strategic signaling

Although not yet built, Hesselø is a clear case of strategic signaling that ultimately lost momentum. Originally included in the DEA's 2021 tender schedule, the project was later postponed due to seabed conditions that had not been fully assessed (Windpower Monthly, 2023). Since then, it has seen repeated delays and no new timeline has been announced. This reflects a signal that was issued prematurely, possibly for political or planning optics without full technical preparation or follow-through.

4.5 Scenario planning analysis

While Flyvbjerg's disruption typology helps explain why early signals failed to produce timely outcomes in past projects, it does not offer a direct way to anticipate what might happen next. Here, the focus shifts to applying the scenario planning framework developed by Schoemaker (1995) to assess how political and regulatory developments influence the reliability of early indicators, specifically tenders and permits in forecasting offshore wind activity in Denmark. Scenario planning offers a structured approach to decision making under uncertainty, particularly when data availability is limited or inconsistent. The scenarios presented here are not intended as predictions, but as structured narratives that explore how different policy and regulatory environments may influence the effectiveness of indicators-based forecasting and strategic planning, particularly in the context of infrastructure actors such as the Port of Aalborg.

4.5.1 Key uncertainties and logic

The scenarios developed in this thesis are based on two critical uncertainties identified through earlier projects and policy analysis: the frequency of government offshore wind tenders and the transparency and speed of the permitting process. These two variables directly affect the quality and predictability of early indicators, such as tenders and permits, which are central to this study.

These uncertainties were selected because they combine high relevance, shape infrastructure timelines and developer confidence, with high unpredictability, as both have varied across recent offshore wind projects in Denmark. Tenders may be delayed, irregular or politically driven, while permitting procedures may be slowed by legal appeals, consultation processes or administrative bottlenecks.

By combining different states of these two uncertainties, the three different probabilistic scenarios were constructed. Each scenario reflects a different level of political and institutional stability, creating a realistic context for exploring how early indicators like tenders and permits might behave and how reliably they can signal project progression.

4.5.2 Scenario narratives

Scenario 1: The great slowdown

Following a political shift in 2027, Denmark deprioritizes offshore wind development in favor of short-term energy stability and inflation control. While public statements still support climate goals in practice, offshore wind tender rounds are being postponed or are irregular. The much anticipated Hesselø re-tender is again delayed without a clear timeline. Tenders which were once reliable indicators of market activation, now appear rarely and without long-term scheduling, minimizing their value as planning indicators. Permitting becomes slower and more unclear. Environmental assessments are extended by legal appeals and local opposition and coordination among agencies weakens. Projects that move forward often do so at uneven rates, as developers are hesitant to invest in early-stage work because the timing of regulatory approvals is unclear.

Indicator landscape:

1. Tenders: low frequency, low predictability
2. Permits: delayed, non-transparent
3. Forecasting confidence: low

Scenario 2: Full steam ahead

In this future, Denmark speeds up offshore wind development to address energy security concerns, public pressure and align with supportive climate policies. A pro-climate government introduces a long-term tender schedule, published in advance by the Danish Energy Agency. The permitting process is simplified through a digital coordination platform that integrates stakeholder input and reduces processing time to 12-18 months. Developers have clear signals and plan infrastructure needs in advance.

Indicator landscape:

1. Tenders: frequent, scheduled, transparent
2. Permits: fast-tracked, digital, traceable
3. Forecasting confidence: high

Scenario 3: Cautious progress

In this balanced future, offshore wind remains a political priority, but competes with concerns about inflation, energy prices and biodiversity. Tenders proceed, though more slowly and irregularly, often linked to EU funding cycles. Developers remain active but more selective, targeting tenders with clearer paths to execution.

Permitting remains comprehensive and legally sound but limited administrative capacity and extensive public consultation slow the process. Approval times stretch to 24-30 months. While delays are common, they are expected and factored into developer planning.

Indicator landscape:

1. Tenders: moderate frequency, some predictability
2. Permits: consistent but slow
3. Forecasting confidence: medium

Table 6. Scenario summary

Indicator	The great slowdown	Full steam ahead	Cautious progress
Tender frequency	Low	High	Moderate
Tender predictability	Unpredictable	Scheduled, transparent	Some predictability
Permitting speed	Delayed	Fast-tracked (12–18 months)	Slow (24–30 months)
Permitting transparency	Low	High (digital platform)	Moderate (legally sound, but slow)
Forecasting confidence	Low	High	Medium

Note. This table summarizes key indicators under three future scenarios for Denmark's offshore wind development. Forecasting confidence reflects the ability of developers to predict project timelines and make investment decisions.

4.5.3 Mapping projects to scenario conditions

Thor offshore wind farm - Scenario 2: Full steam ahead

Thor Offshore Wind Farm reflects the conditions outlined in Scenario 2: Full Steam Ahead, with strong political momentum, transparent procedures and early signals that aligned in a timely and predictable sequence. The project was awarded in 2021 and permitted in 2024, with construction scheduled for 2025. This timeline occurred during a period of strong cross-party support for offshore wind in Denmark and regulatory authorities maintained a clear permitting and tendering process (WSCO law firm, 2019).

However, as the project moved closer to construction, it entered a more uncertain economic environment. In late 2023 and early 2024, offshore wind developers across Europe began scaling back due to rising inflation, high interest rates and cost pressures. Ørsted, Denmark's largest offshore wind developer, cited these factors, also including supply chain bottlenecks, as the key reasons for not bidding on Denmark's largest 6 GW offshore wind tender in 2024 (Reuters, 2024). Danish Minister for Energy and Climate Lars Aagaard acknowledged that the market conditions had shifted significantly, referring to "large price and interest rate increases" as major industry concerns.

Although Thor has not experienced direct delays yet, these external economic factors may influence final investment decisions and construction timelines. As such, while the project clearly fits Scenario 2 based on indicator behavior, its evolving conditions suggest an edge toward Scenario 3 due to emerging financial volatility.

Vesterhav Nord and Syd - Scenario 3: Cautious progress

Vesterhav Nord and Syd are strong examples of Scenario 3: Cautious Progress, where national policy remains supportive, but legal, administrative and social resistance slows implementation. Although the projects received permits in 2020, they faced multiple years of delay due to legal complaints filed by local residents and environmental organizations (Windpower Monthly, 2019).

These challenges centered around the Environmental Impact Assessments (EIA), which were legally contested for not adequately addressing visual and environmental impacts. In 2018, Denmark's Environmental and Food Appeals Board annulled the EIA for Vesterhav Syd, forcing the Danish Energy Agency (DEA) to initiate a new process (Danish Energy Agency, 2021). Vattenfall had to conduct a revised EIA and re-engage in public consultations, extending the timeline significantly. According to OffshoreWind.biz (2021), the projects only cleared their legal hurdles in mid-2021, after most of the 59 complaints were dismissed and the DEA's decisions were upheld.

This aligns with Scenario 3's indicators: tenders and permits were present, but the timeline was shaped by lengthy legal reviews, public resistance and administrative burden rather than lack of political will.

Horns Rev 3 - Scenario 2: Full steam ahead

Horns Rev 3 aligns with Scenario 2, showcasing a steady development trajectory from tender to commissioning. The Danish Energy Agency published the final tender material for Horns Rev 3 in December 2014, following approval from the parties behind the 2012 Energy Agreement, which cleared the way for a transparent and efficient bidding process. (Offshore Wind, 2014).

Vattenfall (2015) won the concession to build and operate the offshore wind farm in 2015. Construction commenced in October 2017, with the first turbines delivering electricity to consumers by December 2018, and the official inauguration taking place in August 2019. The project proceeded smoothly, without significant regulatory issues or local resistance, highlighting how early indicators can be more reliable when there is strong alignment between political, regulatory and local stakeholders.

Anholt - Early-stage example of Scenario 3: Cautious progress

The Anholt offshore wind project, developed between 2009 and 2013, reflects some of the dynamics described in Scenario 3: Cautious Progress. While the project advanced without major delays, it was built during a period when Denmark's offshore wind procedures were still developing (IEA, 2011). The tender process was initiated through a centralized government decision rather than as part of a long-term, scheduled pipeline (IEA, 2011). Permitting and coordination were efficient, but largely handled through internal political mechanisms, with less transparency compared to today's standards (UNFCCC, 2013).

Politically, the project benefited from Denmark's early climate commitments, including the EU 2020 targets (European Commission, 2010). However, from a forecasting perspective, the early indicators in the Anholt project were not part of a fully developed or consistent regulatory framework. Instead, the project relied heavily on political backing at the highest levels, rather than on standardized processes. This reflects broader observations by the International Energy Agency, which emphasized that effective deployment of variable renewable energy (VRE) requires robust forecasting systems, clear market incentives, and standardized regulatory mechanisms, many of which were still evolving during the time of Anholt's development (IEA, 2011). The IEA highlighted the need for integrated planning, short gate-closure times, and the removal of regulatory barriers, all of which point to the institutional maturity that was not yet fully in place in Denmark's offshore wind sector at the time.

Hesselø - Example of Scenario 1: The great slowdown

Although Hesselø was not one of the projects included in the core analysis, it is presented here as a relevant case to illustrate the dynamics described in Scenario 1: *The Great Slowdown*, which was not represented among the previously analyzed projects. The Hesselø Offshore Wind Farm exemplifies how political and procedural uncertainty can undermine development momentum. Initially included in the Danish Energy Agency’s offshore wind plans as early as 2018, the project was delayed in 2021 after seabed conditions were found to be unsuitable, requiring relocation and further investigation. Despite ongoing interest, it was not until April 22, 2024, that the formal tender was finally published via EU Supply, with a bid deadline set for April 1, 2025.

In the years between its initial inclusion and formal tendering, Hesselø became emblematic of the conditions outlined in Scenario 1: low tender frequency, extended uncertainty, and declining confidence in timelines. During this period, industry actors operated without clear or consistent updates, relying instead on high-level political commitments and speculative projections. For infrastructure planners such as the Port of Aalborg, the case of Hesselø demonstrates the risk of over-relying on early announcements or draft tender plans that are not backed by binding timelines or regular progress signals. It underscores a broader reality in offshore wind development: in environments shaped by institutional delay or ambiguity, even well-publicized projects may stall indefinitely, weakening the predictive power of early indicators unless they are supported by clear and formal follow-through.

All factual information about the Hesselø Offshore Wind Farm is based on updates published by the Danish Energy Agency (Danish Energy Agency, 2024).

4.5.4 Scenario comparison and indicator strength

Table 7. Scenario comparison table

Scenario	Tender frequency	Permit speed	Indicator strength	Forecasting confidence	Port implication
The great slowdown	Low	Delayed	Weak	Low	Reactive strategy, risk of underuse
Full steam ahead	High	Fast	Strong	High	High throughput, proactive planning
Cautious progress	Moderate	Slow	Moderate	Medium	Flexible planning, real time updates

The values presented in **Table 7** are not hypothetical estimates but are grounded in patterns observed across the case studies and scenario narratives. For example, in the "Full Steam Ahead" scenario, both the Thor and Horns Rev 3 projects moved efficiently from tender to commissioning under conditions of strong political support, transparent permitting and well aligned stakeholder coordination, justifying the classification of "High" tender frequency, "Fast" permit speed and "Strong" indicator strength. By contrast, "The Great Slowdown" scenario is modeled on the stalled Hesselø project and Denmark's cancelled 2024 tender, where tenders were issued but failed to translate into development. Here, "Low" tender frequency and "Delayed" permits are appropriate, reflecting diminished reliability of indicators and requiring a reactive port strategy. The "Cautious Progress" scenario, reflected in the Vesterhav Nord and Syd cases, demonstrates that even when tenders and permits are present, prolonged legal appeals and administrative friction result in "Moderate" indicator strength and only "Medium" confidence in forecasting. These categorizations thus stem directly from real-world project outcomes, structured within the scenario logic developed in this thesis.

Table 7 demonstrates that the strategic value of early indicators depends less on their existence and more on their consistency and visibility over time. Tenders, while politically significant, lose forecasting value in scenarios where they are delayed or irregular. Permits, on the other hand, prove to be reliable indicators only when they are timely and traceable. By mapping how indicators behave across different futures, the scenario analysis complements the earlier timeline analysis and supports a more adaptive, indicator-aware approach to infrastructure planning. This supports the main goal of the thesis, which is to assess whether offshore wind development can be anticipated in a data-informed way even under uncertainty.

5 Results

This thesis began with a practical question framed within a technical inquiry: Can offshore wind development in Denmark be forecasted using early administrative indicators like tenders and permits? For stakeholders like the Port of Aalborg, this question is not just theoretical; it's operational. The stakes are real: planning space, storage, transport and logistics requires not just knowing what will be built, but when.

Early indicators can be useful, but only if we understand their limitations. What became clear is that prediction in this context is not about data abundance, it's more a matter of interpreting institutional behavior and understanding where clarity ends and complexity begins.

5.1 RQ1

This section provides an answer to the first research question by analyzing the extent to which early indicators such as tenders, permits and related developments can be used to anticipate offshore wind project progress in Denmark. It addresses the strengths and limitations of different indicators, the timeline variability between key phases and how political and institutional conditions influence their predictive value.

5.1.1 Indicators that work and what that really means

Out of all the potential early indicators examined including tenders, permits, job postings, postponements, only tenders and permits consistently met the criteria of visibility, traceability and relevance. However, even these showed inconsistencies that limit their reliability.

Tenders appeared to be the strongest based on formal criteria: published through formal channels, tied to specific projects and backed by legislation. In projects like Thor and Horns Rev 3, they clearly signaled that development was about to start. But in other cases, such as Hesselø, the indicator lost meaning. The project was tendered, delayed, re-tendered, then quietly shelved. The signal was loud, but hollow. This raises an important point: what use is a visible indicator if the system behind it will not act?

Permits offered a different kind of insight. Less consistent in timing, but their impact is often more significant. Once a permit is granted, especially for construction permits the project tends to move. Why? At that stage, financial resources and formal commitments are already involved. This makes permits less useful for forecasting the start of a project but highly valuable for determining when preparation should begin. For a port, that distinction matters.

What about the others? Job postings were late, scattered and hard to link to specific projects. And yet, one indicator turned out to be unexpectedly useful: postponements. These were originally viewed as later-stage outcomes, but they revealed key points of vulnerability in the system. The cancellation of Omø Syd despite formal approvals showed how even “greenlit” projects can collapse under legal tension, outdated rules or stakeholder resistance (OffshoreWind.biz, 2024). Postponements may not tell us what is going to happen, but they can show where problems are likely to occur.

5.1.2 Variability, not just delay

One of the noticeable patterns in the timeline data was that not all phases of offshore wind development are equally unpredictable. This might sound obvious, but the consequences are more significant than they first appear.

The period between tender award and permit approval (T2P) showed the highest level of unpredictability. Across six Danish projects, this phase ranged from 16 months to nearly four years. This was not just a paperwork issue, it reflects challenges such as legal appeals, delays in consultations, changing environmental standards and difficulties in coordination between agencies. As Flyvbjerg (2014) argues in his theory of megaprojects, such variability often arises from deeper structural causes, including optimism bias, institutional friction and the strategic pressures that shape early project planning. The T2P phase, in this light becomes not only a timing issue but a warning sign of systemic risk where formal progress is made, but real momentum is stalled beneath the surface.

From a forecasting perspective, this kind of early uncertainty is the most difficult to manage. For infrastructure planners such as the Port of Aalborg that leaves them with a brutal tradeoff as to act early and risk preparing for a project that's years away or wait and risk being late when it finally accelerates.

In contrast, once permits are granted, the fog begins to clear. The average time from permit to construction (P2C) was far more stable as was construction to commissioning (C2O). These later phases acted with something closer to operational regularity that a port can actually plan around. Which suggests a practical strategy: do not build your logistics around tenders but build them around permits.

But perhaps the deeper insight here is that timeline variability itself is a signal. Long T2P intervals, especially those that exceed 36 months, might be used to flag projects at risk of legal or environmental difficulties. These are not just metrics, they are warnings. And in a system where failure is rarely announced but often implied, warnings matter.

5.1.3 The same indicator doesn't mean the same thing

So, if indicators like tenders and permits can behave unpredictably, what explains it? This is where scenario planning plays a role. It is used here not only as a theoretical framework but as a way to better interpret how indicators behave under different political and institutional settings.

In Scenario 2, which describes the fast, coordinated, climate-urgent future, indicators behaved as they were supposed to. Tenders were published and followed through. Permits were processed quickly. Projects like Thor moved smoothly through the pipeline. In this case the system gave meaning to the signal and it followed through. In Scenario 3, where the development moved more cautious, bureaucratically constrained future indicators were still present but less dependable. Vesterhav Nord and Syd are examples of this pattern. The projects tendered in 2016 but experienced delays for years due to legal appeals and public objections. The project was not abandoned but the signal's clarity was lost in administrative noise. In Scenario 1, which reflects a period of reduced activity and limited political engagement, signals became misleading. Tenders were announced but not followed by further steps. Developers withdrew and project plans were eventually dropped. In this context, signals led to confusion. Planning efforts were based on expectations that never materialized. Hesselø is the closest real-world match where a project that should have moved forward but never did. This example shows that a signal can only be trusted if the surrounding system is functioning properly and committed to moving projects forward.

This is the hidden truth of forecasting infrastructure, it is not just about milestones. It is about the trustworthiness of the system that produces them.

5.2 RQ2

If early indicators are imperfect, inconsistent and heavily influenced by context, then how should infrastructure planners respond? More specifically, what can the Port of Aalborg actually do with this knowledge? The answer is not to give up on forecasting but to rethink how it is used. Ports do not need to predict exact commissioning dates. What they need is situational awareness: a structured idea or sense of when to prepare, when to wait and when to challenge the assumptions baked into project announcements. And that's exactly what this thesis offers, not a "crystal ball" but a logic for reading indicators in real time with a clear sense of their strengths and weaknesses.

5.2.1 Rethinking what a "useful" indicator is

For the Port of Aalborg, tenders should be treated as early triggers, not final confirmations. When a tender is published, it is a prompt to begin monitoring and not mobilizing. It is a signal to start watching for follow-up actions that ultimately lead to the start of the construction phase (i.e. environmental assessments, permit filings, stakeholder consultations or grid connection planning). Only when those begin to materialize does a tender shift from "potential" to "probable." Permits, by contrast should be treated as readiness markers. Once a construction permit is granted, especially after public consultation and legal reviews the likelihood of activity rises significantly (based on the observed cases). This is the point where storage, transport planning and site allocation can begin with reasonable confidence. It's not perfect but it's reliable enough to act.

What this means in practice is that the port needs to develop planning models with different levels of response. Early indicators should lead to increased monitoring and data gathering, while later signals should prompt concrete steps. This is not reactive but conditional. It turns forecasting into a form of contingency planning in which actions are aligned with changing conditions rather than fixed assumptions.

5.2.2 Planning for scenarios, not just projects

Beyond project-specific indicators, the scenario analysis reveals another more strategic layer of insight which is that the port is not just responding to projects. It is responding to political and institutional conditions. If Denmark enters a "Full steam ahead" phase, such as the period Thor was developed in, the port should prepare for high activity volume, overlapping timelines and pressure on space and logistics. This would call for proactive capacity investments and formal coordination with developers. On the other hand, in a "Cautious progress" environment, as seen with Vesterhav Nord and Syd, the port's best strategy would be to be flexible: hold resources lightly, engage early with developers to identify risk and avoid committing to fixed deadlines until key permitting milestones are met. And in a "Slowdown" scenario, like what Hesselø represents, the port must be ready to delay or divert planned logistics altogether. In this setting, even formal tenders cannot be trusted unless backed up by clear, consistent follow-through.

This scenario lens is powerful not because it tells the port what will happen, but because it helps it prepare for how the system might behave and how indicators will change meaning depending on that behavior.

5.2.3 Indicators are only half the story

One of the more subtle findings of this thesis is that forecasting based on indicators alone is incomplete. Because even when the indicators are strong, external shocks such as inflation, subsidy withdrawals or public backlash can override them. The 2024-25 3 GW tender cancellation is a case in point. Despite being Denmark's largest offshore wind tender to date, it attracted zero bids. Not because of a flawed signal but because market conditions were not aligned. For the port, this is a reminder that visibility doesn't guarantee viability. This reflects Flyvbjerg's insight that delays and breakdowns in megaprojects are rarely caused by technical flaws alone. More often, they stem from systemic misalignments between ambition and capacity, between visible progress and institutional readiness. A project may advance on paper, hitting all the needed formal milestones while the foundations beneath it remain unstable. Trusting the indicator then requires more than checking whether it exists; it demands an understanding of whether the system behind it is truly capable of delivering what it promises. And this is where contextual signal monitoring becomes essential. The port should not just watch if a permit is granted, but when, how fast and with what resistance. Long delays in the T2P phase, for example, should be treated as indicators of systemic friction, not just paperwork. Similarly, shifts in developer behavior (i.e., a major player pulling out of a bid) can signal trouble more accurately than any milestone can.

6 Discussion

6.1 Positive reflections

This study set out to explore how early-stage indicators might support more proactive planning in offshore wind development, particularly from the perspective of port infrastructure. While the initial idea was to build a predictive model, it quickly became clear that such an approach would oversimplify the problem. Instead, the study shifted towards a more interpretive framework, aiming to understand the logic and patterns of project development phases through real-world cases. This change in focus proved to be one of the study's core strengths.

One of the valuable contributions of the thesis is the temporal model, which divides offshore wind development into three comparable timeframes: Tender to Permit (T2P), Permit to Construction (P2C) and Construction to Operation (C2O). While not predictive, this model provides a meaningful way to analyze and discuss project timelines and to identify potentially useful signals across phases. It has the potential to be reused or adapted in future research or planning contexts.

Another strength lies in the interdisciplinary nature of the approach. By integrating concepts from scenario planning, infrastructure logistics, business intelligence and policy analysis, the study contributes to a field that is often fragmented. It addresses a gap between academic theory and applied infrastructure planning needs, especially for public actors such as ports, who rarely have access to advanced modeling tools but still need to make long-term strategic decisions.

Furthermore, the study was grounded in practice. The selection of indicators was not based solely on literature or convenience but emerged through engagement with professionals and stakeholders. This reflects a pragmatic research approach that recognizes the complexity of real-world situations and uses expert input where standard research methods are not enough.

This change from trying to make clear predictions or creating a perfect forecast to accepting uncertainty was an important learning outcome of the study. It revealed that early indicators in megaprojects are not always straightforward and that planning often occurs in conditions of uncertainty and incomplete information. In that sense, the study contributes not only findings but also a mindset: one that values interpretability, caution and context awareness over exact measurements or fixed models.

6.2 Critical reflections on the study design

While the study offers practical contributions, it also highlights several broader limitations related to study design in this field. Offshore wind development, like many megaproject domains, poses significant challenges to conventional research methods. The phenomenon under study is both data poor and highly variable, which limits the applicability of common quantitative tools.

A primary constraint was the small sample size, which reflects the nature of the research phenomenon focusing on offshore wind development in Denmark. They are limited in number and each one is shaped by distinct regulatory, geographical and logistical conditions. These differences make it difficult to compare projects in a consistent way, and they limit the extent to which the findings from one project can be applied to others. However, in contexts like this, where large-N datasets are unavailable, research must often work with all available cases, even if few and conclude cautiously.

Data quality and availability presented an even greater challenge. Although offshore wind projects are public initiatives, relevant information was spread across multiple sources, including government websites, press releases and news articles. In many cases, dates for milestones such as permitting or construction were inconsistent or missing altogether. It was often unclear which permits were granted or what specific milestone was being reported. This lack of transparency made consistent data gathering difficult and, in some cases, required interpretive assumptions (e.g., treating Final Investment Decision as a proxy for permitting).

The study also incorporated qualitative input from industry practitioners to help identify which indicators were most relevant. This approach made the research remain context-sensitive and aligned with real-world planning needs. At the same time, it introduced a degree of subjectivity. The selection of indicators was based on expert judgment and professional experience rather than statistical or algorithmic methods. In fields such as innovation and infrastructure planning, these kinds of trade-offs are often necessary due to the complexity and variability of the systems involved. Even so, this reliance on expert opinion limits the reproducibility of the findings and may attract critique from more positivist research traditions that prioritize quantitative rigor and standardization.

The use of scenario-based analysis brought both strengths and weaknesses. While it helped to structure findings and frame discussions, it does not allow for probabilistic conclusions or policy evaluation in a quantitative sense. This shows a common limitation in studies of complex systems, which is prioritizing understanding over prediction.

The study design adopted here reflects the broader methodological constraints of researching complex, large-scale infrastructure development. It reveals both the difficulty of working with incomplete, fragmented information and the importance of building frameworks that are flexible, transparent and grounded in practice. These reflections suggest that while better tools and data systems are needed, there is also value in methods that prioritize interpretability, stakeholder relevance and conceptual clarity.

6.3 Future research

This study offers just one part of a much bigger picture, a single piece in the larger mosaic of research needed to better understand offshore wind development. While it has provided insights into early-stage indicators, many aspects remain only partly explored. There are several ways future research could build on this work. One important direction would be creating a shared, structured database of offshore wind project milestones. During this thesis, it became clear how scattered and inconsistent the relevant information is; it is spread across government websites, press releases and news articles. While much of the data technically exists in the public domain, it is not easy to access or compare. For example, the company 4C Offshore provides what appears to be a comprehensive and well-maintained database of global offshore wind projects. However, access to their platform is commercial and can be quite expensive. This highlights a broader issue: if high-quality project data is only available through paid services, then it is not truly accessible for public actors, researchers or smaller organizations. Future research could therefore focus on developing an open-access alternative, ideally as a collaborative effort across institutions or national agencies. Such a resource would support not only academic work but also help planners, ports and policymakers make more informed decisions based on consistent and up to date information.

Another promising area is the use of Natural Language Processing (NLP) to help track offshore wind developments automatically. In this thesis, we found that key information like permitting updates or construction starts often appears in unstructured formats such as press releases, newsletters and news stories. Manually searching through all of these is slow and difficult to scale. An NLP tool could help by scanning texts and flagging when certain keywords or milestones appear. This kind of system has already been used in other fields, such as financial or political news monitoring. It could also be helpful for international projects, where relevant updates might appear in different languages. Using multilingual NLP models, including translation and cross-language keyword detection, would make it easier to track developments outside Denmark or beyond English-language sources.

Another important direction is looking more closely at project failures and cancellations. Projects like Omø Syd and the North Sea Energy Island show that even when all the official milestones are in place, tenders awarded, permits granted and political support, things can still fall apart. This suggests that just tracking indicators isn't enough. Future research should include cancellations as part of forecasting logic, not treat them as rare exceptions. The goal shouldn't just be predicting when a project will happen but also spotting when it might not. This could include looking for early warning signs or "micro-indicators" of risk. For example, very long delays between tender and permit, signs of legal objections or slow public consultations might signal deeper problems. These signals may not show up in a basic timeline, but they could be important clues for planners or analysts.

Finally, the T2P–P2C–C2O model developed in this study could be taken further. Future research might explore more detailed time phases or include more kinds of events. It would also be useful to compare this timeline structure with projects in other countries to see how different legal and planning systems affect development patterns.

This study offers a starting point, but it's only part of the larger puzzle. Future research that builds better datasets, includes failed projects and applies smart tools can help make planning in offshore wind more informed, more responsive and more realistic.

6.4 Theoretical contributions

Even though this thesis is mainly practical and focused on supporting better planning at the Port of Aalborg, it also offers insights that contribute to academic understanding of wind energy infrastructure. Most research in wind energy forecasting concentrates on predicting energy production or optimizing turbine performance. Far less attention has been given to the early stages of development and how these can be interpreted as signals of future infrastructure activity. Instead of focusing on energy outputs, the work focuses on development milestones and their timing. By structuring these into intervals: Tender to Permit (T2P), Permit to Construction (P2C) and Construction to Operation (C2O), the thesis provides a simple but useful model for interpreting how offshore wind projects progress. While this structure is not complex, it has not been applied in this way in the existing wind energy literature, particularly with a focus on early-stage signal behavior.

A second contribution lies in the application of scenario planning. While this method is traditionally used in high-level strategic settings, this thesis adapts it to the specific context of wind farm project development. By anchoring scenarios in observable indicators such as permitting efficiency and policy momentum, the thesis helps make scenario planning more relevant for operational actors such as ports and logistics providers who must make decisions with limited and uncertain information. This approach translates a typically abstract method into a more practical tool for understanding how future infrastructure activity might unfold under different conditions. To deepen this application, the thesis incorporates Flyvbjerg's theory of megaproject disruption. This approach helps explain why some projects stall, even when the signals look promising on the surface. Putting the two approaches together makes it possible to not just track what might happen but to understand why it might not and that shift is key for better planning.

The contribution of this thesis is not the creation of a new theory, but the development of a structured, cross-disciplinary approach that links indicator analysis with scenario thinking. This approach helps interpret uncertainty in large-scale project environments and opens a new direction for research on data-informed infrastructure forecasting in the renewable energy sector.

7 Conclusion

When we started this project, we thought we were studying offshore wind timelines. But what we were actually studying was trust in systems, in signals and in the institutions that turn policies into action.

Tenders and permits at first look like facts: clean, timestamped and formal. But they are not fixed milestones. They are expressions of intent, shaped by negotiations, complex procedures and shifting political will. What we learned is that information is only as useful as the system that generates it, and those systems behave differently in different places. For planners like the Port of Aalborg, that difference matters. When Port of Aalborg or similar actors consider entering new markets, they should not only assess the formal regulatory frameworks but also examine the less visible structures of trust, signal interpretation and institutional behavior. These elements that are often assumed to be stable or universal can differ significantly across national contexts and have a major impact on project timelines and outcomes. For example, a delay in Denmark might result from cautious following of the procedures, but in other countries, it could reflect deeper issues like unclear responsibilities, rules that are not followed the same way every time, or people and institutions not working toward the same goals. What our research suggests is that the success of complex infrastructure projects depends as much on "reading the system" correctly as it does on technical competence. A forward-thinking strategy would therefore involve talking early with local stakeholders, understanding how trust works between institutions and staying flexible enough to adjust when things do not go as planned, instead of just copying what worked at home.

That is why we approached this work pragmatically. Rather than relying on a single model or methodology, we drew on expert interviews, document analysis, and real-world development cases to build a wider lens. Our epistemological stance was not based on certainty, but on *usefulness,* recognizing that different types of knowledge (technical, experiential, institutional) each carry part of the picture. Conversations with industry professionals across all stages of the wind farm lifecycle were especially valuable. These individuals, embedded in the real dynamics of the sector, often held insights that no model could replicate. They could sense hesitation before it appeared on paper. They understood where formal processes differ from practical reality. In that sense, people with a deep understanding of the system are not just useful, they are irreplaceable. This thesis didn't resolve the tension between knowing and predicting. But it gave us language for it: a way to read early indicators more critically, to anticipate delay not as failure but as a signal and to plan for multiple futures rather than hope for one. When institutions are unpredictable, forecasting is not about certainty, it is about humility, skepticism and asking better questions earlier.

And finally trust, process transparency and political alignment are as much a part of feasibility as supply chains or seabed conditions. In new markets, success may depend less on predictive or forecasting models and more on having people who understand the local landscape who know whom to ask, when to push and when to wait. Because in the end, we did not just map project timelines. We mapped the space between ambition, execution and the messy, political, often invisible forces that shape how fast the future arrives.

8 References

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