Enhancing Tender and Supply Contract Designs for a Robust Offshore Wind Industry

Improving the coordination between government, offshore wind farm developers, and wind turbine manufacturers in the North Sea

CoSEM Master Thesis

Berk Noyan

Delft University of Technology

TU Delft

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by

Berk Noyan

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Thesis committee:	Dr. ir. K. Bruninx,	TU Delft (first supervisor)
	Dr. A. F. Correljé,	TU Delft (second supervisor)
	Ir. D. Kucuksahin,	AFRY Netherlands (external supervisor)

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TU Delft

Preface

As I wrap up my master's program in Complex Systems Engineering and Management at TU Delft, specializing in energy markets and future energy systems, I want to take a moment to extend my heartfelt thanks to the incredible individuals who have supported me throughout this journey.

First and foremost, I would like to express my sincere gratitude to AFRY, where I had the privilege of working for five months in their Utrecht office. The welcoming atmosphere and the helpfulness of everyone I encountered made this experience truly enriching. Special thanks go to my supervisor at AFRY, Dogukan, who held weekly meetings with me, providing invaluable guidance and support. His insightful advice was instrumental in shaping the direction of this project. I also extend my heartfelt thanks to Imke for her supervision and guidance from our initial discussions about the thesis topic to the final presentation of my findings. The entire AFRY team made this experience both enjoyable and enlightening.

I want to give special acknowledgment to all my supervisors at TPM. I am especially grateful to Kenneth, my first supervisor, for his unwavering support and encouragement. His willingness to offer guidance and feedback, always with a warm and welcoming attitude, helped me navigate the challenges and complexities of this work.

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A special acknowledgment goes to my lovely girlfriend, Tugba. Despite the 2500 kilometers that separated us, her unwavering support during my time in the Netherlands was a constant source of strength. Her faith in me and understanding throughout this journey have been incredibly uplifting, and I couldn't have done it without her.

Lastly, I want to thank all the wonderful people I've met during my two-year journey in the Netherlands. Although I can't mention everyone by name, please know that your kindness, friendship, and support have made this experience unforgettable.

This thesis is a testament to all the wonderful people who have been a part of this journey. Thank you all for everything!

Berk Noyan
Delft, August 2024

Executive Summary

Offshore wind is a promising solution in the transition to renewable energy. However, the industry faces numerous challenges, including high project costs driven by macroeconomic factors, uncertain long-term revenue streams, and critical supply chain constraints. The trend toward larger turbines has worsened these financial challenges by shortening development timelines and increasing non-recoverable research and development costs, which in turn increases the cost of negotiating with supply chain partners. Existing tender and supply contract designs often fail to adequately address these complexities, resulting in suboptimal outcomes and inefficiencies.

While much of the current literature focuses on the perspectives of developers in bidding processes, there is a notable gap in understanding the critical role of the supply chain, particularly turbine suppliers. This research aims to fill this gap by investigating the bidding systems for offshore wind projects in the North Sea, with the goal of improving market coordination and interactions between governments, developers, and turbine suppliers. The main research question guiding this study is:

"How can tender and supply contract designs be enhanced for a robust offshore wind energy industry in the North Sea, considering costs, benefits, and risks among governments, developers, and turbine manufacturers?"

To address this main question, four subquestions are posed:

1. What are critical transactions to be considered for understanding coordination problems in the offshore wind industry?
2. How do governments, developers, and turbine manufacturers manage their costs and benefits in offshore wind energy projects, considering the financial risks?
3. How do current tender and supply contract designs for North Sea offshore wind projects address the allocation of costs, benefits, and financial risks?
4. What improvements can be implemented in tender and supply contract designs for a robust offshore wind energy industry in the North Sea?

The first subquestion examines the complex network of stakeholders in the offshore wind industry, including suppliers, contractors, developers, and government agencies. These entities interact through various contractual frameworks that outline the allocation of costs, benefits, and risks. Critical transactions that affect the levelized cost of energy (LCOE) for offshore wind projects include those related to construction work packages. In addition, tender procedures that grant developers exclusive rights to specific sites, the allocation of grid responsibilities between developers and the government, and the mechanisms for revenue generation through power sales are critical elements that shape the dynamics of the industry.

In response to the second subquestion, the study explores how governments, developers, and turbine manufacturers collaborate to manage financial risks in offshore wind projects. Governments use stringent tender requirements and financial assurances to ensure project feasibility and commitment. Developers counteract these challenges by securing pre-orders, using Power Purchase Agreements (PPAs) for revenue certainty, and distributing risks through contractor agreements. Turbine manufacturers manage their financial risks by negotiating cancellation fees to support new production investments. Despite these measures, the study identifies the need for improved tender and contract designs to better address macroeconomic challenges and enhance overall industry stability.

Addressing the third subquestion, the North Sea market's institutional frameworks demonstrate the complexity of tender designs in managing cost and risk allocation. Countries like the Netherlands, Denmark, Germany, and the United Kingdom (UK) use strategies such as pre-investigations and maritime spatial planning to reduce site risks. Germany's approach of offering areas without pre-investigations encourages higher bids to boost offshore wind capacity. Different grid responsibility models are adopted:

the Netherlands uses a centralized system, Denmark prefers decentralization, and the UK and Germany combine elements of both. Tenders now consider both financial and non-price factors, with mechanisms like negative bidding creating immediate revenue for governments. However, these mechanisms can pressure supply chain partners, potentially compromising project quality and reliability. This pressure may result in reduced equipment durability and increased risk of project abandonment if market conditions change, leading to short-term revenue benefits but posing long-term stability challenges for offshore wind projects.

For the fourth subquestion, the research shows that enhancing offshore wind energy development in the North Sea requires incorporating flexibility into tender designs and addressing imbalances in negotiation outcomes. By allowing adjustable project deadlines and incentivizing early framework agreements, tenders can improve fairness and efficiency. The analysis underscores the importance of aligning patience levels between developers and suppliers to avoid skewed price surplus distribution. Governments should support these efforts by coordinating with suppliers to address supply chain bottlenecks and prioritizing advanced-stage projects with proven technologies.

To address the main research question, the study recommends five key policy changes: **1) Clear linkage between tender roadmaps and decarbonization targets** to ensure that offshore wind projects are aligned with broader electrification and decarbonization goals, thereby increasing market stability and developer confidence. **2) Aligning the weight of non-price and price criteria across markets** to ensure a fair allocation of innovation and investment costs across countries. **3) Extending construction timelines and supporting design flexibility** to reduce pressure on developers and accommodate technological advances and supply chain constraints. **4) Prioritizing advanced-stage projects and balancing incentives** to increase project success rates and reduce speculative bidding while ensuring that both bidders and suppliers are adequately motivated. **5) Shift from financial offers to government participation** to reduce project costs and financial risks by having governments take an equity stake in projects, thereby aligning interests and supporting long-term success. These recommendations aim to create a more robust framework for offshore wind development in the North Sea.

The findings have significant implications for policy-making and industry practices within the offshore wind sector. By proposing refined tender procedures, incentivized contract structures, and adaptive regulatory frameworks, the research promotes the development of efficient, resilient, and environmentally sustainable offshore wind projects. These recommendations align with broader climate goals and the European Union's initiatives for renewable energy expansion and carbon neutrality.

Nevertheless, the applicability of these findings may be limited to the North Sea region. Future research should include comparative analyses of different global markets to account for regional variations in tender mechanisms. Additionally, exploring vertical integration within the value chain, such as developer companies building their own vessels or acquiring partners across different work packages, could offer new insights. Integrating these stages under a single company's control may reduce coordination complexities and enhance project realization. While this topic diverges from the primary research question, it presents a promising area for investigation, potentially addressing current industry challenges and improving business cases. Addressing these limitations in future studies will enhance the robustness and broader applicability of findings as the offshore wind energy sector continues to evolve.

Contents

List of Figures

List of Tables

Nomenclature

Abbreviations

Abbreviation	Definition
BOP	Balance of Plant
CoSEM	Complex Systems Engineering & Management
DCF	Discounted Cash Flow
DEA	Danish Energy Agency
EC	European Commission
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPCI	Engineering, Procurement, Construction and Installation
EU	European Union
FID	Final Investment Decision
FIDIC	International Federation of Consulting Engineers
IMCA	International Marine Contractors Association
LCOE	Levelized Cost of Energy
MOU	Memorandums of Understanding
NSEC	North Seas Energy Cooperation
NTP	Notice to Proceed
OEM	Original Equipment Manufacturer
OFTO	Offshore Transmission Owner
OWF	Offshore Wind Farm
PSA	Preferred Supplier Agreement
RES	Renewable Energy Sources
RVO	Netherlands Enterprise Agency
SDE+	Stimulation of Sustainable Energy Production
SEA	Strategic Environmental Assessment
SMA	Turbine Service and Maintenance Agreement
SPV	Special Purpose Vehicle
TSA	Turbine Supply Agreement
TSO	Transmission System Operator
UNCLOS	United Nations Convention on the Law of the Sea
WACC	Weighted Average Cost of Capital
WFSD	Wind Farm Site Decision
WTG	Wind Turbine Generator

Symbols

Symbols	Definition
DEV	Offshore wind farm developer
TM	Offshore wind turbine manufacturers
IV^{DEV}	DEV's initial value
IV^{TM}	TM's initial value
RV^{DEV}	DEV's reservation value
RV^{DEV}	TM's reservation value
T^{DEV}	DEV's deadline

Symbols	Definition
T^{TM}	TM's deadline
T^0	Beginning of the negotiation
Z	Zone of possible agreement
p	Agreed price
$p^t_{DEV \to TM}$	Price offered by DEV to TM at time t
B	Boulware negotiation strategy
C	Conceder negotiation strategy
L	Linear negotiation strategy
U^{DEV}	DEV's utility function
U^{TM}	TM's utility function
δ^{DEV}	DEV's future value factor
δ^{TM}	TM's future value factor
f^{DEV}	DEV's player-specific decision function
f^{TM}	TM's player-specific decision function
ψ	Parameter decide the rate of change in $f(t)$ over time

1 Introduction

In the introductory chapter, the report begins by providing background information (Section 1.1), followed by a statement of the problem (Section 1.2). The knowledge gap in the literature and the research questions are defined (Section 1.3), along with the methodology of the research (Section 1.4). Then, its relevance to the CoSEM program (Section 1.5) is discussed. Lastly, the outline of the report is presented (Section 1.6).

1.1. Background

Offshore wind energy is playing an inevitable role in the endeavor of coastal nations to achieve climate goals. With its five sea basins, the European Union (EU) offers enormous offshore wind energy potential. In 2021, the European Commission (EC) unveiled a 'Fit for 55' package that aims to reduce greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, with offshore wind becoming the main source of electricity [1]. The EU has set ambitious targets, publishing the EU Offshore Renewable Energy Strategy to achieve at least 60 GW of offshore wind capacity by 2030 and 300 GW by 2050 [2]. In May 2022, REPowerEU was launched to achieve an additional 30 GW of offshore wind energy in the EU [3]. Responding to the call for more renewable energy, Belgium, Denmark, Germany, and the Netherlands committed to a joint offshore wind target of at least 65 GW by 2030 and 150 GW by 2050 in the Esbjerg Declaration. This effort positions the North Seas as the Green Power Plant of Europe, justifying its selection as the focused terrain in this research [4]. According to the data presented in Figure 1.1, it can be observed that the North Sea region is home to a significant majority of connected turbines, accounting for approximately 79% of the total capacity of the grid-connected turbines in the EU.

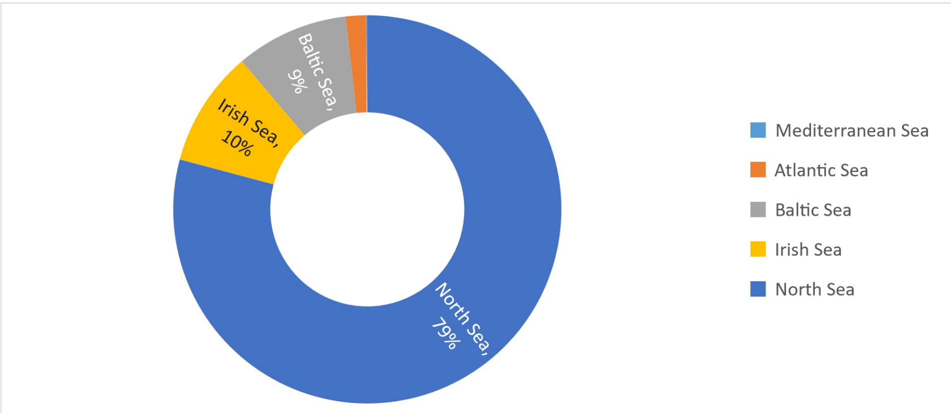


Figure 1.1: Cumulative grid-connected capacity by sea basin [5]

In the following months, the North Seas Energy Cooperation (NSEC) members[1] and the EC agreed to reach at least 260 GW of offshore wind capacity by 2050, emphasizing the need for collective action to achieve EU-wide ambitions. These nations also agreed to achieve 76 GW of offshore wind by 2030 in the North Sea, representing ca. 75% of the overall EU target for that year [6]. Building on the Esbjerg coalition, France, Ireland, Luxembourg, Norway, and the UK joined in April 2023, raising the collective target to 120 GW of offshore wind in the North Sea by 2030 and at least 300 GW by 2050. These efforts represent a concerted push to increase energy security, reduce reliance on fossil fuels, and meet the goals of the Paris Climate Change Agreement.

On the other side, as of the end of 2022, the EU reached only approximately 16 GW in installed offshore wind capacity [7]. Bridging this substantial gap necessitates an average annual installation of nearly 12 GW, representing a tenfold increase from the 1.2 GW installed in 2022 [7, 8]. In 2023, EU countries installed approximately 3 GW of offshore wind energy, while the UK, which is the leading European country in offshore wind capacity, installed almost 1 GW (see Figure 1.2). Moreover, the global offshore wind capacity grew by 32% year over year in 2023, with developers installing 10.8 GW. However, the potential doubling of this increase was hindered by delays in construction, installation, commissioning, and transmission [9]. All these indicate that although the industry has been growing, it needs to accelerate its pace to achieve its objectives.

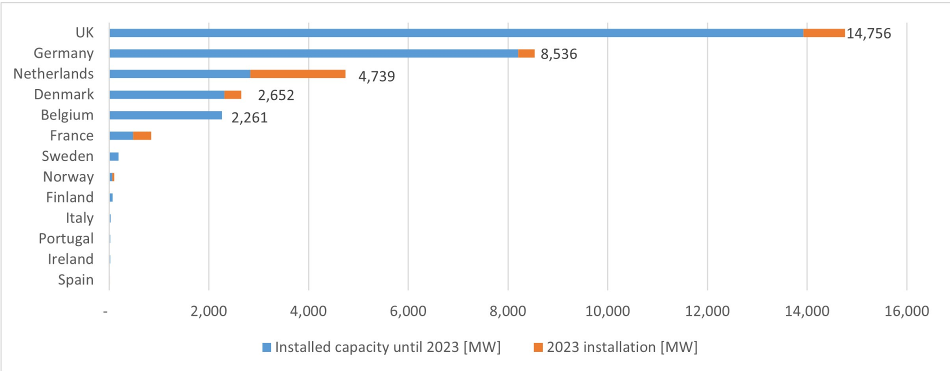


Figure 1.2: Cumulative installed offshore wind capacity in Europe [10]

Some unfavorable developments took place recently. These include a significant drop in the shares of one of the largest offshore wind companies [11], the decision of a Swedish developer to withdraw from a 1.4 GW UK wind farm project [12], and the notable absence of offshore capacity awarded in the most recent UK auction [13]. In 2022, final investment decisions in offshore wind projects reached their lowest point in a decade (see Figure 1.3). Various factors, including, but not limited to, historically high inflation rates, rising interest rates, increasing seabed lease fees, and supply chain bottlenecks, contribute to this downturn by increasing the costs of offshore wind projects [14–16]. In response, the European Union has introduced the European Wind Power Action Plan, which emphasizes the importance of streamlining permit processes, refining auction systems, and improving access to finance to establish a stable supply chain [17].

In 2023, efforts to improve the offshore wind energy industry had a positive impact. Despite the challenges faced during the year, final investment decisions reached a new peak of €30 billion across eight wind farms in Europe [18]. In addition, 2024 is expected to be the busiest year yet for offshore wind energy tenders, with over 50 GW planned [19]. However, the industry's sustainability is still questionable, and the underlying concerns must be addressed to achieve its long-term goals.

[1] Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden

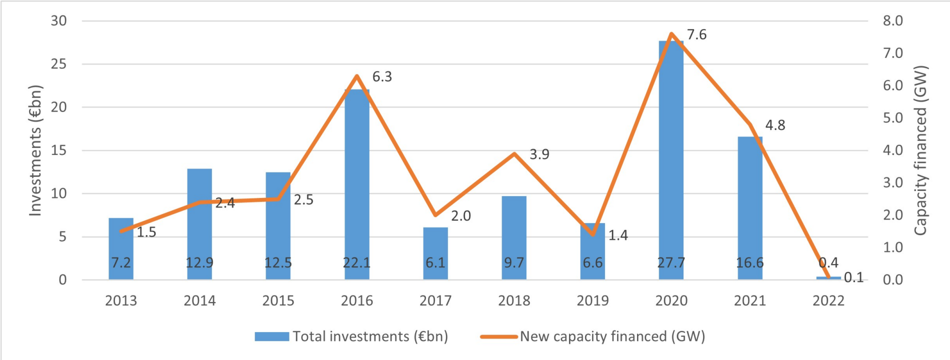


Figure 1.3: Investment in new offshore wind farms in 2013-2022 [20]

1.2. Problem statement

Offshore wind projects are primarily driven by profit-focused private companies. These ventures typically undergo a competitive bidding process known as a tender to gain access to wind resources, which is governed by the country's regulatory framework [21]. Offshore wind tenders have mainly prioritized pricing in line with traditional market norms, emphasizing cost efficiency and competitiveness. However, the economic viability of offshore wind projects heavily relies on upfront capital expenditure, making them vulnerable to fluctuations in financial markets, supply chain disruptions, and regulatory changes [22]. Throughout the project development process, various contractual relationships exist between different stakeholders. Each party aims to maximize benefits and minimize costs while accounting for the risks and uncertainties they face. In today's volatile market, these risks are heightened, leading stakeholders to incorporate them into their contract pricing. This results in inefficiencies and increases pressure on projects that depend heavily on upfront capital expenditure. Consequently, the risk of project delays and cancellations rises.

In offshore wind auctions, the presence of zero bids has increased over time, and non-price criteria have become more important. This shift emphasizes the importance of promoting long-term, sustainable development while reducing offshore wind costs [23]. The idea is that the value of offshore wind projects should not only be determined by their monetary cost but also by factors such as system integration, biodiversity, and social contribution. However, this multi-dimensional approach complicates the bidding process, particularly in volatile and uncertain market conditions. Moreover, the costs and revenues of offshore wind projects, being business ventures, cannot be ignored. To ensure their economic viability, it is necessary to address the financial uncertainties, both short- and long-term, present in the industry. Each stakeholder encounters unique financial risks during the project development process, making the effective management of these interactions more crucial than ever.

In addition to these challenges, Europe wants to prioritize maintaining its local supply chain industry to decrease dependency on foreign suppliers while ensuring local innovation and competitiveness. This requires establishing a strong industry structure backed by collaborative efforts from stakeholders such as governments, developers, and suppliers.

1.3. Knowledge gap and research questions

The existing literature on offshore wind tenders mainly focuses on the bidding strategies and viewpoints of developers and governments. Recent research emphasizes the importance of price competition among developers, but there remains significant scope for investigating zero-subsidy bids and non-price criteria in tenders. However, the biggest gap arises from a lack of understanding of the costs, benefits, and risks shared during the project development processes within the existing institutional framework. Developers play a direct role in the development process for offshore wind projects, but the impact of other stakeholders, such as turbine suppliers, on the projects is poorly focused. Previous research has been inadequate in assessing the influence of supply chain bottlenecks on tender outcomes and the adaptation of stakeholder strategies in different market conditions. This highlights the need for a more comprehensive approach that not only focuses on awarding mechanisms but also considers the perspectives of the supply chain to build a healthy offshore wind industry.

This study aims to fill the gap by examining the contractual relations between turbine manufacturers and offshore wind farm developers and suggests various options to regulatory authorities. Closing the gap between tender and supply chain considerations is necessary to develop a robust offshore wind industry in the North Sea, creating a system that can withstand challenges for long-term success. This research emphasizes risk allocation and associated costs and benefits in offshore wind projects by analyzing interactions among the government, developers, and turbine manufacturers. It provides valuable insights to improve tender and supply contract designs. The main research question is as follows:

"How can tender and supply contract designs be enhanced for a robust offshore wind energy industry in the North Sea, considering costs, benefits, and risks among governments, developers, and turbine manufacturers?"

The sub-questions below are formulated to guide the exploration of the main research question:

1. What are critical transactions to be considered for understanding coordination problems in the offshore wind industry?
2. How do governments, developers, and turbine manufacturers manage their costs and benefits in offshore wind energy projects, considering the financial risks?
3. How do current tender and supply contract designs for North Sea offshore wind projects address the allocation of costs, benefits, and financial risks?
4. What improvements can be implemented in tender and supply contract designs for a robust offshore wind energy industry in the North Sea?

1.4. Methodology

This part of the study aims to give a detailed description of the research methodology. It includes a thorough discussion of the research approach and an explanation of the research methods used to justify and present the data-gathering and analysis techniques employed in the study.

1.4.1. Research approach

This research project aims to use an institutional design approach to improve the tender and supply contracts for offshore wind projects in the North Sea. This approach does not aim to design a full tender and contract process but rather to offer design improvements that can benefit the offshore wind industry. The objective is to promote a healthier industry and enhance both the tender and contract processes for the benefit of various stakeholders. The research provides a more comprehensive understanding of the intricate dynamics in the offshore wind tender process, as well as the contractual relationship between developers and suppliers. The research is mainly focused on turbine manufacturers for the supply side, as turbines account for approximately 30-50% of the capital cost of the projects [24, 25].

There are typical examples of qualitative approaches in the literature, such as case studies or using interviews as a research method [26]. On the other hand, over time, the modeling approaches are gaining momentum in literature, incorporating diverse models like agent-based, stochastic, financial, and real option models [27–31]. Agent-based modeling is suitable for simulating complex systems such as bidding behavior. Bidder behavior in offshore wind auctions is also analyzed using financial and real-time options models to identify the best bidder tactics. Although levelized cost of energy (LCOE) and discounted cash flow (DCF) metrics offer preliminary approximations for non-strategic bid pricing, they possess some limitations, frequently underestimating the necessary compensation since they fail to take risk and uncertainty into account [26]. To overcome these shortcomings, [32] suggests a sophisticated financial modeling technique that works with strategic bidding optimization to generate competitive and risk-adequate auction offers.

This research examines the challenges faced by the upstream segment of the offshore wind value chain, which has been overlooked by existing models focusing on interactions between developers and governments in the tender process. The study analyzes how different interactions among governments, developers, and turbine manufacturers affect offshore wind projects and how coordination problems among these stakeholders can be addressed through various contractual arrangements. The study examines how developers and turbine suppliers are positioned in volatile and uncertain market environments. A quantitative model is utilized to mimic the different market scenarios.

1.4.2. Research methods

This study utilizes both qualitative and quantitative research methods. It starts with desk research and a literature review to conduct an institutional analysis to identify coordination issues and critical transactions in the offshore wind energy sector. Coordination issues are linked to the relevant layers using the four-level framework of the economics of institutions developed by Williamson [33]. Various levels of institutions are associated with different design challenges and economic approaches to achieve the desired system performance in the industry. This research primarily focuses on the institutional environment and the governance structure level, where contracts are forms of governance and transactions are the fundamental unit of analysis.

The insights from transaction analysis are combined with exploratory interviews conducted with developers and turbine manufacturers to validate the findings. These interviews are semi-structured and aim to gain a thorough understanding of how the stakeholders interact with each other and how they manage their costs, benefits, and risks through offshore wind projects. In semi-structured interviews, there's no complete script; some questions are prepared in advance [34]. This interview process follows three steps below:

1. **Preparation:** In this initial phase, planning is undertaken for the upcoming interviews. Relevant questions are formulated, and the target group is defined and informed. Additionally, data management and risk mitigation plans are conducted to create a conducive environment for the interviewee.
2. **Conducting the interview:** The conversation is structured with prepared questions, followed by spontaneous dialogue and follow-up inquiries, and adapted as necessary to cover all pertinent topics while taking notes.
3. **Analysis and reflection:** After the interview, the gathered data is analyzed to identify recurring themes, patterns, and noteworthy insights. The interview notes are also shared with the interviewees for their approval.

A list of interviewees and their corresponding roles are presented in Table 1.1. This composition serves the purpose of gathering primary data sources, enabling us to acquire direct and detailed insights into the perspectives of target stakeholders. The research endeavors to construct a comprehensive understanding of the subject matter by engaging with representatives from both public and private sectors.

Table 1.1: List of the interviewees

Interview #	Related stakeholder	Job title
1	Offshore wind farm (OWF) developer	Bid Manager
2	OWF developer	Contract Manager
3	Wind turbines manufacturers	Head of Offshore Market
4	Consultancy	Offshore Project Manager

Subsequently, this study conducts a desk review to analyze different tender processes in established offshore wind markets in the North Sea. It delves into the critical transactions identified in the institutional analysis, particularly the interaction between government and developers, and provides detailed information on various cases within these jurisdictions.

After assessing the tendering process in the North Sea, attention turns to the post-tender process, which mainly involves building the wind farm. At this stage, the interaction between developers and contractors/suppliers becomes important. This thesis focuses on the relationship between developers and turbine manufacturers. Turbine supply contracts are always separate, and turbine costs form a large share of the projects, making the turbine manufacturer a critical player. Further details are discussed in Chapter 3. Then, the interaction between developers and turbine suppliers is studied using a quantitative modeling method based on a game-theoretic bargaining approach. Various negotiation problems can be modeled in different ways (for details, see Section 2.3.2). This paper uses a bargaining game to analyze the strategic interactions between developers and turbine suppliers under different deadlines and time preferences of the players. A stylized model is used to represent different market conditions and coordination problems discussed in the institutional analysis, helping to define undesirable situations and their causes.

1.5. Relevance for CoSEM

Offshore wind tenders and supply contracts demand institutional interventions due to the challenges in the evolving offshore wind energy system. The distribution of risk in supply contracts and tender processes is examined using CoSEM approaches and methods, including quantitative modeling and institutional economics. This study incorporates components of offshore wind technology and uses techniques from systems engineering, economics, and operations research. The research also helps reconcile the perspectives of the public (i.e., government) and private (i.e., developers and turbine manufacturers) sectors. The main objective is to provide insights for robust offshore wind tender and supply contract designs, ultimately reducing project risks and increasing the realization rate of offshore wind projects to achieve climate goals.

1.6. Outline of the report

The rest of the paper is structured as follows: Chapter 2 reviews the current literature and explains key concepts and relevant theories. The analysis presented in Chapter 3 provides insights into the regulatory and governance structures of the offshore wind industry, identifying critical transactions during the offshore wind development process. It also outlines the views of various stakeholders and highlights how they manage the risks and uncertainty involved in the industry. Subsequently, Chapter 4 discusses how to develop offshore wind projects in the North Sea. This chapter is divided into two main sections. The first part focuses on the critical transactions between developers and the government through the tender process. The second part presents a quantitative model to observe the interaction between developers and turbine suppliers after the tender is awarded. It mimics the coordination problems between the developers and the supply chain, as identified in institutional analysis. Lastly, Chapter 5 discusses the findings, research contributions, and limitations of the work.

2

Theoretical Background

This chapter reviews the existing literature to provide a broader context on offshore wind tenders and contract designs. Additionally, the fundamental concepts involved in offshore wind projects are explained to provide basics of how the offshore industry operates. The concepts discussed in this chapter form the basis for the institutional analysis and market study that will be covered in the upcoming chapters.

2.1. Basics of offshore wind tenders

The offshore wind energy sector offers wind power solutions that are cost-effective while remaining competitive in the electricity market. Tenders are a useful way of allocating wind energy if they are designed appropriately. It is projected that tenders will be the primary method for deploying more than 200 GW of future global offshore wind capacity by 2030, irrespective of jurisdictional policies [21]. The terms tenders and auctions are frequently used interchangeably in the literature [35]. Offshore wind tenders and auctions both refer to competitive allocation processes where developers submit bids to receive support remuneration and/or access to wind resources (sea bed leasing) for the development and operation of offshore wind energy projects [21]. While auctions only consider the lowest price among qualified bidders, competitive tenders, often known as multi-criteria auctions, evaluate both price and non-price criteria [36]. For consistency, the report will refer to both price-only auctions and multi-criteria auctions as tenders.

Regulatory authorities organize offshore wind tenders in designated zones, requiring developers to meet qualification criteria. The allocation mechanism determines which developer gets the rights to develop a project in a specific offshore area and receives a support payment if it is applicable. Through a support scheme such as Contracts for Differences (CfD), developers receive financial support for their offshore wind projects [30]. In Table 2.1, support mechanisms are explained briefly.

Generating revenue from offshore wind farms is not just about selling electricity on power exchanges. Power purchase agreements (PPAs), which are contracts between a power producer and an offtaker, such as an electricity consumer or trader, provide another promising revenue generation option. These agreements specify the quantity of electricity to be supplied and the negotiated power price over a long period of time [31]. With PPAs, the risk of market electricity price fluctuations is reduced. Some countries also consider offtaking to be a criterion or requirement in tenders.

Table 2.1: Overview of subsidy schemes [37]

Support mechanism	Description
Feed-in-Tariffs (FIT)	Renewable energy producers are eligible to receive a predetermined fixed payment, ensuring a guaranteed level of compensation for the electricity they supply to the grid, regardless of fluctuations in wholesale prices.

Table 2.1: Overview of subsidy schemes [37]

Support mechanism	Description
Feed-in-premium (fixed)	Renewable energy producers that meet the criteria receive an additional payment, known as a premium price, on top of the wholesale price.
Feed-in-premium (floating)	Unlike a fixed feed-in premium, the variable premium would be determined by subtracting an average wholesale price from a pre-determined guaranteed price. In essence, this acts as a minimum revenue guarantee, setting a floor price.
Contracts for differences (CfD)	Comparable to a floating premium, but if the wholesale price exceeds the guaranteed price, generators must pay the difference between the guaranteed price and the wholesale price.
Green Certificates	A tradable asset that certifies the production of electricity from renewable sources. These certificates are separable from the energy itself and can be traded independently.

Several studies have delved into the complex process of creating tenders for renewable energy sources (RES) in the past, with a particular emphasis on the offshore wind sector. These studies have analyzed different critical aspects of tender design. The diagram presented in Figure 2.1 is a high-level breakdown of the specific tender design elements discussed in these works, thus offering a concise review of this research field.

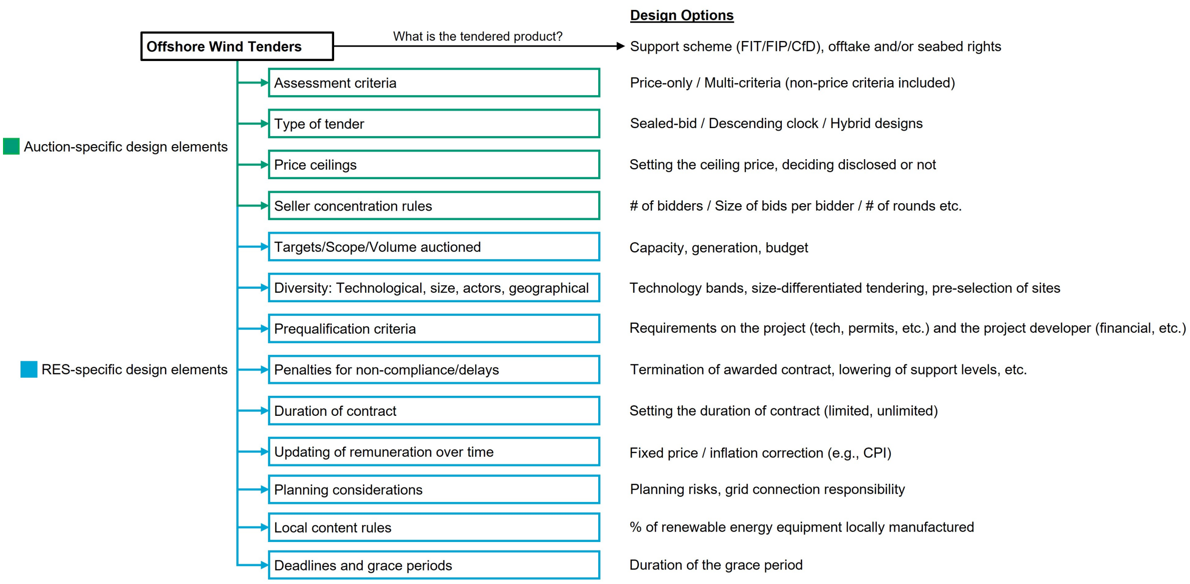


Figure 2.1: A simplified overview of offshore wind tenders design elements [35, 38]

Successful tenders require careful planning. Regulatory authorities must learn and adapt wind business models to evolving tender formats, driving industry improvement and enhancing access to wind energy. In some jurisdictions, support scheme auctions and seabed leasing are separate, such as the USA and UK, while some countries combine them, such as the Netherlands and Germany [21]. Typically, auctions are price-based, with the lowest bid securing the support scheme. However, zero subsidy and negative bids have recently emerged in some regions, indicating that companies not only waive support payments but are also willing to pay for the right to operate. However, negative bids are not always allowed by the government, as they aim to avoid a race to the bottom. To respond to market competition, some governments include non-price criteria in bid evaluations, such as environmentally responsible, socially beneficial, and economically feasible offshore wind farm designs (see Appendix A.1).

Offshore wind tender success is commonly assessed through two key metrics outlined in literature:

effectiveness pertains to the ability to meet renewable energy expansion targets, while efficiency focuses on achieving expansion goals at minimal cost, often measured using metrics like levelized cost of energy (LCOE) [39]. LCOE provides insights into both short-term cost minimization and long-term effects on innovation and potential cost reductions. However, challenges such as price uncertainty can lead to investor hesitation, while low bidding, often driven by speculative motives, aims to secure awards but may compromise project viability. Additionally, complex procedures can pose barriers for smaller developers, limiting their participation in tender processes. Recognizing and addressing these factors is important for optimizing the effectiveness and efficiency of offshore wind tenders. Furthermore, it's essential to acknowledge that there's no one-size-fits-all tender scheme; instead, strategies are tailored to market-specific scenarios to ensure optimal outcomes.

Before proceeding to the next section, Table 2.2 explains some important key terms and concepts to help readers understand the following chapters better.

Table 2.2: Overview of key terms and concepts [37, 40, 41]

Terms and Concepts	Short description
Special Purpose Vehicle (SPV)	SPV is a separate legal entity formed for a specific financial purpose, often used to isolate risk and hold specific assets, such as property or loans, without affecting the sponsoring company's main operations.
Financing	Finance can take various forms, such as project finance without further guarantees or commitments from the owners, or it can be carried out through corporate loans on the developer's balance sheet. In the case of an SPV developer, finance is usually jointly owned by two or more developers. This is becoming increasingly common as it benefits the sponsors, owners, and developers.
Final Investment Decision (FID)	Final assessment of project investment and developer entitlement to proceed with contracts signed prior to FID.
Engineer, Procure, Construct and Installation (EPCI)	A method of hiring contractors to build offshore projects. The contractor uses both internal and contracted resources to deliver on a broad range of responsibilities.
Balance of Plant (BOP)	Everything that is part of the wind farm, except for the turbines, is included in the package. This includes transmission assets that were built specifically for the wind farm.
Contracting	Offshore wind developers often bundle certain parts of the BOP and choose one EPCI contractor. This strategy may involve unfamiliar scopes for the contractor, and there could be changes in scope responsibility during the contracting phase. Timing and sequencing of the three major contracts (cables, substations, wind turbines) are critical for developers.
Notice to Proceed (NTP)	Notice to Proceed is a formal authorization for a contractor to start work on a project.
Framework Agreement / Preferred Supplier Agreement	These agreements are frequently signed before FID. Developers require start-up operations by means of a special agreement or a notice to proceed of the EPCI contract.
Export cable	Electrical cables that run between an AC offshore substation and a DC converter substation, or between the onshore and offshore substations.
Inter-array cable	The electrical cable that runs between the offshore substation and the turbines.
Environmental Impact Assessment (EIA)	EIA is a method used to evaluate a project's impacts on the environment to ensure that actions impact the environment before they are approved or authorized. An EIA is carried out for offshore wind on the export cable route, onshore grid cable route, and designated offshore area.

2.2. Contracting in offshore wind industry

The offshore wind industry presents unique challenges due to the complexity of coordinating various industrial actors involved in building heavy structures at sea. Offshore wind projects require careful orchestration of turbine manufacturers, contracting companies, and suppliers of foundations, cables, and electrical equipment. The project's cost and responsibility are distributed among multiple components, with none claiming more than 30-40% of the construction budget [22]. These projects require deliveries from various sectors, including [37]:

- Wind turbine generators (WTGs)
- Offshore inter-array cables
- Offshore substations
- Export cables
- Onshore substations
- Onshore cables and grid connections

Choosing the appropriate contract strategy is important for the success of any project, as each element plays a vital role. The technical and financial capabilities of the developer influence choices. Even though there are many alternatives for the contracting model of the project, two important variations exist in the offshore industry: a multi-contracting strategy or a wrapped EPCI-based strategy [37].

Multi-contracting involves awarding separate contracts for various project elements, such as turbine supply, foundation supply, installation, and cable installation. This strategy demands careful management of interface risks and supplier deliverables. Experienced developers opt for multi-contracting to cover key wind farm elements. This strategy allows for lower costs and greater control over assets but requires larger internal teams and carries higher financial risks. A simplified illustration of a multi-contracting strategy for an offshore wind project is presented in Figure 2.2, emphasizing the complexity involved. To mitigate interface risks, an EPCI-based strategy that involves contractors managing multiple packages simultaneously may be selected, albeit at an additional cost.

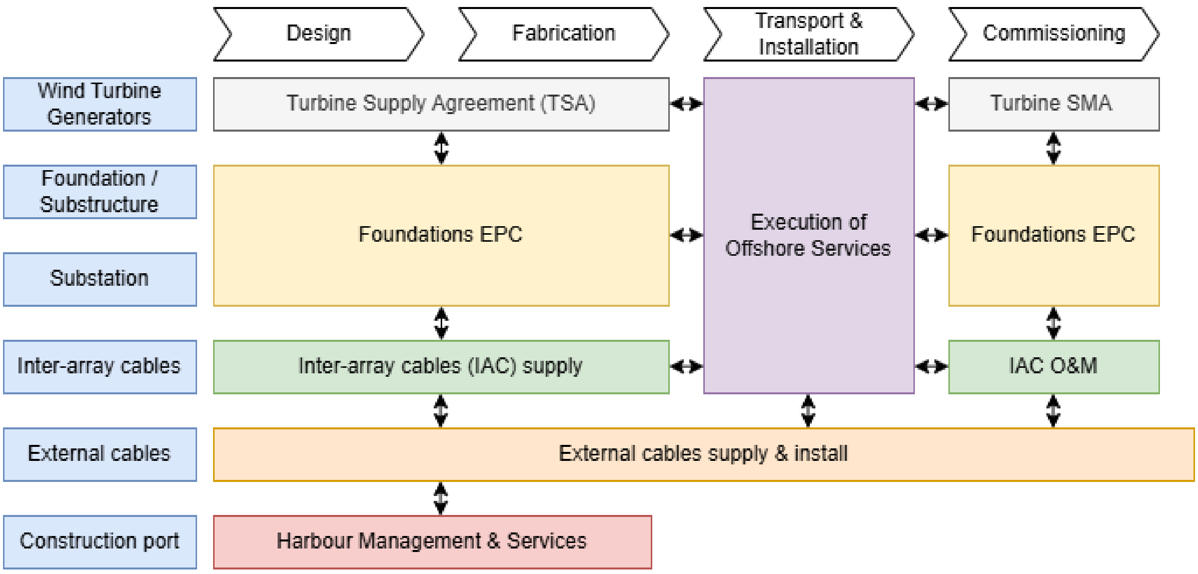


Figure 2.2: A basic overview of the interfaces in an offshore wind project [42][1]

In an EPCI-based strategy for offshore wind projects, multiple contracts are common due to the project's multidisciplinary nature. Instead of a single comprehensive contract, several contracts cover various parts of the project scope. Few contractors have the capability and experience to handle the entire

[1] EPC: engineering, procurement, construction; SMA: service and maintenance agreement; O&M: service and maintenance agreements

EPCI scope. Typically, the client opts for separate contracts for different portions of the project. For instance, foundation, electrical, and cable works may be combined into a single Balance of Plant (BOP) contract. This results in fewer but larger contracts, with each EPCI contractor responsible for a specific part of the project. Each contractor must then establish arrangements with subcontractors, joint ventures, or consortium partners to ensure turnkey delivery. This strategy reduces the number of interfaces for the developer, making it preferable for smaller utilities, private equity-backed developers, or special purpose vehicles lacking the capacity and expertise for extensive coordination.

The offshore wind industry preferred fragmented procurement with multiple contracts, aiding in risk mitigation and cost control over the project. However, there's a recent trend towards fewer contracts for larger projects, simplifying project financing [43]. Fragmentation in contracting reduces the liability of contractors but increases the risk of poor performance and insolvency. It also increases the complexity of managing interface risks, including delays between contractors, which affect project schedules and costs.

In the offshore wind industry, contracting has historically been fragmented for a number of reasons, including resistance from equipment manufacturers who prefer a supplier-only business model [43]. Most players in the sector have their roots in the oil and gas industry, which has led to the adaptation of standard oil and gas contracts to offshore wind projects [37]. However, the lack of standardized contracts tailored to offshore wind projects has resulted in heavily modified or bespoke arrangements, which entail significant negotiation costs [44]. Despite the complexity and cost of offshore wind projects, recent trends indicate a shift towards standardized contracts. Organizations such as the International Federation of Consulting Engineers (FIDIC) and the International Marine Contractors Association (IMCA) are taking initiatives to streamline processes [45]. Risk assessments and delivery strategies are critical to the planning of future offshore wind projects due to the risks involved, such as economic, geopolitical, and supply chain uncertainties.

2.3. Literature review

This section examines the relevant theories and frameworks in the existing academic literature and discusses the previous models built concerning offshore wind tenders and contracts.

2.3.1. Relevant theories and frameworks

In the offshore wind sector, auctions (or tenders) and contracts are pivotal in shaping project development and investment strategies. Auctions, a fundamental economic institution, are analyzed under auction theory, a sub-field of game theory, which examines how bidders maximize profits [46]. This theory explores competitive bidding dynamics and the impact of different auction formats on outcomes. It focuses on designing mechanisms that encourage truthful bidding and competition, considering strategic behaviors like information asymmetry. Insights from auction theory are valuable in various domains, including renewable energy, for creating efficient and competitive auction processes.

Contracts form the basis of economic interactions, defining cooperation limits, risk allocation, and incentives for all parties. Contract theory delves into the complexities of economic transactions, exploring how individuals and organizations navigate challenges such as imperfect information and conflicting incentives. It provides insights into structuring contracts to mitigate risks, align incentives, and promote cooperation.

Oliver Hart's pioneering work has been instrumental in advancing our understanding of contract theory [47]. He focuses on how contracts can address issues arising from incomplete information and misaligned incentives, paving the way for more effective contractual arrangements [48]. One of the primary challenges highlighted by the theory of incomplete contracts is the difficulty in reaching agreements that fully anticipate and address all possible future contingencies. This challenge becomes particularly pronounced in situations involving relationship-specific investments, where parties make investments tailored to a particular transaction, thus increasing the complexity of contractual arrangements [49, 50].

From a variety of angles, theoretical frameworks provide insights into the nature of interactions in industries. Transaction cost economics demonstrates how high drafting and negotiation expenses in comparison to contract value result in incompleteness; for example, a business may choose to purchase contracts with incomplete provisions in order to save money. In order to preserve future bargaining power, parties may intentionally exclude specific conditions from contracts in order to keep flexibility during cost swings. This is only one example of the kind of strategic behavior that is highlighted by game theory.

The relevance of incomplete contracts and game theory is apparent in industries characterized by complex transactions and high-value assets, such as offshore wind energy. Offshore wind projects involve multiple stakeholders, including developers, contracts, and suppliers, each with unique interests and objectives. This highlights the importance of contracts in collaborating and competing. This research applies an institutional economic approach that considers transactions as the fundamental unit of analysis and helps to develop a mental model that can be used to observe coordination problems in the industry.

2.3.2. Models for offshore wind tenders and contracts

In the literature, various models are used, and numerous studies have been conducted on allocation mechanisms and bidding strategies of offshore wind projects. Two articles, [29] and [28], focus on UK CfD auctions and emphasize the need for improved efficiency through modified auction designs. The former uses qualitative analysis and a real options approach, while the latter introduces a stochastic, game-theoretic modeling approach. Regarding German tenders, [51] explores zero-subsidy bids and presents a model approach to redesign the offshore wind auction. The aim is to achieve efficiency and zero-subsidies, and it employs a modified Vickrey-Clarke-Groves mechanism and introduces a vector of contract lengths for bidding flexibility. On the other hand, [31] concentrates on bidding simulation and highlights practical challenges related to transmission and grid costs.

Some studies have focused on remuneration schemes, financing conditions, and policy interplay. One such study is the work of Kitzing [27], which examines investment timing and sizing under different support schemes using the real options model. Jansen [52] analyzes the competitiveness of offshore wind projects by assessing recent cost reductions and subsidy-free prospects through auction schemes and winning bids. In another study, Greve [51] discusses subsidy-free bids for a German tender. Furthermore, [30] explores how different remuneration schemes impact investment incentives and risks, applying a net cash flow model to an offshore wind project. There is considerable overlap between the cost of offshore wind and support schemes. However, it's good to distinguish between them, as support schemes aim to make projects financially viable, whereas the costs of offshore wind projects, particularly capital costs, aim to minimize expenditure. For example, [53] analyses the costs of offshore wind projects using analytical methods by estimating future investment costs based on empirical auction data. This study highlights the sensitivity of costs to parameters such as the weighted average cost of capital (WACC) and electricity prices.

Modeling approaches aren't only used in the tenders process in the offshore wind industry. There are some models in the literature, like [54], which help mitigate conflicts of interest between offshore wind farm owners and maintenance suppliers. Through statistical analysis, iterative processes, and multi-objective optimization techniques, such models help negotiate contract terms and enhance collaboration between stakeholders in the offshore wind sector. This graduation project aims to model the negotiation strategies between developers and turbine manufacturers and their impact within a certain timeline. The process of supplying the turbine is treated as a bargaining problem, focusing on how the price surplus (the difference between the reservation value of buyers and sellers) is divided among players in different market scenarios. There are two main categories of bargaining games: cooperative and non-cooperative. Cooperative games emphasize the fair division of surplus through solutions like the Nash and Kalai-Smorodinsky Bargaining Solutions [55]. It doesn't consider the process and assumes the process is a black box, focusing on how the resources are shared in case of cooperation. Non-cooperative games model the negotiation process explicitly through sequential moves, as seen in the Rubinstein bargaining model, highlighting how strategic behavior and time preferences influence outcomes [56]. Both approaches can be valid. However, since the cooperative approach doesn't consider the effects of time and the strategies players follow during negotiation, a stylized model is preferred to represent the interaction between players, observing the time and information effects on the bargaining process in the offshore wind industry. Explanations of the stylized model and relevant concepts are discussed in Section 4.2.

3

Institutional Analysis

This chapter analyzes offshore wind project development through institutional perspectives, focusing on stakeholder relationships, regulatory frameworks, and associated risks. It identifies stakeholders and market conditions (Section 3.1) and examines formal rules shaping the industry from a property rights viewpoint (Section 3.2). Then, interviews are conducted to validate the interpretation of the transaction analysis and how the governance of these transactions impacts the development of offshore wind (Section 3.3). The critical transactions identified in this chapter and their impacts on practices are examined in Chapter 4 for different mature markets in the North Sea.

3.1. Delineating the design problem

Identifying the different stakeholders involved in offshore wind projects can help understand the challenges. This section will pinpoint the relevant stakeholders and lay the groundwork for exploring coordination issues further.

3.1.1. Relevant stakeholders

Offshore wind projects are complex and involve diverse stakeholders with distinct interests and roles in the development, construction, operation, and regulation of these ventures. The following are the stakeholders involved in the various phases of offshore wind projects:

- **Governments and Regulators:** National and local governmental organizations that set policies, regulations, and permit requirements for offshore wind development. Regulators ensure compliance with environmental, safety, and other regulatory standards. Some examples are the Netherlands Enterprise Agency (RVO), the Danish Energy Agency (DEA), Crown Estate.
- **Developers:** Companies or groups responsible for planning and executing offshore wind projects. They are responsible for site assessment, securing permits, arranging financing, and overseeing construction and operation. Some examples are Ørsted, Vattenfall, RWE, etc.
- **Suppliers and Contractors:** Companies that provide equipment, technology, and services for offshore wind projects. Suppliers provide wind turbines, foundations, cables, and other components, while contractors handle installation, construction, and maintenance tasks. Some examples are Siemens Gamesa, Vestas, GE, DEME, Sif, etc.
- **Banks and Investors:** Individuals, financial institutions, and funds that provide capital and debt for offshore wind projects. They seek investment returns and may include equity investors, lenders, bondholders, and institutional investors. Examples include Rabobank, Allianz, Green Investment Group, among others.
- **Offtakers:** Entities that purchase the electricity generated by offshore wind farms. Offtakers include utilities, power purchasers, corporate buyers, and government agencies that procure renewable energy to meet sustainability goals or regulatory mandates. Some examples are Google, Amazon, ArcelorMittal, etc.

- **Local Communities:** Residents living near proposed or operational offshore wind sites. Local communities may experience direct and indirect impacts from wind farm development, including changes to scenery, tourism, property values, and quality of life. This group may include fishermen and maritime businesses operating in offshore waters near wind farms.
- **Environmental Organizations:** Organizations that advocate for environmental protection, conservation, and community interests. These stakeholders may engage in project siting discussions, ecological impact assessments, and negotiations to address community concerns.
- **Research Institutions:** Universities, research centers, and academic experts studying offshore wind technology, environmental impacts, and policy issues. These stakeholders contribute to scientific research, innovation, and knowledge dissemination in the offshore wind industry.

3.1.2. Coordination problems at stake

The benefits of incorporating a multitude of stakeholders from varied backgrounds and interests into offshore wind projects are substantial; however, they also introduce complex coordination challenges encompassing spatial planning, regulatory compliance, infrastructure development, supply chain management, financial investment, and stakeholder engagement. Below are the primary coordination problems encountered within the offshore wind industry:

- **Spatial planning and site selection:** Efficient allocation of suitable sites for offshore wind farms require coordination to address conflicts with stakeholders such as fishermen, environmental conservation groups, shipping lanes, and military operations. Early discussions and stakeholder management will make it easier to avoid future conflicts, ensuring the sustainable development of offshore wind energy.
- **Consent and permitting:** Offshore wind projects must navigate complex regulatory frameworks during the permitting process. There is a debate about who should be responsible for ensuring that environmental impacts are thoroughly assessed and site studies are carried out. Coordination between developers, regulators, and stakeholders is important to minimize environmental impacts and comply with regulations.
- **Grid connection, interconnection, and transmission:** The key issue at hand is determining who is responsible for connecting offshore wind farms to the onshore grid and overseeing their integration. This task requires cooperation between wind farm developers, transmission system operators (TSOs), regulatory bodies, and other stakeholders to ensure that the grid remains stable and reliable and that offshore wind generation is seamlessly integrated.
- **Supply chain and construction coordination:** Offshore wind projects have complex supply chains, with components sourced from different manufacturers and suppliers in different geographies. It is critical to coordinate this interface efficiently to reduce costs, ensure timely delivery, and maintain quality standards during construction. Collaboration among owners, contractors, and manufacturers is key to the success of such projects. Each actor brings unique capabilities and risks that require interface management to minimize disruptions.
- **Investment and financing:** Securing investment and financing for offshore wind projects is challenging due to high upfront costs and long project lead times. Coordination between project developers, financial institutions, governments, and other stakeholders is necessary to de-risk investments, attract capital, and ensure the financial viability of offshore wind projects.
- **Seabed rights, support, offtake allocation:** The allocation of seabed rights and/or support schemes for offshore wind projects, mainly provided by tenders, needs a transparent and fair process for awarding leases or permits. This process should include the selection of winners based on various criteria such as project feasibility, technical expertise, environmental impact assessment, and community engagement. It is important to balance non-price considerations with financial factors to ensure sustainable development and social acceptance. This raises the question of whether non-price criteria should be considered primarily during the supply chain management phase or integrated into the bidding process for offshore wind project development.

This study identifies the above coordination problems through an economics lens to examine stakeholders' financial risks and broader economic dynamics within the offshore wind industry. The offshore wind energy industry is currently facing a turning point as it struggles to overcome various challenges that hinder its progress while still aiming to meet ambitious targets. This challenging environment in the offshore wind industry worldwide causes the cancellation of power purchase agreements and supply chain disruptions, which have resulted in significant project delays (see Table 3.1).

Table 3.1: Instances of offshore wind projects encountering financial difficulties [57, 58]

Jurisdiction	**Project name**	**Capacity [GW]**	**Remarks**
United States of America	Empire Wind 2	1.3	Initial Offshore Wind Renewable Energy Certificates (OREC) agreements canceled.
United States of America	ASOW Project 1	1.5	Without additional state support, the project is at risk, according to the announcement.
United States of America	South Coast (Mayflower)	1.2	Approval of termination of offtake contracts, with a $60 million payment for termination fees due to projects no longer being financially viable.
United States of America	Attentive Energy One, Community Offshore Wind, Excelsior Wind	4	Complexities arising from technical and commercial relationships between partners and provincial awards.
United Kingdom	Norfolk Boreas	1.4	Not financially viable anymore as cost surged by 40%, another developer will resume development.
United Kingdom	All projects	5	Round 5 of CfD support did not see any developer participation because of the unfavorable maximum bid price.

The emphasis on cost-cutting measures to obtain project development rights is worsening this trend, leading to unsustainable industry practices [59]. Recent results from German auctions have highlighted this issue: developers promise very high payments, but penalties for failing to build are comparatively low, leading to speculative bidding [60]. This results in bidding wars and speculative practices in turbine procurement, negatively impacting the sustainability of the offshore wind sector. Consequently, these market conditions are hindering or slowing down offshore wind development. Therefore, there is an urgent need to reform bidding processes, prioritize long-term benefits over price competitiveness, and consider supply chain scale-up.

3.1.3. Institutional levels

Before moving forward with the analysis, it is important to define some terms and their meanings in economics. Rules establish the rights and responsibilities of parties involved in transactions with one another. Therefore, rules are crucial in the economic distribution of goods and services, bringing us to institutional economics, where "institution" specifically denotes rules. Institutions are defined as "systems of established and prevalent social rules that structure social interaction" [61]. Here, institutions are understood as rules facilitating economic coordination among actors, significantly influencing socio-technical system performance [62]. Transactions involve exchanging property and utilization rights on assets or services, with institutions coordinating these interactions among diverse actors.

Williamson [33] categorizes institutions into four levels based on their frequency of change and the potential for intentional modification to enhance economic effectiveness (see Appendix A.2). Our focus is on Level 3, which centers on governance arrangements like contracts that operationalize the rules from Levels 1 and 2. Levels 1 and 2, representing informal and formal institutions respectively, remain stable, establishing values and legal frameworks. Governance at Level 3 allocates rights and responsibilities among economic actors through transactions, emphasizing our interest in understanding the foundational rules and structures of economic interactions. This includes contractual agreements and frameworks governing resource exchange and utilization. Examining the complexity of these arrangements is intended to provide insight into the underlying mechanisms that shape industry behavior and outcomes.

3.2. Institutional economics in offshore wind development

Understanding the benefits, costs, and risks of stakeholders is key to successfully navigating offshore wind projects from an economic perspective. This section provides an in-depth analysis of the approach to property rights in the offshore wind industry. It explains how economic rights are allocated in the industry and its impact on stakeholders. First, the institutional environment forms the basis for the governance layer, establishing the rules for offshore wind development. Next, the main analysis occurs in the governance layer, where transactions are conducted.

3.2.1. Property rights approach

Property rights in economics

The concept of property rights highlights the difference between the legal recognition of rights by the state and the practical control and benefit that individuals derive from their assets. Legal rights are established by the state, while economic rights embody the ability of individuals to use and benefit from their assets, regardless of legal recognition [63]. Transactions involve the ownership of rights rather than mere physical property. According to Alchian and Demsetz, property is a bundle of rights to use a resource rather than the resource itself [64]. Roman law defines several categories of property rights, including the right to use an asset, to receive benefits, to make changes, and to transfer it at an agreed price [63].

Ownership of seabed rights

Ownership of offshore areas where wind farms are located is one of the main concerns. Governments typically claim sovereignty over these areas, and property rights are often established through leases or permits granted to developers. These rights define who has the authority to develop and operate wind farms in specific locations for a certain period of time. Ownership strength is often linked to the extent of control over resource use [63]. Absolute ownership exists when an owner's decisions dominate resource use. A leasehold, considered a subset of absolute ownership, includes a more limited bundle of rights. However, from an economic rights perspective, this distinction may be negligible in offshore wind seabeds. If developers can fully exercise their rights and bear the consequences, the legal categorization becomes less significant.

Accessing offshore wind resources

Utilization of wind resources is necessary for generating electricity and is also considered a form of property rights. The wind patterns differ across offshore regions, and developers need the authorization to access and use these resources efficiently. Governments may allocate resource rights through a competitive bidding process (tenders) that prioritizes certain uses, such as renewable energy production. Therefore, even though winners of the tenders do not own the seabed rights, they are granted the property rights to access, use, and earn income from the wind farm they can build under their proposed design and related obligations.

Ownership of offshore wind farms

Wind farms can be owned by one or multiple parties, who have the right to transfer ownership to others if they want. Sometimes, multiple parties can have ownership interests in different aspects of the same property. For example, one party might possess the right to use the property for a specific purpose, while another individual could hold a right to access the property for specific needs. This separation of ownership and use can have significant economic implications, as control and possession can be distinct from ownership itself. In the offshore wind industry, decision-making often revolves around a single Special Purpose Vehicle (SPV) representing the shareholders. This SPV typically holds the rights to develop and operate wind projects. While multiple stakeholders may be involved, the SPV is the unified entity exercising control over the resources. This differs from the collective decision-making processes seen in other sectors and is more akin to a centralized ownership structure [63].

In the offshore wind market, there are two types of ownership: private and state. Private entities own and operate offshore wind farms, investing capital and managing operations to generate profit. On the other hand, state ownership is controlled by the government and may involve transfers from private users, such as grid infrastructure, often to ensure regulatory compliance and strategic management of national energy resources. Although uncommon, it is possible for a governmental organization to have a stake in an offshore wind farm.

The way property is owned and managed can significantly impact investment incentives, development strategies, and regulatory frameworks in this sector. This is because property rights shape the economy of offshore wind projects by guiding decision-making authority, asset usage, and benefit distribution. This promotes efficient use of resources while also ensuring that decision-makers are held responsible for their actions. Clear and enforceable property rights can prevent market failure, underscoring the importance of understanding the dynamics of property rights to achieve economic efficiency.

Risks and uncertainties

Risk is a critical concept in understanding property rights, influencing incentives, transaction costs, and economic efficiency. In academic discussions, risk is interpreted differently, with portfolio theory defining it as the probability that actual returns will fall short of expected returns [65]. Uncertainty, on the other hand, involves outcomes that lack quantifiable probabilities and require qualitative assessment, particularly in investment decisions. Effective risk management helps stakeholders reduce uncertainty and hedge its impact, as some uncertainties cannot be fully eliminated. Policies play a key role in fostering an environment conducive to investment and market growth. Poorly designed policies can increase risk and uncertainty and hinder the functioning of the industry. Therefore, policymakers and stakeholders need to understand risk comprehensively in order to manage property rights, incentives, and transaction dynamics to promote sustainable economic development.

Uncertainties abound in the offshore wind industry, ranging from regulatory changes to technological advances. These uncertainties pose significant challenges for investors, developers, and policymakers alike. Regulatory uncertainties, such as changes in permitting processes or government incentives, can introduce unpredictability into project timelines and profitability projections. Similarly, technological uncertainties, such as the development of new turbine designs or the integration of emerging storage solutions, add complexity to investment decisions. Uncertainties related to environmental impacts, grid integration, and market dynamics further complicate the risk landscape for offshore wind projects. All these risks must be carefully considered and managed through contracts that focus on appropriately sharing the associated uncertainties.

3.2.2. Institutional environment

The institutional environment, which is the second level in Williamson's framework, comprises formal rules that establish the legal framework, such as the laws of the state. Institutional environments remain stable, with occasional adjustments over the course of a decade to a century to better serve broader objectives [33]. It provides a foundation for transactions happening at the governance level.

Marine spatial planning

Coastal countries bordering the North Sea have specific legal frameworks that govern offshore wind development. These regulations address a range of challenges, from selecting developers to determining grid responsibility. Offshore wind farms are typically situated within Exclusive Economic Zones (EEZ) or territorial waters, which are governed by the United Nations Convention on the Law of the Sea (UNCLOS) (see Appendix A.3). This authority allows nations to set up wind energy infrastructure and use natural resources within their EEZ. EU Member States, which have jurisdiction over EEZs, must adhere to EU laws such as the Maritime Spatial Planning (MSP) Directive. This directive designates specific areas for offshore wind while managing conflicts with fishing and military activities. Currently, all offshore wind projects operate within EEZ or territorial waters despite advances in floating turbine technology. However, future expansion beyond these zones could become possible with ambitious climate targets and grid improvements. This would require legal collaboration among multiple states, as there is no jurisdiction beyond EEZ limits.

Site selection

Coastal states have control over offshore wind operations in their EEZ and territorial waters, guided by EU directives. Legal frameworks typically consist of open-door or pre-determined site selection approaches for defining offshore wind project sites. The open-door approach allows developers to choose from various potential sites, but it carries the risk of encountering unforeseen conditions that could impact project feasibility and costs. On the other hand, pre-determined site selection involves the upfront designation of specific areas, facilitating pre-site investment such as detailed assessments and environmental studies. This approach reduces risks, providing developers with a clearer understanding of challenges and opportunities in designated areas before starting projects. For example, the Netherlands only uses roadmaps to determine offshore wind development areas. Denmark has moved away from its open-door approach and shifted to a centralized model to align with broader strategies among countries. This shift reflects a trend in offshore wind development favoring centralized approaches to efficiently meet climate goals. Further details about the site selection approach are discussed in Section 4.1.1.

Offshore wind infrastructure

Offshore wind farms and seabeds are not the only assets to consider when building and operating a wind farm. Transmitting electricity generated by offshore wind farms to onshore grids requires infrastructure such as cables and substations. Property rights related to these transmission assets involve access to seabed areas for cable installation and rights-of-way through which cables pass. These rights are often obtained through permits and agreements with relevant authorities.

Table 3.2: Ownership models of offshore wind infrastructure in EU [66]

Jurisdiction	Inter array cables	Offshore substation	Export cables	Onshore substation
Netherlands	Developer	TSO	TSO	TSO
Germany	Developer	Developer	TSO	TSO
United Kingdom	Developer	Developer >OFTO[1]	Developer >OFTO	TSO
Denmark	Developer	Developer	Developer	Developer

The offshore grid infrastructure is the legal responsibility of the Transmission System Operators (TSO) in the majority of Europe [66]. TSOs are in charge of planning and operating the export system, while developers are responsible for inter-array cables of the wind farms. However, the ownership of export cables and substations varies from country to country. Table 3.2 shows the ownership of offshore wind grid infrastructure components in several EU countries. Section 4.1.3 includes a country-specific analysis that outlines the responsibilities and funding sources for each components.

Furthermore, there are some discussions on hybrid offshore wind projects, which can connect offshore wind farms to multiple markets simultaneously through interconnectors [67]. These projects, when combined with offshore bidding zone concepts, which present different price regions for offshore hubs, may offer lower costs and benefits to the energy system by optimizing resource utilization and grid integration. While this research does not cover these discussions, it is important to understand the emerging trends and challenges that need to be addressed in the legal landscape through collaboration between governments and TSOs.

3.2.3. Transaction analysis

Once the formal rules are in place, it becomes necessary to establish more detailed frameworks for where transactions take place. Deciding on the right governance structure is the primary concern in this layer, and contracts are one of the supporting structures for carrying out transactions [62]. This part of the study looks at what transactions are taking place in the offshore wind sector and how they are being structured. When discussing transactions, it is possible to dig into the most minor details of the project. To provide a comprehensive overview of offshore wind project development, the analysis presented in Figure 3.1 shows a bundle of transactions that create a web of responsibilities and liabilities between

[1] Offshore Transmission Owner (OFTO) manages offshore electricity transmission for UK wind farms

the parties, and it focuses on the contractual level. The high-level definition of transaction bundles is presented in Table 3.3.

Table 3.3: Overview of transaction bundles in the offshore wind project

Bundle #	Involved actors	Short definition
1	Owners and SPV	Owners providing capital or resources to the SPV in exchange for equity in the project
2	Debt provider and SPV	Debt provider lending money to the SPV for project financing
3	SPV and contractors/suppliers	SPV paying for goods or services provided by contractors/suppliers for the project
4	SPV and OEMs	SPV obtaining maintenance and operational services from OEMs
5	Contractors/suppliers and regulators	Contractors/suppliers complying with regulations and standards set by regulators
6	SPV and regulators	SPV submitting proposals or bids to regulatory authorities for the development and operation of the wind farm
7	SPV and grid operator	Allocation of responsibilities and ownership for the grid infrastructure
8	Grid operator and regulators	Grid operator complying with regulatory standards and reporting requirements set by regulators
9	SPV and electricity buyer	SPV supplying electricity to the buyer through a PPA or trading electricity on power exchange markets
10	Grid operator and electricity buyer	Grid operators, together with the regulator, determine the transmission tariff for electricity supplied to buyers
11	Electricity buyer and regulators	Buyer purchasing electricity while regulators oversee and enforce compliance with regulations

This analysis uses the property rights approach to enable an in-depth understanding of the transactions involved. Property rights are exchanged in transactions. As mentioned above, during the transaction, not only is ownership of an asset exchanged, but the related rights and liabilities are also exchanged. Ultimately, this analysis provides insights into which transactions are critical and how the risk is allocated among the relevant parties involved.

Financing

Offshore wind projects can be commonly funded through a combination of two financing methods: balance sheet financing or project finance. Balance sheet financing involves using the company's capital reserves or borrowing against existing assets. On the other hand, project finance relies on the project's assets, revenues, and cash flows as collateral for loans. The project company's sponsors or owners contribute equity, thereby acquiring ownership stakes in the project company (Transaction Bundle 1). Furthermore, a bank or debt lender may extend loans to fund the project's capital, entitling them to repayment obligations specified over a defined term (Transaction Bundle 2). If only transactions happen in Bundle 1, the financing method is called balance sheet finance. However, if both transactions in Bundle 1 and 2 exist, then it is considered project finance.

Balance sheet financing involves using a company's own capital reserves or assets, which places the risk on the company itself. This approach requires optimizing a portfolio of several assets, as it does not rely solely on the success of a single project. In contrast, project finance can focus on the success of a single project. It distributes risk among stakeholders, leveraging project assets, revenues, and cash flows as collateral for loans. While balance sheet financing offers autonomy but concentrated risk, project finance spreads risk but involves shared ownership and control, with lenders potentially exerting influence to safeguard their investments. The choice between these methods often hinges on risk tolerance, capital availability, and desired control over project decisions.

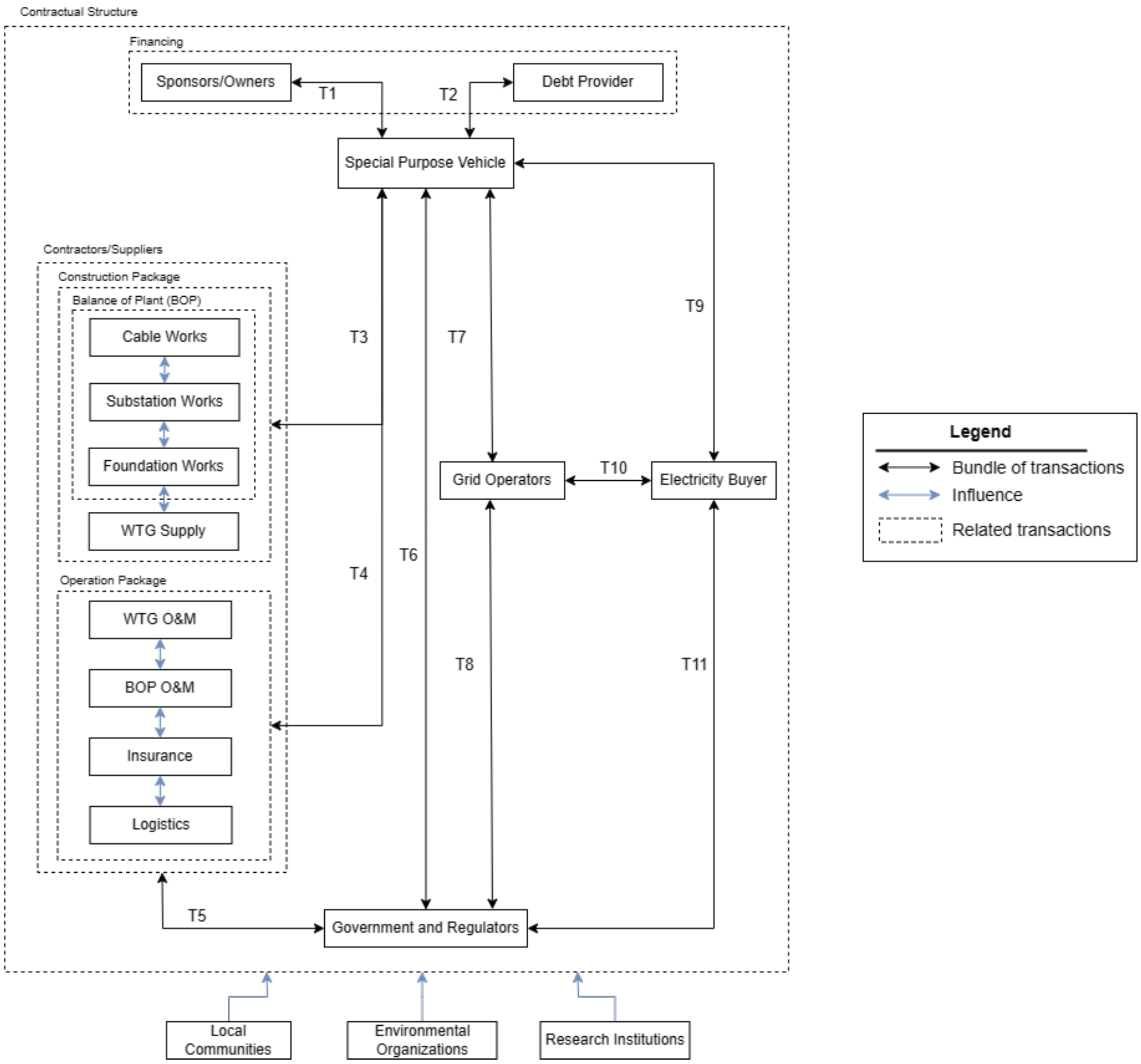


Figure 3.1: Map of transactions within the offshore wind project [22, 42, 68, 69]

Distinguishing between developing and ownership

Developers and owners are two distinct terms that are generally confused in offshore wind projects. Developers are the companies that are responsible for the planning and execution of the project, from securing contracts to getting permits. They oversee site assessment, grid connectivity, approvals, and construction. Developers are also responsible for coordinating contractors and subcontractors to design and build the project. Developers can either be the owners of the Special Purpose Vehicle (SPV) or the SPV itself [37]. Those with a stake in the SPV are called owners of offshore wind projects. Owners see the wind farm as an asset and earn from the electricity sales and take care of financing, deciding the developer, arranging power purchase agreements (if applicable), and concerning the project's profitability [70]. Wind projects are usually started by developers who own them in the early stages of development. The development of an offshore wind farm progresses through various stages, from planning to construction and operation. As the project progresses and obtains necessary permits and grid connections, construction risks decrease, thereby increasing its market value [22]. Once an offshore wind farm project becomes operational and matures, some owners may choose to sell their stake. There are several reasons why developers might choose to sell their stake, including financial considerations, risk management, or a shift in their business focus. For instance, they may sell their stake to realize profits, reinvest capital into other projects, or mitigate risks associated with long-term operation and maintenance. Furthermore, changes in market conditions or regulatory environments could also influence developers' decisions to sell their offshore wind portfolios during the development stage [71]. On the other hand, some owners may decide to maintain ownership of their projects in their portfolio, thereby retaining the right to earn income from the offshore wind farm by selling electricity.

Construction and operation phases

Even highly experienced developers in the offshore wind industry cannot carry out projects independently due to their complexity and scale. They often engage in contractual arrangements with contractors and suppliers for turbines, cables, substations, and other essential assets, effectively transferring bundles of rights related to design, engineering, fabrication, and installation services (Transaction Bundle 3). This transaction bundle encapsulates a significant portion of the risk associated with the construction phase of the projects. Risks in this phase include delays or cost overruns due to unexpected technical challenges, adverse weather conditions, supply chain disruptions, or regulatory hurdles. Additionally, there's the risk of contractor performance and adherence to quality standards, which can impact project timelines and overall success. Managing these risks effectively requires robust project management, thorough due diligence in contractor selection, clear contractual agreements, and proactive risk mitigation strategies to ensure timely and cost-effective project completion. Construction works related to offshore wind projects generally cover four main packages: turbines, foundations (substructures), cables (inter-array & export), and substations (see Appendix A.4).

Procuring turbines is always a distinct contract due to their critical role in project performance, often tied to a long-term maintenance agreement [22]. The project company typically hires operation and maintenance (O&M) contractors to ensure the operational efficiency of the wind farm, which is generally with the same original equipment manufacturer (OEM) as the turbine supplier (Transaction Bundle 4). Recently, there's been a rise in a practice called multi-brand services, where various OEMs offer maintenance for turbines they didn't manufacture. This allows companies to efficiently allocate existing resources in a market, even if they cannot secure the supply contract.

The remaining project components can be combined into a comprehensive balance of plant (BOP) contract, which includes the procurement and installation of all supplementary equipment [22]. In a BOP contract, the employer's control over project execution is more restricted than in a multi-contracting structure. Consequently, the employer typically requests specific performance and warranty assurances for both the supplier's and subcontractors' contributions [72]. Contractors and suppliers who participate in offshore wind projects take on significant liabilities and responsibilities under their contracts with their employers. Their duties include performing tasks on time and in accordance with project specifications, complying with regulations, and ensuring quality standards. Contractors must also maintain safe working conditions, provide insurance coverage, and indemnify the employer against any losses.

Several EPC contracting strategies can be used to manage responsibilities, such as single-point responsibility contracts, split EPC contracts, or task sharing among subcontractors [73]. When transitioning from a single-party responsibility to a multiple-contract approach, total costs tend to decrease. However, this shift also introduces interface and coordination risks that could potentially escalate costs if not managed effectively. The project owner is primarily responsible for coordinating contractors and ensuring joint liability. Effective communication is critical to successful project execution. If contractors fail to meet their obligations, the project company can suffer financial and reputational damage. To mitigate risks, the project company includes penalties and legal liabilities in its contracts with counterparties.

Contractors are also required to obtain various permissions or licenses from regulatory authorities in order to carry out their work within a specific jurisdiction. These permissions or licenses give contractors the legal right to conduct their work and ensure that they are in compliance with all relevant laws and regulations (Transaction Bundle 5). Therefore, contractors must obtain the necessary permissions or licenses before commencing their work. Once all necessary permissions are secured, the project owner issues the notice to proceed (NTP), officially authorizing project commencement. This NTP signifies the start of the project and grants contractors permission to proceed according to the agreed-upon terms and schedule. Failure to obtain the required permissions or licenses before commencing work may result in legal consequences.

Time gaps in offshore wind project procurement

In the offshore wind industry, suppliers and developers often encounter a prolonged time frame from tender submission to contract award and project execution. It takes an average of five years between the awarding of support and the commissioning of an offshore wind farm [74]. This time gap is primarily attributed to several factors: the prevailing licensing regime, the need for subsidy allocation, the time required to secure financial backing and building the wind farm. Developers initiate project preparation at their own risk and expense, seeking firm commitments for main contract packages early on [37]. These commitments are typically secured through framework agreements such as preferred supplier agreements (PSA) to mitigate price and supply risks. However, suppliers face challenges such as reserving production capacity and committing to fixed prices without the certainty of contract awards. They also bear significant pricing risks due to potential cost increases in a high inflation and interest rate environment.

Before contracts become effective, there is always a risk that a project may be discontinued due to various reasons, such as unsuccessful licensing bids or lack of financial support. This can cause losses for suppliers who may have declined other opportunities to work on the project. Therefore, suppliers are seeking compensation in a PSA for any losses they may incur, such as cancellation fees. On the other hand, developers are looking for flexible clauses or measures that can help them control costs effectively. These conversations are typically held between the two parties involved, and the details are not disclosed. The main contract comes into effect after the final investment decision (FID). As a substitute for the framework agreements, some contract components might be operationalized early with limited NTP issued by the developer [37].

Allocation of offshore wind farm rights

The allocation of property rights for offshore wind farm development is a collaborative process between developers and governmental bodies (Transaction Bundle 7). This involves the government granting licenses and designating sites for developers to commence the construction and operation of wind farms at sea. Governments often implement competitive bidding programs to support these ventures, offering subsidies to incentivize development. For instance, in the UK, the Contracts for Difference (CfD) scheme provides long-term contracts to renewable energy projects, ensuring a stable price for electricity generated. This mechanism guarantees developers a certain price for their electricity, thus mitigating financial risks. Different versions of CfD may include variations in contract duration or payment structures.

Offshore wind technology used to be expensive to operate without subsidies. However, improvements in the technology have led to a decrease in the LCOE of offshore wind, resulting in significant reductions in subsidies. Some governments have shouldered site risks to make the market less risky, but as the market becomes more competitive, the cost of site investigations may now fall on developers [75]. In some mature markets, wind farms are now feasible to operate without subsidies [76]. Developers in some tenders are required to cover expenses related to leasing seabed areas from the government or conducting pre-development studies mandated by governmental authorities. Financial bid components, where developers pay for permits for the construction and operation of the wind farm, are also present in the industry today. There are ongoing discussions about the consequences of negative bidding on the supply chain and consumers [60].

Tenders are a standard practice in the offshore wind industry used by governments to allocate offshore wind sites, provide subsidies, or award offtake agreements. They serve as the mechanism for governments to allocate access rights to wind sources. While attempting to de-risk project-related risks and ensure completion, tenders also aim to select the most suitable bidder. The determination of the best bidder hinges on awarding criteria that can vary from a focus on price to non-price factors or a combination of both. Most criticisms of tenders revolve around these awarding mechanisms and their perceived fairness and effectiveness.

Tender formulations closely align with the offshore wind policies and legislation of the relevant jurisdiction, offering valuable insights into industry practices and regulatory frameworks (see Table 3.4). These policies are evolving and adapting to market conditions over time (see Appendix A.5). Chapter 4 explores the various policy applications used in mature offshore wind markets in the North Sea.

Table 3.4: Comparison of North Sea offshore wind mature markets

Jurisdiction	**Support Mechanism**	**Seabed lease auction**	**Site development**	**Grid connection funding**	**Assessment criteria**
United Kingdom	Two-sided CfD	Separate	Bidder	Bidder	Price-only (lowest bid wins)
Germany	One-sided CfD/ zero-subsidy bids	Combined	Socialized (pre-developed)/ Bidder (non-pre-developed)	Socialized	Uncapped negative bidding/ dynamic negative bidding
Netherlands	One-sided CfD/ zero-subsidy bids	Combined	Socialized/ Bidder (from '22)	Socialized	Qualitative assessment with a financial bid
Denmark	Two-sided CfD/ zero-subsidy bids	Combined	Bidder	Socialized (until '20)/ Bidder	Price-only (lowest bid wins)

Grid responsibility

The role of grid operators in offshore wind projects is complex and varied, with different countries assigning different responsibilities. For instance, in the Netherlands, the Transmission System Operator (TSO) is tasked with the construction and management of the offshore grid, as well as the connection of wind farms to the onshore grid. In Denmark, however, the TSO's role is limited to the construction and operation of the grid connection from the onshore substation to the overall transmission grid. The offshore substation and export cables fall under the responsibility of the bidder (Transaction Bundle 7). In the UK, transmission assets of offshore wind farms are typically transferred through the Offshore Transmission Owner (OFTO) regime. Once a wind farm is developed and operational, the transmission assets are transferred to a separate entity called the OFTO.

After securing the tender, developers may also be responsible for TSO's construction costs, depending on the jurisdiction's policy. According to a contractual agreement between the grid operator and developers, if the grid operator fails to meet the deadlines or comply with the conditions, it will be liable for damages and any consequential loss suffered by the developer (Transaction Bundle 7). In some countries, the government owns the grid operators, which are governed by relevant legislative and regulatory provisions (Transaction Bundle 8).

Revenue generation

In any business project, one of the most important aspects, in addition to costs, is identifying the source of revenue. In offshore wind projects, the income is earned by selling the electricity generated. This sale can be done through electricity markets or Power Purchase Agreements (PPAs) (Transaction Bundle 9). Grid operators manage the overall network balance and ensure the physical delivery of electricity in such transactions (Transaction Bundle 10). When electricity is sold through power markets, both buyers and sellers face risks due to price uncertainty. However, when a PPA is in place, the parties agree on a fixed price for a specific term, providing price certainty. PPAs can have different designs based on how the electricity is supplied [77]. Regulatory authorities require electricity buyers through PPAs to ensure that the PPA structure complies with legal frameworks and obliges them to pay as agreed (Transaction Bundle 11).

Interpretation of the transaction analysis

The success of offshore wind projects depends on the smooth execution of various transactions involving multiple parties, such as developers, government entities, turbine suppliers, and contractors. Table 3.5

illustrates the main concerns of key stakeholders. The government and developers play a vital role as they are involved in most of the transactions. On the other hand, supply chain-related parties such as technology suppliers and contractors are significantly important due to their impact on the construction and execution of projects. Even minor disruptions in the supply chain can cause delays, cancellations, or significant costs.

Table 3.5: Key stakeholders and their primary concerns

Key Stakeholders	**Primary Concerns**
OWF developers	Securing permits, maximizing energy production, cost reduction, grid integration, stakeholder management, long-term viability
Government	Energy security, energy affordability, carbon emission reduction, environmental conservation, social and economic developments
Turbine suppliers	Technology advancement, cost competitiveness, customer satisfaction, market expansion, reliability and durability of products
Contractors	Project delivery (on time, within budget), cost control, quality assurance, safety, supply chain management, long-term collaboration

All transactions are important for the success of an offshore wind project, but some transactions are particularly critical due to the risks involved. These critical transactions are categorized under types 3, 6, 7, and 9, all of which involve decision-making processes to manage the costs and benefits of key stakeholders.

Transaction Bundle 3 is particularly noteworthy as it involves transactions with contractors and suppliers during the construction phases. Between the bidding phase and the operation of the wind farms, there is a significant time gap, during which market conditions may change. As the duration of this gap increases, so does the level of risk, which must be reflected in the prices charged by various actors. The offshore wind supply chain is an industry that requires significant upfront costs from different parties, including turbine manufacturers and construction companies. Hence, before making any investments, companies want to be sure that they will receive enough orders and that projects will be completed on time. Any disruptions in these bundles can result in costly setbacks and contractual disputes, potentially leading to project cancellations or delays.

Transaction bundles 6 and 7 are another critical type of transaction that involves developers and government entities in the allocation of property rights, tender process, and grid responsibility. Tender procedures differ significantly according to the offshore wind policies and legislation in various markets, and developers face numerous challenges related to the tender system. Developers have to deal with uncertainty in the bidding process, as the project may not be awarded. Even if it is awarded, cost estimation can be difficult, which can have significant financial consequences. Additionally, the cost of not building, or cancellation cost, adds further financial risk. Abandoning a project after being awarded can result in substantial penalties and sunk costs. These uncertainties and cancellation costs complicate the bidding process, as developers must balance potential revenues against uncertain costs and the financial impacts of project abandonment. This increases risk and volatility in bid submissions, making informed decision-making essential for project viability.

When the tender is awarded, the dynamics shift significantly from the competitive ex-ante stage, focused on planning and bidding between developers and the government, to the collaborative ex-post stage, focused on project execution (see Figure 3.2). Initially, developers compete for rights and face squeezed profit margins due to uncertain future costs. Once awarded, their focus shifts to negotiating with suppliers and contractors to manage schedules, costs, and risks. This transition highlights the dependence on suppliers, especially turbine manufacturers, and the increased risk of delays and cost overruns. Developers often seek early commitments for contract packages to reduce uncertainty, while suppliers may require advance orders to support their investments. Effective negotiation and risk management become critical as the balance of bargaining power shifts, impacting the success of offshore wind projects in a complex and volatile environment.

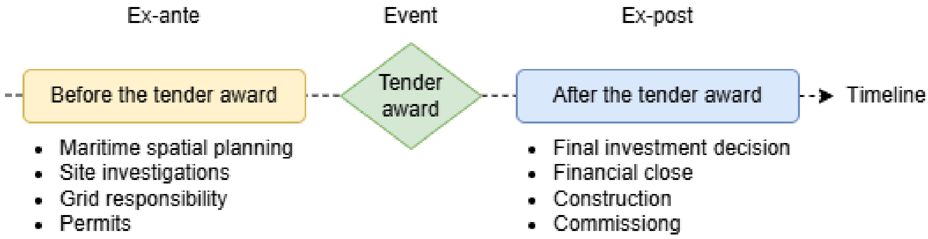


Figure 3.2: A visual representation of ex-ante and ex-post [2]

Revenue-driven transactions, such as Bundle 9, are critical for offshore wind farm owners and offtakers. These transactions involve agreements between the two parties through Power Purchase Agreements (PPAs) or sales on the electricity market. The PPAs ensure the financial viability of offshore wind projects by providing a stable revenue stream for the generated electricity. Sometimes, subsidies are provided by the government to support electricity sales and de-risk projects. These subsidies are also allocated through tenders. However, success still depends on setting reasonable prices for these arrangements, not only on their existence.

Recent market challenges show that project realization should be the top priority in reaching climate goals. Price challenges related to costs are currently the most pressing concerns with supply chain bottlenecks. Companies prioritize these challenges to maintain their competitive edge. Therefore, managing resources and responding to market trends and customer demands are becoming increasingly important to ensure the long-term sustainability of businesses.

3.3. Perspectives of key stakeholders

This section presents the findings of transaction analysis and desk research conducted for the offshore wind industry, along with the perspectives of key stakeholders. The main aim of this section is to validate the analysis and enhance it with primary data, which will help us gain insights from key industry actors: OWF developers, and turbine manufacturers. Other contractors and subcontractors, such as vessels or construction companies, have not been explicitly discussed due to the scope of the project. This section allows us to identify risks associated with offshore wind project development and their corresponding mitigation strategies. The interview notes and questions used are included in Appendix A.6.

3.3.1. Offshore wind farm developer

This subsection focuses on market challenges from the OWF developer perspective. OWF developers are primarily concerned with securing permits, ensuring project profitability, grid integration, and mitigating construction risks and supply chain disruptions. This section of the study discusses the financial challenges faced by developers and the measures they take. It also covers their strategies and expectations from regulatory authorities.

Challenges in the offshore wind market

Here below are some issues faced by OWF developers in offshore wind markets [15, 57]:

- **Cost increase:** In the last two years, developers have faced a significant increase in capital expenditures (CAPEX), with costs rising by 30-50%. This rise is due to multiple factors, such as higher commodity prices, increasing labor costs, geopolitical uncertainties, and suppliers increasing their margins. Furthermore, the offshore wind industry has been greatly affected by the recent increase in interest rates. Offshore wind projects, like other renewable energy projects, have low operational expenses, but they are highly dependent on capital expenditures. This heavy reliance on capital expenditures has negative effects on the market, especially during times of high inflation and interest rates.

[2] Some activities, such as permitting and site studies, may occur before or after bidding, depending on the offshore wind policy of the country.

- **Supply chain bottlenecks:** The lack of supply chain manufacturing capacity is compounded by the cost increase of raw materials, slow permitting, competition from China, and the push for localization. Establishing local supply chains is a time-consuming and costly process, further intensifying these challenges. Developers are becoming more dependent on suppliers if localization requirements are strong. Hence, OWF developers lose bargaining power during the negotiations with suppliers.
- **Margin squeeze:** Developers are facing increasing competition that is leading to a decrease in profit margins. This is driving them to bid on projects with small profit margins, which could result in a deadlock in investment decisions. Bidding requires more resources, which increases the cost of development. On the other hand, competition sets the level at which one must bid. Therefore, the value of a project is determined not only by what one spends but also by what one is willing to pay to win the project. Unrealistic project bids, made to win tenders, can result in unsustainable projects and challenges being passed down the supply chain, ultimately harming the industry.
- **Long-term profitability uncertainties**: The sector faces significant challenges due to fluctuating market conditions. One key issue is the instability of support schemes, making it hard for companies to plan investments. Unclear policy signals add to the difficulty, making it challenging for businesses to comply with changing rules. The absence of subsidy mechanisms, like Contract for Difference (CfD), in some markets exposes developers to market price risks.

Main risks and uncertainties

Offshore wind projects encounter unique challenges that standard contracts may overlook, which can risk their completion. These challenges include the availability of vessels and critical infrastructure, site conditions, and interface risks [44]. During the interviews with developers, it was found that the biggest financial risks arise from supply chain bottlenecks leading to increased costs. However, the issue is not just about the increase in cost. The fixed nature of contractual obligations with counterparties also gives rise to high risk and uncertainty. While bidding on projects, developers are required to commit to project scope, pricing, timelines, technical compliance, and financial security, which cannot be adjusted later, even if market conditions change or unforeseen challenges arise. Hence, the lack of flexibility in the tender process concerning contractual obligations is the biggest risk for developers. When this rigid bidding process combines with cancellation costs, it increases the financial risks for developers. They may face difficulties in meeting their contractual obligations if circumstances evolve differently than anticipated during the bidding stage. Therefore, interview notes support our transaction analysis, which emphasizes the importance of developers seeking firm commitments for main contract packages during project development.

Strategies and policy suggestions

In order to mitigate the associated financial risks, OWF developers implement various risk mitigation strategies and advocate for supportive regulatory policies to address market challenges. These strategies and policy suggestions include:

- **Power Purchase Agreements (PPAs):** Developers establish PPAs to secure a buyer for generated power, ensuring stable revenue streams at a reasonable price over a specific period.
- **Pre-orders and capacity reservation in the supply chain:** Developers are implementing pre-orders and capacity reservation involves securing essential components and services, such as chartered vessels and turbine manufacturing capacity, for a certain duration. This ensures availability and certainty in delivery timelines of the projects, mitigating project-specific risks and reducing supply chain uncertainties. However, developers need to carefully consider the potential cost implications if projects are delayed or canceled, balancing the benefits of assured access with the associated financial commitments.
- **Portfolio view focus:** Developers are adopting a portfolio view rather than a project-specific focus which allows them to leverage synergies across multiple projects, optimizing resource allocation and risk management.
- **Continuous communication and feedback with regulators:** Developers seeking to maintain open communication channels and a feedback loop with regulators throughout the tender and permit processes help to address regulatory uncertainties and streamline project approvals.

- **Clear and explicit terms and conditions:** During the bidding phase, developers want to ensure that the terms and conditions are clear and specific to reduce the risk of misinterpretation. This will allow for a better assessment of the project's feasibility. It is also suggested that timing considerations should be taken into account, including the time gaps between the tender dates and the final investment decision date.
- **Holistic approach by governments:** Governments should encourage developers to consider broader market dynamics and long-term sustainability goals, promoting a holistic approach to offshore wind development.
- **Importance of electrification and decarbonization policies:** In the absence of subsidy policies like Contracts for Difference (CfD), clear policies supporting electrification and decarbonization initiatives in industries are key for sustaining market growth and investor confidence. Otherwise, companies may hesitate to be the first movers in the market, as early adopters often bear the highest costs.

3.3.2. Wind turbine manufacturer

This part of the report focuses on the challenges faced by wind turbine manufacturers in the market. Turbine manufacturers are primarily concerned with innovation, client satisfaction, growth opportunities, product reliability, and reducing costs to remain competitive. This subsection of the study discusses the financial difficulties experienced by wind turbine manufacturers and the actions they take to address them. It also covers their strategies and expectations from regulatory bodies.

Challenges in the offshore wind market

Here below are some issues faced by wind turbine manufacturers in offshore wind markets [78]:

- **Price pressure:** In offshore wind turbine manufacturing, major companies dominate due to economies that raise barriers for smaller competitors. Their dominance stems from significant investments in innovation and technology. Over a long period of time, the industry has been competing aggressively to achieve the lowest LCOE. This competition favors established industry leaders with considerable experience and benefits from economies of scale. This relentless pursuit of the lowest LCOE and the desire to attain higher megawatt (MW) capacities have reduced the development timelines for various wind turbine components compared to the turbines' overall operational lifespan. For instance, over the past decade, the length of turbine blades has more than doubled, which has led to changes in the original design and the use of new materials.
- **Turbine size race:** Installing offshore wind turbines, despite technological advancements, remains a challenging task. It requires extensive planning and precautions, especially due to the increasing size of turbines. The European offshore wind sector has witnessed significant growth, with turbine capacity increasing by over 20% since 2022, as indicated in Figure 3.3. In 2023, the average orders reached a peak of 14.9 MW, compared to 12.2 MW in 2022 [10]. This trend of higher-capacity turbines is likely to continue, putting pressure on turbine suppliers and causing a race-to-bottom in the industry.
- **Volatile market environment:** Developing wind farms entails procuring turbines well in advance, sometimes even before their production begins. This necessitates anticipating future power generation and expenses, while manufacturers must also forecast material costs. Consequently, manufacturers face the dilemma of pricing their products higher to mitigate risks or risking profit margins to stay competitive. Many wind turbine manufacturers are grappling with losses stemming from this challenge, prompting them to renegotiate contracts in an effort to mitigate their financial setbacks.
- **Competition from outside Europe:** Chinese wind turbine manufacturers have rapidly advanced and challenged Western giants. With heavy investment in R&D and government support (tax incentives and cheap land), China has expanded its production capacity. They also benefit from hidden subsidies where companies can sell turbines at a loss and recoup some funding from the government, artificially driving down prices. Their ability to produce cost-effective turbines has led to successful global market entry, putting pressure on Western competitors. China's dominance threatens European suppliers and could reshape the global wind energy landscape.

- **Dependency on policies:** The rapid growth of the wind industry over the past two decades has been driven by economic and energy policies. Some countries have promoted their wind energy sectors through subsidies, which have boosted turbine manufacturers. But they've faced challenges such as falling prices and intense competition. Fluctuating government incentives have led to cycles of growth and stagnation in investment.

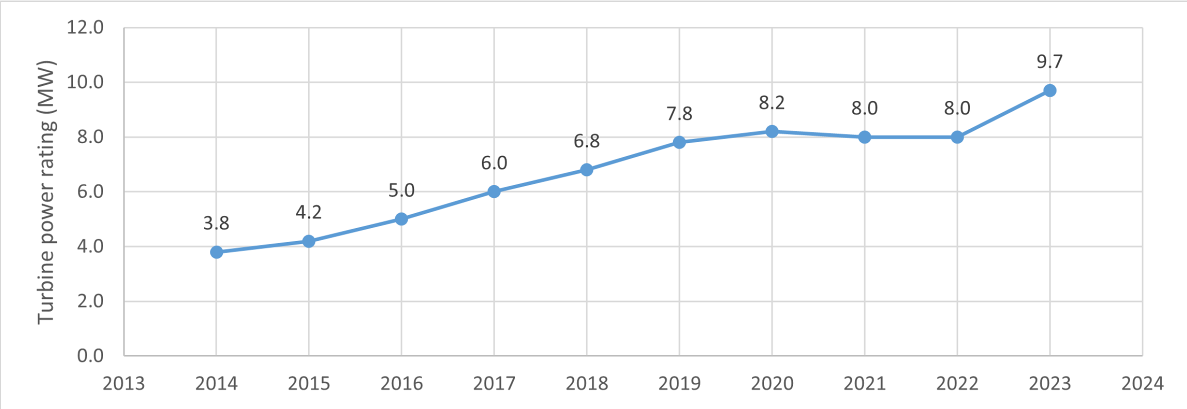


Figure 3.3: Average power rating of installed turbines in Europe [10]

Main risks and uncertainties

The interview underscores several significant risks encountered by turbine manufacturers within the wind energy sector. The most critical issues facing turbine manufacturers encompass price pressure, which directly impacts the company's profitability, coupled with market uncertainty exacerbated by fluctuating government policies. The fluctuating nature of governmental support and subsidies introduces uncertainty regarding revenue streams and market demand, posing a considerable obstacle to manufacturers' long-term planning and sustainability. This uncertainty is exacerbated by the need to make substantial investments in infrastructure, such as building new factories, which typically take four to five years to become operational. Turbine manufacturers must anticipate market demand several years in advance to ensure the viability of such investments. However, with market volumes being highly uncertain forecasting becomes increasingly challenging. This uncertainty in market volumes further complicates manufacturers' ability to maintain a steady pipeline of projects, ultimately impacting their long-term viability and growth prospects. Additionally, there is a belief that using hydrogen and storage solutions will stabilize the electricity market starting in 2030. However, there are doubts about whether these solutions will be scalable by that time. The prices of Power Purchase Agreements (PPAs) are decreasing as wind and solar energy become more prevalent. This has raised concerns about the viability of projects due to the uncertainty of securing future PPAs, particularly in markets without subsidies.

Strategies and policy suggestions

In order to mitigate the associated financial risks, OWF developers implement various risk mitigation strategies and advocate for supportive regulatory policies to address market challenges. These strategies and policy suggestions include [79, 80]:

- **Contracts for Difference (CfD):** Turbine manufacturers view Contracts for Difference (CfD) as a valuable mechanism for protecting revenue, similar to some developers. This is due to the concern regarding the decreasing electricity prices caused by the increasing penetration of renewables in the energy grid. As a result, PPAs are under downward pressure, making project feasibility more challenging. This indirectly impacts turbine suppliers, as developers are their customers.
- **Standardization and industrialization:** The installation of bigger turbines will have significant effects on projects, including the need for larger foundations, upgrades to cranes or vessels, increased voltage levels, and potential challenges with new technology deployment. For this reason, some manufacturers suggest putting a halt to the competition for developing larger turbine

models and instead shifting the focus towards standardization, industrialization, and improving product reliability. There are many discussions and lobbying efforts taking place in the industry regarding this matter. For example, NedZero, the trade association for wind energy in the Netherlands, proposes the North Sea Standard, which defines maximum and minimum tip depths, and minimum installed capacity per foundation from today to 2037 [81].

- **Putting cancellation fees for early works:** Turbine manufacturers often negotiate cancellation fees to protect themselves from risks related to material costs and currency fluctuations. These fees serve as compensation for losses incurred if the project is canceled after the supplier has committed resources or agreed to fixed prices. However, developers usually resist agreeing to these fees until after a Final Investment Decision (FID) is made [37].
- **Shortening permitting process:** Offshore wind projects are experiencing extended timelines from awarding to commissioning, which takes an average of five years [74]. A turbine manufacturer claims that a two-year permitting process for new wind projects and a one-year process for repowering projects can help overcome obstacles hindering the expansion of renewable energy. This process should encompass all administrative work, grid permits, and environmental assessments.
- **Linking lease fees with project revenues:** Unrestricted negative bidding and excessively high lease fees undermine project profitability by increasing financial uncertainty. A turbine manufacturer suggests implementing a strategy where payments for leasing seabed areas or concession fees are tied to project earnings, with a maximum cap set at 2% of yearly revenue to bolster project viability and efficient seabed utilization.
- **Proven technology requirements:** Turbine manufacturers suggest standardized prequalification procedures that include commitments to proven technology, preventing speculative bidding, and ensuring feasibility in the auction process.
- **Harmonized non-price criteria:** Auctions can prioritize projects that benefit the energy system or society, considering factors like sustainability. Non-price criteria should be carefully chosen and harmonized globally or regionally to avoid added costs or complexity. This maintains transparency and accountability without delaying project development.

3.4. Conclusion

Offshore wind projects have historically relied heavily on subsidies. However, costs have notably decreased in the last few decades, allowing some projects to proceed without subsidies. In certain markets, developers are even willing to pay for offshore wind development rights to build and operate wind farms. This change has increased the popularity of financial components in the allocation process, as policymakers recognize offshore wind as an asset that can make money while advancing decarbonization objectives. However, the increased emphasis on financial components can lead to unrealistic project bids, as developers may over promise to win tenders. Such bids can result in unsustainable projects and challenges being passed down the supply chain and consumers, ultimately harming the industry.

Developers seek pre-orders and capacity reservations in advance to secure critical components and services, such as installation vessels and turbine manufacturing capacity, ensuring availability and reliability in project schedules. This approach helps mitigate project-specific risks and minimizes supply chain uncertainties. However, developers must weigh the benefits of assured availability against the potential financial impact of project delays or cancellations. Meanwhile, suppliers also want to ensure that projects will be built. Most contracts with developers are not finalized until the final investment decision of the projects. Even developers can choose to abandon the project, depending on the severity of the penalty for not fulfilling the contract requirements. Suppliers, in turn, hedge their risk by implementing cancellation fees for early commitments, adding another layer of financial consideration for developers. These cancellation fees and conditions are highly dependent on negotiations between the developers and suppliers, with no standard terms. Additionally, the larger turbine race in the industry leads to transportation and installation challenges and necessitates new investments, such as larger vessels. This makes suppliers hesitant to invest in new infrastructure without a demand guarantee for their products and services.

On the other hand, the offshore wind industry is a capital-intensive sector that has recently faced macroeconomic challenges. High inflation and rising interest rates have led to steep cost escalations for all actors through the value chain. Limited supply chain capacity and uncertainties from offtakers further exacerbate these financial hurdles, causing market volatility and price risk for costs for goods/services from suppliers. Consequently, the industry becomes increasingly vulnerable, with financial risks permeating the entire value chain of offshore wind projects.

Based on our analysis, the offshore wind farm development process can be divided into two stages. The first stage, known as the ex-ante, focuses on planning, development and competitive bidding before the tender award. The second stage, called the ex-post, involves permitting, contract negotiations, and project execution after the tender has been awarded.

During the ex-ante stage, the main interactions are between developers and the government. Developers participate in tenders to acquire the rights for offshore wind development, which may include seabed leasing and subsidy schemes. The institutional framework, determined by the tender design and policies of the relevant jurisdiction, encompasses site selection, grid responsibility, awarding mechanisms, and more. Developers compete intensely to secure these development and operation rights. As development costs and the willingness to pay for these rights increase, profit margins get squeezed. Developers face significant risks and limited flexibility due to rigid bidding processes, as they bid without certainty about future expenses and revenues. To ensure revenue certainty in the absence of CfD-like subsidy schemes, offshore wind farm developers often turn to Power Purchase Agreements (PPAs), which provide fixed prices and secure long-term revenue streams. Once the tender concludes (the event occurred), the winners are granted exclusive rights to build and operate an offshore wind farm. At this point, the game changes significantly, and the developer's focus shifts to the realization of offshore wind farm building costs, which are not fully certain during the tender.

In the ex-post stage, interactions between the awarded developer and supply chain actors become much more important because the developer who has the development rights is no longer uncertain. The turbine manufacturers, producing the project's highest-cost component, are pivotal in these interactions. Therefore, they are at the heart of the report to represent suppliers. After winning the tender for OWF development rights, developers must negotiate with suppliers and contractors to ensure that the project is executed within their initial cost and revenue assumptions. However, there is often a significant time gap between the awarding and delivery of the work packages (in this case, turbine supply), which increases both price and supply chain risks. In order to deal with these uncertainties, developers look for early commitments for main contract packages, sometimes even before the tender. At the same time, suppliers might seek advance orders to support their investments, for example, building a turbine factory, a process that may take 5-6 years. On the other hand, suppliers encounter challenges such as reserving production capacity and agreeing to fixed prices without guaranteed contract awards, which can be particularly risky in environments with high inflation and interest rates.

The upcoming chapter analyzes the two aforementioned phases. First, it examines how institutional frameworks are designed in mature offshore wind markets in the North Sea. The second part focuses on the bargaining game between developers and turbine manufacturers to better understand their positions in different market scenarios. A stylized model is built to offer insights into the dynamics between developers and suppliers (i.e., turbine manufacturers) in different market scenarios.

4 Offshore Wind Development in the North Sea

This chapter provides an in-depth analysis of the developing offshore wind projects in the North Sea region, with the aim of expanding on the institutional analysis previously discussed. The chapter is divided into two main sections. The first part focuses on issues in the North Sea region before the tender award, which are mainly the interactions between OWF developers and the governments. The aim is to understand how critical transactions are conducted in different markets. The second part focuses on post-tenders, which are dominated by the interactions between developers and suppliers, specifically turbine manufacturers. It examines how these relationships impact project outcomes using a stylized bargaining model.

4.1. Ex-ante analysis: Before the tender award

Chapter 3 identifies some critical transaction bundles for offshore wind farm development: grid responsibility, allocation of OWF building and operations rights, revenue generation, and construction works. The tender design is a key determinant of how most of these transactions happen. This section focuses on the four major offshore wind markets in the North Sea region: the Netherlands, Denmark, Germany, and the United Kingdom. Each market has its own policies and tender mechanisms to develop offshore wind projects. Therefore, the costs, benefits, and risk allocation between governments and developers depend on the jurisdiction in which the wind farm is planning to operate. The section begins with initial interactions between developers and suppliers. Then, it is followed by spatial planning, site investigations, grid connection, allocation mechanisms, recent tenders and policies in North Sea. This section concludes with a discussion of how these tender design differences affect risk, benefit, and cost allocation between governments and developers.

4.1.1. Spatial planning and approach

The Netherlands

The legal framework for offshore wind energy production begins with early spatial planning. The National Water Plan, governed by the Water Act, designates regions in the Dutch part of the North Sea where future offshore wind farms may be developed. The Ministry of Economic Affairs & Climate Policy and the Ministry of Infrastructure and Water Management allocate wind farm areas. Any wind farm outside these established boundaries will not be granted permits. As a part of roadmaps, the Government releases a report outlining the projected capacity, rollout sequence, and year of tendering for each offshore wind zone and site (see Appendix A.7). After site investigations, Environmental Impact Assessment (EIA), and grid installation decisions, the government is set to publish the Wind Farm Site Decision (WFSD) under the Wind Energy at Sea law. Wind Energy at Sea law requires a WFSD permit for offshore wind farm construction, approving its location, operation, ecological factors, decommissioning, turbine parameters, and cable placement requirements. The WFSD allows design options for innovative and cost-effective development while respecting environmental constraints.

Denmark

The Danish State possesses exclusive ownership of offshore wind energy rights, granted through a competitive tender process overseen by the Ministry of Climate, Energy, and Utilities. Before 2023, developers could also pursue licenses through an open-door procedure. However, this was discontinued due to concerns over potential breaches of EU state aid laws. In June 2020, a landmark climate deal was reached, paving the way for Denmark's ambitious plan to construct two energy islands in the North and Baltic Seas by 2030. These islands will have a total capacity of 5 GW and serve as hubs for offshore wind farms. This strategy emphasizes increasing offshore wind capacity and connecting it to energy islands, marking a shift in Denmark's renewable energy approach [82].

Germany

Germany faces geographical challenges for offshore wind deployment, with limited development close to shore due to the Wadden Sea National Park [83, 84]. Most projects are in the Exclusive Economic Zone (EEZ), managed by the federal government. With a small EEZ and competition for space, Germany has a high installed capacity ratio and targets per surface area compared to other leading countries [83]. The Federal Maritime and Hydrographic Agency (BSH) manages maritime spatial planning, outlining the exclusive economic zone's framework and prioritizing various uses. Based on these plans and installation targets, BSH identifies offshore wind farm (OWF) sites, detailing their size, capacity potential, and necessary grid connections in a Site Development Plan.

The United Kingdom

Offshore wind development in the UK is more complicated than that of other developed markets. Unlike in other countries, where support regimes and seabed rights are tendered together, this is not the case in the UK. Developers must first secure the Agreement for Lease (AfL) by winning the leasing rounds organized by the Crown Estate. Once they have secured these leases, they can only participate in the support scheme tenders, particularly the Contracts for Difference (CfD) auctions. In the seabed leasing rounds, Crown State defines bidding areas, which allows developers flexibility in project planning within designated zones. In the last leasing round conducted, two additional caps were implemented alongside bidder caps [85]. Firstly, no single bidding area could exceed 3.5 GW. Secondly, it was ensured that no projects overlapped in the same bidding area.

Interpretation

The legal frameworks governing offshore wind energy across different regions highlight the importance of early spatial planning to mitigate potential conflicts with existing activities on the seabed, ranging from fisheries to military uses. Clear and proactive spatial planning by governments is important to prevent unforeseen objections and ensure smooth offshore wind farm development. Their role is to provide comprehensive plans well in advance, guiding developers and stakeholders on permissible zones and operational boundaries. This proactive approach not only fosters regulatory certainty but also facilitates efficient project planning and reduces uncertainty for investors and communities alike. By leading discussions on spatial planning, governments can effectively balance diverse marine activities, support sustainable energy goals, and minimize environmental impacts while promoting offshore wind energy.

4.1.2. Site investigations and EIA

The Netherlands

The Netherlands Enterprise Agency (RVO) conducts site surveys and EIA for each wind farm site and provides the collected data to potential developers. Therefore, project developers are not required to carry out their own EIA or fund their site investigations to determine a project's viability. The State, not the competing project developers, is responsible for covering the costs of these surveys. The site data packages will be published and commissioned by the RVO, and each study and investigation has been formally and independently confirmed to be of high quality. Notably, the costs for the site studies and environmental impact assessments were passed on to the tender winner with Hollandse Kust West VI and VII tenders (e.g., 13.5 million EUR) [75].

Denmark

Offshore wind farms are subject to a Strategic Environmental Assessment (SEA) and preliminary investigations before submitting final bids. The TSO conducts pre-investigations focusing on radio links, fisheries, bird surveys, and navigation safety to mitigate risks. Prior studies have also been shown to evaluate wind resources, seabed geophysics, MetOcean data, and environmental conditions. The results of these studies are then made public. The winning bidder must comply with Danish and European regulations and carry out an EIA specific to the project [82]. The winning bidder also has to reimburse the preliminary investigation costs.

Germany

The Offshore Wind Energy Act was reformed in 2022 [84]. Until 2023, the Federal Maritime and Hydrographic Agency (BSH) conducted preliminary assessments for wind farm sites, facilitating bidders with pre-developed sites. From 2023, the Site Development Plan includes sites exempt from pre-assessment, tendered concurrently to accelerate deployment. The goal by 2027 is a 50/50 ratio of pre-developed and non-pre-developed sites, with pre-developed sites predominant until then [83]. Separate procedures are used to tender for each type of site.

The United Kingdom

After the seabed leasing process, a Plan-Level Habitats Regulations Assessment (HRA) is conducted to ensure offshore wind projects do not adversely affect the integrity of protected sites. The process of the HRA includes several stages: screening to identify potential significant effects, conducting an appropriate assessment to analyze impacts on-site features, and developing mitigation measures to avoid or reduce adverse effects. If necessary, alternative solutions are evaluated, and in cases of overriding public interest, compensatory measures are implemented. After the HRA, The Crown Estate awarded the Agreement for Lease (AfL) to ensure that winning projects would not harm the sites involved [85].

Interpretation

Offshore wind farm development across different regions illustrates a trade-off between developers and the government in the responsibility for site studies and pre-investigations. Initially, developers bore the risks and costs of these assessments in the early stages of the industry, which resulted in less investment attraction. In response, governments transitioned to a more centralized and supportive approach, assuming responsibility for pre-investigations and thereby enhancing project attractiveness for developers. As costs have decreased and zero-subsidy projects have become popular, governments have started to demand reimbursement for site study costs, as seen in the Netherlands. Meanwhile, Germany employs both pre-developed and non-pre-developed approaches simultaneously to achieve its climate goals. However, their method of allocating non-pre-developed sites, which relies entirely on negative bidding, has faced criticism from some industry experts. Specifically, these experts argue that negative bidding might cause price pressure within the supply chain and ultimately affect end consumers. Further details on this topic are discussed in Section 4.1.4.

4.1.3. Grid connection

The Netherlands

Transmission System Operator (TSO) TenneT is responsible for building and managing the offshore grid and connecting wind farms to the onshore grid. The government sets the framework for public investments in the offshore grid. TenneT creates an investment plan every two years based on the framework. It is required by law that TenneT be in charge of connecting the wind farms to the onshore electrical grid. However, project developers are still in charge of the inter-array (infield) cables that link the wind turbines to the substation. TenneT and the offshore wind farm operators sign a Connection and Transmission Agreement, followed by a Realization Agreement to develop the substation and connection for the wind farm. If the offshore grid is delayed or unavailable, TenneT is legally obligated to reimburse the wind farm owner for lost or delayed earnings and resulting damages. The TSO uses tariffs to cover the costs of their services, which are passed on to consumers through transmission tariffs or additional charges on electricity bills.

Denmark

Guaranteed grid access is provided to all offshore wind farms by the Danish TSO Energinet, which delivers it to the offshore substation. Before 2020, TSO was responsible for building and financing the transmission grid through tariffs. However, since 2020, the developer has been in charge of building offshore substations and export cables. From the Thor OWF tender, TSO is responsible for constructing and operating the grid connection from the onshore substation to the overall transmission grid. The tender covers the offshore substation and export cables. The developer also must cover TSO's expenses for constructing the onshore grid connection. This decision aims to encourage innovation in the design, construction, and implementation of transmission grids.

Germany

The German Energy Industry Act (EnWG) outlines the TSOs' responsibilities to provide necessary grid connections and compensate for any delays or interruptions. Four TSOs oversee Germany's transmission system and are instrumental in developing and updating the national grid development plan. Once the grid development plan is approved by the Federal Network Agency, it becomes federal law. Transmission system operators then commence planning and implementing grid expansions once the law takes effect. The two TSOs that are mainly active in offshore projects are TenneT and 50Hertz because they are responsible for coastal areas (see Appendix A.8). TSOs plan and build the offshore grid connections, which is funded by grid fees from electricity consumers, after the tender award and during the project construction phase [83].

The United Kingdom

In the UK, developers secure transmission entry capacity by signing a Connection Agreement with National Grid Electricity System Operator (ESO) [85]. Under existing regulations, the physical transmission infrastructure will be constructed, and costs are covered by the offshore wind farm developer and later transferred to an Offshore Transmission Owner (OFTO) through a competitive tender process overseen by Ofgem [21]. An OFTO is an entity that owns and operates the offshore transmission assets that connect offshore wind farms to the onshore electricity grid. The OFTO model is designed to reduce costs and increase efficiency by introducing competition into the ownership and operation of transmission assets. OFTOs are appointed through a tender process run by Ofgem, the UK's energy regulator. This process ensures that the transmission infrastructure is managed by a specialized entity that can deliver the required services at the lowest possible cost to consumers while maintaining high standards of reliability and performance.

Interpretation

The grid connection frameworks for offshore wind farms vary based on regional contexts. In the Netherlands and Germany, where TSOs lead, there is a strong emphasis on standardization and regulatory oversight to ensure grid reliability and alignment with national plans. The downside is that consumers in those countries need to cover the cost. In contrast, Denmark and the UK introduce competition among developers for grid expertise, fostering innovation in grid construction and operation. However, the downside for Denmark and the UK is that developers are responsible for both building and funding the grid connections, which can lead to higher project costs and financial risks for the developers. Despite different strategies, all regions aim to manage the inherent risks in offshore wind projects effectively. Whether through centralized management or competitive market dynamics, the goal remains to achieve sustainable and reliable energy systems that meet environmental targets and consumer needs.

4.1.4. Allocation mechanism

The Netherlands

After the WFSD becomes irrevocable, the RVO coordinates the tender process as a one-stop shop. The tender rules, such as the timing, commissioning deadline, tender amount, base electricity price, capacity, and eligibility criteria, are specified in a Ministerial Order of The Ministry of Economic Affairs & Climate Policy. The Ministry appoints the winner within 13 weeks of the tender closing, although this period can be extended by another 13 weeks if necessary. Competing tender participants can object and appeal within six weeks of the tender award decision. According to the Dutch Offshore Wind Energy Act, four possibilities are available for allocating offshore wind sites in the Netherlands [76, 86]:

- **Competitive subsidy award procedure:** Companies compete for a subsidy grant and permit to build, operate, and decommission a wind farm. The winners are chosen based on the lowest bid price and meeting all requirements. The permit lasts for 30 years, while the subsidy grant lasts for 15 years.
- **Comparative assessment without a financial bid:** Qualitative criteria are used to choose the winner. The key variables are the wind farm development and operation guarantee and the

wind farm's contribution to the country's energy mix. One can add further factors, such as the environmental effect, aquaculture, fisheries, safety, or shipping concerns.

- **Comparative assessment with a financial bid:** Similar to the comparative assessment methodology, the winner is selected based on ranking criteria on a comparative assessment, but the financial bid is included in the ranking criteria.
- **Competitive auction:** Without a subsidy, the developer who makes the lowest bid wins the tender. The successful bid includes a portion of the pre-development environmental impact assessments, site studies, consenting costs, and the socialized cost of the grid infrastructure.

Tenders are not always based solely on price; they can also consider other criteria. These non-price factors can differ from tender to tender and may include considerations related to the environment, ecology, economy, social factors, supply chain, and system integration. In the Netherlands, ecology and system integration are particularly emphasized. Below, six non-price criteria are primarily considered to rank the bids, which may change from tender to tender [87]:

- The expertise and background of the individuals or groups participating in the project
- The quality level of the wind farm design
- The capacity of the project
- The social cost of the project
- The quality of the risk assessment and analysis
- The quality of the measures taken to ensure cost-effectiveness

Denmark

The tendering process for offshore wind farms in Denmark involves several steps. It starts with technical discussions with interested parties to tailor tender specifications to market demands while ensuring fairness and transparency. Next, potential bidders demonstrate their technical and financial capabilities through pre-qualification applications. Negotiations with pre-qualified bidders refine specifications and contract proposals, aiming to lower costs without distorting competition. Final tenders are submitted based on the negotiated terms, and a winner is selected according to the lowest offered price per kWh. The Danish Energy Agency then signs a concession contract with the winner (subject to parliamentary approval) and awards permits for preliminary surveys and establishing offshore wind farms [88].

The auction award criterion in Denmark is determined by the support level provided as a two-sided Contract for Difference (CfD) for every kWh of electricity generated without any indexing [21]. The 2021 auction limited the total support payments for the project's lifetime and capped payments from operators to the State during high market prices exceeding the CfD strike price [89]. The support term for each wind farm is determined by legislation and is calculated over 55,000 full load hours, which is 10-15 years [21].

In the last tender (Thor), a German utility company was granted the concession to develop the project after a lot of drawing, as five out of six bids offered the minimum price of 0.01 øre/kWh. This bid price indicates that the project will not receive a subsidy. Instead, the winner has to pay the Danish State the earnings generated by the project during the first two to three years of operation, up to the DKK 2.8 billion ceiling [21]. This result indicates that a competitive subsidy award procedure is no longer suitable; different assessment criteria are needed to evaluate the project. It could involve qualitative criteria or a financial component that the developer offers to pay.

Previous wind farm tenders had no qualitative criteria for awarding. However, Energy Island Bornholm OWF is expected to introduce community engagement criteria, and North Sea I OWF will have system integration criteria [23].

Germany

Past auctions have shown that bidders find offshore wind projects attractive even without feed-in tariffs or market premiums [83]. This means that bidders can develop offshore wind projects without a subsidy scheme. The German offshore wind tenders, initiated in 2021 under a centralized model, aim to allocate sites for wind farms operating from 2026 onward. These tenders, held annually by the Federal Network

Agency, award sites to developers offering the lowest operating costs. Unlike some countries, successful bidders secure exclusive rights to develop pre-assessed sites without additional lease fees. Until the end of 2022, tenders determine a market premium, with bids indicating the minimum guaranteed price for electricity production. In the tender process, the bid with the lowest cost wins, granting exclusive rights to handle the planning approval, receive subsidies, and connect turbines to the grid. If multiple bids offer no subsidies, winners are determined by lottery. From 2023, the tender system has evolved to a dual tender model, which also includes non-pre-developed sites:

- **Pre-developed site tenders:** Pre-developed sites undergo single-round bidding based on financial bids and qualitative criteria. The financial bid holds significant weight, comprising 60% of the criteria for awarding. Here are the qualitative criteria details [84]:
  - Decarbonization effort (e.g., green hydrogen) - 10%
  - PPA electricity sales percentage - 10%
  - Foundation technology impact on noise and seabed sealing - 10%
  - Skilled labor support contribution - 10%
- **Non-pre-developed sites:** Future auctions will feature many undeveloped sites. The bidding process largely resembles the pre-2022 method, but with one exception: If multiple zero-subsidy are made, a second round begins. Here, the authority sets a price (in EUR/MW), which represents the amount the winning bidder must pay for the site. If multiple bidders agree to this price, the process repeats until one bidder remains.

Figure 4.1 depicts the tender models after 2023. Financial fees from successful bidders in both programs are used primarily to reduce electricity costs (90%) through the TSO, with the remaining portion split equally between marine conservation (5%) and fishery efforts (5%) funded by the federal budget. These adaptations respond to the rapid trend towards zero-subsidy bids, ensuring efficient project selection and meeting updated deployment targets.

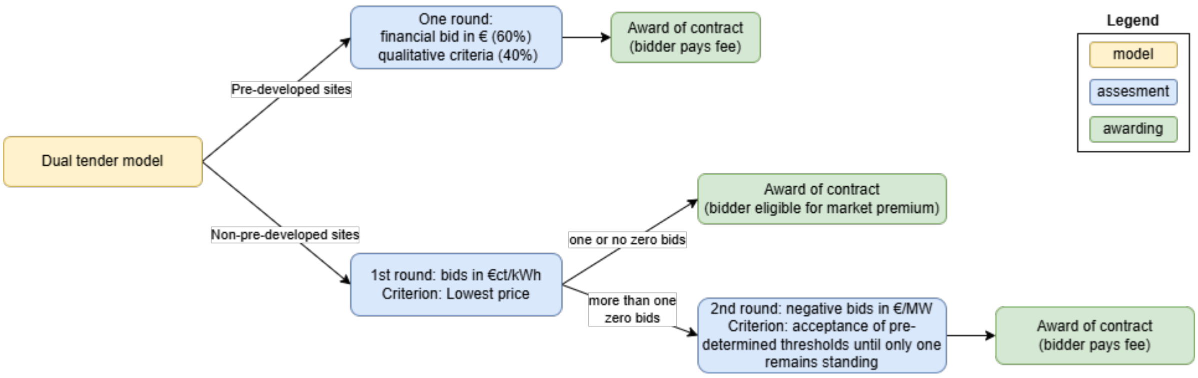


Figure 4.1: Tender models in Germany after 2023 [83]

The United Kingdom

In the UK, the offshore wind seabed leasing process and support schemes are allocated through separate tenders. Developers must secure seabed rights before applying for the support scheme, which operates as a two-way Contract for Difference (CfD). The seabed leasing process consists of two main phases [85]:

- **Pre-Qualification Questionnaire (PQQ):** This phase assesses potential bidders' financial capability, technical experience, and legal compliance. Successful bidders pre-qualify for the Invitation to Tender (ITT) process, becoming Pre-qualified Bidders.
- **Invitation to Tender (ITT):** This is a formal request issued by The Crown Estate or other relevant authorities, inviting potential developers to submit detailed proposals for offshore wind farm development. The ITT is divided into two stages:

- **ITT Stage 1:** The financial and technical strength of projects submitted by pre-qualified bidders is evaluated at this stage. Projects that successfully pass this stage will have eligible bidders and projects for the ITT Stage 2 process.
- **ITT Stage 2:** This stage includes a multi-cycle bidding process, where eligible bidders submit Option Fee Bids (£/MW/year) to compete for contracts. One project is granted per daily bidding cycle, and cycles continue until the capacity limit is reached. Upon winning a daily bidding cycle, bidders submit an Option Fee Deposit which is equal to Option Fee Bid times the capacity of the project.

After the ITT stages and the designation of preferred bidders, a plan-level habitats regulations assessment (HRA) follows. Successful bidders then enter into a Wind Farm Agreement for Lease (AfL) with The Crown Estate. Once the AfL is obtained, consent agreements are secured, including grid connection. After these steps, the project can participate in support scheme auctions.

The UK's primary support scheme for offshore wind, the Contract for Difference (CfD), replaced the Renewables Obligation scheme and functions as a power price hedge. Generators receive payments based on the difference between market prices and a bid strike price. Since its full implementation, five CfD auction rounds have occurred between 2015 and 2023, with prices for offshore wind projects steadily declining until Allocation Round 4. However, in the fifth round, no offshore wind projects secured CfDs due to rising costs and insufficient government support [90]. In March 2024, the UK government opened CfD Allocation Round 6. The maximum strike prices for fixed-bottom and floating wind projects have increased by 66% and 52%, respectively, compared to the fifth round [91]. The budget for AR6 is the highest of any CfD round so far.

Interpretation

Initially, countries supported offshore wind development through schemes like Feed-in Tariffs (FIT) and market premiums. These were allocated via tenders, and the winners requested the lowest subsidy. In most regions, these support schemes and seabed rights were tendered together, although the UK in the North Sea had a distinct approach.

As technology advanced and costs decreased, countries demonstrated their adaptability by introducing new assessment criteria to determine tender winners. This shift came about because some projects became economically viable without subsidies. With subsidies decreasing and a growing emphasis on sustainability and social impact, tender mechanisms have also diversified. The allocation of tenders has evolved into three main formats: price-only, multi-criteria, or beauty contest. There are two extreme perspectives: one where developers are evaluated based solely on qualitative criteria such as ecological impact, social benefits, and system integration. The alternative approach involves conducting financial auctions, where winners are determined by the highest bid for the rights to develop and operate offshore wind farms. A combined approach has also emerged, blending non-price criteria with financial components and using a ranking system to determine the winners.

However, determining the best allocation mechanism remains complex. Governments continuously refine their approaches through market dialogues and learning from experience. Despite the trend towards incorporating non-price criteria, financial considerations often carry greater weight in deciding winners. This imbalance has drawn criticism from industry stakeholders because it might cause speculative bidding and price pressure. This pressure affects the supply chain and ultimately impacts end-consumers.

Allocation mechanisms that favor the highest bid create incentives for developers to consistently reduce costs and increase energy yields. A common approach to achieving this is to use larger turbines to boost energy yields. However, the demand for these larger turbines shortens component development cycles, leading to challenges in the supply chain's ability to keep up. This persistent pressure on the supply chain may result in an unsustainable business model and potential delays, impacting both the development process and the final cost to the consumer.

Additionally, non-price criteria in the allocation design influence developers' expectations from their supply chain partners. Instead of focusing on methods that drive up costs, assessment criteria should be selected to guide developers and suppliers toward sustainability and system integration. However, it's important to recognize that such qualitative criteria can also raise development costs, as they require more rigorous evaluation and compliance measures. Having clear guidelines for evaluating these non-price criteria ensures a transparent process, but overly rigid scoring systems might stifle innovative solutions.

During offshore wind tenders, several risks and challenges can be addressed, including technical, financial, regulatory, operational, and environmental aspects. Technical risks are mitigated through comprehensive site surveys, detailed design and engineering requirements, and technology specifications. Financial risks are managed by requiring detailed financing plans and bank guarantees to ensure financial solidity and the ability to cover potential cost overruns or project failures. Regulatory and permitting risks are addressed by outlining clear guidelines and compliance requirements. Providing permit ease or grid connection guarantees also mitigates these risks by ensuring that developers can obtain necessary permissions without delay and have a guaranteed connection to the grid, reducing uncertainties related to project timelines and energy network integration. Operational risks are covered by mandating maintenance plans and performance guarantees.

However, some risks remain out of scope, including market risks like electricity price volatility and demand variability, macroeconomic challenges, political risks, and force majeure events. Additionally, global supply chain disruptions, such as delays in critical components due to logistical or geopolitical issues. Similarly, technological advancements that could make current technology obsolete are beyond the tender process's control. These risks are unpredictable and cannot be fully managed through the tender process.

After the tender is awarded, the permitting and monitoring processes follow. However, since these processes are not the main focus of this research, they are not discussed in detail in the main body of the research. Additional information can be found in Appendix A.9.

4.1.5. Recent tenders and policies

The Netherlands

The Netherlands government launched tenders for the IJmuiden Ver Wind Farm Zone off the coast [92]. To support climate goals and speed progress, the Government has merged the initial four 1 GW project sites into two more prominent sites, Alpha (2 GW) and Beta (2 GW). These two sites are the largest tender in the history of the Netherlands. The tender results were announced in June 2024, and both sites are expected to become operational in 2029 [75]. The IJmuiden Ver Alpha site was awarded to a consortium of SSE Renewables and Dutch state pension fund APG, who will pay €40 million. The IJmuiden Ver Beta site went to Vattenfall and Copenhagen Infrastructure Partners for €800 million [60]. IJmuiden Ver Gamma is the third site of the IJmuiden Ver Wind Farm Zone and will be tendered in 2025.

IJmuiden Ver Wind Farm Zone Alpha and Beta tenders use a ranking system like Hollandse Kust West rounds. Points are based on the aforementioned non-price criteria, such as corporate responsibility guidelines, knowledge of ecological consequences, and value preservation in wind farms [93]. Specific to each site, Alpha's conditions include its impact on the Dutch North Sea ecosystem, while Beta's conditions involve integration into the Dutch energy system and measures to reduce disturbance to Harbor Porpoises during construction [75].

Minister for Climate and Energy announced that despite the recent cost increase and high interest rates, they are pleased with developers' interest [92]. On the other hand, some developers are unhappy with how the tender was designed and publicly stated their reasons for not attending, along with their concerns for the future. Here are some discussion topics:

- Market conditions for offshore wind power are deteriorating due to rising supply chain costs and uncertainties about electricity prices and sales volumes.
- A developer suggests Contract-for-Difference (CfD) to stabilize fluctuating prices and ensure viable business cases for offshore wind projects. They also propose linking the fixed electricity price to material price indices to prevent sudden cost increases that could lead to project cancellations.
- For specific offshore wind sites, a combined tendering process for wind and hydrogen energy is recommended. By integrating wind and hydrogen energy, financing options for both improve due

to opposing risks associated with electricity prices. When electricity prices are high, the wind farm benefits, while lower prices favor the electrolysis developer.

- Some developer believe the recent tenders prioritize financial offers over quality criteria, allowing bids up to EUR 420 million per year for forty years. This turns the tender processes into financial auctions, potentially undermining societal goals and raising wind farm costs.

Denmark

To meet its 2030 ambitions, Denmark launched its largest offshore wind tender on six sites (North Sea I, Kattegat, Kriegers Flak II, and Hesselø) with a minimum combined capacity of 6 GW by 2030. The potential capacity could exceed 10 GW, allowing excess green power to be exported or used for hydrogen production.

The tender does not include subsidies; instead, it requires an annual concession fee to be paid to the state over 30 years. The leases extend for 30 years, with the Danish state holding a 20% stake in the offshore wind farms. The anticipated cost to build each gigawatt of capacity is approximately USD 2.3 billion [94].

Germany

Germany's initial dynamic bidding auction for offshore wind areas attracted significant interest from major oil and gas companies. BP and TotalEnergies have both obtained contracts for offshore wind areas totaling 7 GW in capacity, offering to pay €12.6 billion in total [95]. However, this new tender system, which relies on developers making substantial payments upfront, has faced criticism.

Traditional offshore wind developers, who do not have the financial resources of large oil and gas companies, are concerned about being marginalized in this new environment [96]. The trend of high or unlimited bidding amounts raises worries about market domination and its potential to disrupt electricity markets. Critics argue that these bidding strategies could increase consumer energy prices, creating affordability challenges. While the involvement of oil and gas majors could speed up the industry's shift to renewable energy, it may put smaller players at a disadvantage.

In 2024, Germany's Federal Network Agency (BNetzA) has initiated tenders for offshore wind projects in the North Sea, with a total capacity of 8 GW. Bids for 5.5 GW on pre-investigated sites are due by 1 August 2024, and bids for 2.5 GW on non-pre-examined sites are due by 1 June 2024 [97]. Tenders for non-pre-examined sites were recently announced. TotalEnergies secured the N-11.2 site (1.5 GW) for €1.958 billion, and EnBW obtained the N12.3 site (1 GW) for €1.065 billion [60]. Penalties may apply if a project isn't completed on time, with securities set at 200 k€/MW for each non-pre-developed sites [25]. It is interesting to note that RWE withdrew at the last minute from its consortium with TotalEnergies because the bid amounts were deemed excessively high. This highlights the significant financial pressures and challenges developers face under the negative bidding approach.

The United Kingdom

The Crown Estate has initiated the 4.5GW Round 5 Celtic Sea lease auction by releasing a Pre-Qualification Questionnaire, leading into a two-stage formal Invitation to Tender [98]. This process aims to identify preferred bidders for three 1.5GW plots off south Wales and southwest England. The UK's first commercial-scale floating wind turbines are anticipated to be operational by the mid-2030s [99]. Detailed tender requirements were released in December 2023, including efforts to minimize risks for developers and expedite project deployment [98]. To begin the leasing process, a comprehensive marine survey program and an early Plan-Level Habitats Regulations Assessment will be conducted. This will be the first time The Crown Estate has undertaken such an assessment in advance. The leasing process begins with the Pre-Qualification Questionnaire (PQQ), followed by the first stage of Invitation to Tender (ITT), which evaluates the bidder's technical, safety, and environmental capabilities. In ITT Stage 2, an ascending clock auction method will be used instead of the previous sealed bid methods. In this method, the price is incrementally raised until only one bidder remains, ensuring a clear and open process that promotes competitive and fair bidding.

4.1.6. Interactions with supply chain partners

Before the tender is awarded, developers operate in a competitive and uncertain market environment. They bid aggressively to secure development rights, often squeezing their profit margins to submit more attractive offers. The decision-making process for developers involves assessing market conditions, technological advancements in turbine technology, and the competitive landscape among suppliers. This evaluation helps developers determine which supplier to engage with and how to structure their bids effectively. Suppliers, aware of the intense competition, try to attract developers with innovative technologies and competitive pricing. However, they avoid allocation resources before the tender is awarded because of the risk of investing time and resources in negotiations with a developer who might not win the bid. Even if developers win the project, they might not make the final investment decision or decide to abandon the project. To mitigate the risk of project cancellation, countries implement various policies as shown in Table 4.1.

Table 4.1: Project cancellation policies in the North Sea [25]

Country	**Pre-FID investments required**	**Securities to put up**
Netherlands	Although the specific eligibility criteria may vary for each tender, permits are issued only if projects are technically and economically viable and adhere to the site decision. Projects must also be finished within a set timeline.	A bank guarantee or deposit is required for the period between permit issuance and the full commissioning of the wind farm.
Denmark	To be eligible for pre-qualification in the tenders, applicants must fulfill the minimum requirements related to economic, financial, and technical capacity.	The Danish Energy Agency mandates that specific guarantees be provided for payment, defective performance, and decommissioning.
Germany	Tender payments for non-pre-developed sites necessitate substantial financial capabilities, as these payments are distributed over the lease period and made annually. Penalties are imposed if a project is not completed within the specified timeline.	Securities of €200,000 per MW are required for pre-developed sites and €100,000 per MW for non-pre-developed sites.
United Kingdom	Before the CfD tender, developers will have made substantial investments in a project, and development costs may be at risk if the project does not proceed. Projects awarded a CfD must meet specified milestone dates, or they risk CfD termination.	Projects are required to pay for site land leases before the CfD tendering process, but no specific security payment is required during the CfD tender process.

Turbine manufacturers operate in an environment where the viability of production depends on achieving economies of scale. They are currently under significant cost pressure caused by increasing raw material prices and supply chain disruptions. As a result, they have raised prices and implemented stricter contract terms. The rapidly expanding offshore wind market is straining their capacity, with only a few suppliers able to provide the specialized equipment required. This scarcity makes it difficult for developers to secure agreements. Additionally, turbine suppliers must navigate the complexities of offering customized solutions and maintaining confidentiality during the competitive bidding. This often requires dedicated sales teams and resources for each developer, which complicates contract negotiations [100].

The intense competition in tenders pressures turbine manufacturers to produce larger turbines to lower the Levelized Cost of Energy (LCOE) for projects. However, focusing only on innovation and creating larger turbines does not ensure long-term profitability. While these advancements can make turbines more attractive to developers, each new model requires a substantial number of orders to justify the investment and start production. Without a steady stream of orders and a stable business environment, even the best technology might not lead to lasting financial success.

4.1.7. Conclusion

Offshore wind policies and tender designs are shaping the interactions between developers and governments. Our analysis delves into mature markets within the North Sea, specifically the EU's largest installed capacity countries: the UK, Germany, the Netherlands, and Denmark. Despite their maturity, each market has its own narrative, with no complete success story. The challenges these markets face underscore the need for continuous adaptation and innovation in tender systems and policies. Governments' limited experience and the complexities involved necessitate a learning-by-doing approach. Understanding the nuances of tender designs and policies is paramount for offshore wind development. Common issues that need consideration in tender processes include the deciding tendered product, site pre-investigations, grid responsibility, and bid assessment.

The tendered product is typically the right to use the seabed. Governments try to mitigate site risks by conducting pre-investigations and early studies about site conditions and developing maritime spatial plans to reduce future conflicts and increase project attractiveness. Markets converge to mitigate site-related uncertainties and make opportunities available to all interested developers. An exception is Germany, which also designates certain areas for developers willing to take higher site risks. With this approach, they aim to increase their installed capacity and generate additional financial resources through a negative bidding allocation mechanism.

Grid responsibility allocation varies among these countries. Differences in allocation are driven by each country's energy policy, regulatory environment, and historical context. The Dutch government prefers a centralized approach for consistency and efficiency, reflecting its TSO's expertise. Denmark's decentralized model supports competition and technological advancement through private sector innovation. The UK and Germany seek to balance centralized control with market-driven solutions, influenced by their regulatory landscapes and government intervention levels. These variations highlight the impact of national priorities on grid infrastructure responsibilities.

Assessing bids is another critical aspect. With the reduction in developer risks over time (e.g., site analysis) and technological advancements, costs have decreased. This has enabled the development of projects without the need for support schemes, and assessment criteria have evolved accordingly. There are two main approaches: one focusing on non-price criteria such as sustainability and system integration, and another where companies offer financial bids to the state. These approaches are sometimes combined, as seen in the Netherlands, leading to discussions about the role and impact of financial components, the implications of negative bidding, and whether financial caps should be imposed.

Many countries view offshore wind energy as a dual opportunity to generate revenue while achieving their climate goals, often integrating financial components into tenders. While adding financial components provides short-term benefits, the long-term effects remain unclear. For instance, recent Dutch tenders, organized with an uncapped financial component, saw winners paying €400,000 and €20,000 per MW for two 2GW sites. In contrast, the latest German tender, based solely on negative bidding, required winners to pay €1.3 million and €1.1 million per MW for 1.5GW and 1GW sites, respectively. This differentiation highlights that non-price criteria can significantly increase costs for developers, reducing potential government revenue. Financial components also simplify evaluation by enabling straightforward numerical comparisons rather than complex qualitative assessments. These reasons makes governments more inclined to adopt financial components, sometimes relying entirely on them.

However, financial bidding creates price pressure within the supply chain. As developers commit to higher payments, they may push for lower costs from suppliers, potentially impacting the quality and sustainability of the components and services provided. This pressure can ripple through the entire supply chain, affecting everything from raw material procurement to project execution, ultimately challenging the overall stability and health of the offshore wind market. This result isn't surprising, given that tenders are fundamentally competitive bidding processes that allocate resources efficiently. Their nature inherently maximizes competition, and squeezing margins becomes an expected outcome when price is the primary basis for competition. However, the main issue is more than squeezed margins; the reliability of the high financial bids is also questionable. For instance, in a previous German tender, winners promised to pay around €1.8 million per MW but offered prices dropped significantly (to around €1.2 million per MW) within a year. This volatility demonstrates the market's instability and the challenge for developers to predict long-term financial commitments. Consequently, relying on developers to estimate payments for a project based on current market conditions is risky and often unreliable. The real concern is whether they will complete the project and make their promised payments.

Some developers believe that a CfD-like mechanism is important to guarantee revenue and reduce market price risks. However, introducing CfD mechanisms may not be effective if even a single developer claims they can build without a subsidy, as seen in current market trends. Therefore, if any CfD mechanism is applied, it should be considered separate from the seabed lease, as is done in the UK. Otherwise, multiple projects may submit zero-subsidy bids, leading to a situation like the Thor tender in Denmark, where the winner was decided by lottery. Even in that case, we still need to figure out how to allocate seabed rights tenders. At this point, it's important to understand why these developers are interested in a CfD-like mechanism. The primary goal is not merely to seek additional money but to ensure revenue stability and mitigate the risk of market price fluctuations. At the end of the day, companies that currently submit zero or negative bids are not necessarily motivated by societal benefits; instead, they factor in future price risks when making these offers. Mitigating these risks and uncertainties throughout the development process is important to address the industry's unsustainable business practices, which might cause project delays and cancellations. Unfortunately, this is not the main consideration in tenders and it requires more attention than merely adapting assessment criteria. This is why issues are not resolved when the tender is awarded. It is important to understand how market scenarios affect the interactions among developers, suppliers, and contractors.

As highlighted in our institutional analysis, once projects are awarded, the dynamics shift, and the focus transitions to the collaboration between developers and suppliers/contractors. Prior to the award announcement, developers compete for building and operational rights, but post-award, the emphasis lies on project realization, necessitating agreements with suppliers and contractors. Effective collaboration between developers and suppliers/contractors is not just important; it's paramount to distributing risks evenly to build projects at the lowest cost on time. In the subsequent chapter, we focus on the developers' role in navigating a bargaining game with suppliers and discuss strategies for equitable risk-sharing before project awards.

4.2. Ex-post analysis: After the tender award

In the previous section, most of the critical transactions identified in the institutional analysis were examined for various mature markets in the North Sea. This section addresses construction work package-related transactions between developers and turbine suppliers. Unlike the tender process, jurisdictional differences are less relevant because these interactions are similar across countries due to the global and highly concentrated nature of the turbine market, dominated by a few major players. This section begins with the bargaining concepts, followed by the negotiation model, scenarios (reflecting market dynamics), strategies employed by developers and turbine suppliers, equilibrium agreements, and the discussion. The objective is to analyze the equilibrium outcomes of different market scenarios, discuss the bargaining power in these scenarios, and examine how the surplus is shared, determining if the outcomes are efficient and fairly distributed.

4.2.1. Bargaining concepts

After the tender is awarded, winning developers need to finalize agreements with contractors and suppliers for different work packages (i.e., turbines, foundations, cables, substations) for the offshore wind farm project. Turbine supply agreements are distinct work packages that require prioritization. Given the current market discussions on balancing standardization and innovation, we prioritize turbine manufacturers as key suppliers in the offshore wind development process. Consequently, the rest of the section focuses on turbine procurement transactions between developers and manufacturers.

Depending on project and market conditions, developers seek agreements that align with their timelines, budget constraints, and quality requirements. Meanwhile, turbine suppliers prioritize maximizing profitability through efficient production and scaling capabilities, often investing in R&D to enhance their competitiveness in the turbine market. However, varying industry conditions may lead to unequal bargaining power, potentially resulting in inefficient resource allocation and unfair distribution of project benefits. This dynamic highlights the importance of negotiation mechanisms to ensure fair outcomes in the development of offshore wind farms.

In negotiations between a buyer (OWF developer) and a seller (turbine manufacturer), a trade is possible only if the buyer's reservation value is equal to or higher than the seller's reservation value. Reservation value, in economics and finance, refers to the maximum amount a buyer is willing to pay for a good or service, or the minimum amount a seller is willing to accept to part with it. It represents the individual's or entity's threshold for transaction acceptance. If the buyer's reservation value is lower than the seller's reservation value, the trade will not occur unless a subsidy is available from a third party (e.g., the government). When both parties have the same reservation value, trade can only proceed at that specific value, with no opportunity for further negotiation since they both agree on that price. However, if the buyer's reservation value is higher than the seller's, a value surplus exists between them. Negotiations then focus on how to distribute this surplus between the buyer and the seller to reach an agreement beneficial to both parties (see Figure 4.2).

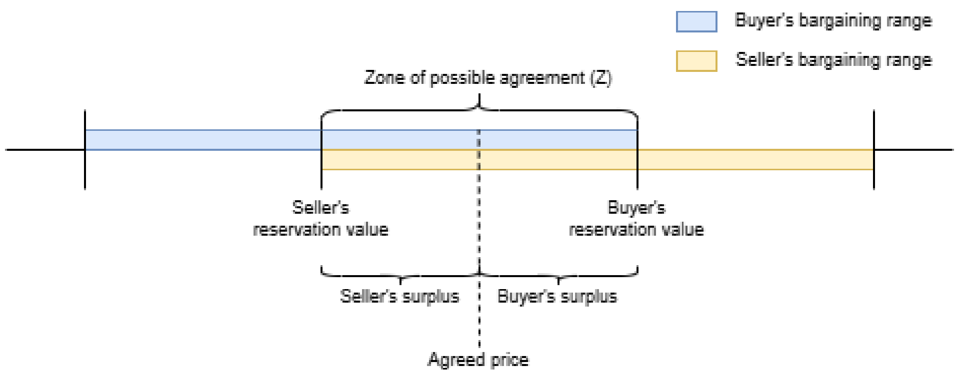


Figure 4.2: Simple representation of bargaining

When the buyer's reservation value is equal to or less than the seller's reservation value, the outcome is clear and no negotiation is needed. However, in the more common scenario where there is a surplus between buyers and sellers, negotiation becomes a complex process that determines how this surplus is allocated and presents a challenge to all parties involved.

Time, a key concept in institutional analysis, is central to the development of offshore projects and agreements between developers and contractors/suppliers. The unique time preferences of each party, whether patient or impatient, can significantly influence the negotiation process. For instance, a patient negotiator might delay an agreement to gain more value over time, adding complexity and strategic depth to the negotiation process.

Another important aspect of negotiation is the information state of the parties involved. In negotiations, each party must decide whether to accept and how to make offers to maximize their benefits from the agreement. Therefore, each participant develops a strategy based on their knowledge at that moment. This information depends not only on their players' own parameters but also on what they know about the parameters of their opponents.

Two types of information states can exist in negotiations: complete and incomplete. In a scenario with complete information, all parties fully know each other's preferences, constraints, and potential outcomes. This allows each participant to make highly informed decisions and strategies, leading to more predictable and potentially equitable outcomes. On the other hand, incomplete information, which reflects real-life situations, occurs when parties have limited knowledge about the other parties' preferences, constraints, and strategies. This uncertainty can lead to strategic behavior, as each party must consider the unknown factors that could influence the negotiation.

Sometimes, there is symmetric information, where both parties have the same information and uncertainty about each other. However, it is also possible to encounter asymmetric information scenarios, where one party has more or better information than the other. Asymmetric information can significantly impact the negotiation dynamics. The party with more information might have a strategic advantage, enabling them to make offers that better serve their interests while potentially exploiting the less-informed party's uncertainties. This imbalance can lead to less optimal outcomes for the disadvantaged party and may even create opportunities for manipulation. In the offshore wind sector, the interaction between developers and turbine manufacturers often exemplifies asymmetric information scenarios. In this context, the developers and turbine manufacturers each possess distinct sets of information that can significantly influence the negotiation process.

Efficiency and distribution are important concepts in negotiations and should be understood before proceeding. Efficiency ensures that agreements maximize utility without waste, achieving Pareto optimality, where parties can only benefit at the expense of others. This shows the effective use of resources. Distribution, on the other hand, is concerned with how the gains from trade are shared, either equally or in favor of one side. Fair distribution is preferred, while unbalanced gains can lead to long-term problems. Both concepts are relevant to the evaluation of negotiation outcomes.

4.2.2. Negotiation model

Bargaining protocol

Our negotiation model involves an alternating offers protocol in which the OWF developer and the turbine manufacturer take turns making offers until an agreement is reached. This section adapts the bargaining protocols of the single-issue negotiation model between a buyer and seller in [101] and [102]. In this model, DEV represents the developer, and TM represents the turbine manufacturer. Each party has an initial value IV, which is the starting price in the negotiation, and a reservation value RV, which is the minimum price TM is willing to accept or the maximum price DEV is willing to pay.

For the developer, the range of acceptable prices is from their initial value to their reservation value $[IV^{DEV}, RV^{DEV}]$. Similarly, for the turbine manufacturer, the acceptable price range is $[IV^{TM}, RV^{TM}]$. The zone of agreement, where the price is acceptable to both parties, lies within the interval $[RV^{TM}, RV^{DEV}]$. The difference between the reservation values, $RV^{DEV} - RV^{TM}$, is known as the price surplus.

The negotiation process involves the players making offers alternately at discrete time intervals denoted by $t \in T = \{0, 1, ...\}$. Each player has a deadline, T^{DEV} for the developer and T^{TM} for the turbine manufacturer. The negotiation begins with one player randomly chosen to make the initial offer.

During the negotiation, the turbine manufacturer's action when the developer's offer at time t, denoted as:

$$A^{TM}(t, p^t_{DEV\to TM}) = \begin{cases} \text{Quit} & \text{if } t > T^{TM}, \\ \text{Accept} & \text{if } U^{TM}(p^t_{DEV\to TM}) \geq U^{TM}(p^{t+1}_{TM\to DEV}), \\ \text{Offer } p^{t+1}_{TM\to DEV} \text{ at } t+1 & \text{otherwise.} \end{cases}$$

The utility function for players $U(p,t)$ is the product of two components: $U_p(p)$, representing the utility derived from the price, and $U_t(t)$, representing the future value factor, which is the ratio of the value of a payoff one time step in the future compared to its value today. It incorporates both the time value of money, which accounts for the potential earning capacity of money over time, and the option value, which reflects the added worth of having flexibility or choices in future decisions. This factor helps in evaluating how future payoffs are valued relative to present payoffs, taking into consideration the combined effects of interest rates, volatility, and strategic opportunities. Here are the utility functions of the developer and turbine manufacturer:

$$U^{DEV}(p,t) = U^{DEV}_p(p)U^{DEV}_t(t),$$

$$U^{TM}(p,t) = U^{TM}_p(p)U^{TM}_t(t).$$

Both components have the same dimensions. The following formula is used to calculate the utility function's price and time components:

$$U_p(p) = \begin{cases} RV^{DEV} - p & \text{for the OWF developer,} \\ p - RV^{TM} & \text{for the turbine manufacturer.} \end{cases}$$

$$U^{DEV}_t(t) = (\delta^{DEV})^t, \text{ where } \delta^{DEV} \text{ is the future value factor of } DEV.$$

$$U_t^{TM}(t) = (\delta^{TM})^t, \text{ where } \delta^{TM} \text{ is the future value factor of } TM.$$

An agent's time preferences reflect how they value payoffs at different points in time. To simplify, we consider two possibilities for the future value factor: it can be either greater than one or less than one. A higher future value factor (above 1) means the agent places more importance on future payoffs, indicating they prefer future benefits over immediate rewards. Conversely, a lower future value factor (below 1) means the agent discounts future payoffs significantly, showing a stronger preference for immediate rewards.

Making offers

In formulating offers and counteroffers in our negotiation model, both DEV and the turbine manufacturer TM employ time-dependent price strategies. These strategies are chosen to strategically navigate the negotiation toward a favorable agreement while considering their respective reservation values and the dynamics of the negotiation timeline. The offers generated at time t are determined by player-specific decision functions $f^{DEV}(t)$ and $f^{TM}(t)$:

$$p^t_{DEV\to TM} = IV^{DEV} + f^{DEV}(t)(RV^{DEV} - IV^{DEV}),$$

$$p^t_{TM\to DEV} = RV^{TM} + (1 - f^{DEV}(t))(IV^{DEV} - RV^{DEV}),$$

where $f^{DEV}(t)$ and $f^{TM}(t)$ are defined as:

$$f^a(t) = k^a + (1-k^a)\left(\frac{\min(t, T^a)}{T^a}\right)^{1/\psi}, \quad a = \text{DEV, TM}.$$

These functions $f^{DEV}(t)$ and $f^{TM}(t)$ encapsulate each player's negotiation strategy over time. Here, k determines the initial offer's proximity to the initial value or reservation value, ensuring $f(0) = k$ starts at IV and $f(T) = 1$ ends at RV. The parameter ψ governs the rate of change in $f(t)$ over time, influencing the speed of adjustment towards RV. Negotiation strategies can vary widely based on ψ, which determines the rate of adaptation over time. Generally, these strategies can be categorized into three main types:

- **Boulware (B):** Start negotiations with minimal concessions, maintain a firm stance, and secure favorable terms by asserting initial strength and delaying concessions. Represented as $\psi < 1$.
- **Linear (L):** The linear strategy progresses steadily and predictably over time, adjusting at a consistent rate towards the reservation value. Represented as $\psi = 1$.
- **Conceder (C):** Prioritizes relationship-building and flexibility, adapting offers over time to accommodate the other party's preferences and facilitate agreement. Represented as $\psi > 1$.

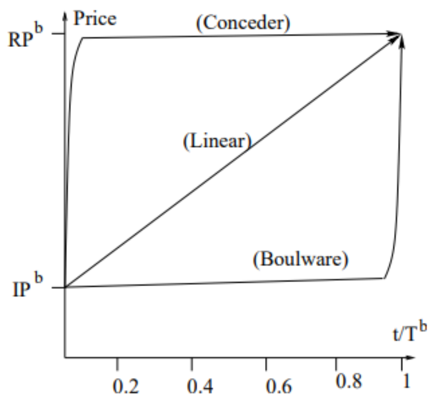


Figure 4.3: Decision function types for the developer [103]

Through this structured protocol, both the developer and the turbine manufacturer evaluate and respond to each other's offers until they find a mutually acceptable price or one party decides to quit the negotiation. An important assumption is that both players prefer reaching an agreement over conflict because the utility of an agreement is always better than that of a conflict. Without an agreement, both players face the risk of receiving nothing or incurring additional costs associated with conflict. Even if outside options are available, they might come with uncertainties and potential drawbacks. A contract on the table is always much safer, providing a guaranteed outcome and minimizing the risks and uncertainties associated with unresolved negotiations or alternative options. This assumption makes the idea that both players prefer reaching an agreement over conflict a logical and practical foundation for our bargaining model.

4.2.3. Information states and dynamics

Asymmetric information shapes negotiations between OWF developers and turbine manufacturers, particularly in the period leading up to and after the tender award. These dynamics influence how both parties negotiate turbine procurement agreements.

Once a developer is awarded the tender, negotiation dynamics shift significantly. The developer's project timeline and specific requirements become clearer and publicly known, allowing suppliers to evaluate their ability to meet these demands. Developers now have a definitive project scope and timeline, which provides suppliers with critical information to tailor their offers and negotiate terms more precisely. However, suppliers continue to maintain confidentiality regarding their production capabilities, technological deadlines, and minimum order requirements. This information asymmetry persists post-tender award, influencing their negotiation strategies as they strive to maximize profitability and operational efficiency while meeting developer expectations.

Developers and turbine manufacturers have confidential information related to project valuation and finances. Both parties use valuation metrics to determine their reservation value and future value factor. Developers base their bid prices on financial models, market assessments, and profitability targets, while turbine manufacturers consider production costs, profit margins, and market competitiveness to set their pricing strategies.

4.2.4. Market scenarios

Various market scenarios arise in the negotiations between OWF developers and turbine manufacturers, reflecting different deadlines and future value factors for each party. These scenarios illustrate how these parameters influence negotiation dynamics and strategies.

Key parameters

In defining market scenarios, two critical parameters must be considered for each player: the agreement deadline and the future value factor.

- **Deadline:** Two cases arise depending on whether the developer or the turbine manufacturer holds urgency. Developers often face stringent schedules, whereas manufacturers may have varying priorities among projects. As discussed in the information state section, only the turbine manufacturer has knowledge of both deadlines, whereas the developer is aware only of their own.
- **Future value factor:** This parameter, which can exceed or fall below 1, determines time preferences. In institutional analysis, while it is theoretically possible for developers to maintain a future value factor above 1, it doesn't align with current market conditions. Due to factors like high inflation and volatile market conditions, developers typically maintain a future value factor below 1, necessitating reevaluation. Issues such as supply chain scarcity and increasing global demand may also hinder future supply capacity availability. For turbine suppliers, however, the situation may differ. While they may prioritize early agreements due to ongoing production needs and the strategic importance of securing orders, their future value factor can also be below 1. Nonetheless, they may anticipate better terms in the future, especially if there is no available capacity from competitors, making them the sole option. In such cases, their future value factor could exceed 1.

Scenarios

Here are the scenarios outlined based on the parameters we discussed previously:

1. **Scenario 1:** Turbine manufacturers are more flexible with deadlines ($T_{DEV} < T_{TM}$), but both parties lose utility as time progresses ($\delta_{DEV} < 1$ and $\delta_{TM} < 1$), motivating them to reach an early agreement. Developers are under pressure due to stringent project schedules, while turbine manufacturers are also motivated to secure orders promptly.
2. **Scenario 2:** Developers have more flexibility with deadlines compared to turbine manufacturers ($T_{DEV} > T_{TM}$), but both parties still experience utility loss over time ($\delta_{DEV} < 1$ and $\delta_{TM} < 1$). This scenario encourages both sides to negotiate early to avoid potential losses and capitalize on current market conditions.
3. **Scenario 3:** Turbine manufacturers have more flexibility with deadlines ($T_{DEV} < T_{TM}$), and they gain utility as time progresses due to anticipated better terms or less competition in future ($\delta_{TM} > 1$). But developers will be under increasing pressure and potential loss of business until the deal is in place ($\delta_{DEV} < 1$).
4. **Scenario 4:** Developers are more flexible with deadlines than turbine manufacturers ($T_{DEV} > T_{TM}$), but TM gains utility over time as they anticipate improved terms or market conditions ($\delta_{TM} > 1$). This scenario puts DEV at a disadvantage ($\delta_{DEV} < 1$) if they cannot expedite negotiations or if TM holds out for better terms .

4.2.5. Optimal strategies

In negotiations between OWF developers and turbine manufacturers, four elements shape players' strategies. The initial offered price serves as the starting point, influencing subsequent offers and setting a benchmark for the negotiation's direction. The final conceded price represents the threshold beyond which a player is unwilling to make further concessions, balancing the pursuit of a favorable agreement with the risk of negotiation breakdown. Timing the offer of the final price is other element, it is reflecting each party's assessment of negotiation progress and readiness to finalize terms. This timing is influenced by market conditions and strategic goals. Lastly, the ψ dictates the rate of adjustment towards the reservation value over time—whether players adopt a Boulware (minimal concessions), Linear (steady adjustment), or Conceder (flexible and accommodating) approach. Selecting an appropriate ψ depends on factors such as negotiation deadlines, market dynamics, and the opponent's strategy. These elements collectively shape how OWF developers and turbine manufacturers navigate negotiations.

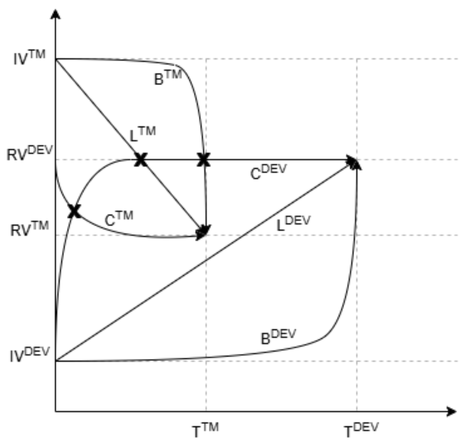


Figure 4.4: Possible outcomes when the developer has a later deadline

Perspective of OWF developers

OWF developers face a unique challenge in negotiations due to their lack of knowledge regarding the TM's deadline. Without this information, developers cannot be certain whose deadline is earlier, complicating their strategic decisions. However, the primary goal for developers is to reach an agreement rather than face a conflict, as any agreement is preferable to the uncertainties and potential losses of a breakdown in negotiations. As illustrated in Figure 4.4, there are three possible strategies that TM can follow: Boulware (B), Linear (L), or Conceder (C). If the DEV knew their deadline was earlier than TM's, they could tailor their strategy to align with their time preferences. This would allow them to negotiate more aggressively if time permitted or to expedite concessions if time was short. However, in the absence of this deadline information and given the possibility that DEV's deadline might actually be later than TM's, the most prudent approach is to adopt a Conceder strategy. The Conceder strategy ensures that developers gradually make concessions over time, increasing the likelihood of reaching an agreement. This approach is the dominant strategy in all scenarios because there is always uncertainty about the opponent's deadline. Developers also set their reservation value as the final price when their deadline comes.

Perspective of turbine manufacturers

TM has an advantage in the negotiation process due to their awareness of both their own and the DEV's deadlines. This additional information allows TM to strategically offer their reservation value by comparing both deadlines and making the final price offer at the earliest one. This approach ensures that, regardless of their strategy, whether Boulware, Linear, or Conceder, an agreement will be reached. Therefore, when deciding their strategy, TM need only consider their time preferences, which depend on their future value factor.

When TM's future value factor is above 1, the optimal strategy is Boulware regardless of the opponent's strategy. This approach allows TM to achieve the highest price at the latest possible time, thereby maximizing the utility function. The rationale is that a future value factor above 1 indicates that TM values future payoffs more highly, so delaying concessions and holding out for a better price is beneficial.

However, when the future value factor is below 1, the situation becomes more complex due to the trade of between time and price preferences. In this scenario, TM must consider two cases based on the relationship between the price surplus (Z), the time to deadline (T), and the future value factor:

- **Small Z, large T:** When the price surplus (Z) is small and the time to deadline (T) is large, the optimal strategy for TM is Conceder (C). This is because the small price surplus offers limited room for bargaining gains, and with ample time available, TM can more easily afford to concede in order to secure an early agreement. The rationale is that TM prefers to reach an agreement sooner rather than risk protracted negotiations that may not significantly increase the final price. In this situation, the focus is on ensuring that an agreement is reached without incurring additional time costs that might outweigh the benefits of a slightly higher price.
- **Large Z, small T:** when the price surplus (Z) is large and the time to the deadline (T) is short, the optimal strategy for TM is Boulware (B). Here, the significant potential gains from a large price surplus justify a more rigid bargaining stance, even as the deadline approaches. With a large surplus, TM aims to secure the maximum possible price, knowing that the urgency of the deadline will pressure DEV to accept a higher offer. The limited time further incentivizes TM to maintain a strong position as the pressure on DEV to close the deal quickly increases. Thus, TM can exploit the situation to extract the highest possible price, prioritizing immediate payoffs over the risk of losing the deal.

By leveraging their knowledge of both deadlines and adjusting their strategy based on their future value factor, TM can navigate the negotiation process effectively to secure a favorable agreement.

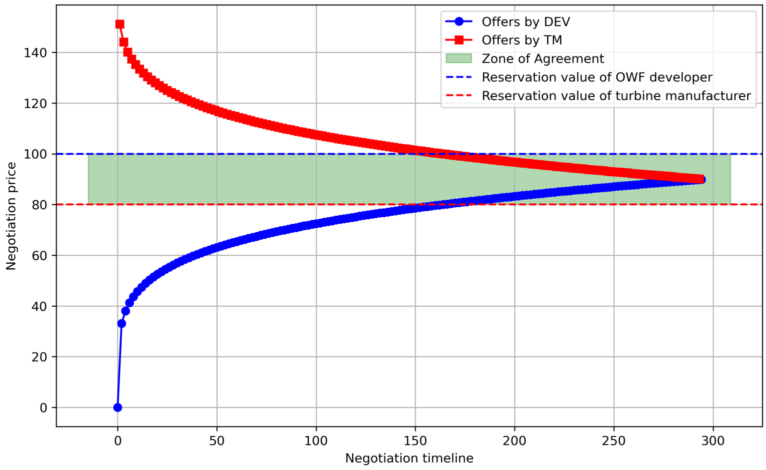
4.2.6. Equilibrium agreements

This section analysis the equilibrium outcomes of negotiations between OWF developers and turbine manufacturers across the four market scenarios outlined previously. By examining these outcomes, we can better understand the dynamics of bargaining power, the distribution of surplus, and the efficiency of agreements reached under different market conditions. In Appendix A.10, the negotiation strategies that parties follow under different scenarios and associated outcomes are presented.

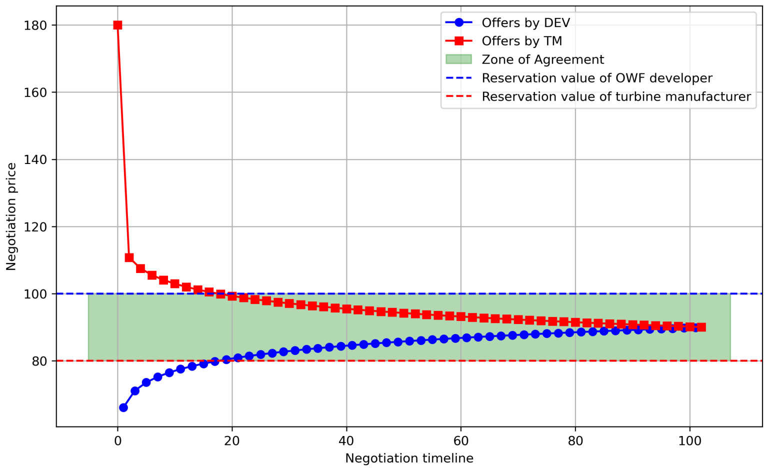
Scenario 1

As it is discussed above, DEV always follows Conceder strategy to ensure an agreement. Meanwhile, TM decide his strategy upon his priority between time and price.

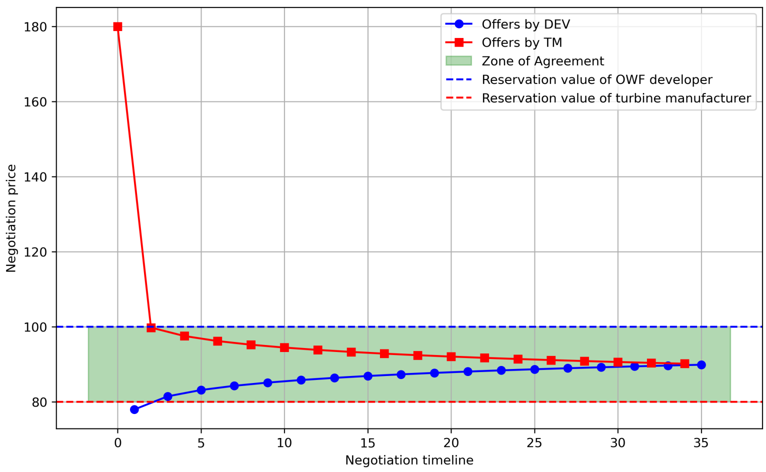
(a) If TM prioritizes time, they should adopt a Conceder strategy. When both DEV and TM are motivated to reach an early agreement due to decreasing utility over time, the optimal approach for both is to concede. This leads to an equilibrium price near the midpoint of their reservation values, indicating a fair distribution of surplus. As both parties increase their tendency to concede (higher ψ), the equilibrium is reached earlier and converge to beginning of the negotiation (T_0). The urgency of DEV and TM's willingness to compromise over time drive the negotiation toward an efficient and equitable outcome. A numerical application is illustrated in Figure 4.5.



(a) Bargaining process for $\psi_{DEV,TM} = 5$



(b) Bargaining process for both $\psi_{DEV,TM} = 15$



(c) Bargaining process for both $\psi_{DEV,TM} = 25$

Figure 4.5: Possible outcomes in Scenario 1a for different ψ values

(b) If TM values price as the most important factor, then he should consider following the Boulware strategy. Despite TM's decreasing utility over time, the benefits he receives outweigh the decrease in time utility. TM's best approach is to take a firm stance with minimal concessions until the final stages of negotiation. Doing so makes the final price likely closer to TM's ideal price, resulting in a more favorable outcome for TM. As TM employs more of a Boulware strategy, the final price remains closer to TM's initial offer until near the end of the negotiation. The urgency of DEV and TM's firm stance guides the negotiation toward a more advantageous outcome for TM. It's important to note that this outcome is inefficient, as both parties experience decreased satisfaction due to the late agreement. They would both have a better result if they had agreed on the same price at T_0. Therefore, this outcome is not Pareto optimal. A numerical application is illustrated in Figure 4.6.

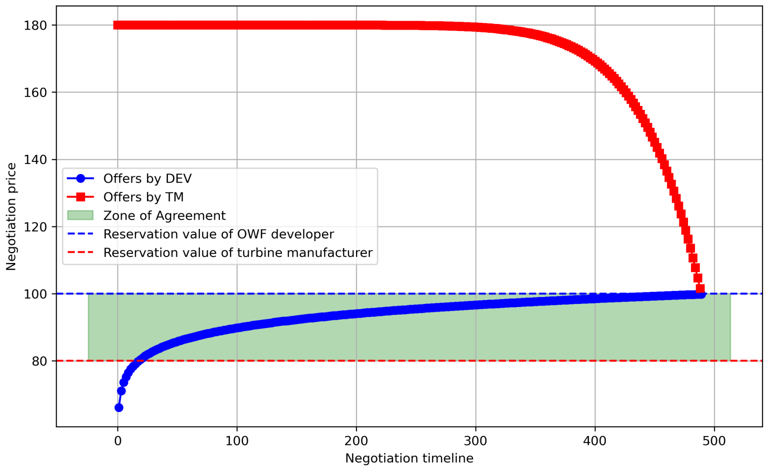
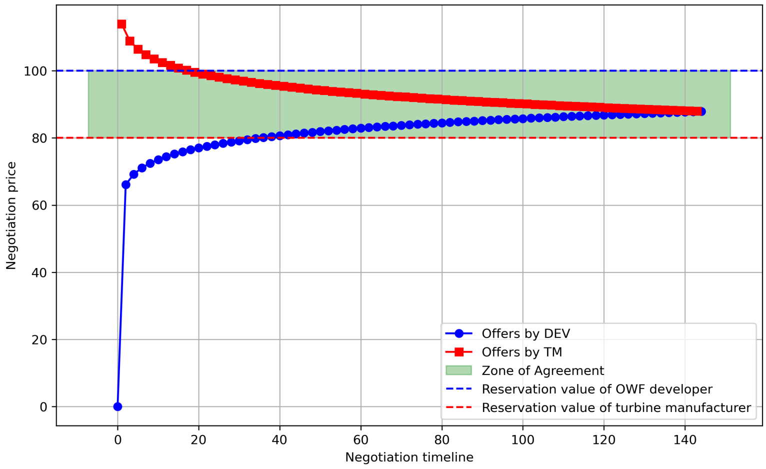


Figure 4.6: A possible outcome in Scenario 1b

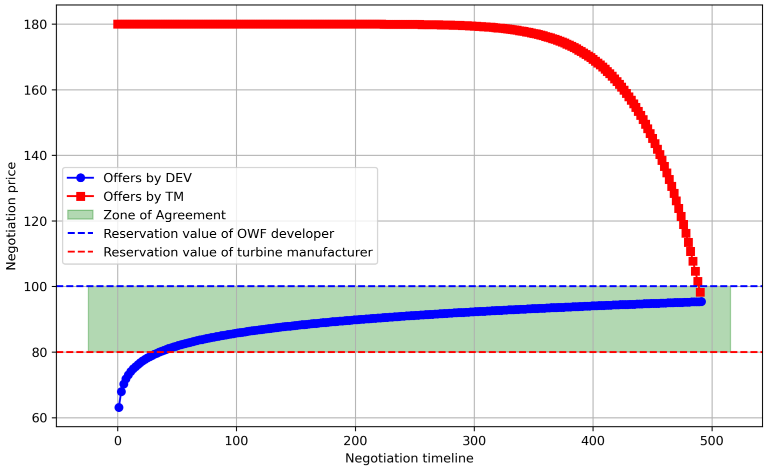
Scenario 2

In this scenario, TM faces a tighter deadline, which puts pressure on them to reach an agreement quickly. DEV, having more flexibility, however he is not aware of it. Therefore, DEV will follow the same strategy as in scenario 1. TM decision still depends on how they value time and money to decide Conceder (scenario 2a) or Boulware strategy (scenario 2b). However, this time TM offer its reservation value at the developers deadline, in that way TM ensure an agreement.

The equilibrium outcomes are similar to the first scenario. In scenario 2a, the final agreed price converge to the midpoint between both parties' reservation values, determined early in the negotiation, as they both tend to follow a more conceding strategy. In scenario 2b, TM will receive all the surplus, but the agreement will occur close to TM's deadline. This is not efficient because both parties could achieve a better payoff if they agreed on the same price through an early agreement. A numerical application is illustrated in Figure 4.7.



(a) Bargaining process for Scenario 2a



(b) Bargaining process for Scenario 2b

Figure 4.7: Possible outcomes in Scenario 2

Scenario 3

In Scenario 3, TM will employ a Boulware strategy, holding out for improved terms as they accumulate more value over time. TM can request their reservation value at DEV's deadline to secure an agreement. DEV, feeling pressured to come to an agreement due to their loss in value, will be compelled to concede more quickly. The final result will see TM obtaining a larger portion of the surplus, as DEV's urgency for a timely agreement outweighs their bargaining power.

The final agreed price will likely be closer to DEV's reservation value, reflecting the imbalance in bargaining power. The agreement is efficient because there is no better pay-off for both parties, but the distribution of surplus will be skewed in favor of TM, reflecting their strategic advantage in this scenario. A numerical application is illustrated in Figure 4.8.

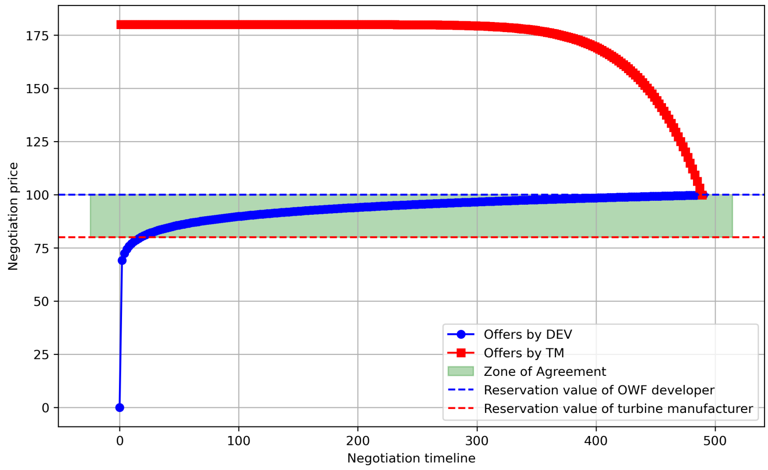


Figure 4.8: A possible outcome in Scenario 3

Scenario 4

In this scenario, TM will adopt a Boulware strategy again, leveraging their increasing utility over time to hold out for better terms. However, TM offers his reservation value this time on his deadline rather than on DEV's deadline. Despite having more flexibility with deadlines, DEV has no information about TM's deadline, which leads him to follow the Conceder strategy to ensure an agreement is reached.

The outcome of the negotiation will heavily favor TM, as they can afford to delay concessions and wait for a more favorable agreement. The final price will be closer to DEV's reservation value, and the surplus distribution will strongly benefit TM. Despite this, the agreement remains Pareto optimal, as no party can improve their payoff without negatively impacting the other party. A numerical application is illustrated in Figure 4.9.

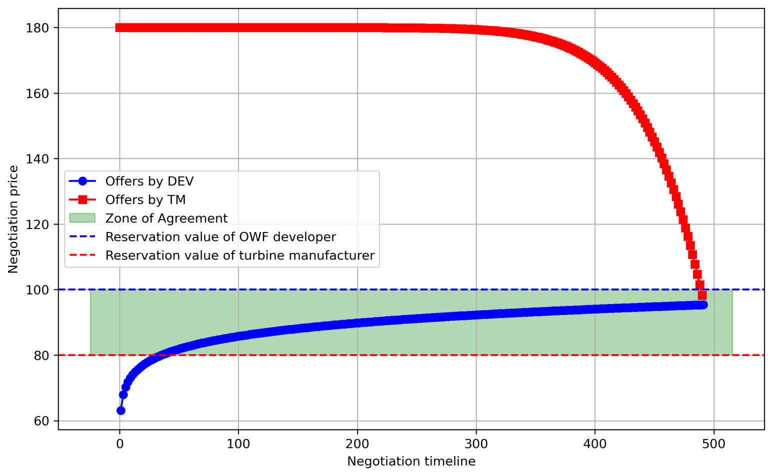


Figure 4.9: A possible outcome in Scenario 4

4.2.7. Discussion

The outcome of the bargaining process are shown in Figure 4.2. Scenarios 1a, 2a, 3, and 4 illustrate different surplus distributions and highlight an efficient equilibrium. Scenarios 1a and 2a show a fair distribution of surpluses, with both parties benefiting from concessionary strategies that lead to earlier agreements. Conversely, scenarios 3 and 4 show imbalances, especially when one party adopts a dominant strategy, such as Boulware, and secures a disproportionate share of the surplus.

Scenarios	Agreed price	Agreed time	Pareto optimal	Fair distribution
1a	$(RV^{\mathrm{DEV}} + RV^{\mathrm{TM}})/2$	T_0	yes	yes
1b	RV^{DEV}	T^{DEV}	no	no
2a	$(RV^{\mathrm{DEV}} + RV^{\mathrm{TM}})/2$	T_0	yes	yes
2b	RV^{DEV}	T^{TM}	no	no
3	RV^{DEV}	T^{DEV}	yes	no
4	RV^{DEV}	T^{TM}	yes	no

Table 4.2: Equilibrium outcomes under different scenarios

Bargaining power and schedule flexibility play a critical role in negotiations. Deadline flexibility confers bargaining power only if the parties have this information, which must be considered alongside the opposing party's time preferences and strategic considerations. Utility dynamics also shape negotiations; parties who gain utility over time can adopt aggressive strategies such as Boulware, significantly influencing outcomes in their favor.

Our model assumes that stakeholders prefer reaching agreements over conflict. In reality, better alternatives and strategic priorities can impact negotiation dynamics. Unlike our deterministic model, real-world negotiations are stochastic and involve multiple issues. Developers often negotiate with various contractors and suppliers on price, schedule, quality, and more. While our model assumes that payments indeed shift when an agreement is reached, actual payments are usually tied to delivery schedules. Despite these assumptions and simplifications, our model offers a valid framework to help stakeholders understand the impact of different negotiation strategies and surplus distributions.

The insights from this model can inform the design of tenders and contracts, emphasizing the need for fair price surplus distribution during supply chain agreements. In current market, developers often submit low-margin bids to win tenders. However, if developers finalize work package contracts at their reservation value after making such tight commitments, unexpected cost increases after the FID could lead to project withdrawals by developers. Our model shows that impatient players tend to receive a smaller share of the surplus when parties have differing levels of patience—due to factors such as waiting for a better deal. Therefore, aligning the patience levels of developers and supply chain partners is crucial to ensure a fair agreement. From a government perspective, there is also a need to accelerate project completion, which requires both parties to be impatient to reach an agreement while minimizing the difference in their patience levels.

To reduce the risk of project withdrawals, the tender process should prioritize more advanced projects. This can be achieved by either awarding extra points to developers with framework agreements with suppliers or making such agreements an eligibility criterion. The latter option is preferable because it prevents suppliers from gaining excessive bargaining power. When developers compete for extra points, suppliers could use this competition to strengthen their negotiating position, making it harder for developers to secure favorable terms. Additionally, given the current supply chain bottlenecks, developers are already motivated to secure early commitments. Requiring framework agreements as an eligibility criterion ensures that turbine manufacturers are actively involved in these projects.

5 Conclusion

The final chapter provides a summary of the research findings in this thesis. Section 5.1 addresses the research questions introduced in Section 1.3. Subsequently, Section 5.2 discusses the main research question and presents some policy recommendations. Furthermore, Section 5.3 examines the societal and academic contributions of this study. Finally, Section 5.4 evaluates the research process and suggests potential areas for future investigations.

5.1. Answering the research questions

This research focuses on the tender systems for offshore wind projects in the North Sea and seeks to identify solutions to coordination problems in the market, particularly by enhancing the interactions between developers and turbine suppliers. The study's main research question is, *"How can tender and supply contract designs be enhanced for a robust offshore wind energy industry in the North Sea, considering costs, benefits, and risks among governments, developers, and turbine manufacturers?"*. The question is addressed by first applying an institutional analysis to identify the critical transactions during the offshore wind development process. It then follows with an in-depth analysis of development phases in two stages: before and after the tender process. The pre-tender award process is investigated for the mature North Sea markets by focusing on tender design elements. The post-tender analysis is illustrated with a stylized bargaining model representing the negotiation dynamics between developers and turbine suppliers. Here are the answers to the four subquestions to address the main research query.

What are critical transactions to be considered for understanding coordination problems in the offshore wind industry?

This question is answered in Chapter 3. The offshore wind industry involves a complex network of stakeholders, including suppliers, contractors, developers, and government agencies, all working together to bring offshore wind projects to fruition. These interactions are governed by contractual frameworks that define the allocation of costs, benefits, and risks associated with each transaction. In the current market environment, certain transactions have gained prominence due to their critical nature: in particular, the interactions between developers and supply chain partners, especially WTG supply packages, are key as they directly impact the levelized cost of energy (LCOE) for projects. Additionally, tender designs that grant developers exclusive rights to develop sites, the determination of grid responsibility between developers and the government, and revenue generation through power sales are key elements that shape the industry's dynamics.

How do governments, developers, and turbine manufacturers manage their costs and benefits in offshore wind energy projects, considering the financial risks?

This subquestion is focused in the last part of Chapter 3 and supported by the interviews conducted. In the current offshore wind energy market, all three key actors—governments, developers, and turbine manufacturers—face significant financial risks due to macroeconomic challenges and market volatility.

Governments face the risk of non-feasible business cases for projects, which can lead to abandonment and undermine the success of their renewable energy initiatives. To manage this risk, they implement stringent tender requirements, including pre-FID investments, bank guarantees, and cancellation fees, to ensure that developers are committed and capable of delivering viable projects. Developers contend with the difficulties of rigid tender formats and volatile market conditions, which complicate financial planning and increase the risk of unsustainable bids. Additionally, the gap between the tender award and project commissioning introduces further uncertainty, as costs and market conditions can change significantly during this period. To manage these risks, developers secure pre-orders and capacity reservations, utilize Power Purchase Agreements (PPAs) for revenue certainty, and distribute risks through agreements with contractors. Meanwhile, turbine manufacturers face rising costs and price pressure due to the demand for larger turbines and uncertain market conditions. They mitigate these risks by negotiating cancellation fees with developers for early work to ensure that their investments in new production capacity are supported by confirmed orders. Collectively, these strategies help mitigate financial risks and support a more stable offshore wind energy sector. However, despite these individual efforts, the industry still requires intervention in tender and contract designs to better address and minimize the costs arising from macroeconomic challenges.

How do current tender and supply contract designs for North Sea offshore wind projects address the allocation of costs, benefits, and financial risks?

After understanding the critical transactions and stakeholder's perspective, this question focuses on how exactly these institutional frameworks are applied in the North Sea market. It forms the core section of the report and is discussed in Chapter 4. It is analyzed in two stages: before and after the tender award. Current tender designs for North Sea offshore wind projects address the allocation of costs, benefits, and financial risks through various mechanisms tailored to the specific contexts of countries like the UK, Germany, the Netherlands, and Denmark. These mechanisms aim to balance financial contributions with climate objectives while maintaining overall market stability.

Typically, the tendered product is the right to use the seabeds, with governments mitigating site risks through detailed pre-investigations and maritime spatial planning. Germany further designates some areas without pre-investigations, allowing developers to make higher financial bids to secure project rights. This approach aims to make money while boosting offshore wind installed capacity. Grid responsibility allocation varies by country: the Netherlands adopts a centralized model for consistency and efficiency, leveraging its TSO's expertise; Denmark opts for a decentralized approach to foster competition and innovation; and the UK and Germany strike a balance between a centralized approach and market-driven solutions.

Assessment criteria for tenders have evolved to include both financial bids and non-price factors, such as sustainability and system integration. Financial bidding mechanisms, such as negative bidding, where developers pay to secure project rights, provide immediate revenue for governments but create pressure on the supply chain partners. The financial commitment from high bids forces developers to negotiate aggressively with suppliers and contractors, which can compromise the quality and reliability of key project components. Suppliers may be pressured to lower prices, potentially affecting the durability and performance of equipment, and this pressure can ripple through the entire supply chain, impacting everything from raw material procurement to project execution. Moreover, the reliability of high financial bids is increasingly questionable. Developers who commit to high payments may face difficulties if market conditions shift, leading to significant fluctuations in project costs. If a developer promises a high fee but encounters unexpected cost increases or market downturns, they may not meet their financial commitments, leading to project abandonment. This volatility makes it challenging to ensure that projects are completed on time and to the required standards. Therefore, while financial components in tender mechanisms provide short-term revenue benefits for governments, they also place substantial cost pressure on the supply chain and introduce risks related to the long-term financial stability of offshore wind projects.

What improvements can be implemented in tender and supply contract designs for a robust offshore wind energy industry in the North Sea?

This subquestion is answered in Chapter 4 by the support of a stylized industry model. The negotiation model analyzes how developers and turbine manufacturers strategize and reach agreements post-tender awards. It evaluates different scenarios based on factors like deadline flexibility and future value considerations to assess equilibrium outcomes and the distribution of price surplus. This analysis discusses improvement areas for the interaction between developers and suppliers to foster efficiency and fairness in offshore wind energy development in the North Sea.

To enhance the offshore wind energy industry in the North Sea, several key improvements to tender designs are necessary. Tenders should incorporate deadline flexibility to allow adjustable project timelines, helping developers avoid penalties for minor delays and maintaining balance in bargaining power. Additionally, addressing unfair price surplus distribution requires aligning the patience levels of developers and suppliers. Disparities in patience often lead to imbalanced outcomes, with more impatient parties receiving less favorable terms.

Encouraging early commitments through framework agreements can help balance these negotiations. Tenders should offer bonuses or additional points to developers who secure framework agreements with key suppliers before bidding, ensuring smoother project execution. Prioritizing advanced projects by rewarding developers with comprehensive plans, including pre-negotiated agreements, helps reduce delays and cancellations. Making framework agreements an eligibility criterion can further ensure that only well-prepared projects are considered.

Governments play a critical role in supporting supply chain availability to address supply chain bottlenecks. They should coordinate with suppliers to ensure that the necessary resources and capacity are available for upcoming projects. Additionally, governments can prioritize advanced-stage projects by implementing tender criteria that favor projects with proven technologies. This approach helps mitigate delays and enhances the overall efficiency of the tendering process. These targeted changes can establish a stronger framework for the entire value chain in North Sea offshore wind projects.

5.2. Reflection and policy recommendations

The analysis presented in this thesis underscores the complexities and challenges of the offshore wind industry, particularly in the North Sea. Through an examination of tender and supply contract design, critical transactions, and stakeholder interactions, this research highlights the need for systemic improvements to create a robust offshore wind sector. The findings emphasize the importance of aligning tender mechanisms with market realities and the negotiation dynamics between developers and suppliers.

One key takeaway from this research is the delicate balance required between the allocation of costs, risks, and benefits between governments, developers, and turbine manufacturers. The evolving nature of offshore wind projects requires flexible and adaptable policies to address new challenges and opportunities. Here are five key recommendations to improve the tender and supply contract designs for a robust offshore wind industry:

1. **Clear linkage between tender roadmaps and decarbonization goals:** Tender roadmaps must be explicitly linked with national decarbonization goals. This connection should be reinforced with specific sub-goals that integrate offshore wind capacity targets with broader electrification objectives for industries. By aligning offshore wind goals with the overall electrification of sectors such as manufacturing and transportation, governments can ensure that their policies not only support renewable energy expansion but also contribute to the comprehensive decarbonization of the economy. This approach provides a clear and structured pathway for investment and development, enhancing the coherence of the transition to a low-carbon economy. Developers also want to see that there will be consistent demand from major energy consumers for the green electricity produced. This assurance allows developers to plan their projects with greater confidence, knowing that there is a secure and stable market for their output at a predictable price.
2. **Aligning the weights of non-price and price criteria across markets:** It is important to understand that countries also compete with each other to attract investors. To ensure fair competition between governments, it is important for countries to collaborate globally on balancing non-price and price criteria in tenders. When a market emphasizes non-price criteria such as sustainability or technological innovation, bidders must invest their resources to meet these requirements, which often results in lower financial bids. This means that while these pioneer markets push for higher non-price standards, they may attract fewer bids or lower financial offers

due to the increased cost burden on bidders. Conversely, markets that use negative bidding—where developers pay for the right to develop projects—allow companies to allocate more funds to financial offers and can leverage innovations from other markets without incurring the full cost of developing those innovations. Meanwhile, countries that focus on negative bidding benefit from advancements made elsewhere without contributing to their development. To address market imbalances and prevent free-riding, countries, especially within the EU, should standardize the weight of non-price and price criteria in tenders, such as an 80/20 balance. While markets can tailor non-price criteria to their specific needs, a consistent overall weighting ensures fair competition and supports the equitable distribution of innovation and investment costs between the governments.

3. **Extending construction timelines and supporting design flexibility:** Rigid tendering requirements and tight timelines place a heavy burden on developers, especially when negotiating with supply chain partners. This pressure is compounded by overlapping global project schedules and the increasing size of wind turbines and foundations. As these components increase in size, the availability of suitable construction vessels decreases, further complicating procurement [25]. To address these challenges, tenders should offer more flexible construction schedules and allow for design flexibility. For example, developers who win a seabed lease tender should be able to make adjustments to their project design and turbine specifications within a defined period of time before construction begins. This flexibility would allow developers to optimize their designs based on current market conditions and technological advances. However, to ensure fairness for those who do not win the tender, the scope of allowed design changes should be clearly defined before bidding. This ensures that losing bidders are not unfairly disadvantaged by extensive design requirements that they cannot recoup, while still allowing winners to adapt their projects in response to market conditions.
4. **Prioritizing advanced-stage projects and balancing incentives:** To increase project success rates and minimize speculative bids, tender systems should prioritize advanced-stage projects by including specific eligibility and evaluation criteria. These criteria can be designed to award commitments from bidders. For example, tenders may contain elements that prioritize bids with memorandums of understanding (MOUs) for PPAs, framework agreements with supply chain partners, or the involvement of supply chain partners as stakeholders in the bidding company. Projects that commits to use the proven technologies should also receive advantages, as this demonstrates reliability and reduces technological risk. Such criteria can be applied either as eligibility requirements or assessment factors, with the choice depending on current market conditions and stakeholder input gathered through market dialogues. However, simply incentivizing bidders may not be sufficient, as it could inadvertently increase the bargaining power of suppliers. As suppliers bring additional value to projects, they also need appropriate incentives to ensure their active participation. Therefore, a balanced approach that addresses both bidder incentives and supplier motivations is necessary to achieve fair and successful project outcomes. To support this, subsidies should be provided to supply chain partners involved in early stage projects. The amount and necessity of these subsidies may vary from tender to tender based on current market conditions.
5. **Shift from financial offers to government participation:** Most current seabed lease bidding mechanisms involve financial bids from developers to secure project rights. While this provides governments with short-term revenue, it increases project costs and financial risks, potentially hindering project realization and disrupting the supply chain. To address these challenges, we recommend that governments shift from requiring upfront financial bids or long-term lease payments to taking an ownership stake in projects. This means that instead of demanding immediate financial contributions, governments would acquire a stake in the project, contribute to the investment, and benefit from the project's revenues over its lifetime. The exact size of the equity stake, the length of time the government holds it, and the ability to sell it at certain points should be determined based on the specific risks and size of the tendered project. For developers, having the government as a stakeholder can increase the attractiveness of the project, make it easier to secure financing, and reduce initial financial risks. For governments, this approach sacrifices immediate capital but allows them to invest in promising projects by partnering with the winning bidder. By taking an equity stake, governments align their interests with the long-term success

of the project. This creates a win-win situation: it supports the completion of the project and allows the government to benefit from the operating revenues generated by the project over time.

In addition to these recommendations, it is important to recognize that some areas of the offshore wind sector are already working well in many markets. Conducting thorough site studies before granting seabed leases helps ensure that projects are based on accurate and reliable data. The one-stop-shop approach to permitting streamlines the approval process. Clear allocation of network responsibility avoids confusion and ensures that all parties understand their roles. Tender roadmaps provide a structured path for project development, and the willingness of stakeholders to engage and listen to feedback creates a collaborative environment. These practices are making a positive contribution to the industry, and continuing to build on these strengths will further enhance the success and growth of the offshore wind sector.

5.3. Research contributions

This research makes substantial contributions to both academic theory and practical applications in the offshore wind sector, addressing key issues from multiple perspectives with validation from AFRY's independent study for the Dutch Ministry of Economic Affairs and Climate Policy.

5.3.1. Academic contribution

This research represents a significant academic contribution by employing a unique interdisciplinary approach that combines institutional economics with game theory to analyze the bargaining dynamics between developers and turbine suppliers. While many studies have explored tender design and dynamics, this thesis stands out by focusing on how various tender designs impact the entire supply chain rather than viewing risks from a singular perspective, such as that of developers. The findings align with established game theory literature, which suggests that more patient actors can secure better outcomes in bargaining situations. By integrating quantitative game-theoretic modeling with institutional analysis, this study offers a holistic view of industry operations and underscores the importance of creating balanced frameworks that accommodate diverse stakeholder needs. This comprehensive perspective not only advances theoretical understanding but also provides practical insights for aligning industry practices with European Union climate objectives and national energy policies.

5.3.2. Practical contribution

This research offers practical contributions to the offshore wind industry, particularly in the areas of tender and supply contract design. It aligns closely with AFRY's independent study for the Dutch government, which underscores the importance of flexible construction timelines, fostering innovation through qualitative criteria, and stimulating electricity demand to keep pace with growing offshore wind capacity [25]. AFRY's recommendations also stress the need to reassess bidding criteria, consider turbine size standardization, reduce site sizes to manage risk, and address labor shortages to avoid project delays. Besides, this research places additional emphasis on equitable risk-sharing among stakeholders.

While AFRY's recommendations focus on structural and technical aspects of the market environment, this thesis explores the intricacies of bargaining between developers and suppliers. It offers comprehensive policy recommendations that advocate for a balanced ecosystem where all stakeholders are incentivized appropriately, and risks are distributed fairly. This approach not only helps attract investment but also supports long-term growth by promoting collaboration and reducing conflict. The thesis thus provides a holistic view of enhancing the resilience and effectiveness of the offshore wind sector.

5.4. Limitations and future work

The study offers valuable insights into tender and supply contract designs within the North Sea offshore wind sector. However, its findings may not be fully applicable to other regions, such as Asia and America. Future research should broaden the scope to include comparative analyses across different global markets. This would deepen our understanding of how regional variations in tender mechanisms impact industry development.

A key challenge of this study was the confidentiality surrounding negotiations between developers and suppliers, which contrasts with the transparency of tender results. This confidentiality limited our ability to fully understand the relationship dynamics that affect tender outcomes.

Additionally, the study used a simplified model to represent the offshore wind industry. In reality, stakeholder interactions are much more complex, involving simultaneous negotiations and detailed contractual arrangements that extend beyond the model's scope. Future research should aim to include both major and minor transactions with various suppliers and contractors to provide a more comprehensive view of industry dynamics.

Another limitation is the integration of non-price criteria and financial components in tender designs. Although these factors are becoming more popular, there is limited empirical data on their long-term effects and the challenges of predicting their impacts, especially the balance between short-term benefits and long-term supply chain consequences. Addressing these limitations will enhance the robustness and applicability of findings in the evolving field of offshore wind energy development.

Furthermore, future research could explore vertical integration within the value chain, such as developer companies building their own vessels or acquiring partners across different work packages. This approach could align the motivations and interests of various stakeholders, as the buying company would own both upstream and downstream entities. By integrating these stages under a single company's control, the complexities of coordinating with multiple independent entities could be reduced, potentially resulting in more streamlined operations and better business cases. While this topic diverges from the primary research question of this study, it presents a new area for investigation, offering valuable insights into how vertical integration can address current industry challenges and enhance project realization.

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A

Appendix

A.1. Non-price criteria on a global scale

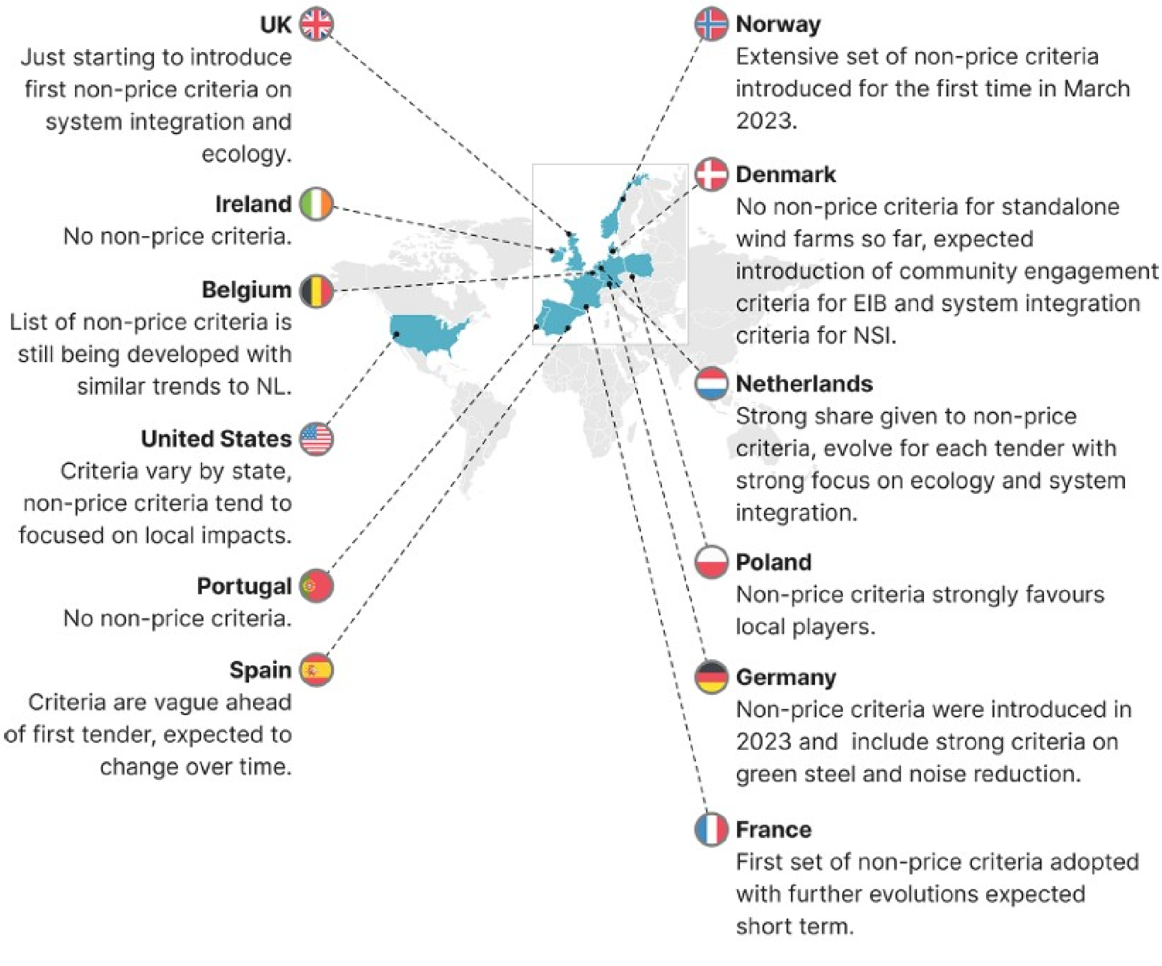

Figure A.1: Non-price considerations in offshore wind tenders on a worldwide scale [23]

A.2. Institutional economics

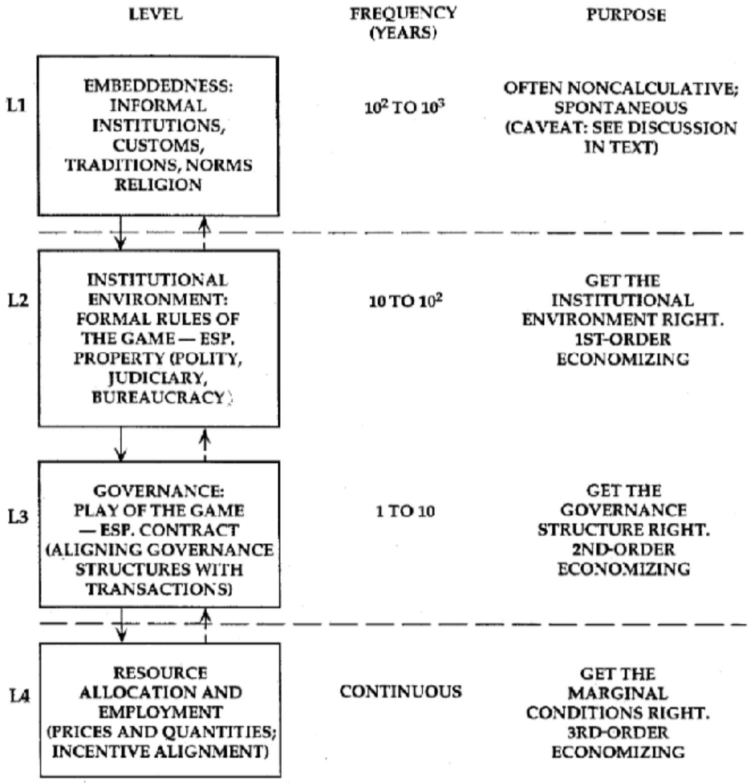

Figure A.2: Four-level scheme of economics of institutions [33]

- **Level 1 (Embeddedness):** These are informal and socially inherited institutions, such as norms, values, customs, or religion. They change very slowly and are not influenced by economic calculations. These include cultural attitudes toward protecting natural resources and the need to address climate change for our case.
- **Level 2 (Institutional environment):** These are formal institutions that set the legal rules, such as the structure of the state, property rights, public organizations, or bureaucracy. For instance, in the Netherlands, national laws, like Wind at the Sea, define the responsibilities of actors in the jurisdiction. Design challenges belong to this level, which is more closely tied to governments and international organizations, extending beyond the companies' decision-making power. Recommendations and potential improvements require a collaborative approach from higher authorities.
- **Level 3 (Governance):** These are the specific arrangements that translate and operationalize the rules of levels 1 and 2, such as contracts, firms, or public bureaus. In our case, contracts should specify the terms and conditions for delivering and installing offshore wind turbines, cables, and foundations. Tender procedure and bids are in this layer as well. Generally, transaction cost economics guides this domain, aiming for efficient governance given imperfect information, opportunistic behavior, and specific investments.
- **Level 4 (Resource allocation and employment):** These are the outcomes of the interactions between the agents and the institutions at levels 1, 2, and 3, such as prices, quantities, incentives, or distribution. These institutions change frequently and reflect the market conditions and institutional performance. In this case, companies will focus on profit maximization in this layer under the domain of neoclassical markets and microeconomics.

A.3. Maritime zones

Under international law, coastal states have sovereignty over the territorial sea (12 nautical miles from the coastline) and special rights over the Exclusive Economic Zone (EEZ) up to 200 nautical miles from the shoreline. Coastal states have exclusive rights to explore and exploit natural resources, including the seabed and subsoil (see Figure A.3). Countries are investing in offshore wind energy projects within their EEZs and continental shelf areas, and coastal states regulate and manage offshore wind development within their maritime zones.

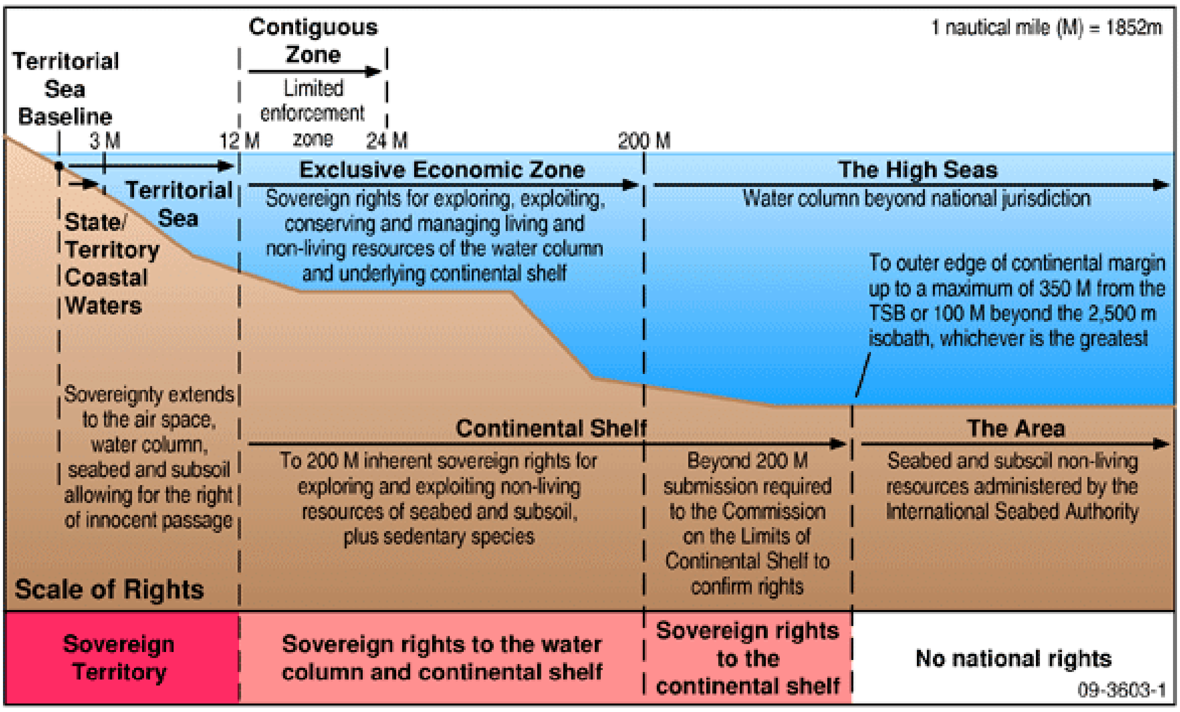

Figure A.3: Maritime zones under the United Nations Convention on the Law of the Sea (UNCLOS) [104]

A.4. Main contracting packages

Table A.1: Main contracting packages during the project execution [72]

Scope of work	Some insights
Wind turbines (TSA and SMA)	Typically, power curve and noise guarantees in turbine supply agreements (TSA) are generally capped at 15% of the contract price to ensure performance standards. In turbine service and maintenance agreements (SMA), an availability guarantee ensures that turbines will remain operational for a specified period of time, which is critical to project success. Contractors provide advance payment, performance, and warranty guarantees. Guarantee amounts can adjust with contract price increases.
Foundation / substructure	Foundations for offshore wind farms are tailored to specific locations, accounting for factors like water depth. The sequence of production, delivery, and installation is pivotal and may require adjustments. Construction permits commonly impose noise restrictions on piling activities for monopile foundations to safeguard marine life. While contractors historically hesitated to guarantee noise levels, advancements in noise reduction technologies are altering this stance.

Table A.1: Main contracting packages during the project execution [72]

Scope of work	Some insights
Inner-array and export cables	Contractors tend to avoid assuming soil risk for cable burial depths, opting for specific laying vessels and tools with reasonable endeavors. If the contractors cannot bury at the specified depth, they may only commit to additional efforts if reimbursed for extra costs and granted extensions in construction time. Crossing agreements are vital for export cables intersecting with other cables or pipelines, delineating design, method statements, liability regimes, insurance coverage, and dispute resolution.
Offshore substations	Offshore substation design and certification delays have historically impeded installation and commissioning. Quality concerns have emerged due to the novelty of offshore substation construction. Uncertainty surrounding applicable and conflicting standards, especially for auxiliary systems like helidecks and telecommunications, has posed significant challenges. However, international standards have been developed and effectively applied in recent years, offering potential solutions to these challenges.
Balance of plant (BoP) contracts	BoP contracts, which include design, procurement, installation, and commissioning, exclude wind turbines. In these contracts, clients have less control but seek security through assigned performance and warranty claims. Defined milestones are critical to penalties for delays, and caps on damages and liability are typically lower than in TSA contracts. BoP contractors argue that despite the lower caps, employers are in a better position than in multi-contract scenarios.

A.5. History and background

A.5.1. The Netherlands

The Netherlands is a leader in the cost-efficient offshore wind market. However, until 2019, there were only a few operational projects in the Dutch North Sea due to high costs, risks, and uncertain permitting processes [75]. The project developers took responsibility for site selection and investigation and navigated the permitting procedure for projects with no promise of approval. Hence, despite the 80 initial applications, only four wind farms were built, and the combined capacity was less than 1 GW [75]. The Energy Agreement for Sustainable Growth was launched in 2013, aiming to increase the share of renewable energy to 14% by 2020 and 16% by 2023 [75]. To achieve this, the Government implemented a more supportive regulatory framework for offshore wind development, which streamlined site selection, permitting, and grid connection. This centralized approach provides favorable conditions for developers with planned zones, pre-selected sites, state-owned grid connections, and streamlining permitting.

A.5.2. Denmark

In 1991, Denmark pioneered offshore wind energy by installing the Vindeby wind farm, featuring 11 turbines at 450 kW each. This milestone led to further developments, including the construction of Horns Rev I and Nysted offshore wind farms, with outputs of 160 MW and 165 MW, respectively [88]. Horns Rev 2, Denmark's first offshore wind tender, occurred in 2005. Every tender is decided upon separately through a political procedure that involves the national parliament. In 2016, nearshore areas were auctioned as part of a multi-site tender [21]. Danish offshore wind tenders are typically single-item auctions with predetermined sizes, but there has been increasing flexibility with additional capacity options in recent years.

A.5.3. Germany

The German government aims to obtain 80% of the nation's electricity from renewable sources by 2030 [105]. In 2020, offshore wind energy made up 6% of the total installed renewable energy capacity, and it is expected to increase to nearly 9% by 2030 [83]. Alpha Ventus, Germany's first offshore wind farm, commenced operations in 2010 [84]. This 60 MW wind farm served as a pilot project to address the planning, permitting, and technical challenges, and it played a key role in initiating the development of offshore wind energy in Germany [83]. Initially, the growth of Germany's offshore wind sector was supported by a fixed feed-in tariff, which was effective at first but later shifted to a market premium model. Developers initially encountered difficulties in identifying and securing suitable sites, similar to the situation in the Netherlands, leading to suboptimal site allocation and investment risks. These challenges led to the introduction of the first Spatial Offshore Grid Plan and the implementation of centralized planning.

A.5.4. The United Kingdom

The United Kingdom leads globally in offshore wind energy, contributing about 20% of the world's offshore wind capacity with 11.3 GW currently in operation [106]. The UK holds the position of having the second-largest installed offshore wind capacity worldwide. The government aims to increase its capacity more than fourfold by 2030, targeting 50 GW, including 5 GW from floating offshore wind projects. The offshore wind journey in the UK commenced in the early 2000s, marked by the commissioning of the North Hoyle offshore wind farm [85]. The UK government has been supporting offshore wind development, recognizing its potential to provide large-scale, renewable energy and reduce carbon emissions. As an independent business, the Crown Estate manages land across the UK, including communities, countryside, coast, and seabed, to benefit the nation.

A.6. Interview notes and questions

A.6.1. OWF developers

OW developers' issues:

1. Cost Increase: Costs have increased sharply over the past two years. This increase has been driven by higher commodity prices, rising labor costs, geopolitical uncertainties, and suppliers seeking higher margins. In addition, rising interest rates have exacerbated the situation and have had a significant impact on the industry. It is also driven by the negotiation position of the suppliers. Due to supply chain bottlenecks, the bargaining position is shifted.
2. Supply chain bottlenecks: Lag in manufacturing capacity. Not only post-pandemic resilience efforts and the push for localization exacerbate these challenges, as building local supply chains is time consuming and costly.
3. Margin Squeeze: Increasing competition among developers is driving down margins, pushing them to bid on small profit margins and risking a deadlock in investment decisions. One side, Bidding requires more sophistication and resources (DEVEX is higher). On the other side is competition sets the level to bid! It is not only about what you spend but it is also about what you want pay to be awarded. So it is also about perceived value of a project. Emerging markets face early saturation with intense competition, risking unsustainable projects and passing challenges down the supply chain, damaging the industry.
4. Developer long term outlook issue: Macro trends such as fluctuating support schemes and unclear policy signals, coupled with supplier profitability issues. If no Cfd then you need very clear policy on electrification.
5. Innovation Challenges: Developers are pushing for bigger turbines by focusing on next-generation turbines to reduce LCOE, creating standardization challenges. Rapidly evolving turbine sizes create bottlenecks and technical risks for developers, especially in floating technology, where the economics are debated.
6. Lack of flexibility: Contractual obligation with government when you bid: this covers big scope, price of project, timing, technical compliance, financial security etc. Set the moment you bid.

Interview questions for OWF developers:

1. Are there any other significant financial challenges for offshore wind (OW) developers not covered above?

2. Which challenge is most critical for your company's profitability?
3. What strategies has your company adopted to address these challenges? (in terms of contracting, bidding , etc.)
4. How can government policies support OW developers in overcoming industry challenges?

A.6.2. Turbine manufacturers

Turbine suppliers' issues:

1. Price Pressure: For years, the industry has fiercely competed for the lowest LCOE. Only industry giants with extensive learning curves and economies of scale can effectively compete in this price battle. The lowest Levelized Cost of Electricity (LCOE) and the race to reach higher megawatt (MW) capacities have led to significantly shorter development cycles for various wind turbine components compared to the turbines' overall operational lifespan.
2. Volatile market environment: Wind farm development involves ordering turbines years in advance, often before they're even produced. This requires predicting future power output and costs, while manufacturers must forecast material costs. It leads to manufacturers either pricing high to hedge risks or risking profit loss to remain competitive. Many wind turbine manufacturers are experiencing losses due to this issue, prompting renegotiation of contracts to minimize losses.
3. Competition from China: Chinese wind turbine manufacturers have rapidly advanced and challenging established Western giants. With heavy investment in R&D and government support (tax incentives and cheap land), China has expanded its production capacity. Their ability to produce cost-effective turbines has led to successful global market entry, putting pressure on Western competitors. China's dominance could reshape the global wind energy landscape.
4. Dependence on government incentives: The rapid growth of the wind industry over the past two decades has been driven by economic and energy policies. Some countries have promoted their wind energy sectors through subsidies, which have boosted turbine manufacturers. But they've faced challenges such as falling prices and intense competition. Fluctuating government incentives have led to cycles of growth and stagnation in investment.

Interview questions for turbine suppliers:

1. Are there any other significant challenges or issues that you believe are important for turbine suppliers in the offshore wind industry that haven't been addressed?
2. Among the challenges discussed, which do you consider the most critical or predominant for your company's profitability?
3. What specific strategies or approaches has your company adopted to tackle these challenges?
4. What role can government policies and incentives play in assisting turbine suppliers in overcoming the challenges they face?

A.7. Offshore wind development roadmap in the Netherlands

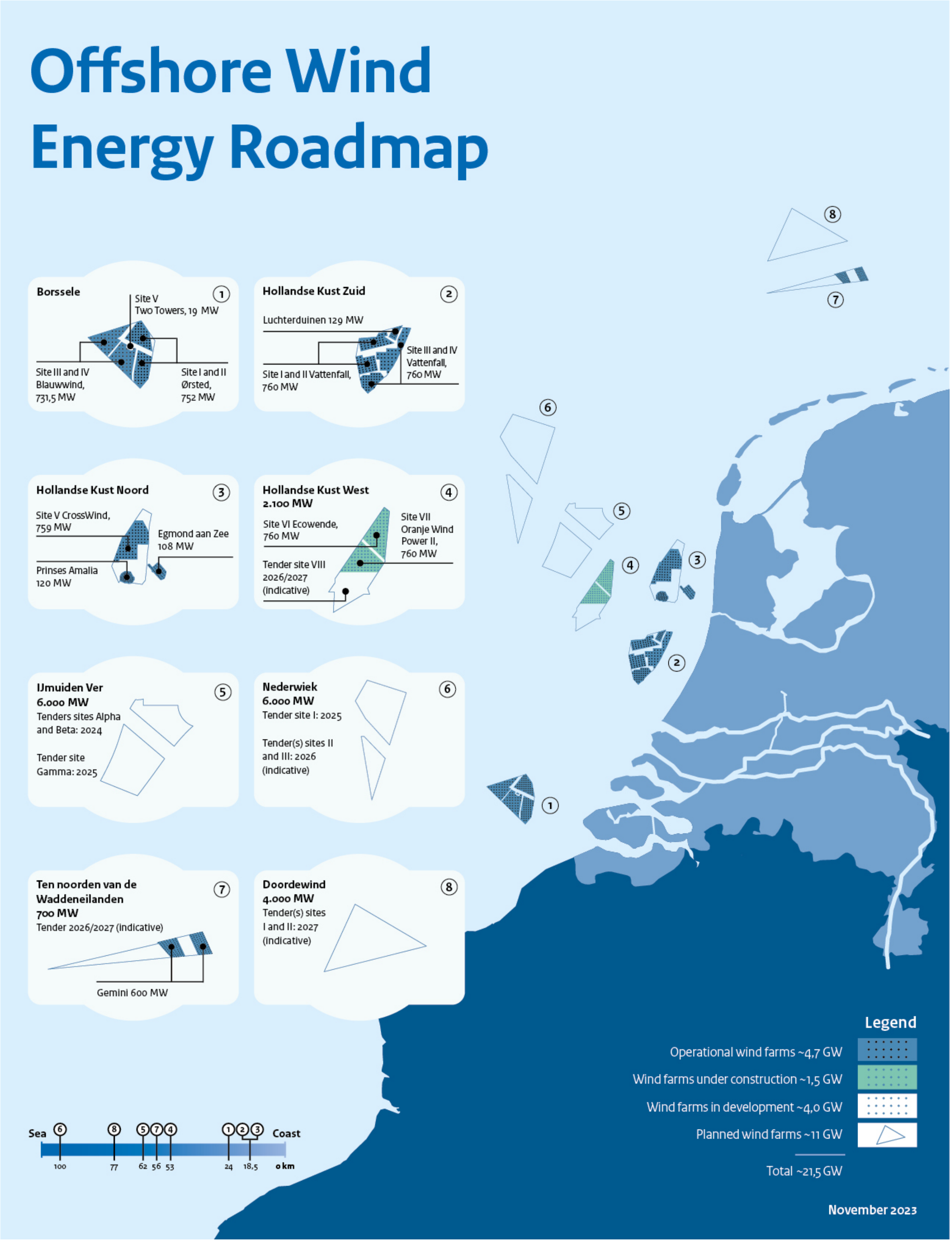

Figure A.4: Roadmap 2030/2031 with the newly designated energy areas in the North Sea 2022-2027 Program (published in November 2023) [107]

A.8. Transmission system operators in Germany

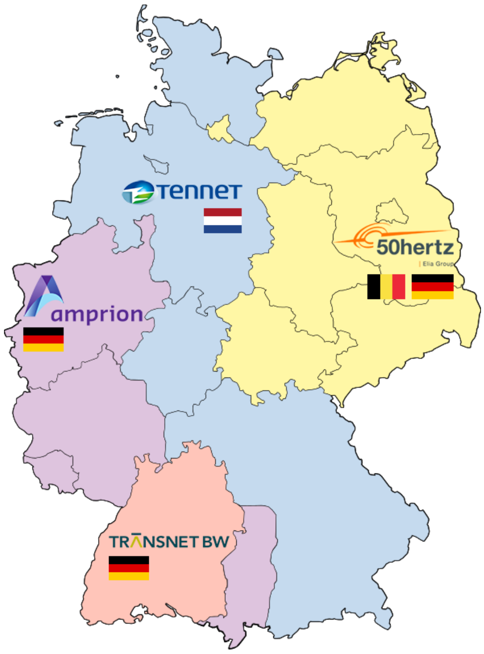

Figure A.5: Transmission system operators in Germany [83]

A.9. Permitting and monitoring

A.9.1. The Netherlands

The Government provides permission to construct, operate, and decommission the wind farm upon being awarded the tender. The permit remains valid for a maximum of 40 years and necessitates the wind farm to be built within four years. After being granted a permit, a wind farm developer must adhere to the plan outlined in their initial proposal. The permit can be modified to allow for changes in technology or cost reduction, such as altering the number or placement of turbines, hub height, or foundation type. However, any changes to the original plan require an exemption from the Minister of Economic Affairs and Climate Policy. Rijkswaterstaat oversees the wind farm planning, construction, and operation. The monitoring activities vary depending on the phase. During the planning phase, they evaluate the work plans of permit holders. In the construction phase, inspections are carried out by the ships and aircraft of the Netherlands Coastguard and the State Supervision of Mines. Rijkswaterstaat monitors wind farm operations, including maintenance. The permit is valid for 40 years, after which the wind farm is decommissioned and removed.

A.9.2. Denmark

The Danish Energy Agency (DEA) plays a vital role in the approval process for offshore wind projects in Denmark. They handle planning, production, and grid connection licenses issued sequentially. Four licenses are required, including preliminary studies, installation of turbines, energy use, and compliance with electricity production. After each permit is issued, appeals procedures are performed for affected individuals and environmental organizations. Thorough strategic planning is essential to minimize appeals. The DEA acts as a one-stop shop, coordinating approvals from various agencies involved in offshore wind development to facilitate efficient processing [88].

A.9.3. Germany

Unlike the Netherlands and Denmark, Germany does not have a one-stop-shop approach. This means several authorities are responsible for different aspects of the process. To build and operate offshore wind farms in Germany, applicants must undergo a rigorous planning assessment process overseen by the Federal Maritime and Hydrographic Agency (BSH). Permit applications are restricted to auction winners and are due within 12 or 24 months [83]. Applicants must demonstrate environmental, transport, and national defense safety, as well as compatibility with existing or planned infrastructure. Pre-developed sites may require less documentation.

A.9.4. The United Kingdom

Offshore wind projects in the UK undergo a rigorous consenting process, particularly under Round 4 developments, where projects are deemed Nationally Significant Infrastructure Projects (NSIPs). This classification is attributed to the sizable scale requirements set forth. NSIPs necessitate a unique form of consent known as a Development Consent Order (DCO), mandated by the Planning Act 2008 [85]. The DCO process involves extensive pre-application consultations, spanning years, to gather stakeholder feedback. The Planning Inspectorate (PINS) reviews applications and offers recommendations to the Secretary of State for Business, Energy and Industrial Strategy (BEIS) for the final decision.

A.10. Strategies and associated outcomes in the negotiation

Scenarios	OWF developer	Turbine manufacturer	Agreed price	Agreed time	Pareto optimal	Fair distribution
1a	Offer RV^{DEV} at T^{DEV}, follow Conceder strategy	Offer RV^{TM} at T^{DEV}, follow Conceder strategy	$\frac{RV^{\text{DEV}}+RV^{\text{TM}}}{2}$	beginning of the negotiation	yes	yes
1b	Offer RV^{DEV} at T^{DEV}, follow Conceder strategy	Offer RV^{TM} at T^{DEV}, follow Boulware strategy	RV^{DEV}	T^{DEV}	no	no
2a	Offer RV^{DEV} at T^{DEV}, follow Conceder strategy	Offer RV^{TM} at T^{TM}, follow Conceder strategy	$\frac{RV^{\text{DEV}}+RV^{\text{TM}}}{2}$	beginning of the negotiation	yes	yes
2b	Offer RV^{DEV} at T^{DEV}, follow Conceder strategy	Offer RV^{TM} at T^{TM}, follow Boulware strategy	RV^{DEV}	T^{TM}	no	no
3	Offer RV^{DEV} at T^{DEV}, follow Conceder strategy	Offer RV^{TM} at T^{DEV}, follow Boulware strategy	RV^{DEV}	T^{DEV}	yes	no
4	Offer RV^{DEV} at T^{DEV}, follow Conceder strategy	Offer RV^{TM} at T^{TM}, follow Boulware strategy	RV^{DEV}	T^{TM}	yes	no

Table A.2: Scenarios and outcomes in the negotiation process