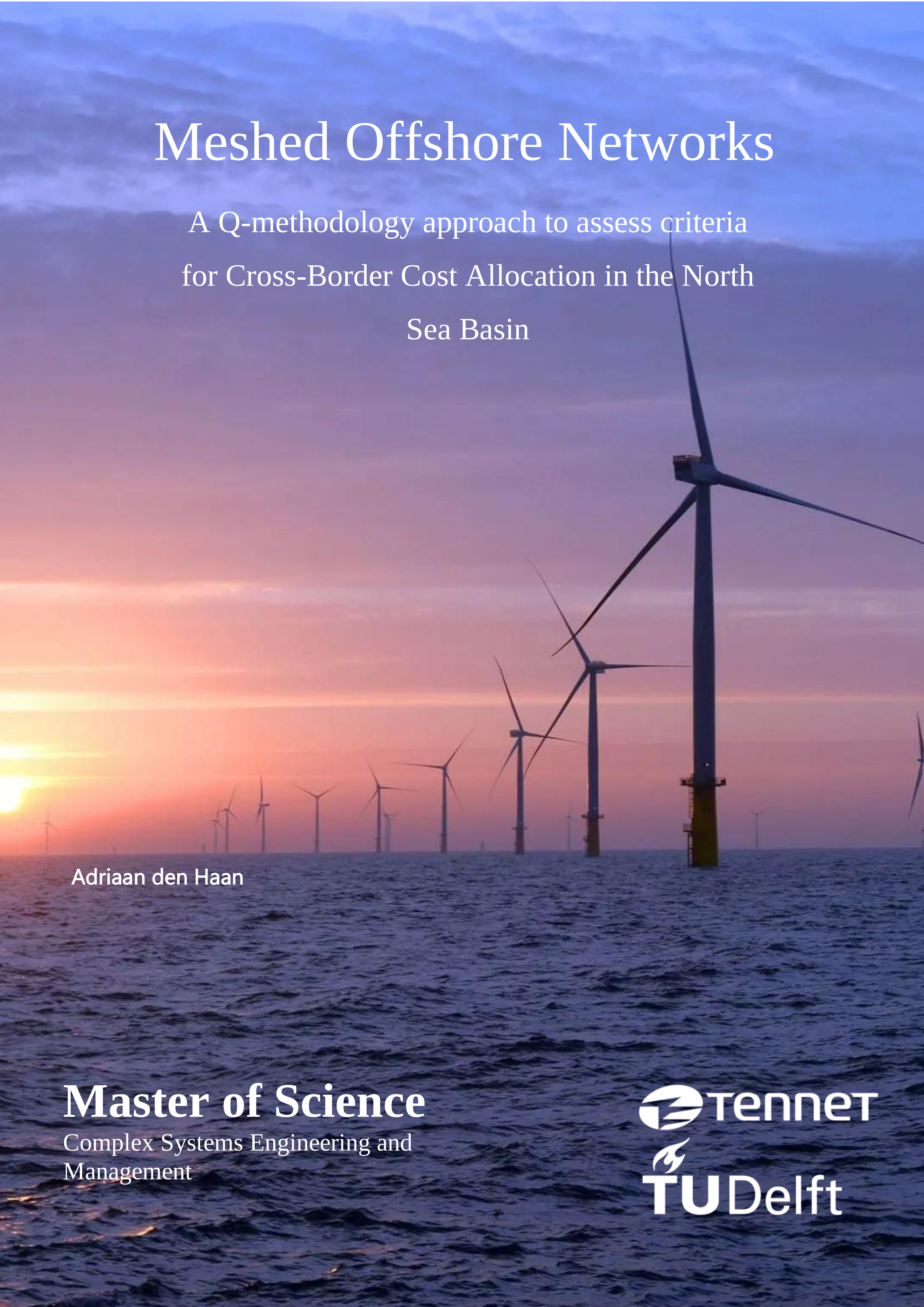

Meshed Offshore Networks

A Q-methodology approach to assess criteria for Cross-Border Cost Allocation in the North Sea Basin

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Preface

"You can't always get what you want…"

This research is the product of months of hard work, marking the final period of my Master Complex Systems Engineering and Management. After one less successful year at the Delft University of Technology, studying Maritime Engineering, and having finished a bachelor's degree in science, Business & Innovation, and a bachelor's degree in law in Amsterdam, returning to Delft for a master's was somewhat tense. Although it did not always go as planned, I am proud to complete my eight years of studying in Delft.

The energy sector has proved to be a challenging but interesting topic for a master's thesis. I am thankful for the opportunity to conduct this research at the Dutch TSO TenneT. They provided me with this most interesting research topic and a great deal of guidance, for which I am truly grateful. To my first supervisor, Mark de Bruijne, thank you for the guidance and feedback throughout the research. I enjoyed the conversations we had, philosophising on the outcome of the research and bringing it to this level. And to Laurens de Vries, for putting me in contact with TenneT and leading to this fascinating research. In addition, to any colleague of TenneT that reads this thesis, thank you for being so cooperative and helping me get to grips with this challenging topic. And for vouching for me to fellow TSO contacts to help me with my research. Especially to my company supervisor Aernout Klokgieters, thank you for your tireless guidance throughout the research. Lastly, thank you to my parents for being so patient and supportive over the past eight years!

Although I cannot disclose it, I take great pride in the list of organisations and individuals that took part in this research. With that, I cannot express my gratitude enough to everyone willing to do so. You know who you are! The energy sector has fascinated me, and even after 11 months of reading and researching, it feels as if I barely understand any of it. Hopefully, the findings of this research make it worthwhile to all those who helped me.

"… but if you try sometimes, you get what you need" – Mick Jagger

Executive Summary

The climate crisis is one of the biggest crises currently facing the world, testing our adaptability and power to change. 195 parties signed the Paris Climate Agreement, committing to decades of change. Due to the electrification of numerous sectors, electricity demand is rising. The European Commission has identified the North Sea as the future "Powerhouse of Europe", providing renewable energy to a large part of Europe. According to this strategy, 60 GW of offshore wind is to be installed in the North Sea by 2030. By 2050, it should be 300 GW. Furthermore, the EU aims to work towards an integrated European electricity system to reduce the isolation of less-favoured regions. This expansion of offshore wind requires enormous expansion in offshore transmission infrastructure to transmit electricity to shore. In this regard, a meshed offshore network has been mentioned as a cost-efficient way forward, connecting offshore wind and interconnecting Member States. However, the costs of a meshed offshore network are enormous, and the benefits exceed the demand of the North Sea countries. Thus, Member States must agree on a certain allocation of costs to realise the targets set.

In this master thesis project, the possibility of allocating costs for a meshed offshore network has been explored. The focus of this research is on a meshed offshore in the North Sea. First, a literature study was executed to establish a sufficient level of background knowledge on the developments in offshore transmission infrastructure and possible means to allocate costs across borders. A Cross-Border Cost Allocation (CBCA) procedure is currently the designated procedure to allocate costs for a project the size and complexity of a meshed offshore network. However, a CBCA has never been applied to any project comparable to a meshed offshore network.

To explore how infrastructural costs of a meshed offshore network in the North Sea can be allocated, a Q methodology approach was adopted. This methodology combines qualitative and quantitative techniques to study subjectivity, perspectives and opinions. Based on input from experts, four key criteria were identified for a CBCA: relevant benefits, allocation keys, political acceptability, and time. Out of these four criteria and the input from experts, 44 statements were compiled. 21 participants from Transmission System Operators, National Regulatory Authorities and ministries sorted the statements on an 11-point scale ranging from "completely disagree" to "completely agree". Following the methodology, four perspectives were extracted from the data using PQMethod. These perspectives were then interpreted and used to get a better understanding of the cost allocation of a meshed offshore network.

The four perspectives resulted in several findings, which revealed a wide consensus: in the 300 GW meshed offshore network scenario, non-hosting Member States must contribute one way or another. However, a CBCA may not be the optimal tool to find a suitable cost allocation for a meshed offshore network due to its complexity and the various points of disagreement found. In short, the research revealed many points of disagreement, indicating that the base of support for a CBCA is insufficient when applied to a meshed offshore network. Whatever cost allocation procedure will be used to allocate the costs of a meshed offshore network, the research shows that the CBA is an important basis for the CBCA, in which benefits provide the best justification for costs allocated to Member States.

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ACER	Agency for the Cooperation of Energy Regulators
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CBCA	Cross-Border Cost Allocation
DSO	Distribution System Operator
EC	European Commission
EENS	Expected Energy Not Supplied
EEZ	Exclusive Economic Zone
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
GDP	Gross Domestic Product
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IPCC	Intergovernmental Panel on Climate Change
MS	Member State (of the EU)
NRA	National Regulatory Authority
NSWPH	North Sea Wind Power Hub
OPEX	Operational Expenditure
OWF	Offshore Wind Farm
PCI	Project of Common Interest
RES	Renewable Energy Sources
SEW	Socio-Economic Welfare
SoS	Systems-of-Systems
TEN-E	Trans-European Energy Networks
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan

1 Introduction

1.1 Rise of Renewables

The energy sector and society have made a substantial transition since the 1990s. Electricity was predominantly generated using fossil fuels, and renewable energy was virtually unheard of. Since then, a lot has changed. Awareness has risen, and Member States have started giving more attention to topics like global warming and the dramatic consequences this has for society. The war in Ukraine led Europe further into an energy crisis, revealing the urgent need for independent sources of electricity. On April 4th, 2022, the IPCC released their latest findings on climate change and global warming, stressing the urgency of reversing the process (Intergovernmental Panel on Climate Change, 2022). The share of renewable energy sources (RES) has increased substantially since 1990 and is continuing to increase over the next years (European Commission, 2021).

This increase in RES is fuelled by technological innovation and the goals that have been set in the past decade. International agreements were signed to work towards a decarbonised economy. The Paris Agreement, which came into force in 2016 and was signed by over 180 countries, was the first global agreement to limit global warming to 1.5 °C (Andrey et al., 2021). Moreover, the European Commission signed the European Green Deal, setting the goal of becoming the first climate-neutral continent by 2050 (European Commission, 2021). As a first step, the 2030 climate target plan set the goal to reduce greenhouse gas by 55% by 2030, compared to the emissions of 1990. With the European Green Deal, there is a lot of work to be done before 2050. The increasing share of RES is one of the main solutions, but more is needed to realise the ambitious goals set by the EC.

1.2 Offshore wind generation

Different methods of renewable electricity generation have been on the rise with the increasing demand for “clean energy”. Offshore wind energy has expanded considerably, especially in the North Sea and Baltic areas. It has become a mature technology that is able to provide electricity at a competitive price and compete with fossil-based power plants. Over the past decade, significant cost reductions have been achieved in the development of offshore wind, which plays a crucial role in its competitiveness (Gorenstein et al., 2018). For the decades to come, the European Commission has identified the North Sea to play a pivotal role in achieving the decarbonisation goals of the economy (Andrey et al., 2021). The North Sea is ideal for installing large amounts of wind capacity because of its location and characteristics. For example, the shallow waters are favourable for the construction of wind farms, and the North Sea wind climate provides high yields. Furthermore, the North Sea is situated close to large ports and energy consumers (Martínez-Gordón et al., 2022).

In 2016, offshore wind energy already became the second largest form of generation capacity in Europe, and for the Netherlands alone, offshore wind capacity is scheduled to reach 70 GW by 2050.

For the entire North Sea basin, this pivotal role entails a target of 300 GW of installed wind capacity by 2050 (European Commission, 2021). Recently, the Dutch Transmission System Operator (TSO) TenneT announced the commission of offshore capacity expansion by 23 billion euros, marking one of the most important infrastructural projects of the century (Gualthérie van Weezel, 2023).

1.3 Towards a meshed offshore network

This expansion of the capacity of offshore wind electricity does, however, bring about several challenges. Until now, Offshore Wind Farms (OWFs) were connected radially. In addition to these radial connections, point-to-point interconnectors were constructed to connect the power systems of different countries. This is illustrated in the left part of Figure 1-1. With the ambitious expansion of the offshore capacity, the use of radial connections is no longer economically viable (Dedecca et al., 2019). This is due to the fact that OWFs will start to move further offshore due to a lack of space close to shore. Consequently, transmission lines will become more expensive. The main challenge in the development of large offshore wind projects lies in transmitting power generated offshore to the onshore electricity grids (Ryndzionek & Sienkiewicz, 2020). A cost-efficient transmission infrastructure will become increasingly important.

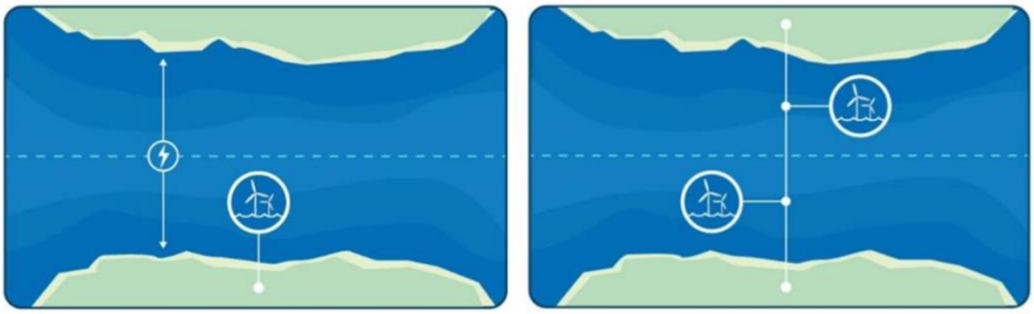

Figure 1-1: Radial connection and interconnector separate versus hybrid project (European Commission, 2021).

The benefits of an increasing share of RES can only be fully exploited if congestion and curtailment are minimised. The intermittent nature of renewable energy causes problems on a regional level, especially if the share of RES increases. By expanding the cross-border transmission capacity, this can be reduced because it allows for balancing of demand and supply at a higher level (ACER, 2023b). However, the transmission capacity has to increase by a factor of 5 by 2050 to facilitate the projected deployment of offshore wind (Andrey et al., 2021). A meshed offshore network is a cross-border infrastructural concept that combines the functions of transmission of offshore wind electricity and interconnection across borders. It has been identified as a cost-efficient way forward for the North Sea because of its socio-economic and environmental benefits, moreover because this region qualifies as an adequate location for the concept (Dedecca et al., 2019). The first step in combining interconnection and transmission of electricity is a hybrid project, illustrated in Figure 1-1 on the right. The development of hybrid projects between two countries is seen as an intermediate step to a full-size meshed offshore network. The Kriegers Flak is the first and only hybrid project to connect the markets of two countries, Germany and Denmark, combined with multiple OWFs (Wu et al., 2019).

1.4 Problem statement & Research question

The Kriegers Flak has proved the concept of an offshore hybrid project. However, there are still a lot of challenges to realise the full-scale multinational meshed offshore network. In this research, the focus will be on identifying the driving criteria for a cost allocation. One of the major challenges is the cost of realising the infrastructure of a meshed offshore network. These costs have been estimated to be in the region of €800 billion (North Sea Wind Power Hub, 2022). To put this in context, the Netherlands' 2023 annual investments for offshore infrastructure was a meagre €2.5 billion (Tennet, 2023). In Denmark, €41 billion will be invested from 2023 to 2026 (Energinet, 2023). In this research, a meshed offshore network is regarded as the complete system that "clusters" OWFs to offshore hubs that connect to each other and subsequently connect to the North Sea countries.

In principle, hosting MSs[*] bear the costs for projects in their respective Exclusive Economic Zone (EEZ) based on the "territorial principle" (ACER, 2020). However, with the projected scale and installed capacity of 300 GW, benefits grossly exceed the borders of hosting MSs. As mentioned, investments will be a multitude of current expenditures. Distributing these exorbitant costs among hosting MSs and neighbouring countries is one of the main barriers to a meshed offshore network (Dedecca et al., 2019). Hosting MSs and neighbouring countries are "sentenced to cooperate", seeing that the costs are too great a burden for the hosting MSs on their own.

Without realisation, the enormous green potential of the North Sea will not be materialised (Energy Community Secretariat, 2015). Herein lies the difference between a regular cross-border infrastructure project and a meshed offshore network. Amongst many other characterising differences, perhaps the most obvious and important is the enormous scale of a meshed offshore network compared to an interconnection or even an offshore hybrid project. Furthermore, it is complex to define the actual costs and benefits because the meshed offshore network will develop over time, bringing uncertainties about costs and benefits. But more importantly, the dimension of these uncertainties is significantly greater compared to conventional cross-border projects (Konstantelos et al., 2017).

Currently, a Cross-Border Cost Allocation (CBCA) process is used for cross-border infrastructural projects that would not materialise otherwise (ENTSO-E, 2016). It is a means for National Regulatory Authorities (NRAs) to determine which countries will contribute to financing a project and in which proportion. Countries can be included in the investment costs of a project when they experience benefits. If a project will not materialise because the default cost allocation results in a net loser, a CBCA is used to allocate costs differently (ACER, 2015). A CBCA has been argued to be the solution for the distribution or allocation of costs for a meshed offshore network (Jansen et al., 2015). Although CBCA decisions have been made in the past, it is not a "one size fits all" solution. As seen in Figure 1-2, CBCA decisions have been made in Europe to realise projects. However, there has not been one CBCA decision that transferred costs to non-hosting MSs in electricity infrastructure projects (ACER, 2020). In that regard, there is no precedent to rely on in finding a CBCA to allocate the costs of a meshed offshore network across hosting and non-hosting

[*] Member States in which the infrastructure will be built are known as hosting MSs, in this case neighbouring the North Sea.

MSs. Although ENTSO-E and the European Union Agency for the Cooperation of Energy Regulators (ACER) have published recommendations to improve the current CBCA framework, they do not make for a guide on how to complete a CBCA, stating it should be simple and fair (ENTSO-E, 2016).

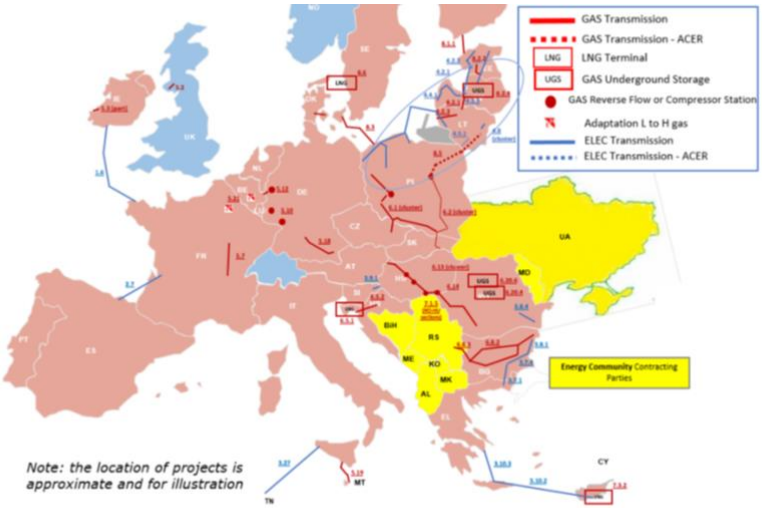

Figure 1-2: Map of projects with CBCA decisions (ACER, 2020).

The scope of this research is to provide insight into the complex dynamics and considerations regarding the cost allocation of a fully meshed offshore network in the North Sea. Because of complications with Brexit, the UK is left out of this research. With hydrogen being a possible alternative energy carrier, a meshed offshore network could become a combination of electricity infrastructure and hydrogen infrastructure (North Sea Wind Power Hub, 2022). However, the costs and benefits of electricity and hydrogen infrastructure are different, and unlike electrically connected OWFs, hydrogen has not yet been applied in OWFs. In this research, the integration of hydrogen in the meshed offshore network is deemed beyond the scope. To assess the criteria important for different countries involved in the cost allocation process, the research question is stated as follows:

How can the costs of a meshed offshore network in the North Sea Basin be allocated?

This research is performed at the Netherlands' TSO TenneT. TenneT is the TSO of the Netherlands and a part of the German transmission system with over 7,400 employees. TenneT is wholly owned by the Dutch State, under the Dutch Ministry of Finance. In relation to this research, TenneT is involved in the conceptual consortium North Sea Wind Power Hub (NSWPH), a collaboration between TenneT, Gasunie and the Danish Energinet to explore and develop the concept of a meshed offshore network.

1.5 Research approach

To answer the research question of section 1.4, a research approach must be formulated. As briefly mentioned, there is no project of comparable size to a meshed offshore network scenario in which costs were allocated across borders. A meshed offshore network represents a type of electrical infrastructure that is unprecedented. Although the sharing of investment in electrical infrastructure across European national borders has existed since the beginning of the European Union, and the theory on this has been well established, these primarily concern smaller-scale projects in which the impact is more transparent and more certain compared to a meshed offshore network. For the latter, costs are significantly higher, and along with the benefits, more uncertain, with multiple Member States potentially involved. It is, therefore, uncertain whether existing knowledge and theory are applicable to a project of distinct properties and a multitude of uncertainties.

Subsequently, academic research on the allocation of costs for a transnational infrastructural project of this sort is limited. There is no theory to be tested or precedent of sufficient similarity to address this research, meaning that this is exploratory research. This merits research that is predominantly qualitative, exploring the interplay between actors in the system and the cost allocation process (Creswell, 2009).

To realise this, the research consists of two main components that combined provide the answer to the research question. First, literature research is performed to get a comprehensive understanding of the different elements involved in a meshed offshore network, the allocation of costs and the system of actors. Second, Q methodology is applied to research the criteria that should be included in the cost allocation. Here, the goal is to explore the elements that should be considered in the process of allocating costs for a meshed offshore network, not to determine a balance of costs and benefits. In sections 1.5.1 and 1.5.2, the main components and the choice for Q methodology are discussed in further detail.

1.5.1 Literature research

Literature research is conducted to get a better understanding of different complex systems in this research. To get a complete overview, different elements must be addressed. In this regard, three main elements can be distinguished in the literature research. The electricity system and its offshore components are the first complex system addressed in the literature research. In general, there has been a lot of academic research on the construction and development of the electricity system. Therefore, Scopus and snowballing techniques through scientific literature can be applied to get an understanding of this system. Furthermore, internal documents are used to get a better understanding of the most recent developments in the electricity system and the concept of a meshed offshore network.

Second, the system of allocating costs for cross-border electricity infrastructure projects in the EU is a complex system. This is partly described in scientific literature but also dictated by EU legislation. Therefore, a combination of scientific literature and grey literature is used to get an understanding of the system of cost allocation. EUR-lex is used to research EU legislation and get an understanding of the governance framework that dictates the procedures in cross-border projects. Furthermore, organisations like the European Union Agency for the Cooperation of Energy Regulators (ACER) and the European Network of Transmission System Operators for Electricity (ENTSO-E) publish monitoring reports and recommendation papers that provide a better understanding of the most recent developments in cost allocation of large infrastructural projects.

Third, there is a system of actors that interacts with the electricity system and the system of cost allocation, a highly political system of actors. Theory on identifying and analysing a multi-actor landscape can be used to get a better understanding of the actors involved in the development of a meshed offshore network and the subsequent allocation of costs. Different techniques can be used depending on the purpose of the evaluation; in this regard, a guideline is used as a first step (Bryson et al., 2011). Following this guide, an evaluation technique is chosen to reveal the field of stakeholders and identify their role in the process of finding the right cost allocation for a meshed offshore network.

1.5.2 Q methodology

Throughout the literature research, three complex systems are discussed: the electricity system, the system that is used to allocate costs for electricity infrastructure projects, and the system of actors that interacts with the other two systems. To explore the perspectives in the system of actors on elements that should be considered in the process of allocating costs, different research methods can be used. For instance, in-depth interviews, surveys, focus groups, Delphi method, or Q methodology can all provide different insights. Conducting interviews can provide insights in a conversational, open-ended manner, whereas surveys allow the researcher to collect structured data from a large number of participants. On the other hand, focus groups and the Delphi method allow the researcher to bring together a small group of experts to engage in the research question and reveal dynamics and shared perspectives. Lastly, Q methodology provides a reproducible study of subjectivity, combining quantitative and qualitative approaches to find different viewpoints among a set of stakeholders (Brown, 1980). Participants are asked to sort a set of statements and elaborate on the choices made. Following the methodology, shared perspectives can be identified from the sorts.

Seeing that this research concerns a highly political subject, participants might not be willing to engage in research that exposes views that can be traced back to their organisation. Because of this, focus groups or Delphi method are less suited as they require participants to speak openly in a panel setting, potentially not providing complete answers. On the other hand, engaging in interviews might prove too open-ended because of the complexity of the research question, whilst a survey leaves very limited room for discussions. Based on these considerations, the Q methodology is chosen as a method that most aligns with the research question and the background of this research. It is a middle ground between most of the methods discussed, allowing for conversation guided by statements, with the possibility of anonymity.

As far as known, no prior research has been conducted in the specific field regarding the realisation of an international infrastructural project of this scale. This makes the research unique, and in that context, it would be valuable to delve deeper than engaging in interviews and discussions with experts. Q methodology enables the researcher to analyse the consistency of answers provided by participants. Furthermore, because the allocation of costs across borders is a politically sensitive topic, participants are not keen on sharing their thoughts openly, as would be the case in other interviewing methodologies. Using the Q methodology, however, anonymity can be offered to participants. Although anonymity can also be provided in Delphi, Q methodology is better suited to understanding the interlinkages and patterns of perspectives, which is why it was chosen in this research (Mukherjee et al., 2018).

1.6 Sub-questions

Sub-questions were formulated from the research question and the subsequent aspects stated earlier. The answers to these questions contribute to the answer to the research question. The sub-questions are formulated as follows:

1. *How are costs for cross-border electricity infrastructure projects allocated?*

2. *What is the European Union's perspective on cross-border electricity infrastructural projects?*

3. *What are the possible criteria for allocating the costs of meshed offshore networks?*

4. *How do the criteria related to a meshed offshore network compare to conventional cross-border infrastructure projects?*

1.7 Research phases

The research is performed in different phases, aiming to answer the sub-questions related to these different phases. The research approach and sub-questions have been formulated in a manner that uses insights from the sub-questions for the next question. Out of the sub-questions, the research is divided into different phases, which are here after discussed.

Phase I

The first step to answering the research question is to get an understanding of the systems mentioned before: the electricity system, the system of cost allocation, and the system of actors. Herein lies the foundation of the research. This phase of the research is characterised by gathering theory and information on all topics. Academic literature and grey literature are used to find answers to the first two sub-questions. The academic literature is used to get an understanding of the characteristics of the electricity system and the theory on transmission tariffs. Grey literature is studied to get an understanding of the European policies and procedures that govern the allocation of costs for cross-border infrastructure projects. Lastly, the theory of multi-actor systems is used to identify and evaluate the actors involved. This phase is discussed in Chapter 2, addressing the first and second sub-questions mentioned in section 1.6. The first two sub-questions provide a better understanding of the cost allocation of cross-border projects of electricity infrastructure.

Phase II

In the second phase of the research, all preparations for the Q methodology are made. Based on the insights from the literature study and input from experts, statements are compiled to be used in the Q methodology. The Q methodology is designed using input from different experts and following a matrix to develop statements. Furthermore, actors identified in the literature study are selected to take part in the research. This phase is discussed in Chapter 3, providing the design of the Q methodology used in this research. In essence, this is what the third sub-question aims to capture.

Phase III

In phase III, the Q methodology is conducted using the set of statements designed in the previous phase. Participants conduct the Q methodology in an online environment guided by the researcher. This provides a unique sorting of statements by every participant, which is, in turn, analysed using Q methodology software. Furthermore, all sorting interviews are recorded and transcribed in this phase. Chapter 3 discusses in detail how the Q methodology was conducted.

Phase IV

The previous phases were used to collect and explore new insights for the allocation of costs in a multinational setting. In this phase, the Q-sorts resulting from the sorting interviews are analysed. Following the methodology, using the program PQMethod, the data is analysed for shared perspectives, which are extracted as “factors”. Every factor resembles a shared perspective and is provided with a generalised sort, showing how participants in a given perspective would sort the set of statements. A full description of the analysis and underlying principles is provided in Chapter 3, and the perspectives are discussed in Chapter 4.

Phase V

In the last phase, the results from the PQMethod analysis are interpreted. Every factor that came out of the analysis is inspected using the generalised sort. Furthermore, the interview transcripts are axially coded using Atlas.ti, so any comment made on any statement can be used to interpret the perspective. A conclusion is formulated on the perspectives, and further recommendations for future research are discussed. This is discussed in Chapter 5 and 6. In these Chapters, the fourth sub-question is addressed, discussing the outcome of the Q methodology and comparing that with conventional cross-border projects.

1.8 Research Flow Diagram

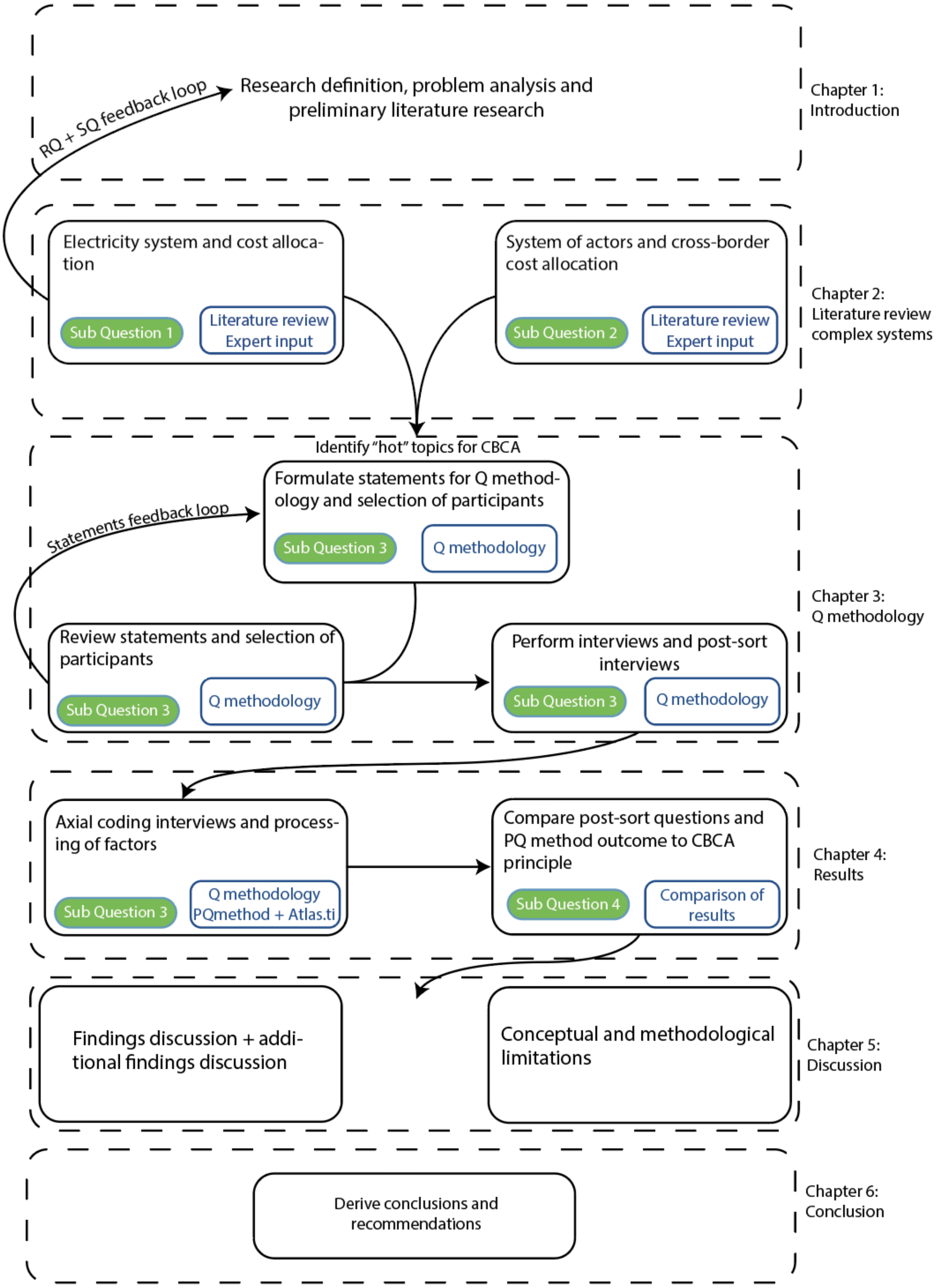

Figure 1-3: Research Flow Diagram.

2 Literature study

To establish the theoretical basis for this research, a literature study was conducted. The literature study is divided into three different sections to cover different aspects of a meshed offshore network that need addressing to find an answer to the research question. In the first section, the electricity system is discussed, outlining the characteristics of the system and the concept of a meshed offshore network. Second, the characteristics of costs and benefits are discussed, together with the European Union's (EU) system to allocate costs for cross-border infrastructure projects. In the third section, the system of actors is evaluated to identify the most important actors involved in this topic.

2.1 Electricity System

In this section, different elements of the electricity system are discussed to get a better understanding of the electricity system and the development of a meshed offshore network. First, the electricity system is described in general. Following this general description, the development of offshore infrastructure and the meshed offshore network are discussed.

2.1.1 Electricity system description

The electricity system is the entire system where electricity supply and demand of electricity meet. This system consists of consumers, generators and the physical grid to transport the electricity from generation towards consumer. The transmission network is separated into different voltage levels to serve different consumers or loads and to minimise transmission losses (Laloux & Rivier, 2013). The electricity that is generated both on land and at sea flows through the high-voltage transmission network and consequently through lower voltage distribution networks to consumers. The distribution network is used to transport electricity to consumers at lower voltages on a regional basis (Gómez, 2013). The transmission network is used to transport electricity over longer distances at high voltages of up to 380 kV (Laloux & Rivier, 2013). The networks are operated by different operators: the transmission system operator (TSO) and the distribution network operator (DSO). Both TSOs and DSOs are responsible for a safe and reliable grid. On top of that, the TSO is responsible for maintaining the balance between demand and supply within a power system (Batlle & Ocaña, 2013).

The energy transition brings several challenges to the current power system. First of all, due to the increasing share of Renewable Energy Supply (RES) and its inherent intermittency, the transmission network is under constant stress. Maintaining physical balance in the transmission network is vital (Rivier et al., 2013). To maintain this balance and serve the electricity market, investments are made for expansion and other forms of improvements to the network. For instance, the development of Offshore Wind Farms (OWFs) necessitates the construction of offshore networks to transport offshore generated electricity to shore. However, the expansion of the transmission network, especially the offshore transmission network, is costly (Bilgili et al., 2011). Second, being incentivised to become more sustainable, the increasing electrical demand of the industry exerts pressure on the TSOs as well. Several industries, like the mobility industry, pursue sustainability by electrification, thereby increasingly relying on the TSOs' efforts to expand the network (Boßmann & Staffell, 2015). To achieve the sustainability goals and roadmaps, it is crucial to facilitate industries in their sustainability developments too (Biancardi et al., 2021).

As was briefly explained in Chapter 1, for the decades to come, the European Commission has identified the North Sea to play a pivotal role in achieving the decarbonisation goals of the European economy (Andrey et al., 2021). This is explained by the fact that the North Sea is ideal mostly because of its favourable wind conditions and shallow waters, allowing for relatively cost-efficient construction of offshore wind generation. Furthermore, the North Sea is situated close to large ports and energy consumers (Martínez-Gordón et al., 2022). In order to unlock this potential, many OWFs have emerged, requiring the traditional transmission system to expand offshore. The offshore transmission network consists of high-voltage alternating current (HVAC) and high-voltage direct current (HVDC) connections, depending on the conditions and geographical location. HVDC connections are used to minimise electrical losses when distances to shore increase. The first OWFs were installed close to shore, in which case an HVAC connection is the better solution (Li et al., 2023). Investments made for the development of these expensive infrastructural improvements must be earned back by the TSO, which poses a dilemma. On the one hand, TSOs must invest to facilitate the expansion and innovation of the electricity sector, and on the other hand, transmission costs have to be controlled (Biancardi et al., 2021).

2.1.2 Offshore Network Development

As mentioned before, offshore wind energy plays a pivotal role in the decarbonisation of the European market. This has resulted in the exponential growth of OWFs over the past decade, especially in the North Sea basin (Global Wind Energy Council, 2023). To facilitate the expansion of offshore wind, the demand for offshore transmission capacity has risen over the past decade and is projected to grow exponentially over the years to come (ENTSO-E, 2021).

Depending on the scale and location of an OWF, the collection and transmission of electricity differs. Since its beginning, most OWFs in the North Sea area were built relatively close to shore, at a range of under 120 km (Bilgili et al., 2011). OWFs built within the range of 120 km have been connected mostly by HVAC connections. The use of HVAC connections has served the development of OWFs well over the past decade, providing a mature solution for transport (Li et al., 2023). The application of HVAC has its technical limitations and is usually applied to smaller-scale OWFs because of the losses incurred with larger capacity and greater distances (Ryndzionek & Sienkiewicz, 2020). With the projected growth of offshore wind and shared use between Member States (MSs), OWFs are moving farther out to sea (Liang & Feng, 2015).

For OWFs installed beyond the 120 km range, the use of HVAC becomes uneconomical. At this point, the benefits of HVDC over HVAC outweigh the costs. For example, the cable weight per unit length is lower, allowing for the transport of longer sections, fewer cable joints and reduced installation time (Maciver et al., 2016). The components of a HVDC connected OWF are shown in Figure 2-1. Electricity is collected from the turbines at an offshore hub to be converted to DC. From this hub, electricity is transmitted to shore. The onshore converter station converts DC electricity back to AC, then feeds the electricity into the high voltage onshore transmission network.

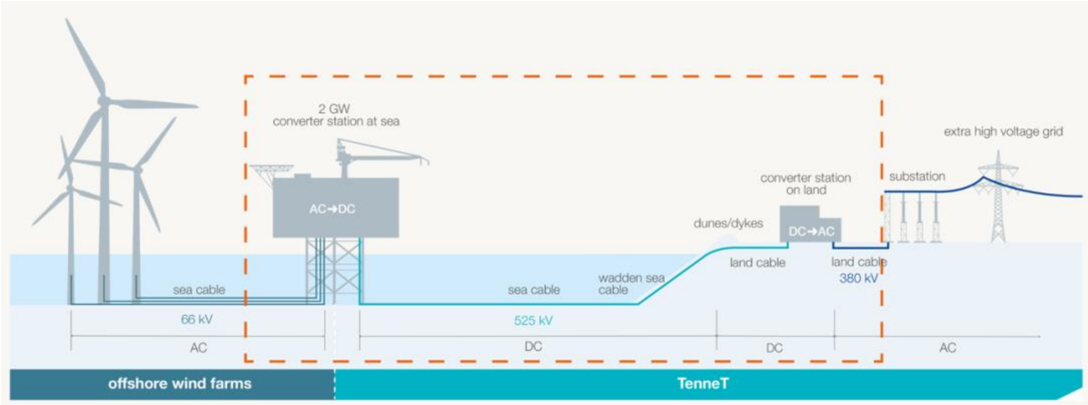

Figure 2-1: Components of an OWF with HVDC connection to shore (TenneT, 2023b).

2.1.3 Meshed offshore network

The scale of OWF projects has increased over the past years, with 2 GW converter stations to be built in the years to come in the North Sea (TenneT, 2023a). Seeing that numerous 2 GW projects will be realised to reach a total installed capacity of 72 GW in 2050 for the Netherlands alone, a big shift is expected in the transmission network to accommodate the flow of electricity (European Commission, 2021). In this regard, the expansion of cross-border electricity trade is seen as one of the primary solutions to improve the flexibility of the transmission network that is needed as the offshore wind industry continues to expand (Maciver et al., 2016). This is envisioned for 2050 as a meshed offshore network that connects multiple platforms and MSs in the North Sea basin (North Sea Wind Power Hub Consortium, 2020).

The realisation of a meshed offshore network does not happen at once but will gradually start to form over the next decades. Because of the intermittent nature of RES, the need for a more flexible system increases. Curtailment for situations in which there is more wind production than demand or available transmission capacity already occurs in today's offshore wind generation, compromising the profitability of offshore wind (TNO, 2022). To accommodate flexibility in the grid, it is therefore vital to expand the cross-border interconnection capacity (North Sea Wind Power Hub Consortium, 2020). The combination of offshore wind grid connection and cross-border interconnection capacity, known as hybrid projects, is seen as a necessary intermediate step to do so as ENTSO-E expects offshore infrastructure to evolve gradually (ENTSO-E, 2020). Ultimately, the formation of a meshed offshore network follows by connecting multiple member states in this manner (Navigant, 2020). ENTSO-E's vision of the road towards meshed offshore networks is shown in Figure 2-2, from the current system of separate interconnectors and radially connected OWFs on the left to a meshed offshore network in the future on the right.

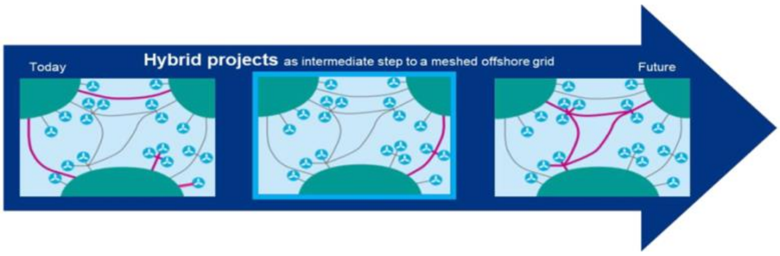

Figure 2-2: Towards a meshed offshore network (ENTSO-E, 2020).

A meshed offshore network has many advantages compared to conventional radial connections. Significant savings can be realised over the project lifetime, ranging from 5-10% of total project costs, depending on the scale (Roland Berger, 2019). This is mostly because of the cost-effectiveness of meshed offshore networks, as the use of cables combines the integration of offshore wind and the facilitation of cross-border electricity trades. Thanks to the connection and feed-in options to multiple countries, a meshed offshore network leads to less curtailment of the connected OWF compared to a radial connection. This, in turn, contributes to the profitability of an OWF and less CO_2-emitting generation being dispatched. So, the additional interconnection capacity relates to increased socio-economic welfare, reduced CO_2 emissions and security of supply (Roland Berger, 2019). Given these advantages and the North Sea's characteristics, a meshed offshore network is advocated as a solution to accommodate the projected growth of offshore wind energy in the North Sea in the decades to come (Andrey et al., 2021).

However, it should be noted that the large-scale deployment of offshore renewables has a major impact on the onshore transmission network as well. In the case of the North Sea, one of the challenges will be to land and distribute 300 GW to shore. Specifically, congestion in the onshore transmission network can limit the large-scale deployment of offshore wind after 2030 (Andrey et al., 2021). The onshore grid expansions necessary to be able to push 300 GW of electricity into the European grid are, therefore, inherent to the offshore expansion of RES. The costs of a meshed offshore network are intertwined with onshore costs and, therefore, difficult to determine. In that regard, further alignment of offshore and onshore grid planning processes is needed. However, including onshore grid expansions in the CBCA of a meshed offshore network would further complicate a CBCA that is unprecedented in terms of scale and reach in the first place. Whether onshore grid expansion should be included in the cost allocation of a meshed offshore network is unknown. As illustrated in Figure 2-3, a large onshore and offshore grid expansion is planned for the connection of a meshed offshore network and the subsequent 300 GW of offshore RES. Although the Figure only shows Dutch and German connections, it gives an impression of the overall grid expansion that is to be realised.

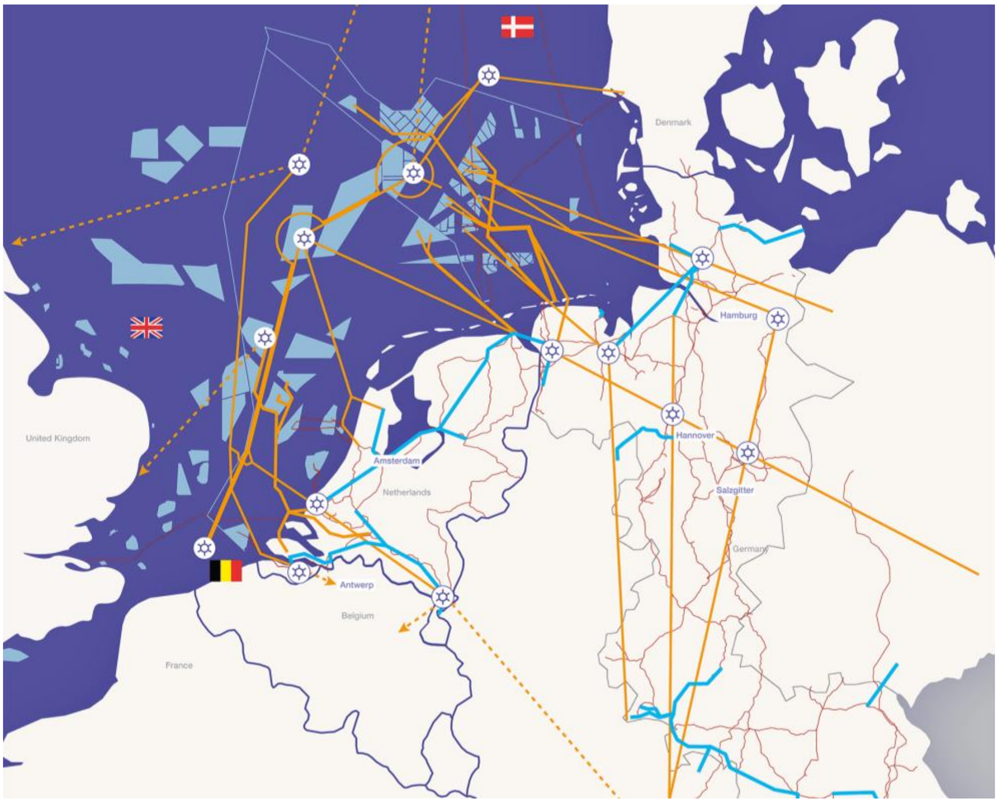

Figure 2-3: Expansion of offshore and onshore network with upgrades in blue and planned DC expansion in orange (Target Grid, 2023).

2.2 Cost allocation system

Since 2011, the EU has determined its strategy to expand and modernise the electricity network across borders towards an integrated system. This is incorporated in Regulation (EU) 347/2013, also known as the Trans-European Energy Networks (TEN-E) Regulation. Following the development of increased cross-border trade and the subsequent development of a meshed offshore network, the development of offshore electricity infrastructure becomes a multilateral effort. Subsequently, costs can be allocated across borders to the MSs involved.

To get a better understanding of the domain of infrastructural investments and the distribution of those investment costs, this section looks into the following topics. The system of cost allocation across borders, benefit indicators and project costs are discussed in the first sub-sections. Then, the transmission tariff system is discussed to get a better understanding of how costs are recovered by a TSO. Lastly, the European system of allocating costs for cross-border projects is discussed.

2.2.1 Benefits

Having established the advantages of developing a meshed offshore network, a project has to be net beneficial. The CBCA relies on the investment assessment of costs and benefits considered in the Cost-Benefit Analysis (CBA) that precedes the CBCA. To distinguish and determine benefiting parties, the EU has mandated ENTSO-E to establish a guideline for CBAs. It is the only European guideline that allows the assessment of transmission and storage projects across Europe and represents the main input for the European Commission's (EC's) list of Projects of Common Interest, which is discussed in section 2.2.2. The guideline includes nine benefit indicators that can be used to determine to what degree a MS benefits (ENTSO-E, 2022). It should be noted that there is overlap between different benefit indicators.

Socio-economic welfare (SEW) is seen as one of the benefit indicators of relevance for the CBA. SEW comprises the sum of short-run economic surpluses of electricity consumers, producers and transmission owners, thereby reflecting the contribution to increasing transmission capacity. Because of this, SEW is a benefit indicator that allows for a direct link to the economic value gained by parties. However, it does not reflect the total economic benefit provided by transmission investments, which are described by the other benefit indicators.

Additional societal benefit due to CO_2 variation is used to indicate the change in CO_2 emissions related to a project. It is based on the societal costs of CO_2, representing the contribution of a project to reducing the main greenhouse gas produced by the electricity sector. According to ENTSO-E, this indicator is divided into two parts: pure CO_2 emissions and its monetisation. It is, however, difficult to assign the contribution to climate change on a regionalised basis, even though the CO_2 variation can be calculated per MS.

RES integration benefit refers to the additional ability of the system to connect RES as a result of a project or investment. As mentioned before, curtailment of RES generation already occurs nowadays. The RES integration indicator measures the reduction of curtailment in MW or MWh (avoided spillage) as a result of a given project.

Non-direct greenhouse emissions benefit reflects the non-CO_2 emission variations in the power system as a result of a given project. Like the CO_2 variation benefit, the non-direct greenhouse emissions are calculated based on their impact on climate change in tons per year; the indicator is not monetised.

Variation in Grid losses benefit refers to the beneficial changes in transmission system losses that can be attributed to a project. More specifically, projects can contribute to the energy efficiency of the transmission system because of load-flow pattern improvements and constant power-flow levels that reduce thermal losses in the grid. However, increasing transmission over long distances can also lead to increasing grid losses. In the case of a meshed offshore network, the assessment of this particular indicator should, therefore, include both hosting MSs and neighbouring countries to cover all countries that can have a significant impact on the cross-border capacity. Based on the high costs of grid losses, this can be attributed on a regional basis. Seeing that grid losses require an increase in generation and, therefore, CO_2 emissions, it could also be used at the EU level.

Adequacy to meet demand benefit reflects the power system's ability to provide an adequate supply of electricity at any time of day. Especially with geo-temporal fluctuations in intermittent RES, a meshed offshore network can make a difference because it provides access to a more diverse array of RES. Thereby, countries could provide power to one country temporarily facing adequacy risks. This benefit can be regionalised by looking at the decreased need for (peak) generation capacity and decreased Expected Energy Not Supplied (EENS) volumes per MS.

System flexibility benefit captures the system's ability to balance energy needs in terms of non-dispatchable electricity generation. By connecting across larger geographical areas, the system's ability to "absorb" fluctuations increases and "the variability of RES effectively decreases and its predictability increases". Especially in the case of a meshed offshore network, the adequacy and flexibility benefit indicators resemble the added value over conventional interconnection projects. However, it remains difficult to accurately calculate the socio-economic welfare to be expected from these benefits.

System stability benefit is included to measure the change in system stability as a result of a given project. This indicator consists of four sub-indicators, all contributing to the overall system stability: qualitative stability, frequency stability, blackstart services and voltage power services. This indicator is measured in qualitative measures and is, by default, not monetised.

Reduction of Necessary reserves for redispatch power plants is the ninth benefit indicator, which aims to describe the impact of a project on the required levels of contracted redispatch reserve power plants necessary in the system. It is assessed by comparing the maximum power of redispatch with and without the project in concern.

The guideline covers most relevant and substantial benefits related to, amongst others, Projects of Common Interest like a meshed offshore network (ENTSO-E, 2022). However, the benefits that result from cross-border infrastructure are highly uncertain (Puka & Szulecki, 2014). Although benefits can be calculated to a certain degree, due to the unique characteristics of electricity transport, it is difficult to determine how the benefits will be distributed. It is, therefore, difficult to determine beneficiaries to a specific degree. This is discussed further in section 2.3.1. Furthermore, MSs might have different interests in the benefits resulting from a meshed offshore network. In Norway, for example, security of supply might be prioritised over RES integration benefits because Norway has a large share of hydropower. If severe weather causes a dam to collapse, foreign capacity is vital to keep the system running. At the same time, the Netherlands or Belgium might be more interested in the societal benefit due to CO_2 variation to achieve climate goals. Seeing that the CBA precedes the CBCA procedure, it might be interesting to explore the underlying interests for certain benefits between MSs.

2.2.2 Project Costs

The infrastructural costs regarding a meshed offshore network are described by two indicators in ENTSO-E's guideline. Capital Expenditure (CAPEX) resembles all investments necessary to realise a project. This includes costs of obtaining permits, conducting feasibility studies, ground, designing, installation, etc. (ENTSO-E, 2022). Once a project has been realised, annual operating and maintenance expenses associated with the project or investment are described in the Operating Expenditure (OPEX). While there are also uncertainties in cost estimations, they are second order compared to the uncertainties afflicting the estimation of benefits of cross-border projects (Puka & Szulecki, 2014).

2.2.3 Transmission tariffs

Transmission tariffs are levied on the users of the transmission network to recover costs. By getting an understanding of the theory behind transmission tariffs, an understanding of the impact and limitations of costs for offshore infrastructure is formed. As illustrated in Figure 2-4, a TSO levies charges for the use of the network, for connection and for individual services. With its network charges, a TSO has to cover a variety of costs like transmission losses and maintenance. More importantly, building and upgrading expenses of transmission infrastructure are also covered through network charges.

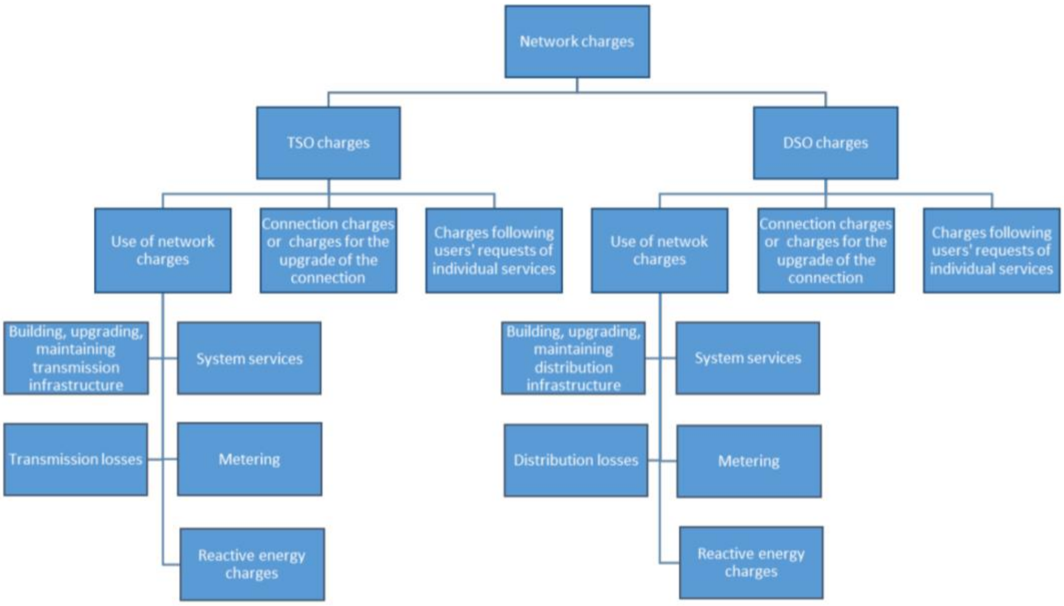

Figure 2-4: Segmentation of network charges (ACER, 2023a).

Electricity transmission services are, however, characterized by a number of peculiarities that affect the appropriate type of regulation. The peculiarities include very distinct timing issues, a superiority of monopoly supply and vertical economies with generation and load-serving entities (LSEs) (Vogelsang, 2001). Furthermore, differences in short-term and long-term pricing make for a complicated task. The lack of storability and transmission capacity constraints require the right pricing to prevent congestion in the short term. On the other hand, prices have to drive operating and investment decisions by TSOs and generators (Vogelsang & Boston University, 2005). A trade-off must be made between different time horizons. Besides these factors, the costs of electricity transport are characterised by high fixed costs and low variable costs. In essence, this means that the investments, maintenance and operational costs have to be distributed amongst the users without too many complications (Hakvoort et al., 2013).

In practice, setting the right tariff has proven to be more complex. Electricity follows the route of least resistance. This is also known to cause loop flow problems (Vogelsang & Boston University, 2005). Because electricity flow is not fully controllable, specific network flows and the subsequent costs and benefits from the network cannot be fully assigned to beneficiaries. Even in hindsight, determining power flows is complex (Puka & Szulecki, 2014). Besides the aforementioned peculiarities, transmission tariffs have to comply with EU regulations. The most important goal of transmission tariffs is the fair and equitable allocation of costs and to promote efficient use on a "user pays" basis (Hakvoort et al., 2013). The transmission tariffs are dictated by the EU in directive 2019/944. In Article 59(1)(a) of Directive (EU) 2019/944, the EU has laid down the responsibility of fixing or approving the network tariffs with the NRAs. Following the directive, the NRA assesses whether the tariffs have been set in a cost-reflective, transparent and non-discriminatory way. However, this can be obtained in different ways as long as the core values are adhered to. This means that charges applied by network operators for access to networks, including charges for connection to the networks, charges for use of networks, and, where applicable, charges for related network reinforcements, shall be cost-reflective, transparent, take into account the need for network security and flexibility and reflect actual costs incurred insofar as they correspond to those of efficient and structurally comparable prices.

ACER has identified three approaches to cost models to determine the network tariffs (ACER, 2023a). These models are based on average costs, incremental costs and forward-looking costs. The average cost model, which is used most often, divides the target revenues by the projected electricity quantities. If projections are accurate, the average cost model thereby ensures full recovery (ACER, 2023a). The incremental and forward-looking cost model, on the other hand, estimate additional costs due to increasing cost drivers based on historical data and a simulation model, respectively. The Netherlands, Germany and Denmark use the average cost model, whereas Norway uses the incremental cost model. Besides the cost models, some costs of a voltage level are allocated towards users connected at a lower voltage level, also known as cost cascading. This either occurs from transmission to distribution or from transmission to transmission. In Europe, at least 89% of transmission costs are cascaded to the distribution level (ACER, 2023a). This shows that investments earned back through tariffs are ultimately paid by consumers.

The target revenues are determined by the total network costs, which consist of three categories: network cost of the current infrastructure, future network investments and incentive factors to invest efficiently in the network (Hakvoort et al., 2013). Hence, the large-scale investments needed for meshed offshore networks will have a big impact on the tariffs. That also means that in the final CBCA decision, consumers pay. This underlines the importance of a just allocation of costs, but also the politically sensitive aspect of a CBCA decision that exceeds hosting MSs. In a way, sovereign states are in this case forced to explicitly pay for infrastructure beyond their borders. Although investments can be incorporated in transmission tariffs, TSOs are bound to set cost-efficient tariffs, deterring them from undertaking projects in the absence of sufficient incentives (Poudineh et al., 2017). Transmission tariffs can only provide for a small part of the investments involved with a meshed offshore network, and the tariffs are lagging the expenditures of TSOs. Especially for investments of this order of magnitude, this is a problem because it requires TSOs to finance the project (Biancardi et al., 2021).

2.2.4 Projects of Common Interest

Before discussing CBCA, it is important to get an understanding of Projects of Common Interest (PCIs). As mentioned, TSOs are constantly improving and expanding their transmission networks. Their investment plans are integrated into the Ten-Year Network Development Plan (TYNDP), a European-wide vision of the future power system. Given the investments required to execute the EU's strategy, the TEN-E regulation defined categories of projects that can obtain the PCI status (Schittekatte et al., 2020). The EU has set criteria to determine whether a project is to be qualified as a PCI in Article 4 of Regulation (EU) 347/2013. Some of the key features that a PCI must include are:

1. Cross-Border nature: Projects that provide interconnections between the networks of a minimum of two MSs and have an impact across borders.
2. EU energy policy targets: Projects contribute to the overall EU energy strategy, such as competition, sustainability, and security of supply.
3. Overall benefit: Projects deliver overall benefits that outweigh their costs, including in the longer term.
4. Infrastructure types: PCIs can include a variety of energy infrastructure projects, including electricity transmission lines, gas pipelines, and smart grids. These projects are essential for attaining the EU's energy and climate objectives.

To obtain the PCI status, ENTSO-E, with supervision by ACER, has designed a methodology that must be followed to conduct a CBA. Based on the CBA, the PCI status is determined. Obtaining the PCI status is interesting as it provides accelerated permitting procedures, financial incentives from NRAs and access to the Connecting Europe Facility (CEF) fund, a fund that is only applicable to PCIs (Meeus & Schittekatte, 2020).

2.2.5 CBCA

Besides the advantages of the PCI status mentioned in the previous section, PCI status grants access to the CBCA procedure. The TEN-E regulation introduced the CBCA as a regulatory tool to facilitate the implementation of PCIs. In cross-border projects, asymmetric distribution of costs and benefits can become a barrier to realising the project. To overcome this barrier, net losers must be compensated. Beyond bilateral or multilateral case-by-case agreements, CBCA is regarded as a promising option for cost-sharing in a meshed offshore network (Jansen et al., 2015).

Following Article 16 of the TEN-E Regulation (EU) 2022/869, investments with a cross-border impact can be divided between MSs with a net positive impact. Specifically, investment costs of PCIs that fall under the energy infrastructure category shall be borne by MSs to which the project provides a net positive impact. When a project becomes sufficiently mature, a consultation of all TSOs that have a significant net positive impact is held. Following the consultation, project promotors are required to submit an investment request to relevant NRAs, including a CBCA request. The request includes a project-specific CBA, a business plan evaluating the financial viability and a CBCA proposal. From then on, the relevant NRAs become active, assessing the CBCA and seeking mutual agreement on the allocation of costs amongst the system operators. If they fail to do so within six months of the investment request, NRAs must inform ACER. In that case, the CBCA decision is taken by the agency within three months.

In its most recent monitoring report on CBCA, ACER provides an overview of the CBCA decisions made in the period from 2014 to June 2020, a total of 43 decisions (ACER, 2020). As seen in Figure 2-4, 17 CBCA decisions were adopted in the electricity sector and 26 in the gas sector.

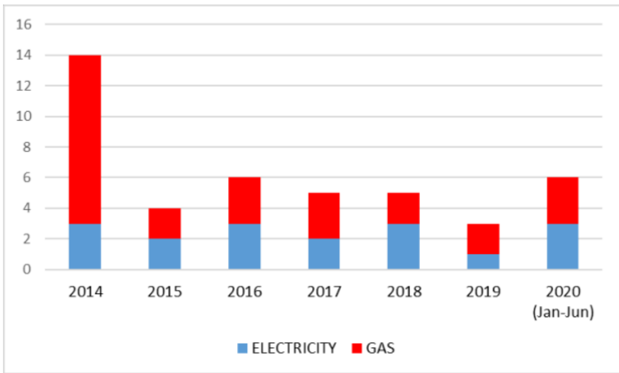

Figure 2-5: ACER monitoring overview of CBCA decisions taken since 2014.

However, this is a collection of all CBCA decisions. Only 40% of the CBCA decisions are for interconnectors; in electricity, a mere 9 out of 17 CBCA decisions concerns an interconnection project. The rest of the CBCA decisions concern internal projects. For electricity interconnections, the average investment cost is €670 million per CBCA decision. In total, all CBCA decisions combined amount to approximately €16.5 billion, still only a fraction of the investment costs of a meshed offshore network. Furthermore, since the adoption of PCIs in 2013, only 2 out of 43 CBCA decisions were made by ACER because of disagreements between NRAs. But even more important, there has never been an electricity project where costs were allocated beyond hosting MSs (ACER, 2020). The gas interconnection between Poland and Lithuania (GIPL) is the only interconnection project where costs were allocated beyond hosting MSs. Collectively, non-hosting MSs were called upon to contribute €130 million, which accounted for less than 1% of the overall investment costs for all projects. To conclude, there is no precedent for the cost allocation of a meshed offshore network. Not in terms of the financial scale, number of NRAs involved, and certainly not in terms of allocation beyond hosting MSs.

2.2.6 Cost-sharing methodology

Initially, MSs would agree on cross-border investments, assuming that each MS would pay for the assets in their territory (Schittekatte et al., 2020). This is also known as the "territorial principle". Together with the "50/50 cost allocation", the territorial principle is the traditional principle for allocating costs. According to ACER's most recent monitoring report, traditional principles were followed to allocate costs in over 70% of all CBCA decisions made so far (ACER, 2020). However, in the case of a meshed offshore network and the projected 300 GW of offshore capacity, the scale transcends the interest of North Sea countries. Under those circumstances, it is probable that non-hosting MSs will be required to contribute. In that case, by definition, the territorial principle is inadequate.

With the involvement of multiple MSs in a meshed offshore network scenario, it is likely that the cost-sharing methodology will become increasingly complicated (PROMOTioN, 2020). In the literature, three approaches for cost allocation of interconnecting infrastructures across countries are discussed.

1. Following the beneficiary-pays approach, costs are allocated to ensure that every stakeholder ends up with the same cost-benefit ratio (De Clercq et al., 2015).

2. Following network flows, costs are allocated based on the realised power flow that is caused by the beneficiary (Jansen et al., 2015). There are five methods to apply a flow-based approach, all resulting in an ex-post way of allocating costs (De Clercq et al., 2015).
3. Following the "Postage stamp" principle, network costs are allocated uniformly among network users (De Clercq et al., 2015). This can be based on consumed or produced energy or other indications of the user's usage of the electricity system.

Besides these specific approaches for cost allocation, there are other metrics used to determine MS contributions to causes of collective interest. For example, Regulation (EU) 2018/842, better known as the Effort Sharing Regulation, establishes a national target for the reduction of greenhouse gasses for every MS. By differentiating targets according to Gross Domestic Product (GDP) per capita across MSs, it acknowledges the different capacities of MSs to take action.

2.3 System of Actors

To get a better understanding of the system of actors, stakeholder theory is used to identify actors that might have a perspective on the allocation of costs for a meshed offshore network that should be included in this research. Bryson et al. provide an overview of how to map a system of actors and identify their role in that system, which is used as a starting point in this analysis of the system of actors. A power versus interest grid is used to determine stakeholder interests (Bryson et al., 2011). However, the meshed offshore network is characterised in the context of Systems-of-Systems (SoS) first. This is used to explain the position of this research in the system.

2.3.1 Systems-of-Systems

Although there is no widely accepted definition for a SoS, it is generally described as a large-scale distributed system in which the components are complex systems themselves (Maier, 1998). To characterise the meshed offshore network in a SoS context, it is evidently a large-scale system to start with. Spanning across the North Sea, connecting multiple countries and facilitating 300 GW of offshore wind capacity, the scale of the meshed offshore network is unlike anything built so far in offshore energy. Moreover, a meshed offshore network fits the description of a systems-of-systems because it is a specification; there are underlying systems that make up the meshed offshore network, both physical and non-physical. Within every system, the introduction of a meshed offshore network raises different questions. For example, developing OWFs and interconnectors, energy markets, regulation, allocation of costs, and even the North Sea could be regarded as a complex system within the meshed offshore network. For every system, the meshed offshore network will raise different questions involving different actors. This research focuses on the allocation of costs for a meshed offshore network. To get a better understanding of how costs should be allocated for a meshed offshore network, the system of actors is evaluated in the following section.

2.3.2 System of actors

Within the cost allocation of a meshed offshore network, the system of actors is evaluated in this section using the power versus interest grid shown in Figure 2-6. However, power and interest can be interpreted in various ways. In this research, interest is interpreted as the degree to which a given actor has an interest in the way in which costs are allocated for a meshed offshore network. Power is referred to as the influence that a given actor can exert on the cost allocation of a meshed offshore network.

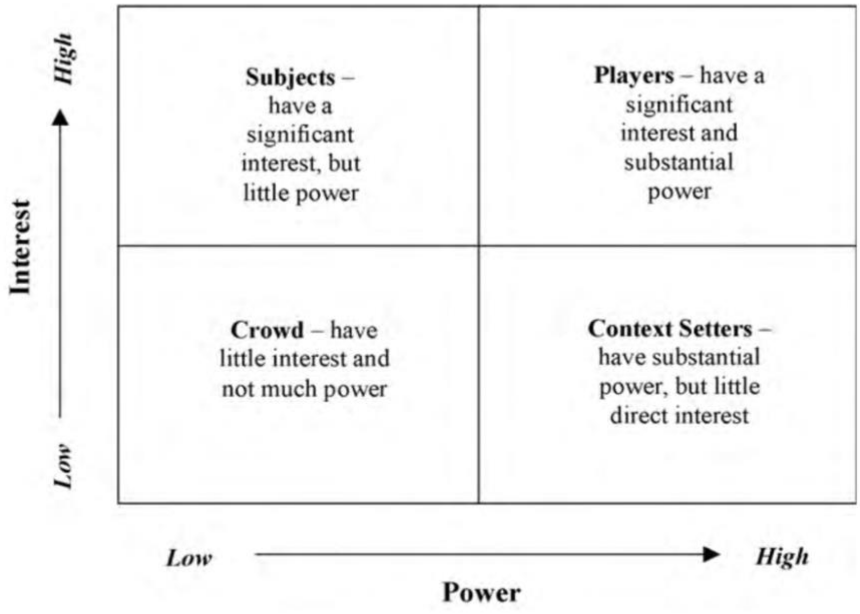

Figure 2-6: Power versus interest grid.

Each of the quadrants should be seen as a range, meaning that within each quadrant, actors can have different positions (Bryson et al., 2011). To illustrate their relative position in allocating costs for a meshed offshore network, actors have been positioned in the matrix shown in Figure 2-7.

In the "crowd" quadrant, three actors are identified that have a relatively low interest and power in the allocation of costs for a meshed offshore network. As discussed in section 2.2, households and industry pay for the costs of the system through transmission tariffs, which will be affected by the costs of a meshed offshore network. The other way around, households and industry will have little impact on the way costs will be allocated in a meshed offshore network. However, if there would be an interest, the industry is more likely to be able to convey this in comparison with households. Therefore, the industry is positioned as slightly more powerful. Furthermore, electrification of the industry is also causing electricity costs to take a larger share and weigh more on profits. The industry is slightly more likely to have an interest in the allocation of costs of a meshed offshore network compared to households. Third, generators are identified as actors in the "crowd" quadrant, close to being a subject. Compared to households and industry, generators are likely to have a higher interest in the way costs are allocated. If generators were to bear part of the costs, this would affect their business case. With national wind associations being able to exert pressure, the power of generators is deemed higher than the other two actors in this quadrant.

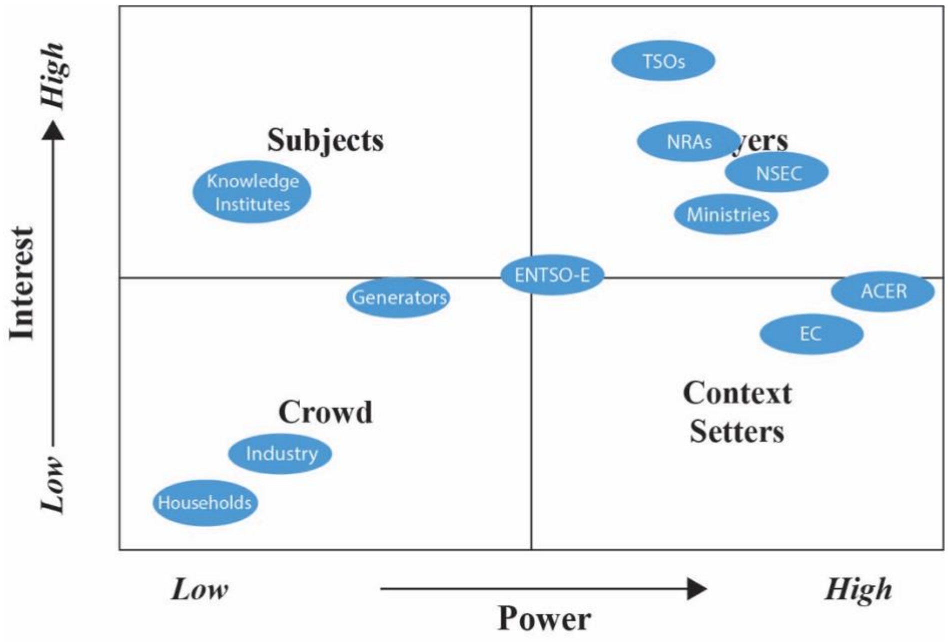

Figure 2-7: Power interest grid with actors ranked related to cost allocation of a meshed offshore network.

In the "subjects" quadrant, several organisations have been identified to have an interest in the allocation of costs for a meshed offshore network, summarised as knowledge institutes. Organisations like the North Sea Wind Power Hub (NSWPH), Florence School of Regulation (FSR) and Copenhagen School of Energy Infrastructure (CSEI) have published several Articles on the development of meshed offshore network solutions and are likely to have a higher interest in the cost allocation of a meshed network. Although, in theory, they can influence the cost allocation process through the Articles they publish, this power is likely to be low.

Furthermore, several actors have been positioned in the "players" quadrant. To start with, TSOs will most likely have a pivotal role as they are likely to introduce steps towards a meshed offshore network. In this case, TSOs from North Sea countries are meant. If the TSO model is used in the meshed offshore network setting, TSOs will pay for the offshore infrastructure. In that case, TSOs are most likely to have the highest interest in the allocation of costs. Furthermore, TSOs are some of the most knowledgeable actors in this topic. Considering this, TSOs are likely to have a high interest and significant power in the cost allocation process. However, North Sea countries' TSOs are mostly state-owned, often involving public funds to finance capital expenditures (Henriot, 2013). In this regard, ministries and NRAs are also involved. Their interest might be slightly lower than the TSOs', but the way costs are allocated in a meshed offshore network is still very much their interest. As NRAs monitor TSO investments, NRAs are placed in a slightly more powerful position compared to TSOs and a slightly more knowledgeable position compared to ministries. Lastly, the North Seas Energy Cooperation (NSEC) has been positioned in this quadrant as well. NSEC is a cooperation of nine MSs to support and facilitate the development of the offshore grid. Being an official high-level group of the European Commission, NSEC is an actor likely to have a high interest and significant power.

Lastly, three actors have been positioned in the "context setters" quadrant. ENTSO-E has already been mentioned as an important organisation. Being the association for the cooperation of European

TSOs, representing 35 countries, ENTSO-E's mission is to ensure the security of the interconnected power system. Representing a broader group of TSOs across the European continent, the interest and power of this actor in the cost allocation of a meshed offshore network is smaller compared to the TSOs mentioned as "players". Besides ENTSO-E, the European Commission and ACER have been identified as actors in finding the cost allocation for a meshed offshore network. ACER is one of the EU's decentralised agencies that ensures the integration of national energy markets and the implementation of legislation. Furthermore, ACER's role is discussed in section 2.2.5. Considering the power vested in ACER by the EU and its role in CBCAs, ACER is perhaps the most powerful actor in the cost allocation of a meshed offshore network. However, ACER's role is supportive, and, in that regard, their interest in the cost allocation process is deemed lower compared to the actors positioned in the "players" quadrant.

2.4 Conclusion

As mentioned in the introduction, the EU has set out a strategy to achieve the European climate goals. As part of this, the EU has identified the North Sea as the "Powerhouse of Europe". With its favourable wind climate and shallow waters, the North Sea provides an opportunity to exploit wind power. The objective is to establish a minimum of 60 GW of offshore wind power by 2030 and 300 GW by 2050 in the North Sea. A target that exceeds the demand of North Sea MSs. Furthermore, the EU has laid down its ambition for an integrated European electricity system in the TEN-E regulation to reduce the isolation of less-favoured regions.

To effectively expand offshore wind capacity, a significant increase in the offshore transmission infrastructure is necessary. Achieving this in a cost-effective manner entails moving the integration of the European electricity system out to sea. Hybrid connections, which combine transmission and interconnection, will replace conventional radial connections. Ultimately, a meshed offshore network is envisaged as the offshore transmission network to bring the offshore wind capacity to shore. However, the expenses for the interconnecting infrastructure are staggering, with current estimates reaching €800 billion. CBCA is used in accordance with the TEN-E regulation to allocate costs for cross-border electricity infrastructure. Even though this procedure was introduced in 2013 and has covered 43 CBCA decisions to date, it has never been used in a project of the scale of a meshed offshore network. The literature study reveals that based on the CBCA decisions taken so far, the knowledge and experience on CBCA is rudimentary and inadequate to utilise the CBCA procedure for the allocation of costs for a meshed offshore network.

Several actors have been identified and evaluated based on their influence and interest in the cost allocation of a meshed offshore network. Depending on their role, these actors have potentially differing perspectives on how costs should be allocated, which are as yet unknown.

3 Q methodology

The Q methodology has been mentioned as the chosen methodology for this research. Based on the findings from the literature and input from several experts, the Q methodology was conducted. In this Chapter, the background and steps of the methodology are discussed in detail.

3.1 Q methodology overview

Q methodology, developed by British physicist and psychologist William Stephenson in 1935, is a unique approach that bridges the gap between qualitative and quantitative research (Watts & Stenner, 2005). It is a methodology that is geared to find the subjectivity within an individual's viewpoint in a structured and systematic manner. Q methodology is particularly useful when dealing with subjective phenomena, opinions, and attitudes. It has been widely used in different fields of study, such as psychology, environmental studies, and transport. At its core, Q methodology concerns the study of subjectivity using a Q-sort, a tool designed to systematically rank and categorise statements or items. Participants are presented with a set of carefully chosen statements, often referred to as the "Q-set", and asked to sort them according to their personal opinions or preferences (Coogan & Herrington, 2011). Using statistical analysis software programs, shared perspectives can be identified, providing a consistent analysis of patterns or perspectives.

3.2 Key concepts and principles

3.2.1 Q-sort

The Q-sort is the core element of Q methodology, where participants rank a set of statements or items based on their personal perspectives. This process allows for the identification of shared patterns or perspectives among participants. The actual process of sorting the statements comes down to filling the statements in a predetermined grid, which is shown in Figure 4-1. This can either be a fixed distribution or a free distribution. In general, it is recommended to use the fixed distribution (Brown, 1980). This means that participants must adhere to the number of statements that can be assigned to each rank. This provides the participants with structure and is also more convenient for the researcher to analyse the sorts.

In research with a Q-set ranging from 40 to 60 statements, Brown recommends a kurtosis of the distribution from -5 to +5. On the one hand, it provides the researcher with a manageable range of sorting, but on the other hand, it allows participants to display certain nuances in their sort. Then, depending on the subject and the expertise of the participants, the slope of the grid must be determined. Again, participants must be able to express nuance points whilst being forced to choose the extremes at the same time. Given the variety of criteria and components in this research that can co-exist, there needs to be room for several statements in the extremes. On the other hand, it is also important to force participants to make trade-offs in the extremes, for which the participants that were selected are deemed sufficiently knowledgeable. Therefore, a moderately steep Q grid is used with two places in the -5/+5 ranks and three places in the -4+4 ranks, as shown in Figure 3-1.

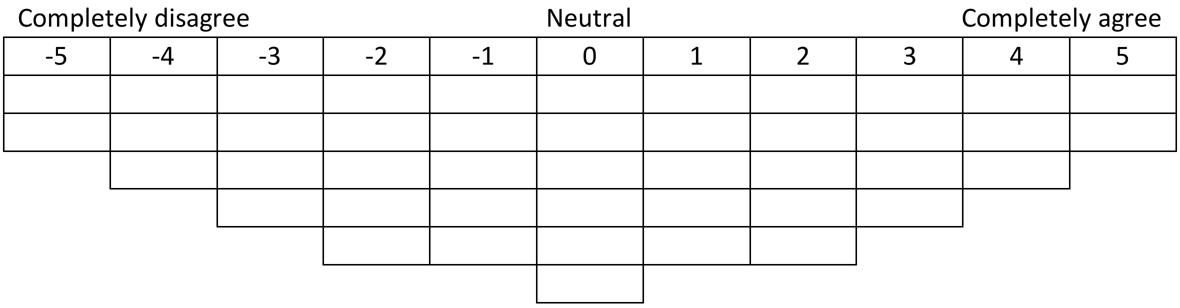

Figure 3-1: Q-sort distribution used in the research.

3.2.2 Factor Analysis

Once the Q-sort data is gathered from all participants, factor analysis is applied. A factor represents a common viewpoint identified in the data. In factor analysis, this statistical technique is used to uncover underlying patterns or perspectives within the subjective data. The goal of the factor analysis is to identify groups of participants that show similar patterns of ranking the statement, which would suggest a shared perspective (Watts & Stenner, 2012). The factor analysis is performed in two steps. First, following a set of rules, factors are extracted from the data. Then, the factors that were extracted are rotated. Both factor extraction and factor rotation are discussed in further detail in section 3.6.1.

3.3 Research Design

3.3.1 Rationale for Q methodology

The Q methodology was chosen for this research for several reasons. Perhaps most important because Q methodology is an exploratory technique. Although it cannot prove hypotheses, it can provide coherence to research questions that have many potentially complex and contested answers (Stainton Rogers, 1995). As mentioned, a CBCA that includes non-hosting MSs is unprecedented, highly political and complex. Another reason for using the Q methodology is that compared to other qualitative methods, the Q methodology provides a more systemic comparison of perspectives. Moreover, it can reveal certain differences and points of agreement (Watts & Stenner, 2012). This is valuable considering the CBCA process and the highly political negotiations that have yet to come.

However, there are also limitations and potential downsides to the use of Q methodology. Being praised for exploring subjectivity, the Q methodology itself is sensitive to subjectivity for multiple reasons. The interpretation of factors relies on the researcher's judgement; participants might misinterpret statements, and factor loadings can be challenging to interpret (Stainton Rogers, 1995). Despite these potential downsides, the aforementioned qualities of Q methodology outweigh them in the relatively unknown topic of this research.

Having identified the shortcomings of Q methodology, improvements were made to improve the reliability of this research. Most importantly, participants were assisted throughout the sorting process. In doing so, misinterpretations of statements were prevented. Furthermore, participants were encouraged to elaborate on their considerations throughout the sorting process in addition to the post-sort questions that were asked. The post-sort questions are, however, susceptible to ex-post rationalisation by participants (Festinger, 1957). Effectively asking participants to verbalise their thought processes throughout the sorting process enhances the accuracy of the researcher's interpretation. In that regard, all interviews were recorded and transcribed, generating over 600 pages of conversation. Every transcript was then axial coded based on the statements, providing an overview of anything said related to a given statement. This makes the analysis more thorough.

3.3.2 Creating the P-set

As mentioned in section 2.3, several actors are involved in a CBCA decision for a meshed offshore network in the North Sea. All these actors have different roles with different interests. A P-set should include all types of stakeholders likely to have an original viewpoint on the matter (Brown, 1980). In this regard, TSOs, NRAs, and ministries have been identified as some of the most important actors to express a viewpoint. Furthermore, there are international organisations like ENTSO-E, with expertise in subjects such as CBCA. Besides this, there are several partnerships between organisations working on this topic, such as the NSWPH and the North Seas Energy Cooperation (NSEC). The goal was set to include all TSOs, NRAs, and ministries and international organisations in this research, together with experts from institutes.

To realise the involvement of these actors, multiple channels were used to get into contact with potentially relevant participants. First, because it was not readily apparent which people were working on this topic in different MSs, inquiries were made throughout the network available. A snowballing technique was added to this, where people were asked to forward the request to any colleagues possibly better suited to participate. Besides this, there are several task forces and regional partnerships that are working on topics like CBCA and meshed grid solutions. Convenors of task forces were asked to raise awareness of the research. The secretary of NSEC provided contact details of members of the cooperation that could be valuable to include in the research. Aside from the potential participants related to the actors identified in the literature study, authors of papers on the subject were invited.

Through these channels, a list of 59 potential participants was compiled, shown in Appendix D. All potential participants were contacted using the letter included in Appendix C.1, in some cases with an introduction from the linking person. The most important criterion for selecting participants was sufficient knowledge of the subject of offshore infrastructure and the developments in the sector. This meant selecting participants working on topics such as cost allocations and cross-border infrastructure. Furthermore, participants were selected based on their involvement in one of the organisations identified in the literature study. In other words, participants that work for either a TSO, NRA or ministry in one of the hosting MSs. The combination of these two criteria often led to experienced senior employees of the aforementioned organisations. However, participants were hesitant at first due to the political nature of the research. Furthermore, several potential participants that were contacted were either not yet working on the topic of CBCA or deemed themself insufficiently knowledgeable to take part, thereby not satisfying the most important criterion. To overcome the political sensitivity problem, anonymity was offered to participants.

Out of the 59 potential participants who were invited to participate in the research, 21 replied positively. However, in two cases, participants decided to take part in the sorting procedure together. Therefore, the P-set consists of 21 participants, but the research has 19 data points. The 19 data points consist of:

Confidential – Table deleted

Q methodology does not require a large number of participants, but there are a few rules of thumb. Q methodology is based on the assumption that the number of coherent viewpoints is exceeded by the number of participants, a so-called finite diversity. The aim is not to obtain the truth but to explore the variety of accounts people construct (Kitzinger, 1987). In this line of reasoning, the number of participants should not exceed the number of statements in the Q-set (Watts & Stenner, 2012). To add to that, a ratio of one participant is advised for every two statements (Brown, 1980). With a Q-set of 44 statements being sorted by 22 participants over 19 sorts, this research satisfies the rules set for the P-set.

3.4 Instrumentation

In the following sub-sections, the different instrumentation that was used in the methodology is discussed. In section 3.4.1, a detailed description of how participants conduct the Q-sort is provided, including any instructions or guidance provided. Second, the Q-set that was administered to participants is discussed in the next sub-section, explaining the process of creating the set of statements. Lastly, the post-sort questions that were used in the sorting process are described.

3.4.1 Q-sorting procedure

As mentioned before, the methodology and the sorting of statements, in particular, are sensitive to interpretive errors. To ensure that participants were rightly informed of their participation in the research, a document was sent to all participants one day before the sorting interview was scheduled. A copy of this document can be found in Appendix C.2. After a brief introduction and acquaintance with participants, the information document was once again addressed. By briefing all participants in this way, the right starting point was ensured so that participants knew the setting in which statements should be interpreted. Throughout the sorting process, participants could ask questions regarding the statements. This way, participants were helped to interpret the statements as they were intended. Furthermore, participants were asked to elaborate on the thought process as much as possible. Lastly, a set of post-sort questions was presented to participants at the end of the sorting process.

3.4.2 Creating the Q-set

In Q methodology, the set of statements presented to participants is referred to as the Q-set. In compiling the Q-set, the first step is to establish the concourse on the subject. The concourse is a collection of statements that resemble the range of viewpoints on a certain topic, gathered from various sources and compiled by the researcher (Coogan & Herrington, 2011). In this case, on CBCA or cost allocation for a meshed offshore network in the North Sea. The concourse is typically a multitude of the final Q-set used in the research. Because of this, statements must be selected for the Q-set. Although there is not one definitive method to generate the Q-set from the concourse, it often involves setting criteria to obtain the Q-set from the concourse.

In this research, the concourse is based on a variety of sources, following a mix of structured and unstructured methods to generate the Q-set. In the first place, the concourse is based on the literature study sources that were scoped by the research question. However, at this point, a deviation from the methodology should be noted. In establishing the concourse, it became apparent that the scoping was too broad to define a concourse that fitted the scale and timeline of this research.

To find a scope better suited, several off-the-record and on-the-record interviews were held with experts from multiple organisations across different countries. A description of the process is found in Appendix A. The outline of the concourse that resulted from this process is as follows. The allocation of costs is best justified if it is based on benefits. In that case, agreement on the benefits is a prerequisite. If all parties agree on the benefits to be included in the CBA that precedes the CBCA, the next question would be how to allocate costs in a certain relation to benefits. As was established in the literature study, this can be done using a variety of allocation keys. Furthermore, there are several aspects regarding political acceptability and how the CBCA is constructed with regard to time that parties need to agree on. Of all possible criteria from the broader concourse, these four topics were widely regarded as the most important to be explored. Following the process described in Appendix A, the Q methodology concourse is based on four themes:

1. Relevant benefits
2. Possible allocation keys
3. Aspects of political acceptability
4. Aspects of time

Even within this scoped concourse, every aspect of the CBCA has great ramifications. Therefore, a seemingly simple statement can already prove to be complex. Therefore, a compromise must be found in setting up the Q-set. On the one hand, the statements must do justice to the important trade-offs at hand. Yet, statements must be comprehensible and unambiguous. Literature and the understanding gained throughout grey literature formed the basis for the statements.

Additionally, the process described in Appendix A provided ample input for statements to be drafted for the Q-set. From this point, the matrix shown in B-1 of Appendix B was used to compile statements in a systemic manner. These statements were tested with six experts from two different TSOs. Based on their input, statements were refined, and some were discarded. The final Q-set contains 44 statements and can be seen in Table 3-2.

Table 3-1: Overview of statements in Q-sort.

1	Socio-economic welfare is a benefit that must be included in the CBA when designing a meshed offshore network
2	Renewable Energy Supply integration benefits resulting from the realisation of a meshed offshore network should be considered in the CBA
3	Reduction of Greenhouse gasses per country due to the realisation of a meshed offshore network should be considered in the CBA

4	Gains in resource adequacy per country that can be attributed to the meshed offshore network should be considered in the CBA
5	All countries involved in the meshed offshore network will experience benefit of resource adequacy
6	Introducing a meshed offshore network will provide system flexibility gains and must therefore be included as a benefit in the CBA
7	Countries that do not experience reductions in CO_2 cannot be financially involved in the cost allocation principle
8	In a cost sharing principle, more weight should be placed on producer surplus over consumer surplus (countries with more PS should pay relatively more)
9	In a cost sharing principle, more weight should be placed on congestion income raised as a result of the meshed offshore network
10	Increased cross-border trade as a result of a meshed offshore network is a benefit that should be accounted for in the CBA
11	The redistribution of congestion income should be accounted for when setting up a sharing principle
12	Scenarios used to calculate the Cost-Benefit Analysis for the sharing principle should be set by a single European entity (ENTSO-E/ACER etc)
13	Positive changes in transmission system losses that can be attributed to the meshed offshore network have to be included in the CBA as benefit
14	Member States that have to invest in additional reserve capacity due to the development of an offshore network, should have to pay less in the CBCA
15	Costs should be settled with beneficiary Member States based on realised power flows resulting from the offshore network
16	The sharing key in the CBCA should be based on CO_2 and non CO_2 emission reductions realised in every Member State due to the network
17	Infrastructural costs should be allocated using an allocation key based on amongst others every Member States' GDP per capita
18	Infrastructural costs should be allocated using an allocation key based on amongst others every Member States' GDP
19	Infrastructural costs should be allocated using an allocation key based on amongst others the number of inhabitants per Member State
20	Infrastructural costs should be allocated using the territorial principle
21	Infrastructural costs should be allocated using the CBA, which aims to identify a cost-benefit ratio per Member State involved
22	Infrastructural costs should be allocated using a cost-benefit ratio, reallocating costs so all Member States end up with the same cost-benefit ratio according to the CBA
23	Infrastructural costs for transmission and interconnection should be covered in separate, project specific CBCA decisions
24	Costs should be allocated based on the expected distribution of socio-economic welfare per Member State involved
25	Subsequent onshore grid expansion has to be included in the CBCA for the infrastructural costs of an offshore meshed network
26	Meshed offshore network infrastructure supports Offshore Wind exploitation, therefore offshore connection costs should be raised so that offshore generators contribute a fair share

27	Infrastructural costs should be distributed via the regulated side of the market (ie TSOs, funding etc.)
28	If costs of a meshed offshore network are shared, countries are eligible to claim part of the interconnected Renewable Energy Capacity to their national targets
29	EU funding is the best mechanism to socialise infrastructural costs for a meshed offshore network
30	A CBCA decision should only consider incremental costs and benefits relative to existing national roll-out scenarios
31	A CBCA decision should cover all infrastructural investment costs (including national roll-out)
32	The TSO model is the desirable financing structure to realise a meshed offshore network in the North Sea (TSO pays infrastructure)
33	A meshed offshore network should be realised using one offshore TSO covering the North Sea, financed by Member States in proportion to their benefits
34	A threshold should be set to distinguish beneficiaries of a certain degree (eg >10%)
35	EU funding/subsidies for CBCA projects should only be used to compensate for/cover costs otherwise charged to small beneficiaries falling below the threshold
36	Costs should be allocated using two CBCA's, one for hosting MSs and one for non-hosting MSs
37	Given the expansion of offshore wind capacity in a meshed offshore scenario, costs should be allocated amongst hosting MSs only
38	All Member States that enjoy benefits from a meshed offshore network should contribute, hosting and non-hosting
39	If costs turn out to be higher than the expected costs at the time of the CBCA decision, there should be a correction
40	A CBCA is only binding for the investment costs, no further partnership should result from it (eg OPEX sharing)
41	Different outcome of costs due to deviation from the time roadmap should be reallocated
42	Increased investment costs due to project delays have to be included in the CBCA
43	Climate goals should somehow be represented in the CBCA
44	CBCA is the preferred route over political agreements to settle cross-border costs for the realisation of a meshed offshore network

3.4.3 Post-sort questions

Once the Q-sort was performed by participants, additional questions were asked to explore the narrative behind the choices made.

1. Please elaborate on your thoughts for picking the 5 statements you most agreed with
2. Please elaborate your thoughts for picking the 5 statements you least agreed with
3. Do you feel certain aspects that should have been included were left out?
4. Do you have any comments on one or more specific statements used in the study?

Using these questions, participants were challenged to reflect on their choices and to elaborate on them. Besides these questions, participants were asked to elaborate on their choices throughout the sorting process as this provides an “unfiltered” response that is most valuable to the research.

3.5 Data Collection

Having established the set of participants and the instruments used in the Q methodology, the data collection processes are discussed in the following sub-sections. First, the steps involved in administering the Q-sort to participants are discussed. Second, a description is given of how the data was recorded and how this data was managed.

3.5.1 Procedure for administering the Q-sort

To administer the Q-sort to participants, statements are usually placed on cards for participants to sort (Coogan & Herrington, 2011). However, in this research, performing the Q-sorts physically was not possible, as that would entail travelling to most North Sea countries. Alternatively, WebQ was used to conduct the Q methodology. WebQ is a JavaScript application that allows the researcher to administer the Q-sort online. The Q-set and distribution grid are entered into the program script by the researcher. Participants received a Microsoft Teams invite to take part in the sorting procedure. Although it was possible to meet some of the participants in person, all sorts were performed using the WebQ program to ensure consistency. Through screen sharing, the WebQ program was shown to participants. Following instructions, participants start by sorting the statements into three "piles" based on their intuition: positive, neutral and negative. This provides the participants with a slightly more manageable overview of the statements in three categories. Then, participants are asked to select the statements they agree with to fill the extreme, working their way towards the neutral rank. The same process is repeated for the statements that participants most disagree with.

3.5.2 Data recording and management

As explained in the previous section, the Q-sort data was administered using WebQ. Upon completion of the sorting process, WebQ converts the Q-sort data of every participant to a format that can later be used in the data analysis. An example of a WebQ data output file is shown in Figure 3-2.

```
Browser: Mozilla/5.0 (Windows NT 10.0; WOW64; Trident/7.0; .NET4.0C; .NET4.0E; .NET CLR 2.0.50727; .NET CLR 3.0.30729; .NET CLR 3.5.30729; wbx 1.0.0; rv:11.0) like Gecko
Q-Sort response array (DO NOT CHANGE!!):
[redacted]      5 2 2 1 0 1 1-3-3 1 2 0 0 2-2-2-1-1 0-5 3-1-2 4 3 2-2 3 5-3 4 4-3 0-5-4-2 3 0-4-1-1 1-4<

You can add comments here: --

more comments here:
```

Figure 3-2: WebQ output data file.

Aside from the Q-sort data that is registered, all participants agreed with the Teams meetings being recorded for the interpretation of the data. Microsoft Teams also enables verbatim transcription of meetings, which was used to record the meetings. This resulted in more than 600 pages of transcripts and over 25 hours of interview recordings. Following the data management plan that was designed and approved in the early phase of the research, all recordings were stored on a separate hard drive.

3.6 Data Analysis

The data analysis is discussed in the following sub-sections to get an understanding of how the perspectives and patterns are obtained from the data. First, the process of factor extraction and factor rotation is discussed. Second, the software that is used to analyse the data is discussed in section 3.6.2. Lastly, section 3.6.3 provides an understanding of the interpretation of the factor analysis results.

3.6.1 Overview of factor analysis in Q methodology

The first step in finding the perspectives in the subjective data from the Q methodology is factor extraction. A factor refers to a variable that represents a shared pattern of subjectivity among participants (Barry & Proops, 1999). Factors can be extracted from the data using two methods: the Principal Component Analysis (PCA) and Centroid Factor Extraction (CFE). Both techniques are used to simplify complex datasets and reveal patterns. In doing this, PCA tries to find a solution that is mathematically optimal. CFE tries to find the average (centroid) of each variable, leaving more room for additional knowledge gained throughout the interviews to be used in extracting the factors. Watts and Stenner (2012) find the CFE method to suit Q methodology better because it is more interpretable. Both approaches can be tested to find the best result.

There are several markers to determine the number of factors to extract from the data. It is suggested to start by extracting seven factors from the data (Brown, 1980; Watts & Stenner, 2012). To assess the relevance of the factors, the Kaiser-Guttman criterion is a rule that is often used in this analysis. According to this rule, all factors with an Eigenvalue greater than 1 should be retained. Besides applying the Kaiser-Guttman rule and starting with seven factors, Brown recommends keeping every factor that is significantly loaded by two participants or more. Significant factor loading is discussed in the factor rotation process in this section. Furthermore, a threshold is set for the explained variance with a minimum of 35% to 40% (Watts & Stenner, 2012). As a general rule of thumb, Watts & Stenner suggest one factor for every six to eight participants.

In factor extraction, the software mentioned in section 3.6.2 tries to find the strongest correlations between the variables from the sorts registered from participants. Visually, this can be thought of as an axis that is drawn through the variables. The software then tries to find another set of correlations, and so on. However, the initial solution may not be meaningful or easily interpretable (Akhtar-Danesh, 2023). Having completed the factor extraction, factor rotation can structure the factors in a simpler way that is easier to interpret by rotating the axes (Thurstone, 1947). To do this, Varimax is the most common technique used in Q methodology factor rotation, often preferred for its simplicity and reliability (Watts & Stenner, 2005). In some cases, there may be reason to manually rotate the factors further after completing the computed rotation. This could be interesting if the researcher wants to differentiate between groups of participants. However, manual rotation requires knowledge and skill from the researcher (Coogan & Herrington, 2011).

In the end, factor rotation results in a rotated factor matrix. In this matrix, the factor loading can be found for every participant’s Q-sort. Every factor loading indicates to what degree every Q-sort corresponds to every factor. As mentioned before, one of the standard requirements to eventually select a factor is that a factor must have at least two Q-sorts that significantly load on it (Watts &

Stenner, 2005). As Watts & Stenner explain, such a significant loading shows that a particular Q-sort is exemplary for a particular factor. In the end, all significant loadings for one factor are merged to form a “generalised sort” that best resembles the pattern that characterises the factor. If one Q-sort loads significantly on two or more factors, it means that the sort is confounded and, therefore, it will be excluded from the generalised sort.

To determine whether a Q-sort loads significantly on a factor, a significant factor loading at P < 0.05 can be calculated using the following formula:

$$Significant\ factor\ loading\ (P < 0.05) = 1.96 * \left(\frac{1}{\sqrt{n}}\right)$$

Where *n* equals the number of items in the Q-set (Watts & Stenner, 2005). At the significance level of P < 0.01, the following formula is used:

$$Significant\ factor\ loading\ (P < 0.01) = 2.58 * (\frac{1}{\sqrt{n}})$$

Depending on the factor analysis results, a researcher can decide to manually raise the significance level. For instance, if many Q sorts are not included in any of the factors because there are many confounded sorts. In that case, a lot of data is potentially discarded. According to Watts & Stenner, this is an example where it might be sensible to raise the significance level.

3.6.2 Software

For the factor analysis, different software tools can be utilised. In this research, PQMethod was primarily used for the analysis. PQMethod is a program tailored to the requirements of Q methodology, providing the correlation matrix, factor extraction, factor rotation and more. The data files generated by WebQ, the program used to administer Q-sorts, can be copied into the PQMethod script. However, PQMethod is only compatible with Microsoft Windows. Alternatively, KenQ analysis provides the same outputs as PQMethod whilst being operated in any internet browser. Both programs provided the same results; both were used in the analysis.

3.6.3 Interpretation of factor analysis results

The last step in the Q methodology process is the interpretation of the extracted factors. Every factor resembles a weighted average, assembled from the sorts of participants that loaded on it. From this, PQMethod creates a “typical” Q-sort with a statement ranking that is indicative of the factor. This is combined with information from participants to formulate a coherent narrative on the perspectives drawn. A procedure was followed to combine the data with knowledge gained throughout the research in a systemic manner.

First, the statements that participants in the factor agreed with most were listed, meaning the statements in the +4 and +5 columns. Together with the statements participants disagreed with most, this gives an overview of the extremes. Furthermore, PQ method provides distinguishing statements for every factor. These statements, combined with the background of participants that loaded significantly on the factor, form the basis for the factor interpretation. Additionally, all “typical” Q-sorts were colour-coded based on the four categories mentioned in section 3.4.2, to provide an extra visual means to analyse factors. This can be found in Appendix E.4 to E.7.

Second, all interviews were recorded and transcribed. Transcriptions were then Axial coded using Atlas.ti. The transcriptions were coded based on the statements from the Q-sort. This provided an overview of everything that was said by participants about any of the statements used to interpret the factor. To validate this process, perspectives were tested with experts upon completion. In one or two-hour sessions, perspectives were explained to experts, showing how statements were related to a higher-level implication for the cost allocation of a meshed offshore network. These experts did not take part in the sorting process. Therefore, their view on the results is new and unbiased, as opposed to participants that might interpret a perspective based on their experience in the research. Based on this input, additional insights were gained and incorporated into the interpretation of the factors.

Additionally, following the Q methodology, PQMethod provides a correlation matrix between factors and a list of consensus statements in the output data. Using these outputs, similarities between perspectives are discussed in a separate section to get a better understanding of the perspectives.

4 Results

Having collected all the Q-sorts, the factor analysis is discussed in the following sections. A complete set of the output data is found in Appendix E. First, the factor extraction is discussed in section 4.1. Following the factor extraction, factor rotation is discussed in section 4.2. The resulting factors and the subsequent interpretation are discussed in section 4.3. Furthermore, similarities between perspectives are discussed in section 4.4. Lastly, some preliminary conclusions are drawn in section 4.5.

4.1 Factor Extraction

As mentioned, factor extraction can be performed in two ways: PCA and CFE. The results of the PCA method are shown in Table 4-1. Following the Kaiser-Guttman rule, using the eigenvalue, PCA factor extraction results in four factors. As seen in Table 4-1, the four factors together explain 65% of the total variance. This is sufficiently above the 35% to 40% threshold recommended. Furthermore, all four factors satisfy the requirement of a minimum of two participants loading significantly on every factor, which is further discussed in section 4.2. Lastly, applying Watts & Stenner's rule of thumb to a P-set of 19 participants would lead to two to three factors (Watts & Stenner, 2012).

Table 4-1: Eigenvalues and explained variance of factors in PCA extraction.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Eigenvalues	8,0856	1,7681	1,3203	1,1736	0,9633	0,8164	0,7845
% explained variance	43	9	7	6	5	4	4
Cumulative % explained variance	43	52	59	65	70	74	78

The results of the CFE factor extraction are shown in Table 4-2. Following the Kaiser-Guttman rule in the case of CFE factor extraction, two factors satisfy the minimum eigenvalue of 1. As seen in Table 4-2, the two factors together explain 46% of the total variance. In this case, too, the explained variance is sufficiently above the recommended threshold. The rule of thumb is also met in the case of the CFE factor extraction with two factors.

Table 4-2: Eigenvalues and explained variance of factors in CFE extraction.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Eigenvalues	7,5448	1,1963	0,1238	0,8125	0,0746	0,6994	0,4131
% explained variance	40	6	1	4	0	4	2
Cumulative % explained variance	40	46	47	51	51	55	57

Although both PCA and CFE factor extraction result in factors that satisfy the requirements mentioned in section 3.6.1, PCA factor extraction provides more factors. After all, the goal of factor extraction is to obtain a high percentage of explained variance (Watts & Stenner, 2012). Therefore, PCA is chosen to rotate factors in this research. The unrotated factor matrix resulting from the PCA factor extraction can be found in Appendix E.2, Figure E-2.

4.2 Factor Rotation

Having followed the steps of factor extraction, the factors are rotated following the process described in section 3.6.1. The group of participants is considered homogenous, and there are no additional indications to perform a manual rotation. The Varimax method was used to rotate four factors, resulting in the factor loadings table shown in Table 4-3. Table 4-3 shows the factor loading for every participant's Q sort. Every factor loading indicates to what degree every Q-sort corresponds to every factor. This is used to determine which participants load significantly on what factor.

As it is better to have a more stringent significance level, the $P < 0.01$ formula was used to determine the significant loadings (Watts & Stenner, 2005). This means that a statistically significant loading must be equal to or greater than $2.58(1/\sqrt{44}) = 0.389$. Based on this threshold, 11 participants loaded significantly on one of four factors. This is also shown in table 4-3 with asterisks marking significant loading on a factor. The other 8 participants either loaded significantly on more than one factor or no factor at all. Furthermore, the factors show a high reliability with an average reliability coefficient of 0.8 and composite reliability higher than 0.8 or 0.9.

Table 4-3: Four perspectives and factor loadings resulting from Varimax rotation, significant loadings marked *.

Participant No.	1	2	3	4
1	0,3837	0,0406	0,7056*	0,1223
2	0,3075	0,4293	0,576	-0,0951
3	0,2418	-0,0214	0,1714	0,7783*
4	0,6823*	0,1746	0,3868	0,0649
5	0,7161	0,0551	0,4566	0,1675
6	0,6724	0,269	0,0031	0,4048
7	0,1293	0,7385*	0,2294	0,1489
8	0,172	0,0414	0,6621*	0,3228
9	-0,0233	0,5547	-0,0545	0,458
10	0,7829*	0,1609	0,2304	0,0432
11	0,1919	0,0727	0,2407	0,6236*
12	0,1406	0,1996	0,8072*	0,1975
13	0,1936	0,5198	0,4332	-0,0704
14	0,7670*	0,331	0,1209	0,206
15	0,7246*	-0,1553	0,2154	0,001
16	0,4386	0,4144	0,4609	0,3594
17	0,7232	0,0793	0,0896	0,4092
18	0,6349	0,2189	0,4279	0,356
19	0,0978	0,7615*	0,0592	-0,0421
% expl.Var.	25	13	16	11
No. Of Defining Variables	4	2	3	2
Average Reliability Coefficient	0,8	0,8	0,8	0,8
Composite Reliability	0,941	0,889	0,923	0,889
S.E. of Factor Z-scores	0,243	0,333	0,277	0,333

4.3 Interpretation of factors

The analysis that is described in previous sections resulted in four factors. Following the interpretation steps described in section 3.6.3, four perspectives were formulated on the allocation of costs for a meshed offshore network in the North Sea. In this section, the perspectives are discussed. For every perspective, the most important statements are listed in a table. The complete generalised sort of every perspective can be found in Appendix E. The four perspectives are summarised using the following labels:

1. CBCA advocators
2. CBCA opposers
3. Leading by procedure
4. Cautious pragmatists

The labels are meant to give the reader an idea of the actors' overall view on the cost allocation of a meshed offshore network. They are based on the most significant aspects that distinguish their perspective the strongest from others, reflecting how underlying values drive a certain way of allocating costs for a meshed offshore network, discussed in the following sections.

4.3.1 Perspective 1: CBCA advocators

Four participants from different organisations across North Sea countries share this perspective on the cost allocation of a meshed offshore network in favour of the CBCA. Two participants have a regulatory background, either at a TSO or NRA. The other two participants are also related to one of the TSOs. This perspective makes up for 25% of the variance. The complete generalised sort of this perspective can be found in Appendix E.4.

The distinguishing and defining statements of perspective 1 can be found in Table 4-4. Based on the statements that participants selected as most agreed upon, Socio-Economic Welfare (SEW) is important both in the CBA and in the subsequent distribution of costs in the CBCA. Furthermore, participants in this perspective prefer an extensive CBCA, both in terms of costs and in reach, including onshore grid expansion costs and national roll-out across all MSs that benefit. This can be seen both in the positive and the negative statements. As one of the participants explained, offshore infrastructure will become increasingly intertwined, both physically and in terms of national versus international purpose. Because of that, it might be better to take a holistic approach to the cost allocation, which could explain the participants being in favour of an extensive, powerful CBCA in this perspective. Furthermore, the participants reacted negatively to limiting the CBCA to CAPEX. Participants that loaded significantly on this factor pointed out the importance of including OPEX as well as looking for partnerships such as RES statistical transfer benefits. To put this in the context of allocating the costs for a meshed offshore network, the ranking of statements implies an unconditional belief in the CBCA to be able to allocate costs in this perspective. The CBCA is a powerful tool that should address all costs, both offshore and onshore, across all MSs in the case of a meshed offshore network. Moreover, the CBCA should provide a wider ground to engage in partnerships. Partnerships that surpass the mere promise of said costs and benefits, for instance, using RES statistical transfer benefits to "sweeten the deal".

The positivity towards an extensive CBCA is also found in one of the distinguishing statements on setting a threshold to distinguish between beneficiaries of a certain degree. Participants from this perspective are relatively negative on this compared to other perspectives, implying that small beneficiaries are to be included as well. SEW is seen as a metric that is, in general, widely recognised and best suited to identify costs and benefits and allocate costs accordingly. Despite the CBCA's extensive coverage, responsibility should remain at MS level to preserve a level of autonomy, as the TSO model is ranked quite positively. Therefore, the belief in CBCA is slightly nuanced, recognising the importance of establishing centralised rules and scenarios to find common ground, and set international safeguards against cherry-picking. Participants expect the EU to play a part in this as well, ranking financial support from the EU positively.

Table 4-4: Perspective 1 statements, distinguishing statements marked with D.

Sorted on	#	Statement
-5 D	33	A meshed offshore network should be realised using one offshore TSO covering the North Sea, financed by Member States in proportion to their benefits
-5 D	40	A CBCA is only binding for the investment costs, no further partnership should result from it (eg OPEX sharing)
-4 D	30	A CBCA decision should only consider incremental costs and benefits relative to existing national roll-out scenarios
-4	35	EU funding/subsidies for CBCA projects should only be used to compensate for/cover costs otherwise charged to small beneficiaries falling below the threshold
-4	37	Given the expansion of offshore wind capacity in a meshed offshore scenario, costs should be allocated amongst hosting MSs only
-2 D	34	A threshold should be set to distinguish beneficiaries of a certain degree (eg >10%)
+2 D	12	Scenarios used to calculate the Cost-Benefit Analysis for the sharing principle should be set by a single European entity (ENTSO-E/ACER etc)
+4 D	31	A CBCA decision should cover all infrastructural investment costs (including national roll-out)
+4	38	All Member States that enjoy benefits from a meshed offshore network should contribute, hosting and non-hosting
+4	25	Subsequent onshore grid expansion has to be included in the CBCA for the infrastructural costs of an offshore meshed network
+5	1	Socio-economic welfare is a benefit that must be included in the CBA when designing a meshed offshore network
+5	24	Costs should be allocated based on the expected distribution of socio-economic welfare per Member State involved

4.3.2 Perspective 2: CBCA opposers

The second perspective found in the data is shared by two participants, making up for 13% of the explained variance. Both participants have a TSO background. Distinguishing and defining statements of factor 2 can be found in Table 4-5, the generalised sort is found in Appendix E.5. The key principle is that participants from this perspective most profoundly oppose the use of a CBCA to allocate costs for a meshed offshore network. This appears to correspond with a preference for

MSs to maintain a level of autonomy that will be compromised with a CBCA. This can be concluded from several statements in the generalised sort. First, the CBCA is ranked distinguishingly negative, meaning that political agreements are favoured over CBCA. Although political agreements are not the only alternative to a CBCA, respondents indicated their preference specifically for negotiating without a CBCA. This is also remarked by the participants, stating that political agreement must be reached rather than choosing one of the instruments at hand. However, reaching a political agreement means negotiating. In the context of a meshed offshore network, this means that the cost allocation is established through negotiation with all relevant parties. Therefore, this perspective is the exact opposite of perspective 1, opposing the use of a CBCA to allocate the costs of a meshed offshore network, let alone the CBCA's extent favoured in perspective 1.

Second, this perspective is distinguishingly negative towards the use of scenarios set by a single European entity. Corresponding with the remark on political agreements, the second participant stated that it would be a cumbersome process with lots of discussion if a common body would impose a CBA. Participants relate this to an underlying problem with the acceptability that already exists. Ex-cathedra imposition of scenarios by the EU would add to this problem. In this regard, opposing perspective 1 as well, which chose the use of scenarios set by a single European entity distinguishingly positive. In this perspective, rather, it should be based on negotiations so that, in the end, MSs can reach an agreement. Adjustments to the current system do not seem to be the starting point in this perspective. This is partly because the imposition of the scenarios is not the only problem. Respondents do not agree with the methodology used to calculate the CBA to begin with. To put this in the context of the meshed offshore network, the first step would be to get negotiations started on the allocation of costs and the methods used to assess the benefits and costs of the project. Even if the methodology were correct, respondents in this perspective would probably not accept the CBCA procedure.

Moreover, generators should be considered to recover the costs of the system. As both participants remarked, costs must be carried at the expense of the profits made. This would entail setting an injection charge or deep connection cost to offshore generators to make sure that in the meshed offshore network, both load and generation contribute a fair share. However, the charges that generators pay might differ significantly between MSs. In the meshed offshore network, it seems likely that the connection tariffs would, therefore, become another point of negotiation. Based on the coding results, this is another aspect that distinguishes this perspective from the other perspectives. In the other perspectives, participants are reluctant to make generators pay more because it might compromise their business case.

Lastly, based on the sorting of statements, this perspective prioritises the political level but also keeps an eye on the interests of the TSOs. The cost allocation should be acceptable and take away uncertainties, which explains why the statements on ex-post corrections are ranked negative as well. The autonomy of MSs can also be found in the positive extreme, seeing that the TSO model is desirable. Furthermore, this perspective favours distributing costs via the regulated side of the market. Lastly, participants do not favour the allocation keys provided in the research, seeing that most of the statements are sorted negatively. Either that or participants prioritise the other aspects discussed in this section.

Table 4-5: Perspective 2 statements, distinguishing statements marked with D.

Sorted on	#	Statement
-5 D	44	CBCA is the preferred route over political agreements to settle cross-border costs for the realisation of a meshed offshore network
-5 D	12	Scenarios used to calculate the Cost-Benefit Analysis for the sharing principle should be set by a single European entity (ENTSO-E/ACER etc)
-4	22	Infrastructural costs should be allocated using a cost-benefit ratio, reallocating costs so all Member States end up with the same cost-benefit ratio according to the CBA
-4	39	If costs turn out to be higher than the expected costs at the time of the CBCA decision, there should be a correction
-4	41	Different outcome of costs due to deviation from the time roadmap should be reallocated
-3 D	11	The redistribution of congestion income should be accounted for when setting up a sharing principle
-1 D	29	EU funding is the best mechanism to socialise infrastructural costs for a meshed offshore network
+1 D	24	Costs should be allocated based on the expected distribution of socio-economic welfare per Member State involved
+4 D	27	Infrastructural costs should be distributed via the regulated side of the market (ie TSOs, funding etc.)
+4	25	Subsequent onshore grid expansion has to be included in the CBCA for the infrastructural costs of an offshore meshed network
+4 D	20	Infrastructural costs should be allocated using the territorial principle
+5	32	The TSO model is the desirable financing structure to realise a meshed offshore network in the North Sea (TSO pays infrastructure)
+5	26	Meshed offshore network infrastructure supports Offshore Wind exploitation, therefore offshore connection costs should be raised so that offshore generators contribute a fair share

4.3.3 Perspective 3: Technocrats

This perspective was shared by participants from different backgrounds and organisations. In total, three participants related to this perspective. Two participants have an NRA background. The third participant is from a ministry. The perspective explains 16% of the variation. The distinguishing and defining statements of factor 3 are shown in Table 4-6. The generalised sort is found in Appendix E.6.

To start with, perspective 3 shows a strong preference for benefits to be included in the CBA, which precedes the CBCA. Statements related to benefits to be included in the CBA were sorted positively, making up four out of five statements in the +4 and +5 ranks. In terms of allocating costs for a meshed offshore network, this perspective is actually more focused on the preliminary processes that lead to the actual cost allocation. The benefits and the scenarios used to assess the distribution of costs and benefits through the CBA are more important in this case compared to the other perspectives. Similar to perspective 1, SEW appeared as the most favourable metric as a benefit indicator to be included in the CBA. In general, as many benefits must be included in the CBA as possible. As one of the participants elaborated, “We are not yet at the point of reducing everything to CO_2”. In this perspective, participants stress that justification for the costs is only found in the benefits gained from the investment. Combined with the fact that scenarios used in the CBA should be set by a single European entity, it must be observed that getting the CBA right is of great importance in this perspective.

Notably, of all perspectives, this perspective is the most optimistic towards the CBCA procedure, with statement 44 being one of the distinguishing statements. However, being ranked only slightly positive, participants admit to the political discussions that inevitably come with this subject. To put this in context, the allocation of costs of a meshed offshore network can be obtained through CBCA or political agreement, as long as the CBA is the basis of it. Therefore, this perspective could be characterised as the technocratic approach, sticking to the technical and economic analyses and accepting a certain allocation of costs that would result from it.

This can also be sensed in participants’ considerations, stating that scenarios should be set by an independent organisation to establish a starting point that is acceptable to all parties. This is a possible explanation for this factor’s orientation towards benefits. At this stage, pinpointing the right allocation key is not important, although all forms of allocating based on demographics have been ranked negatively. Besides these remarks, participants who share this perspective are negative about the use of EU funding. As one explained, the use of EU funding is not necessary for projects that are net beneficial. Assuming a meshed offshore network will only materialise if benefits outweigh costs, the EU should thus not be involved, according to organisations that share this perspective. Although political agreements or political debates are inevitable, this factor seems to be most positive towards a CBCA to distribute costs across beneficiary Member States. In this process, SEW should be the most important metric to assess.

Table 4-6: Perspective 3 statements, distinguishing statements marked with D.

Sorted on	#	Statement
-5 D	29	EU funding is the best mechanism to socialise infrastructural costs for a meshed offshore network
-5 D	7	Countries that do not experience reductions in CO_2 cannot be financially involved in the cost allocation principle
-4	18	Infrastructural costs should be allocated using an allocation key based on amongst others every Member States' GDP
-4	17	Infrastructural costs should be allocated using an allocation key based on amongst others every Member States' GDP per capita
-4 D	19	Infrastructural costs should be allocated using an allocation key based on amongst others the number of inhabitants per Member State
+1 D	44	CBCA is the preferred route over political agreements to settle cross-border costs for the realisation of a meshed offshore network
+4 D	6	Introducing a meshed offshore network will provide system flexibility gains and must therefore be included as a benefit in the CBA
+4	24	Costs should be allocated based on the expected distribution of socio-economic welfare per Member State involved

+4	10	Increased cross-border trade as a result of a meshed offshore network is a benefit that should be accounted for in the CBA
+5	1	Socio-economic welfare is a benefit that must be included in the CBA when designing a meshed offshore network
+5	12	Scenarios used to calculate the Cost-Benefit Analysis for the sharing principle should be set by a single European entity (ENTSO-E/ACER etc)

4.3.4 Perspective 4: Cautious pragmatists

The fourth perspective is shared by two participants, both with a TSO background. This perspective has the lowest explained variance but still explains a reasonable amount (11%). The distinguishing and defining statements of factor 4 can be found in Table 4-7. The generalised sort is provided in Appendix E.7.

This perspective is somewhat more moderate than the other perspectives, sometimes even conflicting, accepting solutions if they are pragmatic. On the one hand, participants are strongly against limiting the CBCA to hosting MSs, similar to perspectives 1, 2 and 3. On the other hand, the inclusion of non-hosting MSs is not definitive either in this perspective. Indeed, statement 38 is one of the distinguishing statements, being the only perspective to sort it on the negative side. It should, however, be noted that the perspective is positive to introduce a threshold to distinguish beneficiaries. As one of the participants elaborated, it is obvious that non-hosting MSs will need to contribute, yet it is important to reach a level of acceptability. This illustrates the underlying pragmatism, admitting that a perfect solution is probably not realistic. Therefore, measures like a threshold are essential to get to an agreement. Moreover, this perspective too prefers MSs to maintain control, advocating the use of the TSO model, similar to perspective 2. Pragmatism can also be found in the remarks made about the use of EU funding. Projects like a meshed offshore network will not materialise without help because it is a zero-sum game, according to one participant.

Furthermore, it appears that allocation keys involving GDP distinguish this perspective from others. This shows that in this perspective, demographics are also a possible allocation key to be used in the cost allocation. One of the participants stated that it is highly unlikely that the right compromise can be captured with a single metric. This means that the statements must be interpreted as such, potentially part of a combination with other metrics. From the generalised sort, SEW is a potential contender. Other than that, the allocation keys proposed were ranked negative in this perspective. In general, most choices in this perspective were made out of the conviction that they are necessary compromises to realise a meshed offshore network. However, throughout the analysis of this perspective, there remains a level of cautiousness, almost indecisiveness. It appears that there is no one strong belief in an approach to allocate costs, and decisions are made to reduce uncertainties. This is seen in setting the threshold and using EU funding to realise the meshed offshore network. Following this perspective, allocating the costs of a meshed offshore network would result in minimising the MSs involved to focus on the main indicator, relying on EU support to realise the project.

Table 4-7: Perspective 4 statements, distinguishing statements marked with D.

Sorted on	#	Statement
-5	37	Given the expansion of offshore wind capacity in a meshed offshore scenario, costs should be allocated amongst hosting MSs only
-5 D	9	In a cost sharing principle, more weight should be placed on congestion income raised as a result of the meshed offshore network
-4	28	If costs of a meshed offshore network are shared, countries are eligable to claim part of the interconnected Renewable Energy Capacity to their national targets
-4	7	Countries that do not experience reductions in CO_2 cannot be financially involved in the cost allocation principle
-4	20	Infrastructural costs should be allocated using the territorial principle
-1 D	38	All Member States that enjoy benefits from a meshed offshore network should contribute, hosting and non-hosting
+2 D	18	Infrastructural costs should be allocated using an allocation key based on amongst others every Member States' GDP
+3 D	17	Infrastructural costs should be allocated using an allocation key based on amongst others every Member States' GDP per capita
+4	29	EU funding is the best mechanism to socialise infrastructural costs for a meshed offshore network
+4	34	A threshold should be set to distinguish beneficiaries of a certain degree (eg >10%)
+4	24	Costs should be allocated based on the expected distribution of socio-economic welfare per Member State involved
+5	12	Scenarios used to calculate the Cost-Benefit Analysis for the sharing principle should be set by a single European entity (ENTSO-E/ACER etc)
+5	32	The TSO model is the desirable financing structure to realise a meshed offshore network in the North Sea (TSO pays infrastructure)

4.4 Similarities between factors

Thus far, the perspectives have been addressed individually, highlighting the statements that stand out for one particular perspective. However, there are also similarities to be found across perspectives. The first step to finding similarities is to assess the correlation between the factors from which the perspectives were drawn. This is listed in the correlation matrix in Table 4-8. A correlation value of 0,1 is considered small, 0,3 is medium and 0,5 is large (Cohen, 1988). There are some factors with a small correlation and some factors with a large correlation, meaning that there are areas of overlap in the perspectives. Factor 1 has higher values of correlations with factors 3 and

4, 0,53 and 0,42, respectively. Factor 2 shows lower values of correlations, with only 0,21 correlation with factor 4.

Table 4-8: Factor correlation matrix.

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1	0,3235	0,5272	0,4236
Factor 2	0,3235	1	0,3253	0,2057
Factor 3	0,5272	0,3253	1	0,4549
Factor 4	0,4236	0,2057	0,4549	1

Correlations between factors can be further examined by analysing the consensus statements. These are statements participants agreed upon across perspectives to some extent, based on the variance across factor Z-scores. A complete list of statements descending from consensus to disagreement can be found in Appendix E.8. This way, specific statements can be discussed with a level of detail that cannot be obtained from the perspectives alone.

Table 4-9: Consensus statements (* indicates significance ($p < 0.05$)).

		Factor Arrays			
No.	**Statement**	**1**	**2**	**3**	**4**
2*	Renewable Energy Supply integration benefits resulting from the realisation of a meshed offshore network should be considered in the CBA	1	3	1	2
3*	Reduction of Greenhouse gasses per country due to the realisation of a meshed offshore network should be considered in the CBA	1	2	1	3
4*	Gains in resource adequacy per country that can be attributed to the meshed offshore network should be considered in the CBA	2	2	3	2
5	All countries involved in the meshed offshore network will experience benefit of resource adequacy	0	1	2	0
8*	In a cost sharing principle, more weight should be placed on producer surplus over consumer surplus (countries with more PS should pay relatively more)	-2	-1	-3	-2
13*	Positive changes in transmission system losses that can be attributed to the meshed offshore network have to be included in the CBA as benefit	2	1	0	0
15	Costs should be settled with beneficiary Member States based on realised power flows resulting from the offshore network	-1	0	-2	-3
16	The sharing key in the CBCA should be based on CO_2 and non-CO_2 emission reductions realised in every Member State due to the network	-1	0	-2	0
23*	Infrastructural costs for transmission and interconnection should be covered in seperate, project specific CBCA decisions	-3	0	-2	-3
36*	Costs should be allocated using two CBCA's, one for hosting MSs and one for non-hosting MSs	-3	-2	-3	-2
37	Given the expansion of offshore wind capacity in a meshed offshore scenario, costs should be allocated amongst hosting MSs only	-4	-3	-3	-5
42*	Increased investment costs due to project delays have to be included in the CBCA	-1	-2	-2	0

In general, the significant consensus statements are relatively neutral, with only a few statements being ranked strongly positive or negative. Among the mildly positive consensus statements are some of the ENTSO-E benefit indicators (statements 2, 3, 4, 5, 8, 13). The main reason for being moderately positive that participants explained is twofold. There is one group of participants that see no reason for deviating from what is already done, seeing that the benefit indicators are currently used in CBAs. That being the case, there are other factors more important for a successful CBCA that they ranked higher because of this. Another explanation is that participants have reservations about the benefit indicators. As participants remark, surely it is good to include any benefit if it can be proven. The latter being the reason for holding back because it will be difficult to prove. Specifically, participants are sceptical about measuring emission reductions and other benefits. Characterising is the statement "I would be positive if it is possible" made by multiple participants.

Similar to the statements listed in the previous paragraph, the perspectives share a mildly positive view towards reduced transmission system losses to be included as a benefit (statement 13). In this case too, participants pointed out the difficulty of measuring changes in transmission system losses and attributing these changes to specific projects. Again, if benefits like these can be substantiated, participants are positive. On the other hand, participants would like to see several benefits included in the analysis, explaining that CO_2 and non-CO_2 emissions alone would not provide a fair allocation of costs (statement 16).

Furthermore, there is a shared view that producer surplus should not be given more weight than consumer surplus (statement 8). Multiple participants mentioned that consumers are not involved in the process. It is, therefore, important that consumers' interests are protected by the government. Besides that, participants see no reason to emphasise producer surplus, seeing that the total gain in welfare is made up of consumer and producer surplus.

Although settling of costs based on realised power flows has only been rated mildly negative (statement 15), there is a strong consensus amongst participants. Many of them sorted this statement negative, in the first place because it is deemed impossible to trace specific power flows across Europe. Even if we were able to trace power flows, participants are still sceptical. Either because they are not in favour of ex-post allocation or because participants are uncertain if power flows properly reflect the distribution of costs and benefits.

The consensus on statements 23 and 36 is explained by participants' aversion to unnecessary complexity, as came forward in several of the sorting interviews. Regardless of the reason for splitting the CBCA, participants replied that it would overcomplicate something that is already complicated to begin with. Aside from complexity, participants also stated their concern for uncertainties. The CBCA should take away uncertainties at hand, which is why many participants replied negatively to forms of ex-post corrections such as statement 42. On multiple occasions, participants mentioned that the CBCA's acceptability is of great importance. Complexity and uncertainties would not contribute.

Another view that is carried across all perspectives is that the CBCA should not be limited to hosting MSs (statement 37). The foremost reason is that a meshed offshore network will not materialise without the help of non-hosting MSs. Several participants expressed their concern for the realisation of a meshed offshore network by hosting MSs alone, suspecting it would put a halt to the green transition. As one of the participants remarked, benefits are not sufficient for hosting MSs to realise the full 300 GW on their own. In that case, hosting MSs would thus only build to their own needs. It should, however, be noted that coding revealed two participants that did not load significantly on one of the factors, to contradict these findings. Their motivation is that it will be difficult to prove net benefits to non-hosting MSs in a CBA that is uncertain to begin with, making the CBCA less acceptable.

4.5 Q methodology conclusions

This subsection marks the outcome of the Q methodology, following its steps leading to the formulation of four perspectives. This forms the basis for getting a better understanding of important criteria for the cost allocation of a meshed offshore network. The four perspectives – CBCA advocators, CBCA opposers, Technocrats, and Cautious pragmatists – all portray a unique view towards this.

In individuals that align with the CBCA advocators perspective, a preference is observed towards an extensive CBCA that includes all costs across all MSs that benefit. Furthermore, the effective implementation of this would necessitate centralised coordination from the EU. Contrastingly, the CBCA opposers prefer negotiating over tools currently available to allocate costs, such as the CBA and CBCA. The Technocrats perspective represents those that primarily focus on the benefits to be included in the CBA, which are also most optimistic about the CBCA. Lastly, in the Cautious Pragmatists perspective, any measure that contributes to the acceptability and feasibility of a cost allocation would be viable. In this regard, EU funding is regarded as contributing.

Despite the different approaches to the allocation of costs, there are also similarities between the perspectives. These were explored based on the consensus statements that were selected in the Q methodology. A CBA should cover the complete array of benefits that can be proven, to which the benefit indicators of ENTSO-E seem to be a good starting point. Besides this, another consensus is found concerning the reach of a CBCA, showing that non-hosting MSs should be included in the cost allocation of a meshed offshore if there is a benefit. In general, and on a higher level, acceptability is an underlying driver that was mentioned in all perspectives.

Identifying these perspectives can help to gain a better understanding of how countries align or differ on the allocation of costs of a meshed offshore network. Authorities can leverage this information to their advantage and potentially tailor CBCA recommendations accordingly. However, there is much information stored in the results that has not yet been explored following the steps of the Q methodology. In the next Chapter, the shortcomings, limitations and other findings are discussed.

5 Discussion

In this Chapter, the findings of the research are discussed in two sections. First, a brief recap of the literature study is provided in section 5.1.1. The findings from the Q methodology are discussed in section 5.1.2. Any findings that did not appear from the steps of the Q methodology are discussed in section 5.1.3. Next, the limitations and potential influence on the outcome of the research are discussed in section 5.2. Within this section the first sub-section discusses the general limitations of the research. The second sub-section discusses limitations to the methodology found throughout the research.

5.1 Findings

Various steps were taken during the course of this research to address the main research question. First, the findings that were obtained through literature research on the development of the offshore transmission network and allocation of costs across borders are discussed. Second, a Q methodology was performed to explore criteria for the Cross-Border Cost Allocation for a meshed offshore network in the North Sea. Lastly, there are findings to be explored that were not revealed in the process of the Q methodology.

5.1.1 Literature findings

The literature study in Chapter 2 showed that the electricity system is subject to major and fundamental changes, the biggest of which are still to come. The meshed offshore grid has a major impact on systems and involves high costs. In this study, the focus is on the issue of cost allocation, for which the experience in cost allocation of cross-border infrastructure projects is basic and insufficient for the cost allocation of a meshed offshore network. It remains to be seen whether a CBCA is robust for such an application. A meshed offshore network will have a great impact due to high costs, involving many actors that have been identified in the literature study. This is the basis for the research, which set out to explore if and how a CBCA can be used to allocate costs for a meshed offshore network.

5.1.2 Q methodology findings

Taking the findings from the literature study as a starting point, the Q methodology was used to explore the most important criteria for the cost allocation of a meshed offshore network. Following input from several experts, four key criteria were selected to be explored in this research. The Q-set was designed based on relevant benefits, possible allocation keys, aspects of political acceptability and aspects of time. Given the multilateral nature of a meshed offshore network, the research sought to involve TSOs, NRAs and ministries from all North Sea countries. Through the Q methodology, four distinct perspectives emerged regarding cost allocation for a meshed offshore network in the North Sea.

The most important consensus revealed by the perspectives concerns the reach of the CBCA. Although there is no consensus on its limits, findings reveal that all perspectives mean to include non-hosting MSs in the CBCA. In this context, limiting the CBCA to hosting MSs would not result in a meshed offshore network of 300 GW capacity. Hosting MSs would lack the motivation to pursue the EU goals for the North Sea as this would grossly exceed their own interest.

Furthermore, the benefit indicators from ENTSO-E's latest guideline seem to offer a good starting point for the allocation of costs, provided that the benefits can be monetised and calculated with certainty. The results emphasise the significance of including the benefits discussed in this research in the CBA, with many participants stressing the need for a comprehensive CBA. While not all benefits hold equal weight, SEW emerged as the most favoured benefit indicator across all perspectives. Nonetheless, a unanimous agreement on the potential cost-sharing mechanism was not reached. The findings reveal that no single metric can fully capture the necessary balance for a successful cost allocation in the meshed offshore network scenario. Instead, suggestions were made to incorporate multiple metrics in the allocation key.

The research findings also reveal several significant points of disagreement between the perspectives. Despite previous successful CBCA decisions, participants were hesitant to apply this methodology in a meshed offshore network scenario due to its complexity and various interests at play. Surely, the CBCA provided a solution in previous cases. However, a meshed offshore network scenario would reveal the shortcomings of the CBCA methodology, according to participants. Notably, the findings highlight the fact that there is no agreement on the ideal structure for a CBCA of a meshed offshore network in the North Sea. Points of contention include:

1. Whether the CBCA is the right tool for the cost allocation of a meshed offshore network at all.
2. Whether EU funding should be used to realise a meshed offshore network
3. Whether a threshold should be set to distinguish beneficiaries based on their degree of benefit.
4. Whether scenarios should be set by a single entity or alternatively, there should be competition in setting the right scenarios.
5. Whether congestion incomes should be eligible for redistribution.
6. Whether a national rollout should be included in the CBCA, or alternatively, the CBCA should encompass all investment costs, including national rollout scenarios.
7. Whether the CBCA should include OPEX or that it should be limited to CAPEX.

The disagreements found between the perspectives are an indication that a CBCA for a meshed offshore network in the North Sea will not receive sufficient support from MSs. Therefore, a CBCA may not be the optimal tool to find a suitable cost allocation at this point. Due to politics' short-term focus and inability to overcome differences of the scale that a meshed offshore network poses, the route of multilateral agreements is not desirable either. As a result, the research highlights an impasse with regard to the allocation of costs for a meshed offshore network.

Besides a lack of agreement on the way a CBCA decision should be made, findings also reveal that there is no consensus on the role of the EU in the meshed offshore network scenario and the CBCA. Findings indicate that regardless of the perspective, participants generally prefer a level of autonomy while also expressing a desire for the EU to assume a leadership role in certain aspects of the CBCA.

In terms of funding, findings do not provide clarity. In some cases, EU funding is found to be desirable as a means to realise a meshed offshore network. In other cases, EU funding is disqualified if a project is net beneficial. These are fundamental elements that need to be sorted to find an agreeable allocation of costs for a meshed offshore network.

5.1.3 Additional findings

All findings that were discussed in 5.1.2 concern findings that were obtained following steps of the Q methodology. Despite thorough analysis of the output data using KenQ analysis and PQMethod, certain outcomes have not yet been fully explored. Upon further examination of the interviews and data, additional insights have come to light. As such, this section delves into these newly discovered findings, which have emerged over the course of the study.

PQMethod provides a list of statements sorted from consensus to disagreement based on the variance across factor Z-scores, which can be found in Appendix E.8. From this list, the program compiles a list of consensus statements that was subsequently used to discuss similarities between perspectives. The consensus statements are defined as "those that do not distinguish between ANY pair of factors". Any statement that is distinguishing for one of the factors is left out. However, PQMethod does not provide a selection of disagreement statements. This could provide a better understanding of the points of disagreement that would need to be overcome in the CBCA for a meshed offshore network. Statements of disagreement and consensus statements worth discussing are listed in Table 5-1.

Table 5-1: Disagreement statements and remarkable statements.

		Factor Arrays			
No.	**Statement**	**1**	**2**	**3**	**4**
35	EU funding/subsidies for CBCA projects should only be used to compensate for/cover costs otherwise charged to small beneficiaries falling below the threshold	-4	-2	-1	-3
1	Socio-economic welfare is a benefit that must be included in the CBA when designing a meshed offshore network	5	2	5	3
25	Subsequent onshore grid expansion has to be included in the CBCA for the infrastructural costs of an offshore meshed network	4	4	2	1
24	Costs should be allocated based on the expected distribution of socio-economic welfare per Member State involved	5	1	4	4
32	The TSO model is the desirable financing structure to realise a meshed offshore network in the North Sea (TSO pays infrastructure)	3	5	3	5
39	If costs turn out to be higher than the expected costs at the time of the CBCA decision, there should be a correction	2	-4	-2	2
26	Meshed offshore network infrastructure supports Offshore Wind exploitation, therefore offshore connection costs should be raised so that offshore generators contribute a fair share	0	5	0	-1
20	Infrastructural costs should be allocated using the territorial principle	-3	4	-3	-4

29	EU funding is the best mechanism to socialise infrastructural costs for a meshed offshore network	3	-1	-5	4
12	Scenarios used to calculate the Cost-Benefit Analysis for the sharing principle should be set by a single European entity (ENTSO-E/ACER etc)	2	-5	5	5

The perspectives clearly share a negative view on limiting EU funding to the blind spot that would be created using a threshold. Participants highlight that EU funding may be necessary to establish a meshed offshore network. Therefore, it would be premature to rule out any other form of EU funding beforehand. However, Table 5-1 reveals a disagreement on EU funding as well (statement 29). This is the second-most frequently discussed statement among participants, indicating that it's a highly contested topic in this research. As this is one of the highly contested topics in this research, an overview of popular arguments is found in Table 5-2, obtained from the coding of transcripts. As a middle ground, regional funds or combined funds with private investors were also mentioned.

Table 5-2: Arguments on EU funding mentioned during interviews.

EU funding			
+	Without EU funding, a meshed offshore network will not materialise	-	There is no need for EU funding in net beneficial projects
+	EU funding can partially take away the complexity of a CBCA for a meshed offshore network	-	Realising a meshed offshore network through EU funding would be “a CBCA through the back door”. Implicitly stating that MSs are not willing to contribute
+	Meshed offshore network follows EU targets, hence the EU should help realise the project	-	EU funding has to come from somewhere as well

As mentioned in section 5.1.2, SEW appeared as the most favourable of all benefits listed in the Q-sort. Across perspectives, SEW was widely regarded as the most important benefit indicator to be included in the CBA. As most participants noted, SEW is important because it is seen as the broadest, most complete benefit indicator available. On the other hand, one of the participants remarked that however comprehensive the SEW may be, it is important to include more benefit indicators. All perspectives are, to a greater or lesser degree, in favour of allocating costs based on the expected distribution of SEW (statement 24).

Another important statement that did not come forward in the analysis of the Q method results is the slightly irregular view on onshore grid expansion (statement 25). Across perspectives, participants are, to a greater or lesser extent, in favour of including the onshore grid expansion in the CBCA for a meshed offshore network in the North Sea. On the one hand, participants pointed out that there is no point in leaving the onshore grid expansion costs out of the CBCA, seeing that they are inherent to the offshore network. On the other hand, participants also admit to the difficulty of pointing out the exact grid expansions necessary for the offshore network and those expansions necessary for other uses. Because of this, as coding revealed, it will be difficult to include onshore grid expansion costs in a transparent way. This means that, although favour including onshore expansion costs varyingly, it will be very difficult to do this in a way that is supported.

The last statement that perspectives positively agree upon regards the TSO model (statement 32). Across perspectives, participants are positive towards the continued implementation of the TSO model to realise a meshed offshore network. While the statement itself may have been somewhat ambiguous, with the TSO model being intended to signify control and governance over offshore infrastructure, participants thankfully understood its intention. The importance of maintaining control over the offshore network was stressed, especially with the introduction of HVDC cables. Accountability is needed, and, in that case, control by private parties would be undesirable. As another participant pointed out, the offshore investments are highly related to onshore developments, so they are best taken into account via the TSO model. This implies that in any outcome of cost allocation, TSOs have to retain ownership and governance over their subsequent part of the meshed offshore network infrastructure.

The ex-post correction of costs in case of financial setbacks that was proposed in statement 39 was met with mixed responses across perspectives. In essence, this is a matter of risk management. Participants recognise the importance of addressing risk in the CBCA to cover for potential cost overruns. Even then, participants point out the uncertainties in predicting project costs over a timeline of five to ten years or more. On the other hand, participants are hesitant to engage in endless reallocation of costs, which would effectively reopen the CBCA decision. Moreover, if costs escalate due to negligence or deliberate actions of a MS, reallocation should not be considered as a viable option.

Throughout the sorting process of the Q methodology, statement 26 sparked interesting discussions on making generators contribute more through offshore connection costs. Most participants were reluctant to favour this statement, fearing that offshore connection costs would compromise a business case that is already slim. Referring to the UK, where tenders for OWF projects remained unanswered. However, a smaller group of participants opposed this, stating that it is more important that costs are charged to profits. Given that the CBA includes both PS and CS, it seems only reasonable that costs are also shared by producers and consumers. In response to the business case remark, it is up to the generators to determine what share of the costs is pushed into the market. Market competition would prevent generators from discounting the total connection costs in their tariffs. Furthermore, this group of participants believes that this approach would bring tariffs closer to the cost-reflectivity principle.

Lastly, statement 12 stands out as a contested statement across the perspectives. Regarding scenarios set by a single European entity, participants had varying views. Some were in favour of a centralised approach, highlighting the benefits of having a common ground to succeed in the CBCA. According to this group, negotiating over scenarios will not result in an agreement. Contrastingly, participants who disagreed with the statement actually prefer scenarios to be established through competition. According to them, it is unlikely that a common body imposing a CBA approach would be accepted, lacking support from TSOs. Furthermore, several participants, including participants in favour of centralised scenarios, stated that in any case, it should not be ACER setting the scenarios.

5.1.4 Support base

Throughout the research, several issues and complexities from different disciplines have been identified that must be resolved to allocate costs for a meshed offshore network in the North Sea. Although several differences were found between perspectives, several participants implicitly indicated an underlying problem that must be resolved to allocate costs for a meshed offshore network. Over 600 pages of transcripts were produced and coded, showing that participants implicitly agree that there is a lack of support for the development of a meshed offshore network and the subsequent allocation of costs. In this case, a lack of support means that measures taken in the cost allocation are unlikely to be supported or accepted by MSs or actors involved, which can be for several reasons. For example, if the costs for onshore grid expansion are to be included in the CBCA as well, participants doubt whether this can be done transparently. In similar other statements throughout the research, participants tried to oversee whether a certain approach to the allocation of costs would be internationally supported. The ramifications of a statement would often lead to complexity, which would compromise the support base. Proceeding to a meshed offshore network, the lack of support base poses a barrier to agreeing on a certain allocation of costs. In essence, this would mean that differences will be too great to overcome or compromise. A lack of support slows MSs in their push for a renewable, integrated energy system. Therefore, international support is another important criterion in finding a solution for the points of disagreement identified in this research.

5.2 Limitations

In the following section, the limitations of this research are discussed. The limitations provide a better understanding of how the findings of this research should be valued. This is addressed based on the different phases of the research. In the first section, general assumptions that were made to conduct the research are discussed. Second, any limitations or shortcomings of the Q methodology are discussed.

5.2.1 General assumptions

Perhaps the most important limitation to mention concerns the overall CBCA approach that is addressed in this research. As mentioned in the literature study, the CBCA has been applied to several projects, but not a single project is comparable to the concept of a meshed offshore network. Conceptually, each MS has a network that consists of generation and load, both situated on land. The system is structured in such a way that the costs are distributed across the load. The load is usually a known area within MS's borders, or rather, the bidding zone. A simplified visualisation of the current system is shown in Figure 5-1. It should be noted that the distribution of costs across the load applies to MSs individually, not across MSs as the figure might suggest. Several actors play a crucial role in this setup. The TSO manages the transmission system and is responsible for the transmission system. The TSO is either privately owned or state-owned. Regardless, the TSO is always under regulatory supervision. Additionally, the Minister of Finance ultimately assesses whether the investments made are in the interest of society or the state, advocating for the state's economic interests. These two entities may not always agree on certain investments. Finally, there is a National Regulatory Authority overseeing the market. These actors all have different interests and uncertainties.

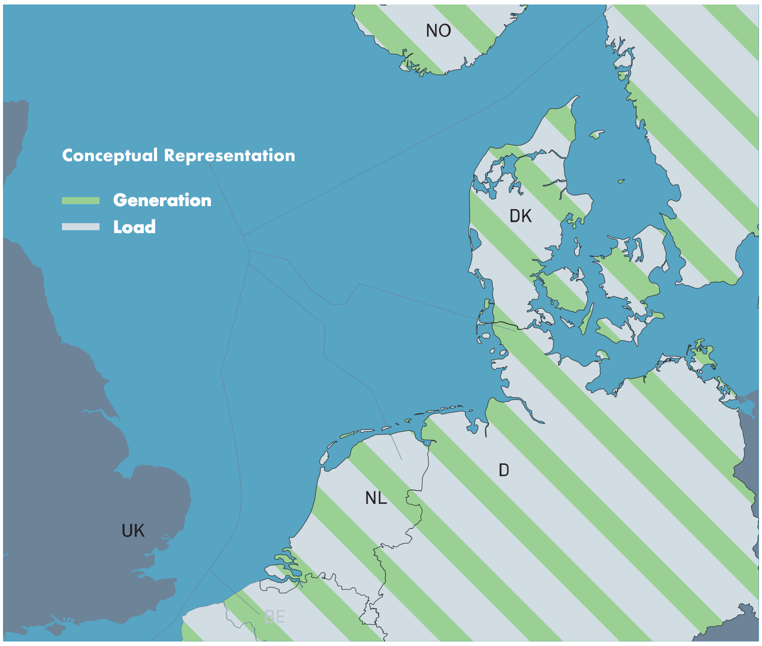

Figure 5-1: Conceptual visualisation of the current system, generation in green and load in grey.

With the introduction of a meshed offshore network, the generation and load are no longer in close proximity. Instead, there is a significant concentration of offshore generation without a corresponding load, as can be seen in Figure 5-2. Moreover, generation now transcends the national load mentioned in the previous paragraph. This means that the area of load on which costs are charged must be redefined and is longer bound by MS borders. In the Figure, this is shown with the dotted line. The question then arises where costs should be incurred to cover for the generation and infrastructural costs. In other words, what is the extent of the CBCA or any other measure to allocate costs? And more importantly, as a shortcoming, how would that address the uncertainties and risks for different actors in each MS, such as a ministry of finance or the TSO? Their interests and uncertainties differ, and it is questionable whether the CBCA answers these uncertainties. This implies that in this research, but also in general, a conventional framework is being applied to a new concept. The question remains whether examining this issue at the EU level provides insights into relevant underlying developments and whether these can be addressed in one research. To conclude, the limitation is assuming the CBCA approach to allocate costs for a meshed network, which is a conventional concept applied to something that is conceptually different from what is known. However, reviewing the costs sector-by-sector is not in the scope of this research.

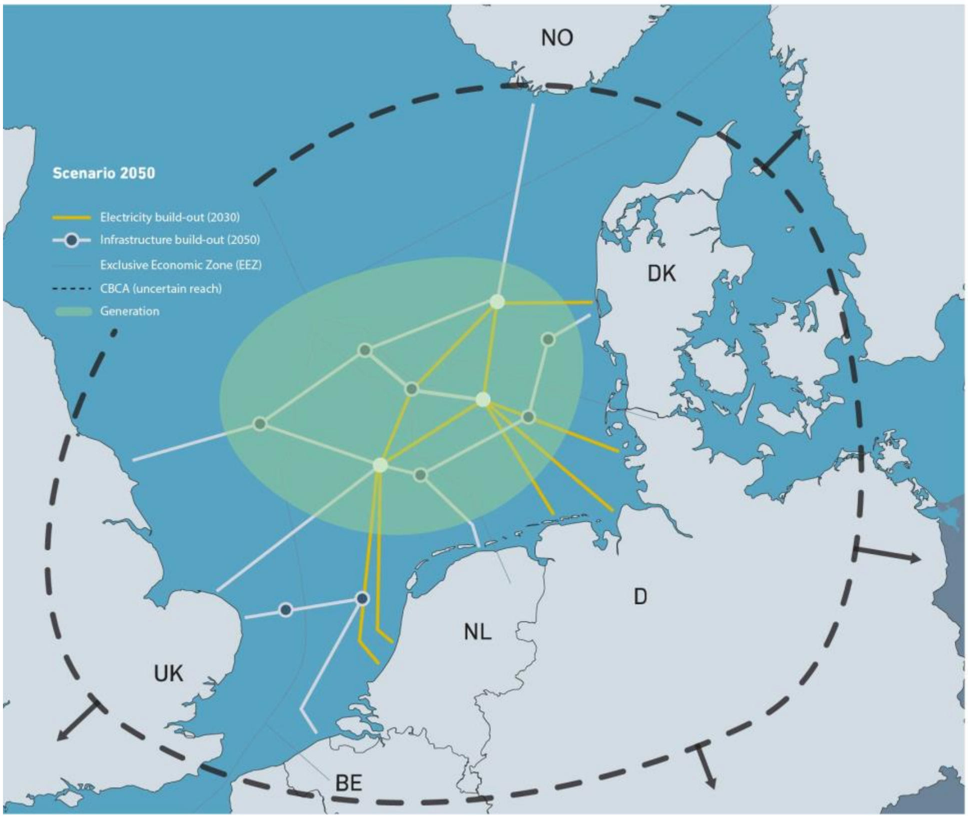

Figure 5-2: Visualisation of the conceptual difference of a meshed offshore network.

The next simplifications that were adopted in this research are the exclusion of the UK and the exclusion of non-hosting MSs. Although it is highly likely that the UK will participate in a meshed offshore network scenario, the choice was made to exclude UK participants from the research because of the additional complexity of the UK's involvement due to Brexit. In this line of reasoning, Norway would also be excluded on the basis of not being a member of the EU. However, Norway is part of the European Economic Area (EEA), which guarantees equal rights and obligations within the internal market, including for energy (Delegation of the EU to Norway, 2021). Therefore, Norwegians were invited to participate in the research. Closely related, the assumption is adopted that following EU regulation, a meshed offshore network is eligible for the PCI status and subsequent CBCA route. If this is not the case, CBCA is ruled out, possibly influencing the perspectives resulting from the participants' stated preferences.

As mentioned, participants from non-hosting MSs were excluded from the research as well. As it turned out throughout the research, finding participants willing to participate proved to be a time-consuming process. During this process, the choice was made to focus efforts on hosting MSs. However, as the results point out, there appears to be a consensus on the inclusion of non-hosting MSs in the cost allocation. This means that if the goals of 300 GW in the North Sea are to be achieved, non-hosting MSs must contribute. If non-hosting MSs were included, this consensus might not have come to light, but on the other hand, the willingness of non-hosting MSs remains unknown. Therefore, no conclusions can be drawn from this research on the willingness of non-hosting MSs to contribute. Despite this, actors from several MSs participated, resulting in this small-scale international research.

5.2.2 Reflection on Q methodology

This section discusses the limitations of the Q methodology applied in this research. The approach of Q methodology applied to the criteria for the cost allocation of a meshed offshore network is discussed in Chapter 4. Throughout this process, shortcomings and limitations of the methodology were identified, and choices were made to proceed.

The first limitation that can impact the outcome of the Q methodology concerns the significant factor loadings. The formula mentioned in section 3.6.1 is used to determine the significant factor loading level. This is the more stringent significance level of $p < 0.01$. However, the researcher can choose to manually raise the level further to optimise the number of participants with significant loadings (Watts & Stenner, 2005). In this research, raising the significance level would lead to more participants loading significantly and, thereby, fewer Q-sorts confounded. On the other hand, adding participants to factors that already satisfy the statistical requirements in theory makes the factors more generic. Because of this, a decision was made not to raise the significance level. This is likely to influence the outcome of the research as additional participants will change the generalised sort of their respective factor. This means that depending on the arbitrary decision of the researcher, the Q methodology will provide a different outcome.

Comparing the sorts of participants that loaded significantly on a factor to their resulting generalised sort, another shortcoming of the methodology is found. For instance, in factor 2, one participant sorted statement 15 at -5, whereas the other participant sorted the statement at +5. Subsequently, statement 15 is positioned at rank 0 in the generalised sort. Because of this, statement 15 does not appear in the analysis of the factor. Surely, this is inherent to a “generalised” outcome that resembles the average of all inputs. However, it casts a level of uncertainty over the outcome of the research, as it is difficult for the researcher to determine the extent of this shortcoming. This means that an unknown amount of data potentially remains hidden in the perspectives.

Another limitation that should be noted is the validation of perspectives drawn from the data. Based on the generalised sort and elaborations provided in the interviews by participants, the perspectives were formulated. The interpretation of the perspectives should be validated with experts outside the P-set. Although some validation sessions were held with credible experts, the validation of the perspectives could have been more elaborate. Furthermore, the set of experts involved in validation does not match the level of internationality of the research itself. However, within the timeframe, the validation, including the involvement of ACER, is considered valuable.

Although there are no definitive requirements for the distribution of statements across different topics within the concourse, it should also be noted that there is a skewness in the Q-set in relation to the four themes identified in the concourse. Based on the process described in Appendix A, time appeared to be a somewhat less interesting theme compared to the others. Subsequently, time was only included in five statements compared to the other themes that were addressed using 12-14 statements. As a consequence, it must be understood that this research can only provide generic insight into time-related aspects of the cost allocation of a meshed offshore network.

Lastly, there are three methodological shortcomings worth mentioning that stuck out throughout the research. First of all, even though participants were stimulated to elaborate their sorting process, the

Q methodology does not gather information on all statements included in the Q-set. This is a limiting factor in formulating a perspective from a factor, as there is no context provided with some of the statements that end up in the extremes of the generalised sort. Second, the factors extracted from the data do not capture all data gathered in the interviews. Following the methodology, input from several participants is discarded from the factors that form the perspectives. Therefore, there may be important considerations that did not emerge in the perspectives simply because they are not widespread amongst participants. Lastly, there is no control over the completeness of the Q-set used in the research. Some components important to the allocation of costs may thus be overlooked in this research.

The Q methodology proved to be a valuable methodology for exploring the perspectives in a highly varying field of actors. However, it does not provide a conclusive answer on how the costs of a meshed offshore network should be allocated. However, it provided valuable insight into the issues that must be addressed to find a way of allocating costs that will be internationally supported. In this regard, this small-scale international research, despite its shortcomings and limitations, provides a better understanding of trade-offs that will potentially play a role in finding the right cost allocation for a meshed offshore network in the North Sea. This can form the basis for further research, which, given the complexity of the subject and its impact on other systems, will undoubtedly be necessary.

6 Conclusion

Conclusions are drawn in this chapter from the outcomes of this research. First, the answer to the research question is discussed. Following the conclusion of the main research question, the its implications are reflected in section 6.2. Furthermore, the academic and societal relevance is reflected in sub-sections 6.2.5 and 6.2.6. Lastly, recommendations on future research and a personal reflection on the research are discussed in sub-sections 6.2.7 and 6.2.8.

6.1 Research Question

The goal of this research is to explore the cost allocation of a meshed offshore network in the North Sea. The EU has developed a strategy to achieve the climate goals set in the Paris Agreement, with a significant role assigned to offshore wind electricity in the North Sea. The North Sea will become the powerhouse of Europe, providing 300 GW of offshore wind electricity. To achieve this, the offshore transmission system will significantly expand in the years to come. Radial connections will make way for hybrid connections, and in the end, a meshed offshore network could be a cost-efficient solution to bring 300 GW of electricity to shore. The costs of a meshed offshore network are expected to be high, and the 300 GW goal exceeds the interests of North Sea countries with potentially more beneficiaries in Europe. The complexity of the allocation of costs for a meshed offshore network resulted in the research question:

How can the costs of a meshed offshore network in the North Sea Basin be allocated?

Except for multilateral agreements, the CBCA is the designated procedure to allocate costs in cross-border electricity infrastructure projects. To explore how different actors perceive the key criteria for the cost allocation of a meshed offshore network, Q methodology was used to conduct this research. This resulted in four perspectives that provide insight into different views on the possible ways to allocate costs across borders for a meshed offshore network. Analysing these perspectives revealed points of agreement and disagreement.

The most important conclusion is that if MSs and the EU continue to push for an offshore capacity of 300 GW in the form of a meshed offshore network, then non-hosting MSs must contribute one way or another. The inclusion of non-hosting MSs was widely agreed upon, and many participants agreed that there would be so many costs involved that a 300 GW offshore network will never be realised without their contribution. At the same time, many participants agreed that the CBCA is not necessarily the best way to allocate costs across MSs. Based on the points of disagreement found, this research comes to the same conclusion. There are too many complicating factors related to the meshed offshore network to get MSs to agree on the outcome of such a cost-allocation procedure.

The following points of disagreement were found within the scope of this research. There is no clarity on the role that the EU should take in the cost allocation, both financially and in terms of governance. It remains unclear whether costs for onshore grid expansion should be included in the CBCA and whether this can be accomplished in a transparent way. Furthermore, participants did not agree on whether small beneficiaries should be cast out of the CBCA using a threshold. But even something elementary as the extent of the costs was agreed upon. Some will limit the CBCA to CAPEX. Others will include OPEX as well.

Considering these points of disagreement, it seems that the current procedure to allocate costs across borders lacks a base of support. It is unlikely that the CBCA will provide a cost allocation that will be accepted by MSs, as the differences are too significant and the stakes too high to compromise. Therefore, a CBCA is currently not suitable to allocate the costs of a meshed offshore network. However, the research revealed points of agreement as well. In finding a cost allocation for a meshed offshore network in the North Sea, it will be important to monetise as many benefits gained from it as possible. Furthermore, there is a consensus that the CBA can serve as a basis for the CBCA or any other cost allocation procedure, as benefits will provide the best justification for costs allocated to MSs. Ultimately, there is a willingness to engage in a certain procedure to allocate costs across hosting and non-hosting MSs, which will be essential to realise a 300 GW meshed offshore network.

6.2 Reflection

6.2.1 The future of CBCA

If MSs and the EU continue to push for an offshore capacity of 300 GW, then non-hosting MSs must contribute to the offshore infrastructure one way or another. That is perhaps the most important finding from the Q methodology analysis. However, the research revealed several points of disagreement with regard to the cost allocation of a meshed offshore network in the North Sea. Based on these points of disagreement, it seems unlikely that the CBCA will, in its current form, be suitable to provide an agreeable allocation of costs. As some form of cost allocation must be achieved, the findings indicate two possibilities to proceed.

In the first option, MSs adhere to the CBCA procedure. Given the problems and points of disagreement identified in this research, changes must be made to the CBCA. This would entail exploring what conditions and aspects are missing that should be incorporated in the CBCA to make it more suitable for the cost allocation of a meshed offshore network. The points of disagreement discussed in sections 5.1.2 and 5.1.3 could be a starting point in this regard. Thought must be given to clarify the role of the EU in realising a meshed offshore network, to the scenarios used in a CBCA, to an agreeable method of including onshore grid expansions related to the meshed offshore network and to the distribution of costs to load and generation, and whether this would be something to include in the CBCA or to be decentralised.

In the second option, concluding that the CBCA is inadequate to allocate costs for a meshed offshore network, the notion of using a CBCA to allocate the costs of a meshed offshore network is abandoned. Given the scepsis participants expressed throughout the research on politics' ability to come to an agreement on the allocation of costs, abandoning the CBCA means redesigning the system of cross-border cost allocation for projects of a certain scale. Although it is difficult to oversee the consequences, this will have an impact on the development of a meshed offshore network, and perhaps even on the future of the electricity market. How this would relate to the EU system of governance remains to be seen. In general, the EU does not tailor policies to a specific area, meaning that the same rules apply in the Mediterranean, the Baltic and the North Sea. The EU's flexibility in facilitating a specific regulatory framework for a meshed offshore network in the North Sea should not be overestimated.

Lessons might be drawn from the past in finding the right approach to allocate the costs of a meshed offshore network. However, there are no comparable electricity infrastructure projects yet. Perhaps the Nord Stream projects come closest to the meshed offshore network concept in terms of scale and number of countries involved. In general, ACER's monitoring report showed a small number of gas projects with successful CBCAs, including to non-hosting MSs. In that regard, it might be interesting to find out more about these CBCAs. However interesting the comparison to cross-border gas projects may be, it should be noted that the characteristics of gas are significantly different from electricity. The uncertainties of benefits and costs of gas are hardly comparable to those of electricity, which is something to bear in mind.

6.2.2 Supranational dilemmas

Based on the conclusion, hosting MSs will attempt to include non-hosting MSs in the cost allocation. What is the meaning of this, considering the way climate targets are set in the EU? As mentioned before, climate targets are set internationally, following the Effort Sharing Regulation. Based on GDP and GDP per capita, climate targets are established per MS. In doing so, different financial capacities of MSs to act in fighting climate change are meant to be recognised. However, in the case of the North Sea, these targets and subsequent costs grossly exceed national interests. Although climate targets have been set based on their financial capacity, hosting MSs will follow a cross-border cost allocation procedure to make non-hosting MSs contribute. If that is the result of ambitious climate targets, the methods for setting climate targets for individual MSs should perhaps be reconsidered. Moreover, a successful cost allocation to non-hosting MSs opens Pandora's box, as other MSs are, in turn, likely to seek reimbursement from neighbouring MSs in their projects.

The insights gained in this research indicate that a lack of supranational coordination and enforcement is one of the underlying problems. Once the climate targets have been set, MSs are responsible for their own targets and the way they are achieved. In this regard, there is hardly any supranational coordination or enforcement. Given the complexities of a cross-border cost allocation procedure on the one hand and the short-term orientation of politics on the other hand, it seems unlikely that MSs will succeed in the cost allocation of a meshed offshore network on their own. Proceeding without supranational coordination and enforcement is, therefore, unlikely to lead to a meshed offshore network of 300 GW.

There might be a reason why the EU is reluctant to assume the position of supranational coordinator, as the EU's coordination of a meshed offshore network and subsequent enforcement on the MS level might be perceived as an infringement of the MSs' sovereignty. This makes any take-off difficult, but one of the actors must take the lead and make the first move to realise the 300 GW meshed offshore network. To quote one of the participants: "At some point, somebody has to stick out their neck.". The question is which actor that should be. The insights gained throughout this research and the complexities of both cost-allocation procedures and politics indicate the need for supranational coordination. Coordination that exceeds setting MS climate targets.

6.2.3 Actor responsibilities

In this research, several actors have been identified, each with different powers and interests. In the literature study, the Systems-of-Systems theory was used to position this research. Introducing a meshed offshore network raises many questions across different systems and disciplines involving different actors. It should be noted that this research is a contribution in a much larger system that will be impacted by a meshed offshore network. Therefore, many technological, regulatory, and other questions remain unanswered. Based on the findings in this research and the actors related to the cost allocation of a meshed offshore network, the following distribution of responsibilities appears to be suitable.

Given the fact that some form of cost allocation is needed either way, it is essential that the eventual cost allocation is supported by the MSs. Based on the actor positions, it seems best to resolve the underlying lack of a base of support on a supranational level. A first step for the EC could be to get MSs to agree on the configuration of the infrastructure necessary to accommodate an offshore RES capacity of 300 GW, both offshore and onshore. Once that has been established, a baseline can be formulated, specifying requirements that each MS must comply within a certain timeframe. This might provide better alignment of the European integrated system, and by doing so, the costs associated with a meshed offshore network can be managed more easily. Such a baseline could contribute to the overall base of support for the cost allocation process.

Actors like ENTSO-E and ACER could assist the EC in this process on a more specific level by engaging with the TSOs, NRAs, and ministries of MSs involved to explore different aspects of the meshed offshore network and subsequent cost allocation. In this regard, onshore grid expansion, scenarios used in the CBA and the possibilities of congestion incomes could be a starting point. By starting with the technical aspects of the meshed offshore network, actors can try to explore the certainties and uncertainties better before it becomes a political discussion. By gathering input from all actors involved, a better overview of the full impact of the meshed offshore network could be obtained first.

Subsequently, TSOs and ministries must do their work on a national level to provide input to ENTSO-E and ACER. On a national level, TSOs and ministries must work out the full impact of a meshed offshore system on their electricity system, both offshore and onshore. Within the TSOs and ministries invited to participate in this research, only a handful of people are working on the subject of cross-border projects and the subsequent allocation of costs. Therefore, it is recommended that TSOs and ministries expand their understanding of the impact of a 300 GW offshore capacity. Perhaps some of the uncertainties can be diminished this way, trying to get as much understanding of the costs, benefits and uncertainties before it proceeds to a political discussion.

6.2.4 Scope and methodology

This section discusses the scope and the methodology of this research and their possible impact on the findings. First of all, for the cost allocation, the meshed offshore network was considered as a whole. Participants were asked to rank the statements accordingly. In reality, however, a 300 GW meshed offshore network will probably emerge gradually over the decades to come. Considering the costs of the meshed offshore network as a lump sum might overcomplicate the cost allocation, and because of that, participants might be more sceptical about the cost allocation compared to a gradual approach. However, there are several reasons to research the cost allocation of a meshed offshore network as a whole compared to a gradual approach. Surely, the meshed offshore network will emerge gradually over the next decades. But it seems unlikely that costs will be allocated to non-hosting countries in that case. As seen in ACER's monitoring report, that has not happened yet, and there is little reason to believe that this would change in the future on a project specific basis. Furthermore, in a meshed offshore network, the investments are conditional to the previous investments, and new projects also have an impact on the value of existing infrastructure. It would be difficult to incorporate this in each CBCA that follows, and above all, it means that strategic behaviour can frustrate the development of a meshed offshore network. Lastly, it seems undesirable to have a CBCA for every project or timestep of the meshed offshore network.

Second, a choice was made to keep hydrogen out of the scope of this research. In reality, plans to include hydrogen as a carrier of energy in the meshed offshore network are already being discussed. If hydrogen is to be used to transport a part of the 300 GW to shore, then the costs for the electricity infrastructure will be lower. This would also apply to the onshore grid expansion, although the total offshore capacity remains the same and the energy produced must somehow be transported to other MSs. In that regard, nothing changes to the fact that non-hosting MSs must contribute through some form of cost allocation procedure. Although it is beyond the knowledge gained in this research, hydrogen seems to be closer to the characteristics of gas than the characteristics of electricity. Because of this, it seems likely that the uncertainties of the costs and benefits of the hydrogen infrastructure are smaller than those related to the electricity infrastructure, which might take away some of the complexities in the cost allocation procedure. It should, however, be noted that it remains to be seen if hydrogen generated in the North Sea can compete with hydrogen generated in the Middle East, as it is expected to be much cheaper due to the abundance of solar energy.

In section 5.2.2, the Q methodology was reflected upon but in this section, the choice for the Q methodology in this research is reflected upon. Given the introduction of a meshed offshore network and its unprecedented scale and complexity, the conclusion that the CBCA is not suitable to allocate the costs of a meshed offshore network may not be a surprise. However, this is not the main finding of the research and reflecting on the insights gained with the Q methodology, it appears that the methodology has been of added value nevertheless. Through the combination of qualitative and quantitative research, the Q methodology has provided a better understanding of different perspectives on how costs should be allocated, especially given the organisations involved in the research. Given the political nature of the subject, anonymity was required. Because of that, it was not possible to assign certain perspectives to certain actors. Regardless, the Q methodology allowed to research the underlying worldviews of participants through stated choice and preference rather than asking for their opinion. This reveals an underlying view on the cost allocation. Combined with participants being able to speak more freely under anonymity, the Q methodology is less prone to strategic behaviour from participants compared to other research methods that could have been conducted.

However, several limitations and shortcomings have also been identified in section 5.2.2 that may have affected the results of this research. The titles of the perspectives have been set somewhat extreme to give the reader a sense of the different perspectives that could be involved in the cost allocation of a meshed offshore network. The reality of the policy debates and negotiations is a much more complex process and more nuanced than it appears in the Q methodology. The perspectives should not be seen as an indication of how actors will behave, nor should they be used to categorise actors.

6.2.5 Academic relevance

Having reflected on the outcome of the research, the academic relevance is reflected upon in this section. As the literature study was primarily used to find the basis for this research, it showed that in the electricity sector, there has never been a CBCA decision that included non-hosting MSs in the cost allocation of a cross-border project. Based on this, the Q methodology was applied to explore several perspectives from relevant actors on the cost allocation process of a meshed offshore network. In doing so, this research is the first to include many actors involved in the possible cost allocation process of a meshed offshore network. Introducing the Q methodology to explore this discussion has never been done before, and in this regard, exploring a new application of Q methodology. Based on the perspectives that resulted from the analysis, Q methodology provided new insights on how several relevant actors prioritise different elements of a meshed offshore network in the cost allocation process. Furthermore, the elaborations provided by participants throughout the process provided industry-specific insights. Because of the anonymity provided, participants were open to sharing their thoughts on the subject. Exploring the underlying worldviews through stated preference using Q methodology can be interesting for future academic research. This application of Q methodology in a highly political, international debate has certainly contributed to the understanding of the relationship between large-scale infrastructure cost allocation and the system of actors involved.

Furthermore, the academic strength of this research can be found in the analysis of the actors to be involved in this research. Combining literature and theory on multi-actor systems, the field of actors was analysed to find a mix of participants that can represent the system of actors involved in the topic chosen for the methodology. Given the limited number of statements and topics to be addressed using Q methodology and the abundance of possible topics, much time and effort was spent on identifying the topics to be addressed in the research. This could provide an inspiration for future academic work on similar discussions of political, multi-disciplinary complexity.

6.2.6 Societal relevance

As mentioned before, in its push for sustainability and electrification, society is searching for innovative solutions. Introducing new systems, of which a meshed offshore network is an example, frameworks may be rendered obsolete and, therefore, need replacing. In allocating costs of a meshed offshore network, this research revealed possible limitations to the application of CBCA and the necessity for a cost allocation procedure. In a broader context, this shows that through innovation in the electricity system, at some point, the limits of the current frameworks will be reached.

Therefore, the research has societal relevance in that it addresses critical issues and contributes to the sustainable development of offshore energy resources. There is a long way ahead in achieving the ambitious climate targets that have been set. By addressing these critical issues and the necessity for an international cost allocation, the research touches upon several aspects impacted by the decarbonisation of the electricity system, such as infrastructure development, energy access and international collaboration.

6.2.7 Recommendations for future research

Based on the outcome of this research and insights gained, recommendations for further research are proposed in this sub-section. As mentioned earlier, the realisation and cost allocation of a meshed offshore network is a socio-technical situation with competing players, and some players possess private information. It is recommended to research how this can affect the cost allocation process in future research. In this regard, future research on game theory and the Shapley value in the context of the cost allocation process of a meshed offshore network could provide valuable insights.

Second, referring to the Systems-of-Systems approach, this research is a contribution in a much larger system that will be affected by the introduction of a meshed offshore network. Future research is recommended to get a better understanding of the impact of the cost allocation on the other systems. For example, this research briefly touched upon the transmission tariffs. How the hundreds of billions are going to be incorporated in the transmission tariffs and how this impacts the market could be interesting grounds for future research. Another recommendation for future research is to research the impact of including hydrogen infrastructure in the meshed offshore network. How would that impact the cost allocation and the system of actors?

Based on a limitation of the research that was mentioned in section 5.2.2, future research is recommended on the cost allocation process amongst organisations from non-hosting MSs. Having excluded non-hosting MSs from this research, it would be interesting to explore the perspectives from actors in non-hosting MSs. Especially given the conclusion of this research, stating that non-hosting MSs must contribute to a 300 GW meshed offshore network.

Lastly, based on the conclusion, the realisation of a meshed offshore network will take many years. Until MSs can come to an agreement, it is important that the MSs align their offshore infrastructure. Otherwise, there is a risk of the North Sea becoming an inefficient patchwork of interconnectors without any form of coordination. Therefore, a recommendation for future research is to continue to explore how the offshore infrastructure in the North Sea is best developed towards a meshed offshore network and how actors can find alignment to do so. This could contribute to the development of a meshed offshore and the cooperation of different actors across MSs. This could perhaps be an interesting starting point for TenneT to take the lead. The Netherlands' EEZ covers a large part of the North Sea that will be used for offshore RES. Together with the Ministry of Economic Affairs and Climate Policy, TenneT could host some form of roadshow with TSOs and ministries of other MSs to explore a better alignment of cross-border electricity infrastructure towards a meshed offshore network.

6.2.8 Personal reflection

Reflecting on the course of this research on a personal level, what started as a challenging master thesis eventually turned into an eleven-month international study. Furthermore, this research marks the last phase of the master's degree in Complex Systems Engineering & Management. Throughout the research, I was confronted several times with the complexity of the problem and the sector. In the first phase, I spent tremendous time familiarising myself with the sector and all its complexities. This led to an overload of information and a subsequent problem in the scope of the research. Although the research was focused on a specific part of a topic where many interesting questions arise, I gained a broad understanding of the sector. Furthermore, being able to perform this research at the Dutch TSO TenneT greatly contributed to the research and the experience. Although I invested a tremendous amount of time and effort in attracting participants, I could not have done that without the help of TenneT. Despite the fact that I cannot mention the organisations and participants by name, their involvement in this research is truly unique, and I am very grateful for that. As a student, I do not harbour the illusion that this research will have a significant impact; ultimately it is up to the various actors and politics to determine how this topic is addressed. However, I do believe that this research has perhaps shed more light on the differences that must be overcome and that, in doing so, it might bring actors to a first step.

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A Scoping process on Q methodology concourse

Having completed the literature study, the Q methodology normally starts with defining the concourse. However, in this research, scoping problems were encountered in defining the concourse. Even though the concourse should be as complete as possible, the main research question proved too broad to directly define the concourse. Therefore, several off the record interviews were held to improve the scope. Interviewees were asked what the most important criteria would be for a successful cost allocation of a meshed offshore network. In this regard, out of the first interviews, combined with knowledge and insights gained from the literature study, an initial (non-exhaustive) list of possible topics to consider in setting up a CBCA was compiled:

- Ex post vs Ex ante
- Fairness/allocation key
- Simplicity
- Transaction costs
- Evolutionary vs Grand Design
- Need for regulatory amendments
- Avoidance of additional risk for time delay
- Calculability and reliability of the calculations or the forecasting
- Methodologies to decompose power flows?
- Alignment with already existing mechanisms
- Interaction with funding options
- Impact on stakeholders
- Stakeholder constellation (complexity of the stakeholder group and ensuring sufficient incentives for stakeholder engagement
- Future robustness
- Impact on risk of stranded assets
- Time in terms of capital costs, depreciation of investments. Both financial and climate bound
- Operational feasibility
- Political acceptability
- Private funding/investors vs TSO model
- Centralised vs Decentralised
- Relevant Benefits

However, in the case of a meshed offshore network, almost every criterion can have many ramifications that would have to be addressed. For example, future robustness can be secured in numerous ways resulting in numerous statements, meaning that a selection should be made. Subsequently, interviewees were asked to narrow the list of criteria down to the most important ones to be addressed in this research. It became clear that many most interviewees remarked the importance of benefits in allocating costs. However, a meshed offshore network potentially provides many benefits. Based on this, their input was to start by identifying what benefits would be relevant to include in the CBCA process. Furthermore, it would be interesting to explore views on cost-sharing methodologies or allocation keys to be used to distribute costs in a certain relation to benefits. Aside from these elementary criteria, interviewees indicated that considering the political nature of the subject, it would be interesting to explore aspects of political acceptability related to the meshed offshore network cost allocation. Lastly, ex post versus ex ante allocation and other aspects related to timing sparked the interest of some interviewees. Therefore, aspects of time were chosen as an overarching criterion that would be valuable to explore.

B Q-set process

Having identified the outline of the concourse following the process described in section 3.4.2 and Appendix A, the Q-set is compiled. Throughout the scoping process, interviewees provided examples by explaining the trade-offs that must be made in some cases. In other instances, interviewees provided examples of statements to be included in the research referring to criteria. As mentioned in section 3.4.2, this was combined with findings from the literature study to follow a semi-structured approach.

Table B-1: Matrix used to compile statements for the Q-set based on the four themes.

Relevant benefits	***What do you want to know?***	***Statement***	***Explanation/background***
Social economic welfare	1. Is this a good benefit indicator to include? 2. What is the best way to use it?	a) Socio-economic wellfare is a benefit that must be included in the CBA when designing a meshed offshore network.	ENTSO-E 3rd CBA guideline benefit
RES integration benefit	Is this a good benefit indicator to include?	Renewable Energy Supply integration benefits resulting from the realisation of a meshed offshore network should be taken into account in the CBA	ENTSO-E 3rd CBA guideline benefit
Greenhouse emissions	Is this a good benefit indicator to include?	1. The reduction of greenhouse gasses per country due the realistion of a msehd offshore network should be taken into account in the CBA	ENTSO-E 3rd CBA guideline benefit
Adequacy benefits	Is het een goede indicator om mee te nemen of niet? Is de verwachting uberhaubt dat overal resource adequacy benefits zijn?	1. The increase of resource adequacy per country due to the realisition of a meshed offshore network in the North Sea is a benefit that has to be included in the CBA 2. All involved countries will experience the benefit of resource adequacy	ENTSO-E 3rd CBA guideline benefit
System flexibility	Is this a good benefit indicator to include?	All countries will experience more system flexibility due to the realistion of the North Sea grid. Thus, this indicator cannot be omitted in the CBA for a meshed offshore network	ENTSO-E 3rd CBA guideline benefit
CO2 reductions	Is this a good benefit indicator to include?	1. Countries that do not experience reductions in CO2 cannot be financially involved in the cost allocation principle when building a meshed offshore network	ENTSO-E 3rd CBA guideline benefit

Producer benefits	Is this a good benefit indicator to include?	1. In a cost sharing principle/CBA, more weight should be placed on producer surpluss over consumer surpluss (e.g. countries with more producer surpluss should pay relatively more) 2. In a cost sharing principle/CBA, more weight should be accounted to congestion income raised as a result of the meshed offshore network	
Increased cross-border trade	Is this a good benefit indicator to include?	1. Increased cross-border trade as a result of a meshed offshore network is a benefit that should be included in the CBA 2. The redistribution of congestion income should be accounted for when setting up a cost sharing principle	
Scenario aspect	Is this a good benefit indicator to include?	Scenarios used to calculate the Cost-Benefit Analysis for the cost sharing principle should be set by ENTSO-E	ACER recommendation No 02/2023
Variation in Grid losses	Is this a good benefit indicator to include?	1.Positive Changes in transmission system losses that can be attributed to the meshed offshore network are benefits that must be considered in the CBA	ENTSO-E 3rd CBA guideline benefit
Reduction of reserve dispatch	Is this a good benefit indicator to include?	1. MSs that have to invest in additional reserve capacity due to the development of the offshore grid, should have to pay less in the CBCA	ENTSO-E 3rd CBA guideline benefit

Allocation key	**What do you want to know?**	**Statement**	**Explanation/background**
Physical power flows	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	Costs should be settled with beneficiary MSs based on realised power flows resulting from the offshore network	Power flow decomposition methodology can be used to determine physical flows,

			to determine which MS benefits to what degree
Local emission reduction	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	The cost allocation key in the CBCA should be based on CO2 and non CO2 emission reductions realised in every MS due to the project	
GDP per capita	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	The infrastructural costs should be allocated using an allocation key based on amongst others every MSs GDP per capita	Derivation from European to national CO2 reduction targets is based on MSs relative wealth, measured by GDP per capita, so apply the same for cost sharing?
Total GDP	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	The infrastructural costs should be allocated using an allocation key based on amongst others every MSs GDP	Like this, the economic situation and the number of inhabitants is considered
# inhabitants	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	The infrastructural costs should be allocated using an allocation key based on the number of MS inhabitants	Using the number of inhabitants to determine a MSs contribution
Territorial principle	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	Infrastructural costs should be allocated using the territorial principle	Territorial principle has also been used to divide costs in cross-border projects
CBA	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	1. Infrastructural costs should be allocated using the CBA, which aims to identify a cost-benefit ratio per MS involved 2. The infrastructural costs should be allocated using a cost-benefit ratio, reallocating costs so all parties have the same cost-benefit ratio according to the CBA	
Transmission vs interconnection	Is a distinction between transmission and infrastructure important or not?	Infrastructural costs for transmission and interconnection should be covered in seperate project specific CBCA decisions	Interconnectors might be valuable for MSs in the North Sea region but land-locked countries have more benefit from the transmission funtion of the network to access the offshore capacity than interconnection between north sea MSs
Social economic welfare	Are MSs willing to bind themselves in paying for a meshed offshore network on this basis?	Cost should be shared based on the expected distribution of socio-economic wellfare per involved "country"	Following ENTSO-E guideline, resulting SEW per MS can be used as a basis to allocate costs in theory

Onshore grid expansion	Should onshore grid expansion investments inherent in 300 GW of offshore wind capacity be included in the CBCA?	Subsequent onshore grid expansion has to be included in the CBCA for the infrastructural costs of an offshore meshed network	Onshore grid expansion is imminent with the construction of 300GW, it can be argued that these expansions have to be considered in the CBCA for a meshed offshore network too
Market vs Regulated	Is there a preferred side (market or regulated) where costs should be recovered?	1.Meshed offshore grid infrastructure supports offshore wind exploitation, therefore offshore connection costs should be raised so that offshore generators contribute a fair share. 2. Infrastructural costs should be distributed via the regulated side of the market (ie TSOs, funding etc.)	
Political acceptability	**What do you want to know?**	**Statement**	**Explanation/background**

Difference in RES targets	Can differences in RES targets be put asside, or do they need addressing beforehand?	If costs of a meshed offshore network are shared, countries are eligable to claim part of the interconnected Renewable Energy Capacity to their national targets	Differences in RES targets can be problematic in agreeing on the design of a meshed offshore network. Is agreement on the design a requirement? Or is there some play?
Level of socialisation	Are MSs aware of different ways to socialise costs and is there an idea of how costs should be socialised?	1. EU Funding is the best mechanism to socialise infrastructural costs for a meshed offshore network 2. A CBCA decision should only consider incremental costs and benefits relative to existing national roll-out scenarios 3. A CBCA decision should cover the all infrastructural investment costs (including national roll-out)	Funding is also a way of socialising part of the costs on EU level, which could be argued seeing the project will benefit a larger part of EU
Public vs Private funding		The TSO model is a desirable financing structure to realise a meshed offshore network in the North Sea	
Centralised vs Decentralised	Is the conventional approach applicable? Or is it prefered to realise this vision from a more centralised position?	A meshed offshore network should be realised using one offshore TSO covering the North Sea, financed by MSs in proportion to their benefits	
Threshold	Is a threshold seen as a viable option to simplify the CBCA procedure?	1. A threshold should be set to distinguish net beneficiaries of a certain degree (eg >10%) 2. EU funding/subsidies for CBCA projects should only be used to compensate for/cover costs otherwise charged to small beneficiaries below a threshold	

CBCA vs Political agreement		CBCA is the preferred route over political agreements to settle costs for the realisation of a meshed offshore network	
Hosting vs Non-hosting		1. Costs should be allocated using two CBCA's, one for hosting MSs and one for non-hosting MSs 2. Given the expansion of offshore wind capacity in a meshed offshore scenario, costs should be allocated amongst hosting MSs only 3. All Member States that enjoy benefits from a meshed offshore network should contribute, hosting and non-hosting	
Time	**What do you want to know?**	**Statement**	**Explanation/background**
Ex post vs Ex ante	Are countries willing to allocate costs afterwards, despite of uncertainties?	If costs turn out to be higher than the expected costs at the time of the CBCA decision, there should be a correction	As stated in ACER recommendation No 02/2023 3.10.3 b.
Partnership duration	What aspect of time is valued most?	A CBCA is only binding for the investment costs, no further partnership should result from it (OPEX sharing)	
Financial	What aspect of time is valued most?	1. Different outcome of costs due to deviation from time roadmap should be reallocated 2. Increased investment costs due to project delays have to be included in the CBCA	
Climate goals	What aspect of time is valued most?	Climate goals should somehow be represented in the CBCA	

C Letters to participants

C.1 Invitation to participate in Q study

Regarding: Invitation to participate in thesis research on Cross-Border Cost Allocation in the North Sea basin.

Dear …,

As fulfilment of the Masters complex systems engineering at the Delft University of Technology, I am currently writing my thesis on the subject of Cross-Border Cost Allocation (CBCA) for a meshed offshore network in the North Sea basin at TenneT. It should however be noted that the research is an independent process, free of any perspectives TenneT might have on the matter.

To exploit the full potential of offshore wind in the North Sea, a meshed offshore grid is envisioned as the long-term solution. In this research, I focus on the (cross-border) allocation of infrastructural costs of an electric meshed grid (meaning hydrogen or other carriers excluded). Because of the concept's complexity and high costs, combined with a great variety of uncertainties, the allocation of costs across multiple Member States is a difficult task. To find a cost sharing key that suits all parties, this research aims to explore the perspectives on what currently seem to be the most important criteria for a certain method of cost allocation.

Based on your experience and knowledge, I hereby invite you to take part in my research. I would like to explore your thoughts on the topic and views on what makes a fair or good allocation key.

To do this, I would like to invite you to a two-step process:

1. First, a set of statements is presented. You will be asked to sort the statements in a grid ranging from "I disagree" to "I agree".
2. Having sorted the statements, a brief interview will be held to reflect on the choices made and to explore the narrative behind certain choices.

In light of the political nature of the topic, all participants will remain anonymous in the research upon request.

Hopefully this strikes your interest, I look forward to make an appointment. The process is estimated to take 1 hour.

I look forward to hear whether you would be interested in taking part in the research. Thank you for taking the time to read this invitation and your possible participation in advance. Should you find a colleague's participation to be more suitable, I would highly appreciate it to get in contact. In case of any questions regarding the specifics of participating, the background of the research or any other questions, feel free to contact me per email or phone.

Kind regards,
Adriaan den Haan

C.2 Additional information before Q-sort process

Dear Mr./Mrs. …,

You are about to take part in the research on Cross-Border Cost Allocation (CBCA) for a meshed offshore network in the North Sea. This research is performed by Adriaan den Haan, a student at the Delft University of Technology, as fulfilment of his thesis project.

A short recap: a meshed offshore network is seen as the ultimate goal, exploiting the North Sea as the "powerhouse of Europe", connecting Offshore Wind Farms and interconnecting North Sea countries in one network offshore. In this research, the option of Hydrogen integration is left out, focussing on the costs and benefits of the electrical infrastructure of a meshed offshore network. Installed capacity targets connected through a meshed offshore network outweigh demand of sea neighbouring countries (hosting MSs). Since electricity is not bound by country borders, but electricity flows are based on the EU-wide market outcomes, it is uncertain how benefits are distributed. As demand of inland Member States is possibly also served, non-hosting MSs might become beneficiaries too. The infrastructure however comes at great costs which must be distributed across beneficiaries of the project. Because of amongst others stakeholder interests and political interests this is a complex task, currently solved using a CBCA decision. However, a CBCA of this scale and complexity has no precedent. The aim of the research is to further explore differences and alignment between parties involved.

Given the numerous uncertainties surrounding this topic, this Master's thesis aims to offer initial insights that can serve as a foundation for future discussions among all relevant stakeholders. Based on input from several experts from different countries, a scope was found that targets some of the CBCA aspects currently noted as most relevant. This scope covers the assessment of:

1. Relevant benefits to be included
2. Possible allocation keys to divide costs
3. Political acceptability
4. Some aspects of time related to the cost allocation

Out of these four criteria, a set of 40 statements has been formulated. You are asked to sort the statements from "I agree" to "I disagree". Once the statements have been sorted, a brief interview is held to reflect on the choices made using a set of predetermined questions. The input from all participants is analysed using software, providing a factor analysis of all the statements. To be able to interpret these results, the session will be recorded and transcribed to get a better understanding of the narrative behind the results. After obtaining transcripts, recordings will be deleted. The transcripts will be destroyed once the research is completed and will thus not be published. Your position or name will not be mentioned without your permission, nor will it be linked to any of the results. Your participance will be in full anonymity. However, recording the session is vital to the quality of the analysis. In return, the research will be shared with you upon completion.

Your contribution to the quality of the research must not be underestimated and is greatly appreciated. Thank you for your willingness to participate in this research and the time you are willing to dedicate to it. If you have any questions, feel free to contact me.

E Q method results

E.1 Correlation matrix

Correlation Matrix Between Sorts

SORTS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	100	45	30	57	56	42	30	46	6	39	26	59	43	42	35	51	42	62	6
2	45	100	8	45	52	31	46	44	22	35	16	51	29	45	31	58	27	50	34
3	30	8	100	36	40	36	21	35	28	29	41	36	9	42	21	31	44	49	5
4	57	45	36	100	58	47	31	41	11	61	31	38	46	65	53	50	49	64	21
5	56	52	40	58	100	55	27	44	11	72	34	54	31	64	59	63	58	66	13
6	42	31	36	47	55	100	34	25	21	53	47	23	25	64	35	51	63	65	24
7	30	46	21	31	27	34	100	22	39	19	17	33	40	42	16	58	18	35	41
8	46	44	35	41	44	25	22	100	23	45	34	47	28	27	29	44	31	49	12
9	6	22	28	11	11	21	39	23	100	19	11	13	18	24	0	32	17	19	21
10	39	35	29	61	72	53	19	45	19	100	18	38	36	59	56	47	62	59	29
11	26	16	41	31	34	47	17	34	11	18	100	30	27	26	31	49	35	37	20
12	59	51	36	38	54	23	33	47	13	38	30	100	43	32	21	60	29	61	25
13	43	29	9	46	31	25	40	28	18	36	27	43	100	36	13	39	21	32	41
14	42	45	42	65	64	64	42	27	24	59	26	32	36	100	48	57	58	76	25
15	35	31	21	53	59	35	16	29	0	56	31	21	13	48	100	36	43	40	-5
16	51	58	31	50	63	51	58	44	32	47	49	60	39	57	36	100	67	65	27
17	42	27	44	49	58	63	18	31	17	62	35	29	21	58	43	67	100	68	14
18	62	50	49	64	66	65	35	49	19	59	37	61	32	76	40	65	68	100	28
19	6	34	5	21	13	24	41	12	21	29	20	25	41	25	-5	27	14	28	100

Figure E-1: Correlation matrix showing correlations between all sorts.

E.2 Unrotated factor matrix

Unrotated Factor Matrix

SORTS	Factors 1	2	3	4	5	6	7	8
1	0.6912	-0.0301	-0.3824	0.1920	0.0405	-0.0921	-0.2692	0.2196
2	0.6306	0.3266	-0.3239	-0.1022	-0.2763	-0.2441	0.1773	-0.1655
3	0.5194	-0.1871	0.3919	0.4854	-0.0429	0.1846	-0.2364	0.0739
4	0.7619	-0.1314	-0.1405	-0.1798	0.0800	0.1776	-0.0461	0.2735
5	0.8156	-0.2441	-0.1556	-0.0571	-0.0853	-0.0229	0.0545	-0.0913
6	0.7061	-0.1626	0.3760	-0.1485	0.1632	-0.1878	-0.0601	-0.0299
7	0.5175	0.5770	0.1573	-0.1067	-0.1585	-0.2562	0.0551	0.3013
8	0.5897	0.0489	-0.2334	0.4115	-0.1633	0.3284	0.2453	-0.1465
9	0.3062	0.4123	0.4950	0.1108	-0.4841	0.2813	0.0986	0.1244
10	0.7391	-0.2241	-0.0432	-0.3088	-0.0659	0.3780	0.0509	-0.2117
11	0.4997	-0.0534	0.2674	0.4060	0.5144	-0.1201	0.4309	0.0461
12	0.6546	0.2388	-0.3723	0.3550	0.0252	-0.0498	-0.1738	-0.1681
13	0.5167	0.4278	-0.1878	-0.1227	0.4000	0.3054	-0.0880	0.3149
14	0.7865	-0.1147	0.1877	-0.2967	-0.0785	-0.0460	-0.1775	0.1123
15	0.5660	-0.4548	-0.1550	-0.2103	-0.0824	0.0251	0.4423	0.2242
16	0.8144	0.1762	0.0546	0.0916	-0.0544	-0.3108	0.1220	-0.0443
17	0.7221	-0.3282	0.2659	-0.0696	0.0104	-0.0887	-0.0955	-0.1887
18	0.8658	-0.0925	0.0297	0.0424	-0.0167	-0.0835	-0.2543	-0.1559
19	0.3493	0.5970	0.1577	-0.3023	0.3336	0.1643	0.0348	-0.3818
Eigenvalues	8.0855	1.7681	1.3203	1.1735	0.9633	0.8164	0.7845	0.7376
% expl.Var.	43	9	7	6	5	4	4	4

Figure E-2: Unrotated factor matrix generated in PQMethod.

E.3 Factor loadings

Factor Matrix with an X Indicating a Defining Sort

QSORT	Loadings 1	2	3	4
1	0.3837	0.0406	0.7056X	0.1223
2	0.3075	0.4293	0.5760	-0.0951
3	0.2418	-0.0214	0.1714	0.7783X
4	0.6823X	0.1746	0.3868	0.0649
5	0.7161	0.0551	0.4566	0.1675
6	0.6724	0.2690	0.0031	0.4048
7	0.1293	0.7385X	0.2294	0.1489
8	0.1720	0.0414	0.6621X	0.3228
9	-0.0233	0.5547	-0.0545	0.4580
10	0.7829X	0.1609	0.2304	0.0432
11	0.1919	0.0727	0.2407	0.6236X
12	0.1406	0.1996	0.8072X	0.1975
13	0.1936	0.5198	0.4332	-0.0704
14	0.7670X	0.3310	0.1209	0.2060
15	0.7246X	-0.1553	0.2154	0.0010
16	0.4386	0.4144	0.4609	0.3594
17	0.7232	0.0793	0.0896	0.4092
18	0.6349	0.2189	0.4279	0.3560
19	0.0978	0.7615X	0.0592	-0.0421
% expl.Var.	25	13	16	11

Figure E-3: Factor loadings matrix generated in PQMethod.

E.4 Generalised sort perspective 1

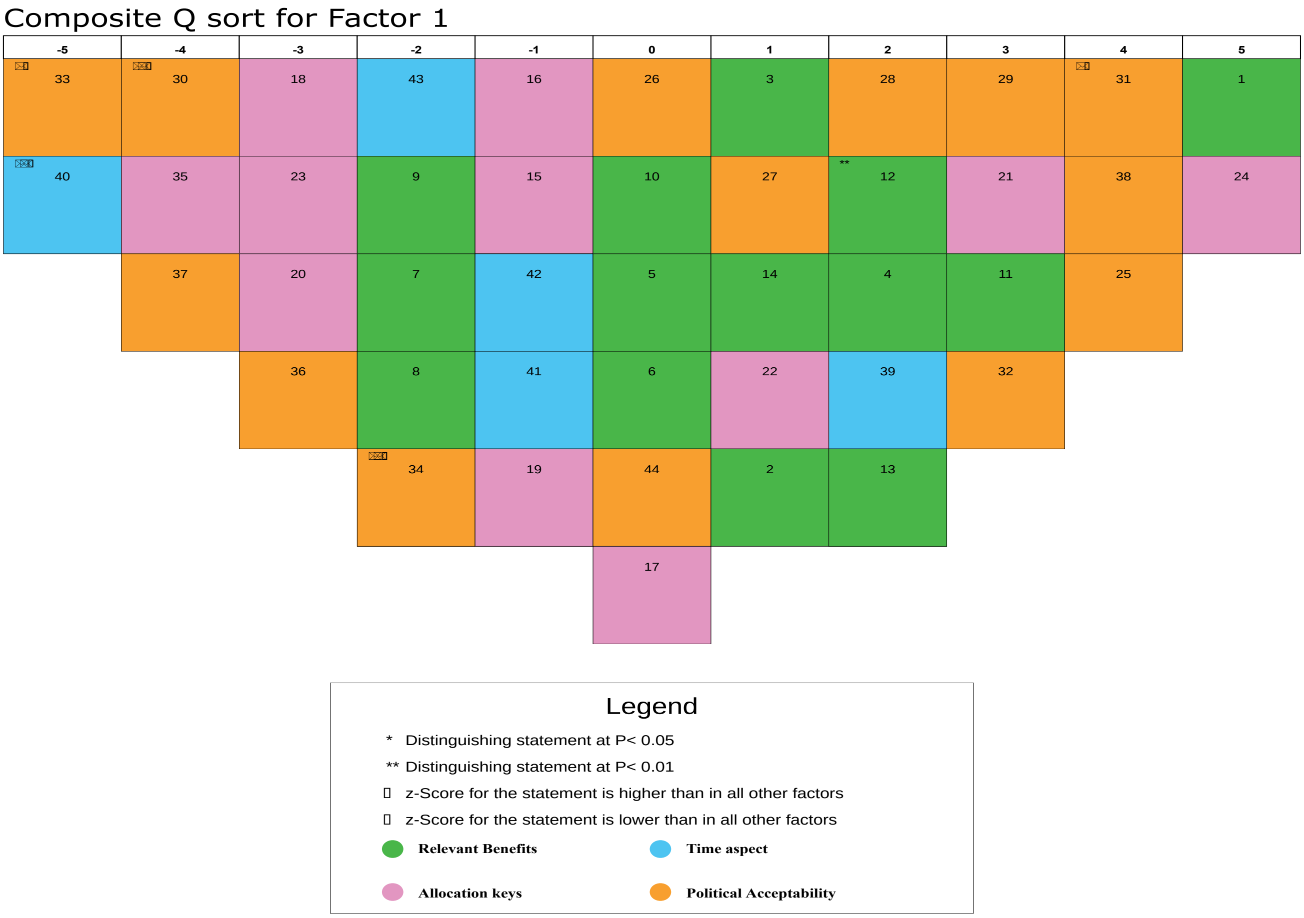

Figure E-4: Generalised sort generated in KenQ analysis for perspective 1.

E.5 Generalised sort perspective 2

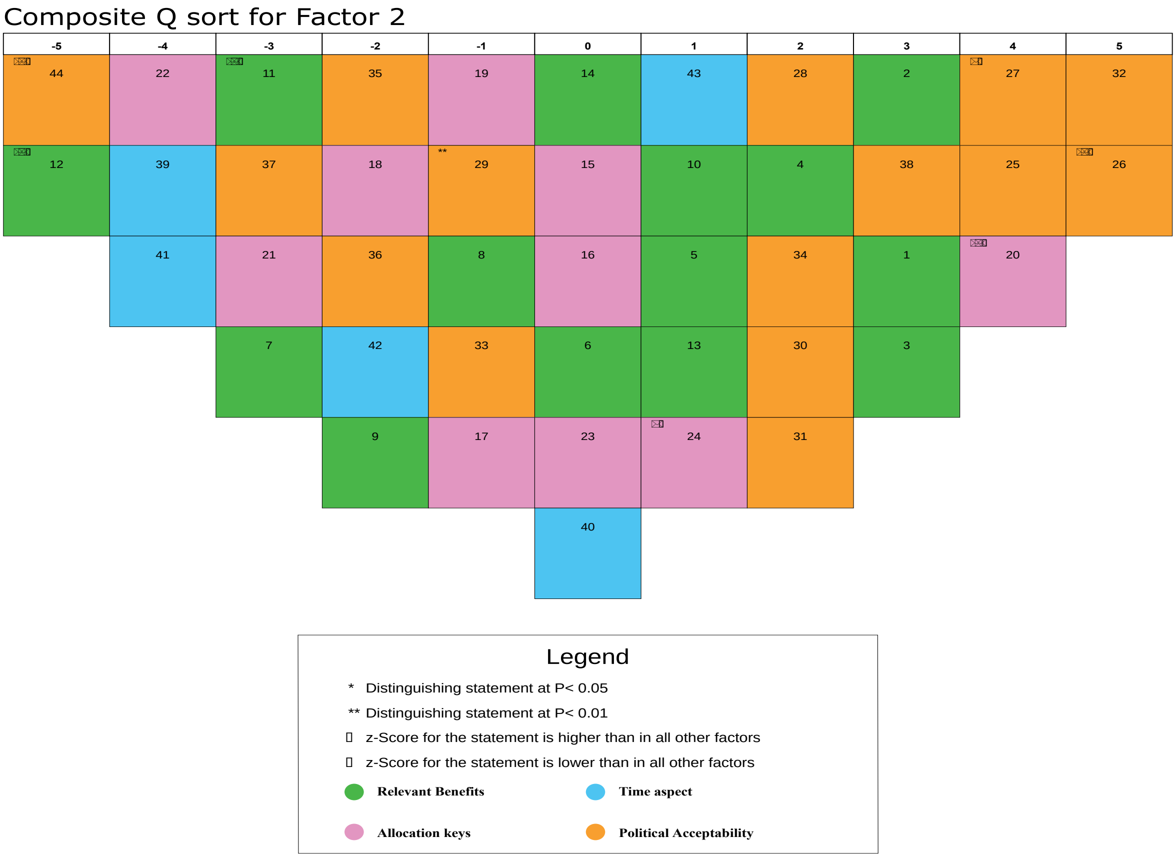

Figure E-5: Generalised sort generated in KenQ analysis for perspective 2.

E.6 Generalised sort perspective 3

Figure E-6: Generalised sort generated in KenQ analysis for perspective 3.

E.7 Generalised sort perspective 4

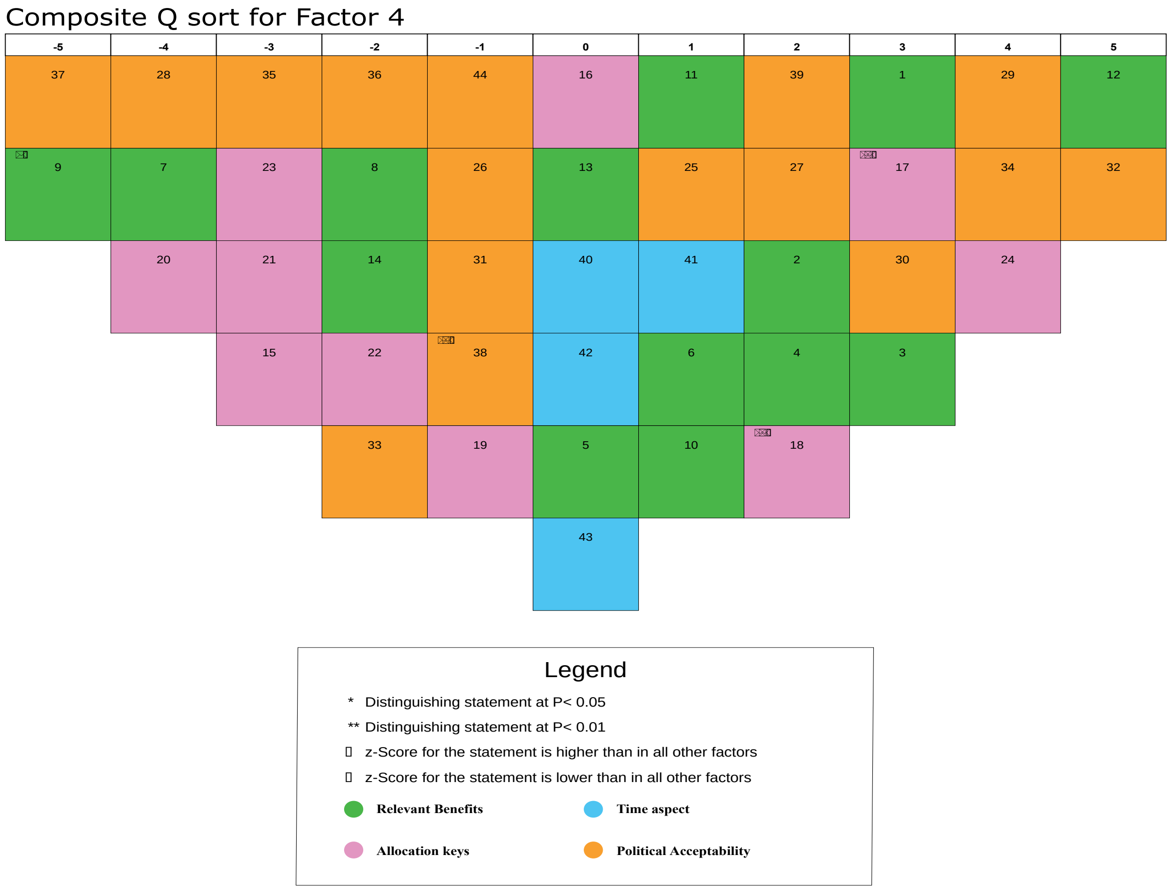

Figure E-7: Generalised sort generated in KenQ analysis for perspective 4.

E.8 Consensus and disagreement statements

Factor Q-Sort Values for Statements sorted by Consensus vs. Disagreement (Variance across Factor Z-Scores)

			Factor Arrays			
No.	Statement	No.	1	2	3	4
13	Positive changes in transmission system losses that can be a	13	2	1	0	0
4	Gains in resource adequacy per country that can be attribute	4	2	2	3	2
8	In a cost sharing principle, more weight should be placed on	8	−2	−1	−3	−2
36	Costs should be allocated using two CBCA's, one for hosting	36	−3	−2	−3	−2
3	Reduction of Greenhouse gasses per country due to the realis	3	1	2	1	3
2	Renewable Energy Supply integration benefits resulting from	2	1	3	1	2
42	Increased investment costs due to project delays have to be	42	−1	−2	−2	0
23	Infrastructural costs for transmission and interconnection s	23	−3	0	−2	−3
5	All countries involved in the meshed offshore network will e	5	0	1	2	0
7	Countries that do not experience reductions in CO2 cannot be	7	−2	−4	−5	−4
37	Given the expansion of offshore wind capacity in a meshed of	37	−4	−3	−3	−5
35	EU funding/subsidies for CBCA projects should only be used t	35	−4	−2	−1	−3
16	The sharing key in the CBCA should be based on CO2 and non C	16	−1	0	−2	0
15	Costs should be settled with beneficiary Member States based	15	−1	0	−2	−3
14	Member States that have to invest in additional reserve capa	14	1	0	−1	−2
1	Socio-economic welfare is a benefit that must be included in	1	5	2	5	3
43	Climate goals should somehow be represented in the CBCA";	43	−2	1	0	0
10	Increased cross-border trade as a result of a meshed offshor	10	0	1	4	1
19	Infrastructural costs should be allocated using an allocatio	19	−1	−1	−4	−1
27	Infrastructural costs should be distributed via the regulate	27	1	4	2	2
33	A meshed offshore network should be realised using one offsh	33	−5	−1	−1	−3
25	Subsequent onshore grid expansion has to be included in the	25	4	4	2	1
24	Costs should be allocated based on the expected distribution	24	5	1	4	4
32	The TSO model is the desirable financing structure to realis	32	3	5	3	5
9	In a cost sharing principle, more weight should be placed co	9	−2	−2	−1	−5
22	Infrastructural costs should be allocated using a cost-benef	22	1	−4	1	−2
6	Introducing a meshed offshore network will provide system fl	6	0	0	4	1
41	Different outcome of costs due to deviation from the time ro	41	−1	−4	0	1
18	Infrastructural costs should be allocated using an allocatio	18	−3	−2	−4	2
40	A CBCA is only binding for the investment costs, no further	40	−5	0	0	0
11	The redistribution of congestion income should be accounted	11	3	−3	3	1
31	A CBCA decision should cover all infrastructural investment	31	4	2	0	−1
38	All Member States that enjoy benefits from a meshed offshore	38	4	3	3	−1
44	CBCA is the preferred route over political agreements to set	44	0	−5	1	−1
34	A threshold should be set to distinguish beneficiaries of a	34	−2	2	1	4
28	If costs of a meshed offshore network are shared, countries	28	2	2	−1	−4
39	If costs turn out to be higher than the expected costs at th	39	2	−4	−2	2
26	Meshed offshore network infrastructure supports Offshore Win	26	0	5	0	−1
21	Infrastructural costs should be allocated using the CBA, whi	21	3	−3	2	−3
17	Infrastructural costs should be allocated using an allocatio	17	0	−1	−4	3
30	A CBCA decision should only consider incremental costs and b	30	−4	2	2	3
20	Infrastructural costs should be allocated using the territor	20	−3	4	−3	−4
29	EU funding is the best mechanism to socialise infrastructura	29	3	−1	−5	4
12	Scenarios used to calculate the Cost-Benefit Analysis for th	12	2	−5	5	5

Figure E-8: Statements sorted from consensus to disagreement.