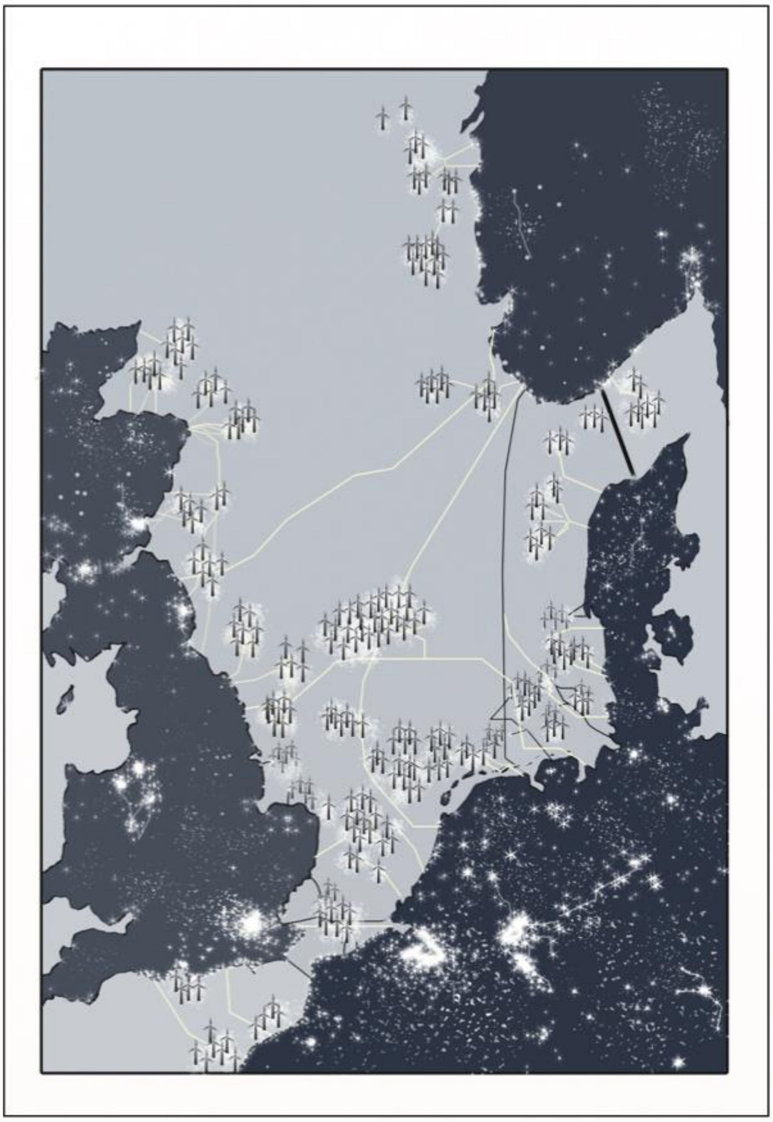


A North Sea offshore grid governance model

The allocation of ownership and operating responsibilities for a Meshed Offshore Grid

Name: Bryan Bono Brard
Graduation date: 30 October 2017

A North Sea offshore grid governance model

The allocation of ownership and operating responsibilities for a Meshed Offshore Grid

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **System Engineering Policy Analysis and Management**

Faculty of Technology, Policy and Management

by

Bryan Bono Brard

Student number: 4025628

To be defended in public on October 30th 2017

Graduation committee

Chairperson	: Prof.dr.ir. M.P.C. Weijnen, section Energy & Industry
First Supervisor	: Dr.ir. L.J. de Vries, section Energy & Industry
Second Supervisor	: Dr. D.J. Scholten, section Economics of Technology & Innovation
External Supervisor	: Mr. D. Abdoelkariem, TenneT TSO b.v.

Preface

This report is the final deliverable of eight months of research conducted to finalize my master System Engineering, Policy Analysis and Management (SEPAM) at the faculty Technology, Policy and Management (TPM) at Delft University of Technology. Moreover, this report is the final (written) deliverable of my educational career at Delft University of Technology of which the research was conducted at TenneT. TenneT is an international Transmission System Operator, owning and operating the high-voltage electricity grid in the Netherlands and a large part of Germany, both onshore and offshore.

The subject of the research presented in this report is the governance of a Meshed Offshore Grid regarding the ownership and operation of the electricity transmission assets. The subject of this research is especially relevant to facilitate and accommodate the future integration of offshore wind energy, which is considered one of the primary contributors to achieve the initiated climate goals by the EU and its member states. Moreover, a Meshed Offshore Grid can contribute to the further integration of the EU energy market.

The primary objective of the conducted research was to design a governance model that can facilitate the efficient deployment of a Meshed Offshore Grid. Reaching this objective will contribute to the scientific community, as current EU and national policies and regulatory frameworks are not harmonized to facilitate the deployment of a Meshed Offshore grid. Hopefully, this research provides relevant knowledge regarding the current governance issues and thus can facilitate future developments for a Meshed Offshore Grid.

While performing the research was a very challenging task, the opportunity to see the real-time developments within TenneT as a graduate intern were extremely inspiring. Moreover, the possibility to witness the developments within TenneT that can serve as the first building-blocks of a North Sea Offshore Grid is something that I'm really appreciative of.

Bryan Bono Brard
Rotterdam, October 11th 2017

Acknowledgements

Before the actual research is presented, I would like to use this opportunity to express my gratitude towards the people who helped me throughout this research project and during my study at the TU Delft in general.

First of all, I would like to thank my entire committee for providing extremely useful feedback and guidance throughout my research project. Without the professional help of my committee, presenting this thesis through this report would not be possible. My first supervisor, Laurens de Vries, was always available for feedback when I needed it and was able to guide me in the right direction in the beginning of the research when I was still searching for the right angle to approach this research. He was also really helpful in providing the applicable scientific literature which could help answering the questions I had. My second supervisor, Daniel Scholten, was also really supportive throughout my research and made me feel more comfortable about my research every time I left his office. He was of most help in providing the right structure to present my research, something that I really struggled with through the research process and therefore Daniel's guidance was extremely valuable to me. I would also like to thank Margot Weijnen, the chair of my committee, for supporting my research from the start, showing interest and providing valuable feedback throughout the meetings with my committee.

Secondly, I would like to thank the Dutch regulation department of TenneT for allowing me to do my research within their department and helping me get valuable insights for my research. It also enabled me to come in contact with a lot of experts within the offshore wind energy domain and through this research I was able to travel around Europe to attend offshore electricity grid related conferences.

Special thanks go out to Daimy Abdoelkariem, my supervisor at TenneT, who was of irreplaceable help during my research. His positive energy and willingness to help me really motivated me to finalize my research. More importantly, his in-depth knowledge regarding regulation and the governance of electricity transmission infrastructure was extremely valuable, since this enabled me to immediately get feedback and get me back on the right track. Of this I am really appreciative.

Finally, I would like to express my humble gratitude towards some people on a personal note. Firstly, I want to thank my brothers for always having my back. Secondly, without the continuing support of my parents, I would not have been able to complete this study. Words cannot explain how grateful I am to them. Last but not least, I would like to thank my fiancé, for your loving support and emotional guidance, I can imagine it must have been hard at sometimes for her too, however, she never wavered her loving support.

Summary

EU climate goals force EU member states to increase the share of renewable electricity generation in their respective electricity markets. To reach these climate goals, offshore wind energy is regarded as one of the main technologies that can contribute to a full transition towards a fossil-free electricity system. Furthermore, 230 Gigawatts (GW) of offshore wind is projected to be necessary within the EU. Additionally, the EU has the objective to further integrate electricity markets within its member states. This further integration will therefore need a substantial increase in interconnection capacity between the current electricity markets. Both the increase in offshore wind energy and the increase in interconnection capacity will require offshore electricity transmission infrastructure.

Currently, offshore wind generation is connected through individual (radial) offshore grid connections and interconnection capacity used for cross border trade is still developed through point-to-point interconnection. However, a meshed offshore grid (MOG) can combine the aforementioned functions of evacuating offshore wind and interconnect electricity markets. Additionally, a MOG is expected to provide additional economic benefits compared with the individual development of offshore wind farms (OWF) grid connections and the interconnection capacity between electricity markets. While a MOG can provide potential economic benefits, current development of a MOG is still lacking, caused by a variety of economic and regulatory knowledge gaps that need to be addressed. One of these knowledge gaps is which governance model, that allocates the responsibilities regarding the ownership and operation of such a MOG, is preferable for coordinated offshore grid developments. This research project is therefore focussing on this knowledge gap.

In order to address this gap, an analytical framework is created through a literature review and desk research that provides both a foundation to conceptually develop the design space of a governance model, while also providing the tools to analyse the expected performance of a governance model. Additionally, a quantitative comparative analysis of currently applied governance models for individual OWF grid connections is performed to provide input for the analysis of governance models that can be applied for a MOG.

Through the design space, four different governance models were constructed and analysed, based on the analytical framework. Three of the constructed governance models rely on long-term contracts and further unbundling of electricity grid activities (being electricity transmission and system operation), while one governance model (the TSO model) relies on regulation and bundling of the electricity grid activities. The analysis of these governance models shows that there is no optimal governance model. However, to facilitate the efficient deployment of a MOG, the TSO model is considered most preferable, as this governance model is able to facilitate the gradual development of a MOG, while also facilitating efficient operation by limiting coordination issues that can arise due to unbundling. This model will rely on current owners of the TSOs to provide the necessary investment capital and it remains to be seen whether these owners have the willingness to do so, provided the enormous scale of investments to reach EU climate goals.

Table of Content

List of Abbreviations

Abbreviation	Explanation
AC	Alternating Current
BOOT	Build-Own-Operate-Transfer
CAPEX	Capital Expenditures
CBA	Cost-Benefit-Analysis
CfD	Contract for Difference
COP21	21st annual Conference of the Parties (*2015 United Nations Climate Change Conference)*
DC	Direct Current
DEVEX	Development Expenditures
DSO	Distribution System Operator
DT	Depreciation Time
EC	European Commission
EU	European Union
FOOT	Finance-Own-Operate-Transfer
FTV	Final Transfer Value
GW	Giga Watt
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IR	Incentive Regulation
ISO	Independent System Operator
ITO	Independent Transmission Operator
ITSO	Integrated Transmission System Operator
MOG	Meshed Offshore Grid
MS	Member State
NPV	Net Present Value
NRA	National Regulatory Authority
OFTO	Offshore Transmission Owner
OPEX	Operating Expenditures
OU	Ownership Unbundling
OWF	Offshore Windfarm
PC	Price Cap
PFI	Private Finance Initiative
PPP	Public Private Partnership
RAB	Regulated Asset Base
RAV	Regulated Asset Value
RoR	Rate-of-Return
SDE+	Subsidie Duurzame Energie +
SO	System Operator

TO	Transmission Owner
TPA	Third Party Access
TRS	Tendered Revenue Stream
TSO	Transmission System Operator
UK	United Kingdom
VIU	Vertically Integrated Utility

List of Figures

1 Introduction

1.1 EU Climate goals: The North Sea offshore wind contribution

In order to meet the European Union (EU) climate goals, EU member states are looking for opportunities to increase their sustainable electricity generation. One of the main pillars to reach these goals, is to increase the amount of offshore wind energy in the North(ern) Sea(s) at an affordable cost for the consumer of electricity (European Commission, 2017).

As shown in Figure 1 the installed offshore wind production capacity in the EU is currently exceeding 12 GW of which 9 GW is located in the North Sea (Wind Europe, 2017), with many offshore wind farms (OWF) currently being planned and initiated. Still, sustainable electricity generation accounts for approximately 30% (of which 5,4% is wind energy) of all consumed electricity in the EU (Eurostat, 2016), while a full transition towards sustainable electricity production is necessary to reach climate goals as agreed upon in the Paris climate agreement (COP21). Transitioning from a fossil-fuel dominated society towards a fossil-free society will therefore necessitate significant investments in fossil-free electricity production facilities, such as offshore wind energy and the required grid infrastructure to evacuate these large amounts of offshore wind energy.

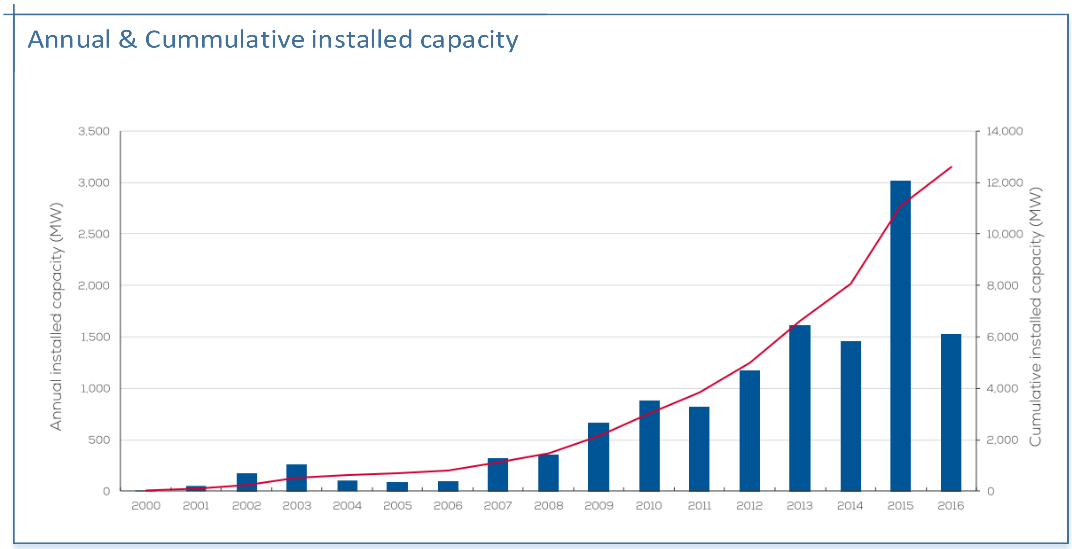


Figure 1: Offshore wind installations (Wind Europe, 2017)

In addition, the European Commission (EC) is pushing for more integrated electricity markets between Member States, thereby pushing for additional interconnection capacity, lowering prices through enhanced energy exchange and competition, and reducing the required overall back-up capacity to maintain the energy system balance (European Commission, 2015). To do so, the EC has defined four electricity infrastructure priority corridors, one of which is the North Sea offshore grid, as laid down in Regulation (EU) 347/2013 on the trans-European energy infrastructure.

1.2 Potential offshore grid developments

Projections for offshore wind deployment in the North(ern) Sea(s) is varying from 44,6 GW (low scenario) up to 98,1 GW (high scenario) in 2030 (Wind Europe, 2017). In order to meet the climate goal of COP21, which implicates a total decarbonisation of the electricity supply, the countries surrounding the North(ern) Sea(s) will ultimately need more than 180 of offshore wind power in 2045 (Ecofys, 2017a). These offshore windfarms require substantial electricity infrastructure. Additionally, to address the requirements for increased flexibility options, 50-80 GW of interconnection capacity between electricity markets is projected to be necessary (Ecofys, 2017b).

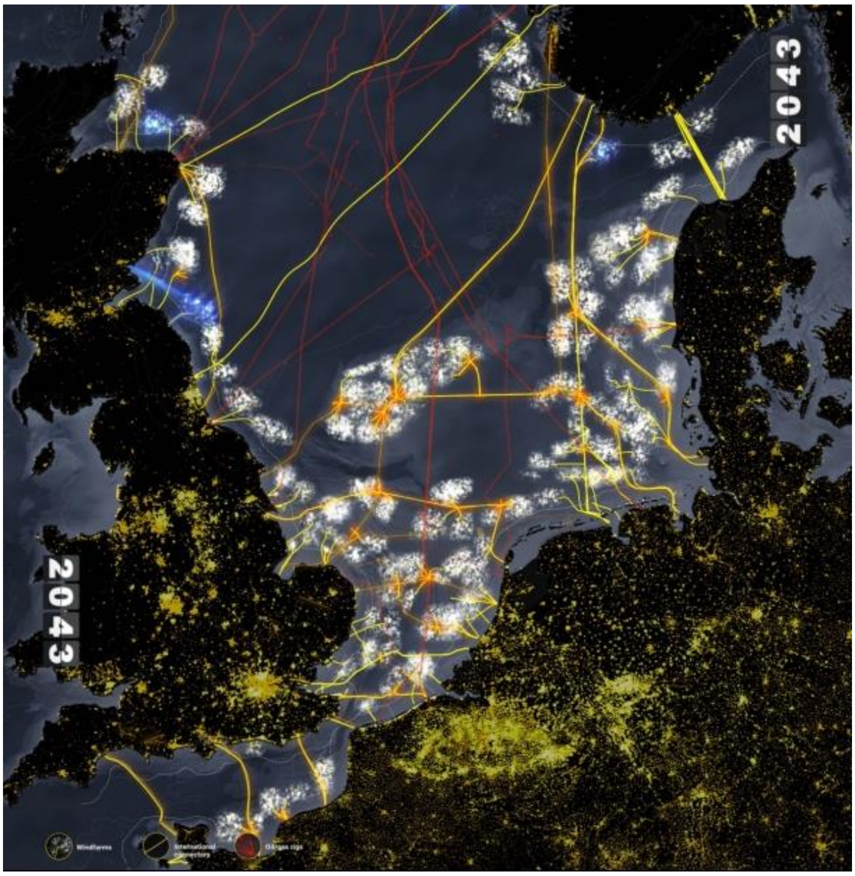


Figure 2: Illustration of possible North Sea infrastructure development (IABR, 2017)

While the cost-trends for electricity grid infrastructure are difficult to forecast, estimations of investment costs for the grid infrastructure are projected to be between €69-108 billion until 2030 (NSOGI, 2014). These estimations include interconnection capacity, which make up 15-30% of total investments and assume 52-100 GW of installed offshore wind power capacity. For the period 2030-2050 no investment cost projections have been made yet, however, given the gap between the 230 GW of capacity which is necessary in 2045 and the assumed 52-100 GW in 2030, it is obvious that large additional investments are necessary within the period 2030-2050.

Where currently offshore windfarm developers, Transmission System Operators (TSO) and other infrastructure investors have the burden to finance offshore infrastructure, more responsibilities were recently allocated to TSOs. Not only the Dutch but also the Danish and German TSOs were made responsible to provide offshore grid connections for OWFs. Coupled with an increase in offshore infrastructure developments in the coming years, the TSOs have an increasing amount of responsibilities. The investments to connect OWFs to the onshore grid, in the TSO model, significantly affect the balance sheet of the TSO. As the necessary investments would require either equity injections by its current shareholder(s) or equity injections by private investors that demand a certain (higher) return on investment to participate in such transactions, affecting the tariffs paid by the users of the infrastructure (PROMOTioN, 2017b).

1.3 Offshore electricity transmission governance: current practice

In the EU, different Member States (MS) apply different regulatory regimes to govern the responsibilities of planning, constructing, owning, operating and maintaining the offshore transmission assets. The application of different regulatory regimes within the EU is a consequence of lacking overarching EU directives, thereby enabling EU member states to design the regulatory framework to their own preference. In addition, both OWF grid connection assets and interconnection transmission assets have different regulatory frameworks across the EU (Müller, 2015).

More specifically, the regulatory regime regarding ownership and operation can be defined through specific governance models. Table 1 provides an overview of these, currently applied, governance models. For the connection of OWFs, three distinct owners can have responsibility of the offshore transmission assets: the owner of the windfarm (generator model), the TSO of the grid to which the OWF is connected (TSO model) or a 3rd-party who will buy or build the offshore transmission assets which are necessary to connect the OWF to the grid (3rd- party model), this 3rd- party model is called the Offshore Transmission Owner (OFTO-model) (Ofgem, 2014). Regarding the interconnection transmission assets, two abstract governance models can be identified in current practice: a regulated governance model, which is driven and initiated by national TSOs, while the merchant governance models rely on third-party infrastructure investors. Appendix A provides a more detailed description of the possible interconnection governance models.

Governance models	
Grid connection OWF infrastructure	Interconnection infrastructure
Generator model	Regulated
TSO model	Merchant
OFTO-model	

Table 1: Applied governance models

1.4 Historic barriers for lacking MOG development

By combining the necessity to increase offshore wind capacity and the necessity to integrate markets through interconnection, an opportunity is created to construct new transmission infrastructure that can achieve both goals simultaneously. A hybrid grid, also called meshed offshore grid (MOG) can enable market integration through the interconnection of these markets. In addition a MOG can transport by offshore wind farms (OWFs) generated electricity in to these interconnected markets (NSOGI, 2014). As such, MOG solutions are characterized by having hybrid transmission assets, as they fulfil two functions: interconnection of electricity markets and connecting OWFs. Such a MOG would not only combine the aforementioned functions, studies regarding the costs and benefits show that such a MOG would also provide economic benefits compared to other alternatives (NSOGI, 2014).

However MOG solutions are still lacking in development. Previous studies have found that the lacking development of a MOG is caused by economic and regulatory barriers (B. Flynn, 2016; Klip, 2015; NORTHSEAGRID, 2015). One of the barriers that caused the lacking development of a MOG was the lacking political support (NORTHSEAGRID, 2015), most likely due to the historical high cost of offshore wind energy which therefore required large amounts of subsidy. However, the cost of offshore wind has been reduced in the last couple of years, evidenced by the recently auctioned subsidies in Germany. One OWF developer won the tender with a "zero-subsidy" bid, which means that the OWF developer will not require any subsidy to deliver the offshore wind energy (Wind Power Offshore, 2017). It is thereby expected that political support for offshore wind energy will increase in the upcoming years.

Currently, point-to-point interconnection and radial grid connections of OWFs are the first options to be explored, mainly because of the fact that OWFs that have been developed up until now were not far shore. When OWFs will be developed far shore, for example, the benefits of MOG solutions will increase as the incremental costs of including offshore transmission assets that simultaneously interconnect electricity markets will decrease. Looking for instance at the Dutch OWFs that lie farther ashore (towards the UK), the incremental costs of providing the interconnection function with the UK electricity market decreases proportionate to the distance of the Dutch OWF to the UK.

Another key barrier is the lacking legal certainty for MOG solutions, as currently there is no separate legal classification for assets that fulfil both the function of connecting the OWF and interconnecting electricity markets (PROMOTioN, 2017c). As a result, TSOs (or other infrastructure investors) don't have the required legal certainty under which regulatory regime they will operate and thus are not certain of the revenues they can obtain by investing in these assets.

Associated with the investment uncertainty for MOG solutions, is a lacking economic framework that enables fair and efficient sharing of costs and benefits (NORTHSEAGRID, 2015). Currently, cost benefit analysis methods lack the ability to monetize all costs and benefits (PROMOTioN, 2017a), thereby creating a situation in which it is not possible to allocate the costs and benefits of MOG solutions proportionately across the involved countries.

1.5 Appropriate governance model as key MOG driver

While the previous section described a variety of barriers that hampered the development of a MOG, this section will introduce a key barrier that will be the focal point within this research.

For new transmission infrastructure, similar to current electricity transmission infrastructure, a natural monopoly of a single ex-post supplier is the effective economical outcome of the market (Joskow, 2007; Vogelsang, 2005; Williamson, 1976). This will therefore require policy makers to address institutional choices of the economic activity which contribute to achieving a socially acceptable economic outcome, preventing the duplication of transmission assets. The institutional choices are related to the allocation of ownership and operational responsibilities.

Hence, prior to the development of MOG solutions, many regulatory aspects will need to be addressed for the natural monopolist to behave appropriately, so that the economic outcome is socially acceptable and therefore maximizes social welfare. Especially given the fact that a specific regulatory framework for the development of a MOG is lacking in the countries surrounding the North(ern) Sea(s) (Flynn, 2016; González & Lacal-Arántegui, 2016; Müller, 2015).

Furthermore, the current trend shows that the share of transmission costs will continue to increase in the overall costs of offshore wind energy (Offshore Wind Programe Board, 2016). These rising transmission costs increase the relevance of introducing policy measures regarding the offshore transmission system that contribute to the objective of lowering the overall costs for offshore wind energy that will be presented to the consumers of electricity.

To initiate MOG developments, one of the key elements is the governance model regarding the ownership and operation of the offshore transmission assets of a MOG. The governance model will ultimately allocate responsibilities over these assets when planned and constructed. A governance model also allocates the roles and responsibilities of the parties involved when the offshore electricity transmission assets are operational. The choice of governance model regarding the ownership and operation of offshore transmission assets influences decision making on investment and ownership responsibilities during the lifetime of the infrastructure assets. In addition, the governance model determines which entity needs to plan, build, finance, own and operate hybrid electricity transmission infrastructure. Selecting the appropriate governance model, which addresses ownership and operating responsibilities, can therefore be considered as an essential driver for the development of MOGs. The aim of this research is to determine the most appropriate governance model regarding the ownership and operation of offshore transmission assets which will facilitate the efficient deployment of a MOG.

2 Research objective & research questions

2.1 Research objective

The introduction has provided the necessary context to rationalize the importance of a governance model to govern the allocation of responsibilities regarding the ownership and operation of offshore transmission assets. As the introduction explained that an overarching EU regulation is lacking to address the allocation of responsibilities regarding offshore transmission assets which can be part of a meshed offshore grid.

Therefore, the objective of this research is to analyse what the governance model for an MOG should be, so that it facilitates the efficient deployment of a MOG. As described in section 1.4, the governance model for a MOG will be integrating the existing governance models which are currently applied for OWF grid connections and interconnectors, as illustrated in figure 3.

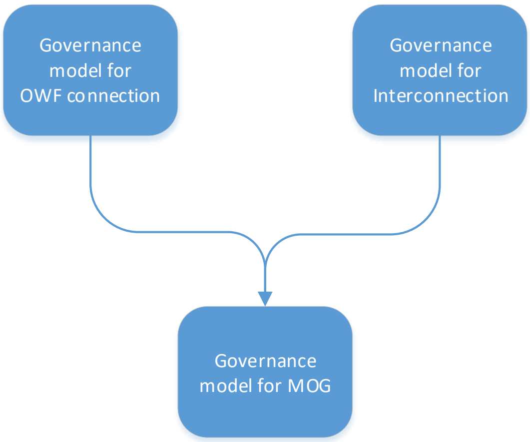


Figure 3: Combination of governance models

This research can contribute to a better understanding of how the allocation of responsibilities regarding ownership and operation should be governed. Obtaining a better understanding of these topics can then contribute to the overall lacking knowledge regarding the content of a regulatory framework how to efficiently develop a MOG.

While the term "governance model" can be confused with many different practices as the term "governance model" is not unambiguous, within this report the term "governance model" will be used to address <u>the allocation (and allocation method) of responsibilities regarding transmission grid activities related to offshore grid transmission assets that fulfil the function of connecting OWFs to the grid and interconnecting electricity markets</u>. These transmission grid activities include: transmission infrastructure planning, financing, constructing, owning, operating and maintaining. The aforementioned grid activities will be explained in more detail within this research.

2.2 Research questions

In order to address the research problem and achieve the research objective, the main research question is defined as follows:

What should the governance model be, in terms of the allocation of responsibilities regarding the ownership of offshore assets and system operation, for a Meshed Offshore Grid to be deployed efficiently?

Given the complex nature of this research question, the following applicable sub-questions have been defined to break down the main research question:

1. *What are the main characteristics of a MOG?*
2. *What theoretical concepts apply to the governance models for the ownership and operation of electricity transmission assets?*
3. *What is the current practice in governance models for radial OWF grid connections?*
4. *Which alternative governance model can be designed to allocate ownership and operating responsibilities in a MOG?*
5. *What is the most appropriate governance model for a MOG?*

2.3 Research structure

In order to answer the main research question and related sub questions, a variety of research methods will be used. Chapter 3 and 4 will have an identical approach and method; as desk research is used to describe the characteristics of a MOG (chapter 3), furthermore a literature review is used in chapter 4 to describe the theories regarding a natural monopoly and the governance of electricity grid activities. Chapter 4 will also include desk research as two case studies, presented in section 4.3, are analysed through a desk research. These two case studies will be concluded in a quantitative comparative analysis in which a cash flow model is used to compare the two cases.

Based on the analytical framework and case studies of chapter 4, chapter 5 will describe the expected performance of potential governance models while in addition the objectives and design space for a governance model will be described. Chapter 6 will describe the alternative governance models in the design space, which is introduced in chapter 5.

Chapter 7 will assess the different governance models through the objectives of a governance model for a MOG. The assessment of each governance model (chapter 7) will be done through both a quantitative assessment, which is based on the cash flow model of the case studies, and a qualitative assessment based on the MOG implications (chapter 3) and the synthesis of the analytical framework (chapter 5).

Subsequently, chapter 8 will provide conclusions and recommendations by answering the main research question and sub questions. Finally, chapter 9 will provide a reflection on the research methods and results presented in this report.

Figure 4 provides an overview of the research structure:

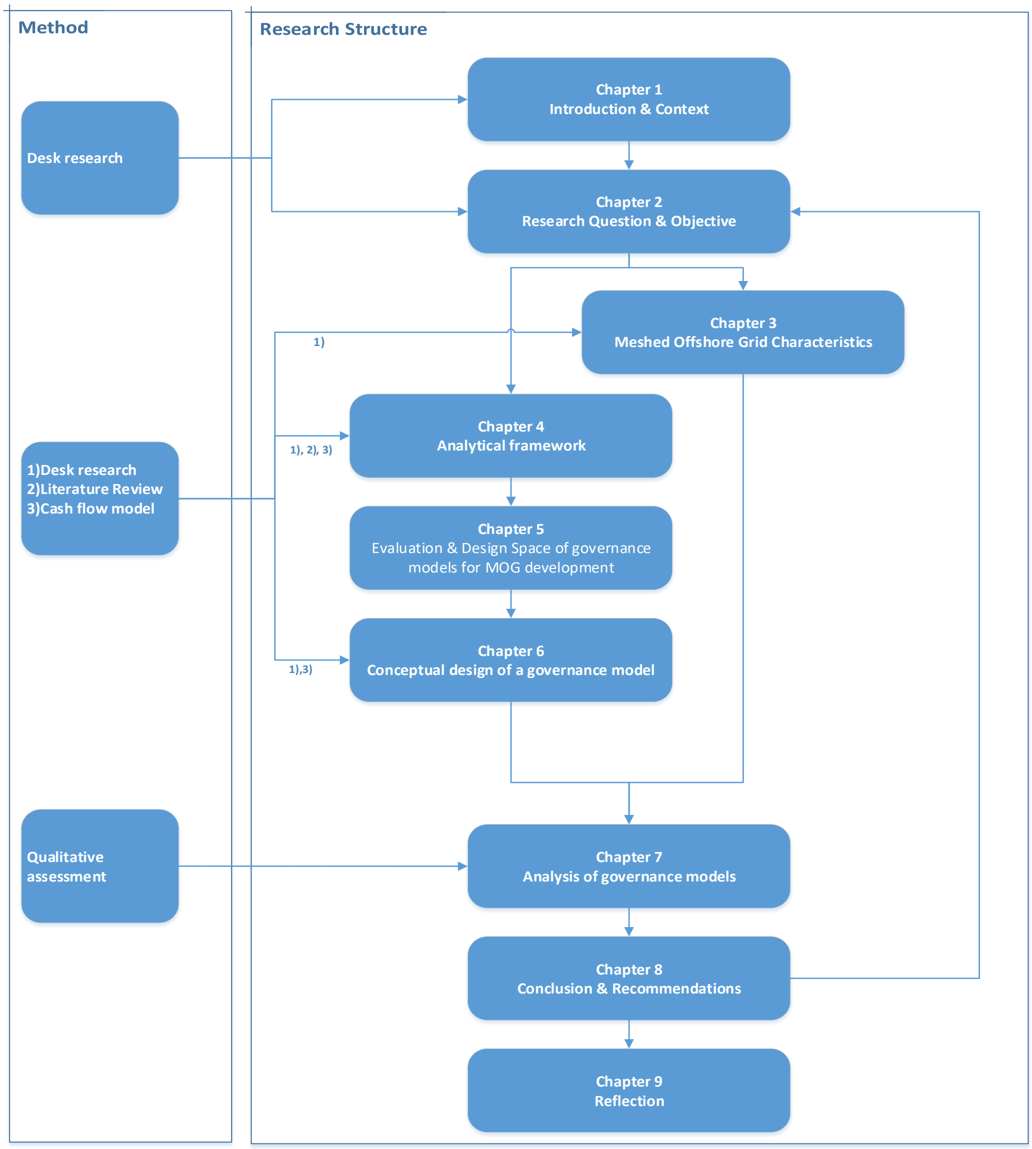


Figure 4: Overview of research structure

2.4 Research scope & positioning

This research focusses on the governance models regarding ownership and operation of a MOG in the North(ern) Sea(s). As explained in the introduction, the surrounding countries of the North(ern) Sea(s) use distinct governance models to allocate ownership and operational responsibilities of the offshore electricity transmission assets. As of now, there is no consensus which governance models is most efficient to connect OWFs, consequently there is no consensus as to which governance model is most efficient for meshed offshore grid infrastructure.

The choice for the geographical focus is primarily driven by the expected developments for offshore wind in this region and the discrepancy of the governance models in the North(ern) Sea(s) bordering countries.

While questions surrounding governance models for ownership and operation are closely related to the regulatory frameworks for (joint) support schemes (e.g. subsidies), market arrangements and costs & benefits sharing mechanisms across the EU, this report will not specifically address these regulatory issues and will instead solely focus on the governance model regarding the ownership and operation of a MOG, as shown in figure 5.

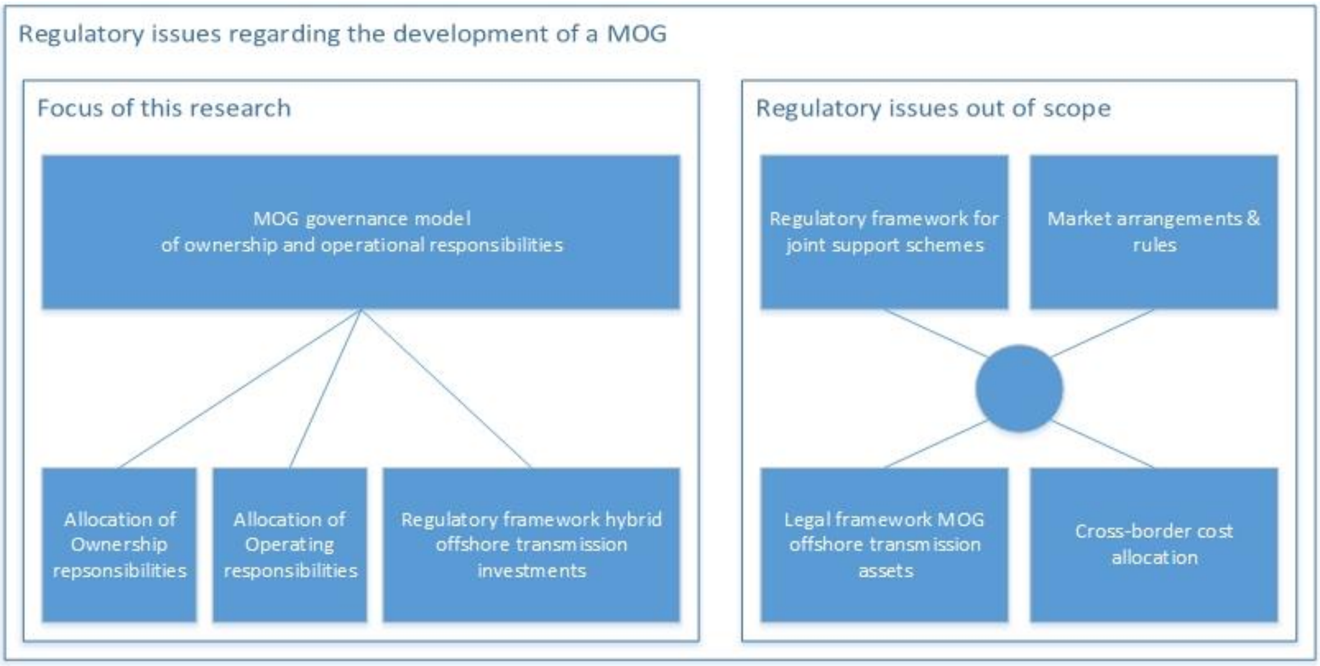


Figure 5: Positioning of research within wider regulatory issues

3 Characteristics of a MOG

This chapter will provide a description of the characteristics of a possible MOG. These characteristics will be described through the functional and economical aspects that define a MOG.

3.1 Functions of offshore electricity transmission systems

Currently, most offshore wind farms are connected to the onshore grid through so-called radial connection, shown in figure 6. While interconnection is realized through so-called point-to-point connections.

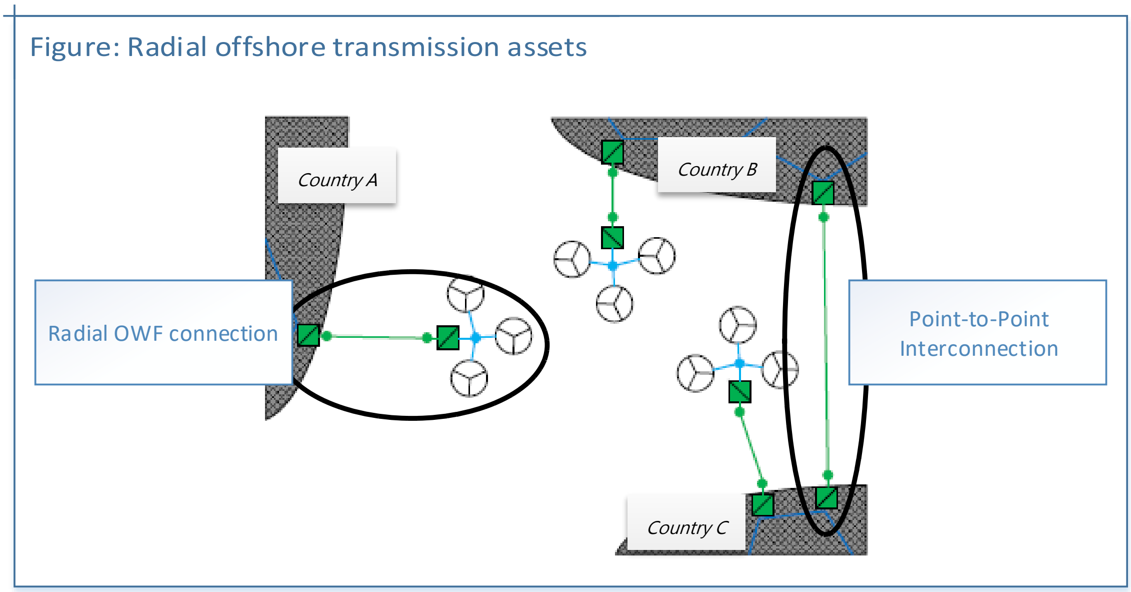


Figure 6: Individual offshore transmission assets

An integrated approach can contribute to achieving a cost-efficient development of offshore transmission assets, and hence optimize the costs for the consumer of electricity (NSCOGI, 2014). Consequently, the development of offshore transmission assets should be taking a total system perspective in the development of cross-border interconnection capacity and the connection of OWFS to the onshore grid. A total system perspective not only takes into account the costs related to the actual OWF grid connection, it additionally optimizes the interconnection function and the onshore grid reinforcements to accommodate the offshore grid developments. Hence, MOG solutions can be constructed to facilitate the offshore wind developments in the North(ern) Sea(s).

Within this report, a MOG is defined as the meshed integration of cross-border interconnection infrastructure with the grid connections of OWFs. A MOG allows electricity flows to take different paths from generation to load, which is different from point-to-point configurations. Within this definition, many degrees of freedom still exist that could lead to numerous final configurations of this MOG. Figure 7 provides an example of how such a MOG could be envisioned. This definition takes a broad scope and thus it does not exclude Alternating Current (AC) or Direct Current (DC) solutions.

Figure: Meshed offshore transmission assets

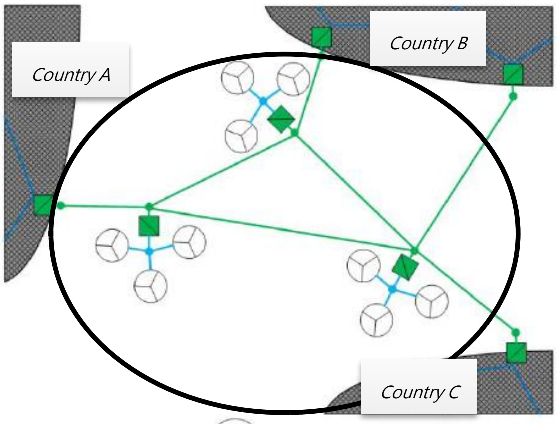


Figure 7: Meshed (hybrid) offshore transmission assets

Zooming in on the costs of specific projects, before a MOG solution is chosen, the exploratory phase of such a grid would need to prove that such a grid would be more cost efficient than a radial connection and interconnection separate (NSCOGI, 2014).

3.2 Economics of offshore electricity transmission systems

3.2.1 Revenue models

As a MOG combines both the function of evacuating offshore wind energy and interconnecting electricity markets, a MOG can derive revenues through two distinct means: arbitrage revenues (congestion rent) and complementary charges which are necessary to recover the total costs of the offshore transmission assets when congestion rent is not sufficient to recover the total cost of ownership (Pérez-Arriaga, 2014). These complementary charges can be necessary, as the transmission asset can be desirable from a social welfare perspective.

If the offshore transmission infrastructure enables the interconnection of electricity markets, revenues or congestion rents can be derived from these markets by arbitraging between these interconnected markets. Price difference between interconnected markets will lead to a transport flow from the market with the lowest price to the market with the highest price through this interconnection transmission asset. The owner of the transmission infrastructure assets will consequently be able to derive revenues from these assets through payments from the users of the grid (Hogan, 2011).

Regarding the grid connection of OWFs, the offshore transmission assets connect the OWF to the load centres onshore, which enables an OWF to transport its produced electricity to the load centres, enabling the entry to a specific electricity market. Vice versa, it enables consumers of electricity to consume electricity produced from OWFs. The transmission costs are ultimately paid by (or partially paid for by) the users of the MOG.

3.2.2 Transaction costs for the OWF system

A perspective regarding the transaction costs is to be distinguished for the development of a MOG and the connected OWFs in general. In view of the overall cost efficiency of a governance model from a consumer perspective, two distinct system levels can be distinguished: 1) the offshore transmission system separately and, 2) the offshore transmission system and the offshore windfarm combined. While the North(ern) Sea(s) countries have different terms and conditions as to how an OWF can be developed, the allocation of ownership for the offshore transmission asset will also impact the amount of transaction costs (born from risks and uncertainties) incurred by the OWF. The Danish, Dutch and German OWF tender regimes are prime examples of these lowered transaction costs. In these tender regimes the TSO takes on the responsibility of providing an offshore connection point to which the OWF can connect, thereby lowering search and information costs (or transaction costs) prior to the subsidy tender for OWFs.

By de-risking the business case of the OWF through the aforementioned lowered transaction costs (associated with the development and construction of the offshore transmission system) a level playing field is created when a specific OWF site is put up for tender through a reverse auction[1] for the amount of subsidy. The creation of a level playing field enhances the competitive environment which should ultimately lead to the lowest possible subsidy amount.

Contrastingly, when the OWF developer is responsible for the offshore transmission system, the OWF developer incurs these transaction costs and will include these uncertain costs (primarily construction risks) in its tender bid or required subsidy level to realize an economically sufficient business case, thereby increasing the costs for the consumer.

3.3 Interim conclusion

This chapter has provided the functional and economic aspects that are associated with the concept of a MOG and the application of a governance model. More specifically, this chapter showed that a MOG provides two functions: 1) connecting OWFs to the onshore grid, enabling OWFs to evacuate their produced electricity to the onshore load centres and, 2) interconnecting electricity markets to increase social welfare in the interconnected countries. Because of the aforementioned functions, a MOG can derive revenues by arbitraging between two (or more) electricity markets, while also charging additional tariffs to recover the total cost of ownership.

Finally, by providing the grid connection infrastructure when OWF sites are put up for tender, transaction costs are lowered (through eliminated uncertainties and decreased risks), thus enabling a level playing field when parties compete for the required amount of subsidy to develop an OWF.

[1] In a reverse auction, the roles of buyers and sellers are reversed. Essentially sellers are competing for the right to delivers a certain service or good to the buyer.

4 Analytical framework

This chapter will provide an overview of the applicable literature regarding the factors that influence the policy choice for a specific governance model for the ownership and operation of a MOG. This chapter will therefore, firstly, go through the overarching economic and regulatory theories in section 4.1, thereby highlighting the institutional choices for policy makers. Secondly, this chapter will describe the theory applicable to the unbundling options of electricity grid activities in section 4.2, by describing the grid activities which need to be performed in order for a transmission grid to fulfil its function, providing short-term and long-term security of electricity transmission. Thirdly, in section 4.3 two case studies will be introduced which will provide examples of the governance of electricity grid activities (applied to radial grid connections of OWFs) and the regulatory and economic theories. Concluding, based on the integration of the technological context, the regulatory and economic theories and the case studies, chapter 4 will provide the necessary input which is synthesized in chapter 5 (illustrated in figure 8).

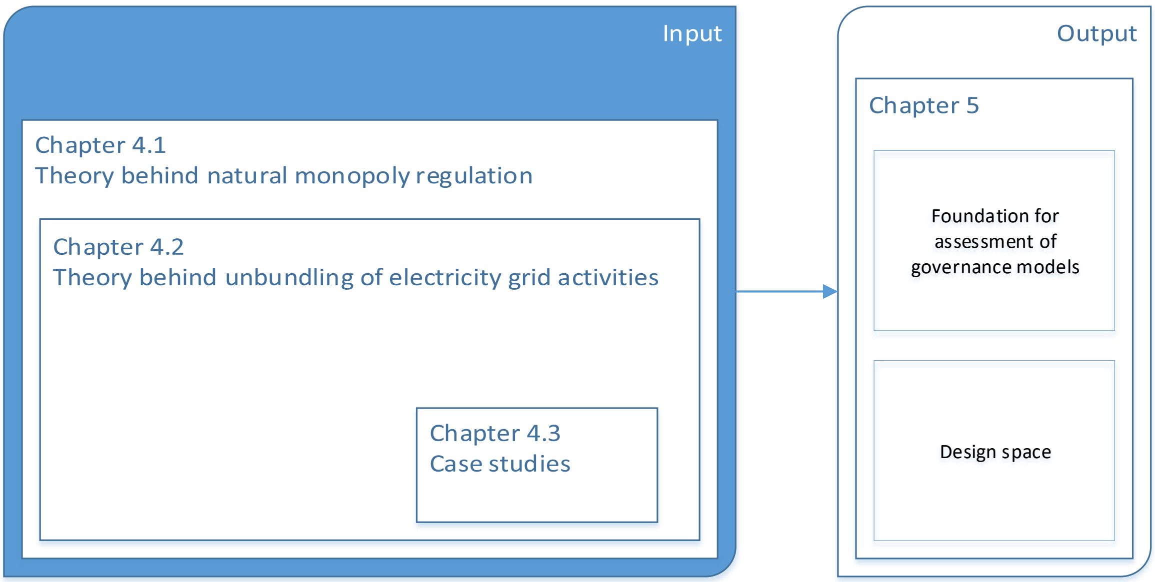


Figure 8: Input-Output diagram Chapter 4

4.1 Theory behind natural monopoly regulation

Whenever economies of scale or externalities make it economically efficient for having only a single supplier for the market, scholars talk about a natural monopoly industry (Demsetz, 1968; Joskow, 2007; Pérez-Arriaga, 2014; Williamson, 1976). Therefore, ownership of a natural monopoly is a widely discussed topic in economic literature as the natural monopolist is able to abuse its market power, charging excessive prices to the consumer which leads to decreasing social welfare (Joskow, 2007). This section will describe the institutional choices for a natural monopoly in general and electricity transmission in specific as both system operation activities and transmission ownership activities are regarded as natural monopolies (Pérez-Arriaga, 2014) and therefore governments intervene by deciding upon the institutional arrangements of these activities.

4.1.1 Institutional choices for a natural monopoly

Within the literature we can distinguish two types of natural monopoly regulation, to prevent the abuse of market power, when the institutional choice is to vertically integrate[2] the natural monopoly: rate-of-return (ROR) and incentive regulation (IR).

Contrastingly, Franchise Bidding tries to include the possibility that ex-ante bidders are available to compete for the market, rather than accepting the fact that there is no competition possible within the market, which is the primary characteristic of a natural monopoly.

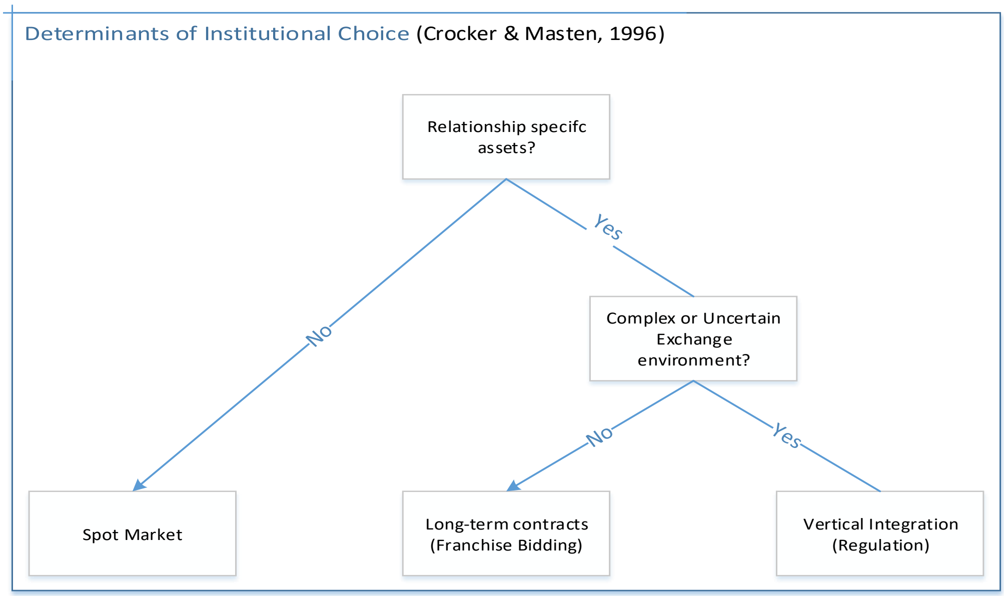


Figure 9: Determinants of institutional Choice, (Crocker & Masten ,1996)

Figure 9 provides a systematic overview of the so-called "determinants of institutional choice" , which originates from the institutional debate on how to regulate a natural monopoly, deliberated upon by Crocker & Masten (1996). Scholars such as Williamson on the one hand are critical on the use of Franchise Bidding for a natural monopoly, due to incomplete contracts and transaction costs (Williamson, 1976) and on the other hand Demsetz (Demsetz, 1968) is proposing Franchise Bidding as an institutional choice that can replace regulation.

The determinants of institutional choice, as proposed by Crocker & Masten, will therefore be the guideline and lens in dissecting the policy choices regarding the institutions for a natural monopoly to prevent the abuse of market power by the monopolist.

While there are two main types of regulation, Rate-of-Return and Incentive-Regulation, when vertical integration is applied, in practice the two types of regulatory approaches are used in hybrid forms, as technology or market specific costs need to be accounted for to optimize the regulation of a natural monopoly (Joskow, 2007), therefore there is not a one-size fits all regulation. In section 4.1.2 the two types of regulation will be discussed and section 4.1.3 will discuss the institutional choice of Franchise Bidding.

[2] Within this report vertical integration is defined as a centrally coordinated allocation of natural monopoly ownership

4.1.2 Vertical integration (regulation)

This section will describe the institutional choice of vertical integration, as shown in figure 10, which relies on regulation to govern the owner of a natural monopoly and thus tries to prevent monopolistic behaviour through regulation.

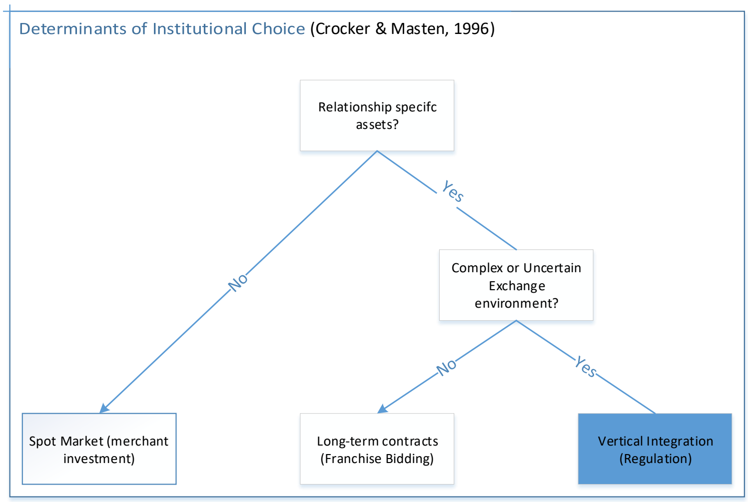


Figure 10: Institution choice- Vertical Integration (regulation)

4.1.2.1 Rate-of-Return regulation

Rate-of-Return (ROR) regulation is regulation in which the total accounted costs to provide a service, predominantly with a one-year time horizon, are essentially the allowed revenues for that specific year (Joskow, 2007; Liston, 1993; Posner, 1969). These total costs of service or allowed revenues usually consist of several types of costs:

Operating costs

These are the costs associated with the daily operation of the natural monopoly and typically consist of maintenance costs, management costs and other market specific variable costs.

Capital related costs

Capital related costs consists of a variety of factors, such as depreciation cost for the asset base of the natural monopolist, cost of debt, cost of equity and tax related costs. The overall cost of capital is related to the risk level of an investment. For example, investments with a low risk profile normally have a high guarantee of the eventual return on these investments. Contrastingly, investments with a higher risk profile have a lower guarantee of the ultimate returns on these investments.

A widely used approach to account for these costs is the Regulated Asset Base (RAB) approach in which the investment costs are entering the Asset Base of the firm and the firm is subsequently allowed to receive revenues based on this asset base. The allowed revenues are a function of the asset base, depreciation costs, taxes and the weighted average cost of capital (WACC), which can be defined as follows:

$$WACC = g * Rd + ((1 - g) * \frac{Re}{1 - Tc})$$

With:

Re = Return on Equity

Rd = Debt interest rate

g = Gearing (ratio between debt and equity)

Tc = corporate tax rate

	Example
Re	6%
Rd	3%
g	50%
Tc	25%
WACC	5,50%

Figure 11: Example of WACC calculation

Allowed Revenues

When using the total cost perspective in ROR regulation, the regulated revenues are then calculated through the following formula:

$$AR = TC = O\&M + RAB * WACC + DC$$

With:

AR = Allowed Revenues

TC = Total costs of service

O&M = Allowed Operating & Maintenance costs

RAB = Allowed Regulatory Asset Base

WACC = Weighted average cost of capital

DC = Depreciation Costs

The previously discussed costs that determine the allowed revenues are subsequently the input for the to be determined tariffs, which will ultimately form the approved price by the regulator (Alexander & Irwin, 1996; Joskow, 2007). While this type of regulation prevents the monopolist to abuse its monopoly power by charging monopoly prices, it fails to incentivize the monopolist to operate efficiently (Averch & Johnson, 1962).

4.1.2.2 Incentive regulation

As the previously discussed regulation of a natural monopoly is inadequate in incentivizing the monopolist to become more efficient in its activities, Incentive regulation is not considered as a new concept of regulation, but more of an addition to rate-of-return regulation (Alexander & Irwin, 1996; Cowan, 2002; Harstad & Crew, 1999b; Joskow, 2007). In general, incentive based regulation is used to stimulate a competitive environment for a natural monopolist, as this competitive force is naturally lacking. The literature is distinguishing three types of incentive based regulatory approaches.

1)Price-cap regulation (PC), in which the regulating authority sets the price which the monopolist can maximally charge the consumers (Liston, 1993). The price can be adjusted upwards or downwards, depending on the rate of return of the monopolist. In practice this price is set by determining the efficient annual costs (and thereby revenues) of a monopolist and dividing this through the annual output of the monopolist.

2)Revenue-cap regulation is very similar to price-cap regulation, however the regulator is setting a revenue cap instead of a price cap and the monopolist is subsequently free to choose its expenditures (Pérez-Arriaga, 2014). By setting a revenue-cap the regulated firm is essentially relieved from volume risk (the annual demand), thereby de-risking the overall business case.

3)Benchmark regulation, in which the costs of identical firms are analysed and a price is set based on the costs of the other firms (Joskow, 2007; Pérez-Arriaga, 2014). Essentially making the firms compete against each other.

4.1.3 Long-term contracts (Franchise Bidding)

This sub-section will describe the institutional choice of long-term contracts, as shown in figure 12, which uses Franchise Bidding to govern the market and thus tries to prevent the firm to show monopolistic behaviour by creating competition for the market.

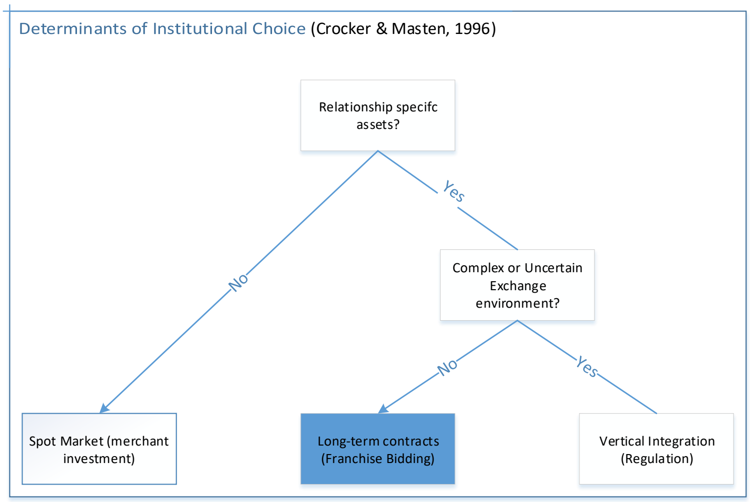


Figure 12: Institutional choice- Long-term contracts (Franchise Bidding)

4.1.3.1 Franchise Bidding

Franchise Bidding is an institutional choice which was initially introduced as a problem solving concept that would solve the issue of how to regulate a natural monopoly. Demsetz (1968) argued that competition for the market would remove the necessity of regulating a natural monopoly with a single ex post supplier. In Franchise Bidding, potential bidders compete for the market and the bidder who offers the most value for money (lowest required net revenue) for the consumer will obtain the contractual rights to be the single ex-post supplier of the market.

Regarding the auction procedures on selecting the preferred bidder in the auction, Demsetz (Demsetz, 1968) argued that Franchise Bidding is superior to regulatory counterfactuals, however the Franchise Bidding, should be designed in such a way that it would restrict the ex-post supplier to levy monopoly prices. Hence, selecting a preferred bidder in the Franchise Bidding procedure on who pays the largest lump sum to acquire the rights to derive revenue should therefore be avoided (Demsetz, 1968; Williamson, 1976). Subsequently, to avoid the previously discussed issue, the award criterion in a Franchise Bidding should be based on a price per unit, in which the preferred bidder in the reverse auction has the lowest price per unit to acquire the franchise rights of the natural monopoly (Stigler, 1974). By introducing a reverse auction, in which the winning bidder will supply the market in return for a predetermined price per unit, a long-term contract is designed to stipulate the formal arrangements between supplier and consumer (Crocker & Masten, 1996). The complications that arise, when using this type of institutional choice on public utilities, such as electricity transmission services, will be described in section 5.3.2.

4.1.3.2 Competitive public private partnership, a modern Franchise Bidding

When Franchise Bidding is applied as suggested by Stigler (Stigler, 1974), it can be seen as a Public Private Partnership (PPP) in which the natural monopoly is privatized through ex-ante competition for the market and the consumers of the product will underwrite the required revenues for the PPP to recover its costs, which are set by the winner of the bid (Dnes, 1995; Harstad & Crew, 1999a).

As for the PPP options, the government can choose from several different PPP structures and the choice for a specific option is depending on the ratio between public and private responsibility (Deloitte, 2006).

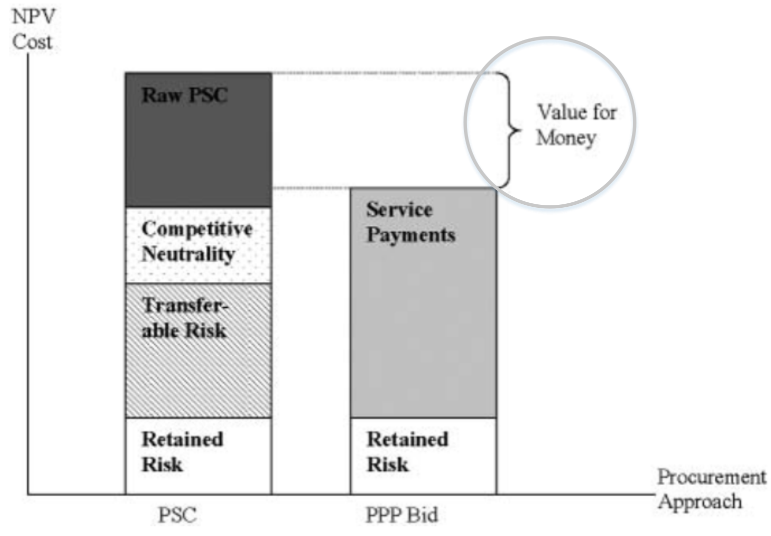
Value for money principle

The choice to use PPPs should be depending on the value for money assessment, which assesses whether the costs and benefits of using a PPP construction outperforms the costs and benefits of other potential procurement options (Froud, 2003; HM Treasury, 2006). This assessment compares the Net Present Value (NPV) of the life-cycle costs when a PPP[3] is used with the NPV of the life-cycle costs when the traditional way[4] is used (Morallos & Amekudzi, 2008), in which the delta between these NPVs is the value for money, as shown in figure 13.

In general the life-cycle costs are identical to the cash flows in the different procurement options. The value for money principle is therefore essentially a Cost-Benefit Analysis which focusses on the eventual costs presented to the ones who will underwrite the revenues for the service provision at hand.

[3] Within this report, the PPP method is referring to life-cycle costs when a Franchise Bidding approach is used
[4] Within this report, the life-cycle costs of the traditional way is referring to life-cycle costs incurred through the current practice when the natural monopoly is allocated centrally (vertical integration)

Value for money Example



Note: VfM = value for money; PSC = public sector comparator; PPP = public–private partnership.

Figure 13: Value for Money calculation

Moreover, empirical evidence shows that the following conditions must be met when a PPP construction delivers more value for money (EIB, 2015):

- Significantly large investment
- Private sector expertise to design and implement complex projects
- Possibility of detailed service description to put into a contract
- Clear definition of risk allocation between contractor and procurer
- Life-cycle costs estimation must be possible
- Stable technology

These conditions are in line with the requirements for an effective Franchise Bidding, as concluded by Williamson (1976).

When applying these requirements on a potential electricity transmission asset, two PPP structures can fulfil these requirements: 1) Build-Own-Operate-Transfer (BOOT), 2) Finance-Own-Operate-Transfer (FOOT). This implies that the electricity transmission assets are either already built by another party (FOOT), or that the winning bidder still needs to build the electricity transmission assets (BOOT). A FOOT PPP structure can also be referred to as a Private Finance Initiative (PFI), which is characterized by the PPP delivering mostly financing solutions. Within this report, the term FOOT will be used to refer to this type of PPP structure.

Theoretically, other PPP structures are possible, however this report builds upon implemented PPP structures for electricity transmission projects, which conclude that other PPP structures are less appropriate and less efficient for electricity transmission projects (CEPA, 2014).

4.1.4 Interim conclusion

While limited empirical evidence is available to determine the effectiveness of incentive based and RoR approaches, Mathios & Rogers (1989) observed lower rates for the AT&T telecommunication network in PC regulated states compared to the rates in AT&Ts telecommunication network in RoR regulated states. These observed lower rates are attributed by Mathios & Rogers (Mathios & Rogers, 1989) to the increased incentive to innovate in a PC regulatory regime to reduce costs and therefore increase profits. Many NRAs are therefore increasingly using incentive regulation to increase the efficiency of the regulated company. One general issue, regarding the effectiveness of incentive regulation, however remains; the information asymmetry associated with determining crucial cost parameters, such as cost of capital and operating costs (Joskow & Tirole, 2003; Pérez-Arriaga, 2014; Vogelsang, 2006).

When determining the effectiveness of Franchise Bidding, there is much debate regarding the implications of Franchise Bidding, especially when applied to public utilities. While Williamson (Williamson, 1976) argues that Franchise Bidding is potentially able to place more discipline on utility companies, its potential benefits are less transparent due to the possibility of incomplete contracts which would add transaction costs when the incompleteness of contracts is addressed in future negotiations (Williamson, 1976). The possibility of incomplete contracts is originating from the fact that public utilities usually require large lump sum investments and the services need to be supplied not only for the lowest price, but also with a certain quality standard for a long period of time. These aspects, added with future uncertainty about the required service, will therefore "leave long-term contracts for public utility services inevitably incomplete" (Crocker & Masten, 1996). Given this contract incompleteness in the public utility sector, a long-term contracted supplier of the service will therefore exercise its contractual rights. By exercising its contractual rights, this will result in additional transaction costs, since the contractor will require financial compensation if contractual rights are not respected or compensated appropriately.

Concluding, the effectiveness of Franchise Bidding is relying on the complexity of the contract and the certainty of the future requirements of the service, as an effective Franchise Bidding can only result from a clear service description for the entire contract duration. A more detailed description of the conditions which contribute to the effectiveness of a Franchise Bidding scheme has been developed through the literature for competitive PPPs.

4.2 Theory behind unbundling of electricity grid activities

As the previous sub-section described the general institutional choices and their implications for a governance model for a MOG, this sub-section will deliberate upon the specificities of electricity transmission services and the possible unbundling options.

4.2.1 Distinguishing the different grid activities

The development of a MOG is characterized by the development of multi-functional electricity transmission assets, as explained in the introduction, where the function of interconnecting electricity markets is combined with the grid connection of OWFs to accommodate the evacuation of offshore wind energy. This sub-section will therefore elaborate on the characteristics of electricity transmission systems to introduce the overall governance aspects and policy choices regarding the transmission assets and its operation.

In general, the following grid activities can be distinguished in relationship to the transmission assets (Pérez-Arriaga, 2014): 1) Investment planning of new transmission assets, which is the planning of capacity, location, timing and overall design of new transmission assets, 2) construction of transmission assets, which is usually conducted by specialized companies appointed through competitive tendering or otherwise selected by the initiator of the transmission investment, 3) maintenance planning of transmission assets, 4) maintenance of transmission assets, 5) operation of transmission assets, which is the real time balancing of the system and managing the electricity flows so that supply and demand are in balance. These activities can be bundled into two specific transmission services, Transmission Ownership (TO) and System Operation (SO) of the transmission assets. TO services covers the overall activities for managing the transmission assets, hence financing, owning and maintaining the transmission assets. On the other hand, SO services covers the transmission tariff administration, congestion management and capacity allocation and overall system balancing of the system by maintaining a predefined system frequency.

The scope of this report does not exclude AC or DC technologies, nor does it focus on one specific technology, as defined in the introduction. However, when DC technology is predominantly used in a MOG, the system balancing activities to maintain the system frequency are likely to be unnecessary, as DC technology has no frequency and therefore a MOG would require less balancing activities. However, it is assumed that with a high penetration of offshore wind energy some sort of balancing capacity will be needed which needs to be coordinated and controlled. To what extent these balancing activities will take place is still unknown and part of a wider research area (PROMOTioN, 2017c). The choice of technology therefore impacts the services which a System Operator needs to deliver.

Figure 14: Stages in transmission projects

Taking into account the different grid activities for the development of new transmission assets, as explained in the previous sub-section, we can therefore define three distinct stages within offshore transmission projects, as shown in figure 14. Within these stages, different entities can take responsibility of the stage. While the construction of the transmission assets is usually conducted by specialized companies and contracting-out of these construction activities is business as usual, the planning and operation phase of transmission assets will be discussed more in depth in sections 4.2.2 and 4.2.3.

4.2.2 Planning stage of new transmission assets

One of the dominant factors in electricity grid activities is the investment planning of new transmission assets, which deal with the planning of capacity, location, timing and overall design of a new transmission asset. Investment planning can be described through four distinct types of investment: public investment, regulated transmission investment, merchant-investment and a hybrid merchant-regulated investment (Wu, Zheng, & Wen, 2006). Public investment for electricity transmission investment is not used very often and is therefore rarely elaborated on in literature as it is inducing economic and operating inefficiencies when governments become responsible for making decisions in a highly specialized industry (Wu et al., 2006).

Merchant and hybrid merchant-regulated investment will be elaborated on in section 5.2, while the rest of the report will focus on regulated investments. The substantiation for this focus will follow from the analysis of merchant and hybrid investment patterns.

The overall criteria in any grid investment is that "investments should be made to reduce electricity system costs, but only if the additional investment cost is lower than the additional savings" (Pérez-Arriaga, 2014). Therefore efficient investment would require information regarding the overall benefits of the investment and the overall costs of the investment. However, both of the overall costs and overall benefits are inherently uncertain in a deregulated energy market (Hogan, 2011; Pérez-Arriaga, 2014), as this depends on a wide variety of factors that are beyond the control of the decision making authority for the planning of efficient transmission investments, as illustrated in figure 15.

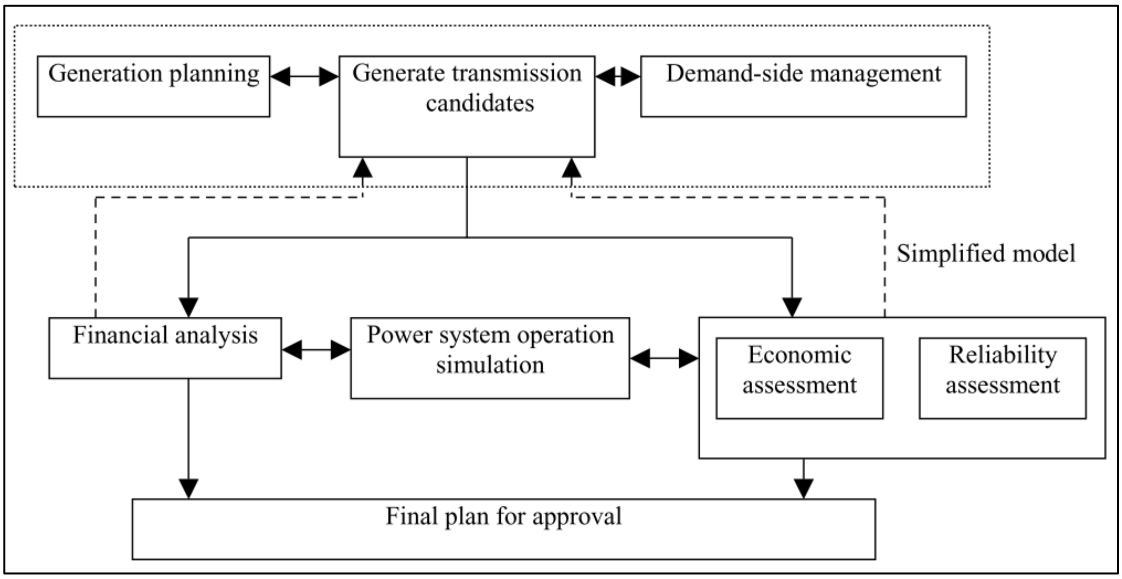


Figure 15: Planning procedure for new transmission investments (Wu et al., 2006)

A long list of criteria, which account for the cost and benefits of a transmission investment, is described by Pérez-Arriaga (Pérez-Arriaga, 2014), such as market integration, increased market competitiveness, emission savings, but also building time, costs of assets and legal issues that may arise on a specific site. Take for example the public resistance when a High Voltage line or substation is planned in rural-, nature preservation- or other economically exploited areas. Moreover, the costs and benefits of transmission investments will depend on the congestion of the transmission system, future loads and generation.

In order to increase the chance that additional investments provide added value for society, the decision maker of the investment plans should have as much information as possible. The SO, who holds the necessary information to decide whether a particular transmission expansion creates added value for the energy system as whole, is therefore best positioned to coordinate investment plans for new transmission assets (Pollitt, 2012).

4.2.3 Operational stage of transmission assets

4.2.3.1 The degree of unbundling grid activities in electricity systems

The allocation of Transmission Ownership (TO) and System Operation (SO), that are necessary to have an efficiently functioning transmission system, is organized in many different ways across the international spectrum of electricity systems. The bundling of previous research of scholars such as Pollitt (Pollitt, 2012) and Oren, Gross & Alvarado (Oren, Gross, & Alvarado, 2002) leads to five identified models of organization to allocate the responsibility of transmission services.

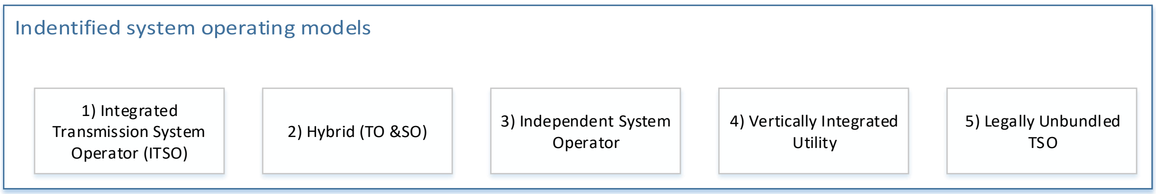


Figure 16: Unbundling options in electricity grid activities

The five models of organization (figure 16), each with a different degree of unbundling, will be described below:

1) Independent Transmission System Operator: ITSO

Within the ITSO-model the SO activities are integrated with the TO activities and the ITSO is also ownership unbundled from other market parties such as generators, suppliers, or distribution system operators (DSOs). The ITSO is therefore responsible for investment planning, initiating and managing construction of the transmission assets, maintenance planning, maintenance of the transmission assets and operating the transmission assets to maintain system balance. This model is currently applied in many European countries such as the Netherlands and Germany.

2) Hybrid (SO & TO)

The hybrid model is a combination of option 1 and option 3, where the SO and TO activities are ownership unbundled from other market parties. Additionally, the SO and TO activities are also ownership unbundled from each other. In this model, the ISO is therefore not owning and maintaining any transmission assets and the TO is subsequently ownership unbundled from the rest of the market parties as well. This model is currently operational in Argentina and the UK for example. In the UK, one SO (National Grid) has an extended operational responsibility over offshore transmission assets and onshore (Scottish) transmission assets that are not owned by the (SO), however National Grid does own a large part of the transmission assets over which it has operational responsibility.

3) Independent System Operator (ISO)

Within the ISO-model, the ISO is unbundled from the rest of the market parties and therefore the ISO is merely conducting SO activities. The ISO is responsible for system balancing and is thereby depending on the availability and capacity of the transmission assets which are owned by other transmission owners where no additional separation of ownership is necessary, hence generators can still own transmission assets in this model. This model is used in the US to perform the SO activities. However in the EU transmission systems that did not exist prior to 2009, SO activities can no longer be operated under the ISO-model (European Commission, 2010).

4) Legally Unbundled Transmission System Operator (LTSO)

Within the LTSO-model, the LTSO is merely legally unbundled from the rest of the transmission system. Therefore one company is responsible for SO and TO activities, however this company can be part of a holding which is also allowed to own other electricity market activities such as generation. While the LTSO-model is currently used in France, EU directives state that any "New transmission systems, in particular systems which did not yet exist on 3 September 2009, will have to follow the ownership unbundling regime." (European Commission, 2010). These directives are thereby effectively prohibiting new transmission systems to be organized and operated under the LTSO-model.

5) Vertically Integrated Utility

This is the model in which all activities, including generation, are integrated in one large utility company. There is no effective unbundling within this model. While this model was widely used before market reforms took place, within the EU various EU directives gradually prohibited this model and thereby replacing this model by one of the previously described models in European transmission systems.

4.2.3.2 Unbundling options for a MOG

As illustrated through the previous sub-section, a variety of unbundling options is possible to increase the efficiency of the overall performance of the electricity system. The current literature is no longer debating the effectiveness of unbundling SO activities from generation and is "associated with competitive wholesale and retail markets and effective regulation of monopoly networks" (Pollitt, 2008). However, there is still debate on whether SO and TO activities should be integrated or unbundled. Based on the current EU directives, new transmission systems (excluding systems built before 2009) should satisfy ownership unbundling and therefore TO and SO should always be separated from generation, suppliers and distributors. We can therefore make a selection regarding the possible system operating models for a MOG, as shown in figure 17.

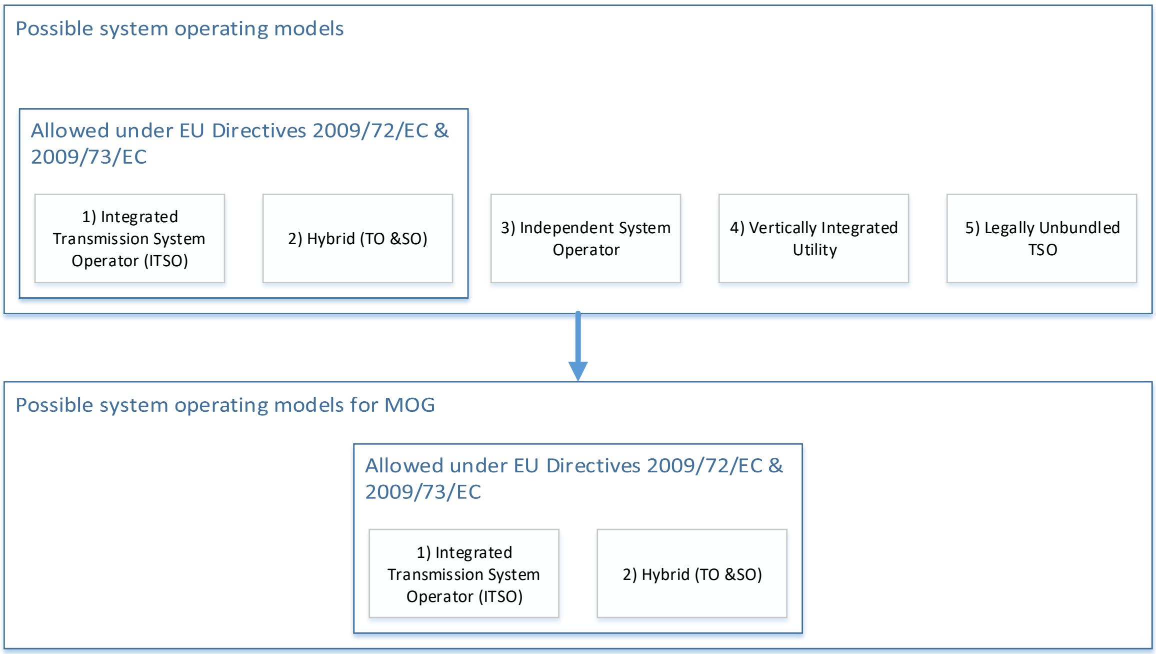


Figure 17: Unbundling options in MOG

4.2.4 Implications of unbundling electricity grid activities

Following from the EU directives and illustrated in figure 16, two distinct operator models can be applied on a MOG. While the EU directives are clear on the operator models and ownership unbundling requirements of any new transmission system, the policy choice to further unbundle the SO and TO activities is not obligatory and decisions regarding further unbundling of these activities are not unambiguous. Whenever the two services are unbundled, transmission policy experts agree that both network operation and congestion management is a task for the SO and the TO is responsible for the realization of transmission assets and the maintenance of the realized assets (Brunekreeft, Neuhoff, & Newbery, 2004).

The ensuing sub-sections will therefore provide an overview of the benefits of unbundling TO & SO activities and the benefits of bundling the TO & SO activities.

4.2.4.1 Benefits of unbundling TO & SO (hybrid)

The benefits of unbundling the TO & SO activities are originating in the conflicts of interest that may arise when the planning of investments is coordinated and influenced by the same entity who receives the revenues based on these investment plans. As previously discussed, the system operator is in the privileged position to hold critical information to decide on which transmission investments improve the overall efficiency of the system, especially when congestion is not made explicit through nodal or zonal prices (the internal congestion problems within a meshed grid). In such a case, an ITSO can favour transmission investments which are inefficient from a social welfare perspective (Pollitt, 2012), as their revenues predominantly arise from investments. The inability of the controlling entities, ministries and regulators, to scrutinize inefficient investment plans because of information asymmetry or lack of independent influence in the planning phase of an investment. However, when the SO is still responsible for congestion management, this entity will likewise favour additional transmission investments. The problem of overinvestment will thus remain when the SO is in charge of transmission expansion plans.

This overinvestment problem is identified by scholars and acknowledged by government institutions in the Netherlands for example (ACM, 2015; Rekenkamer, 2015). To minimize this conflict of interest, more influence from the authorizing entities is necessary. This requires more expertise and capacity from the regulator and the applicable ministries who approve investment plans based on a structured and transparent process. This process should be based on a Cost Benefit Analysis (CBA), which determines which investment plans should proceed or should be cancelled (Pollitt, 2012).

Secondly, when privately owned TOs are relying on the congestion revenues to recover their privately financed transmission assets, the TOs can raise their revenues by strategically withdrawing transmission capacity (through maintenance planning for example) when they are also responsible for SO activities, thereby increasing their congestion rents (Glachant & Pignon, 2002). Therefore, the SO entity should be unbundled from privately owned TOs who earn their revenues through congestion rents.

4.2.4.2 Benefits of bundling TO & SO (ITSO)

There are many synergies between these two activities (Pérez-Arriaga, 2014). On the short- and medium term, these synergies are for example efficient maintenance planning. The planning of maintenance requires it to be organized in such a way that the overall system maintains a certain level of reliability to safeguard the security of supply, however, when the responsibility of maintenance is allocated to the transmission owner and not to the system operator, this requirement cannot be assured since efficient system balancing and maintenance planning are interdependent (Joskow & Tirole, 2003).

Regarding the investment adequacy to safeguard the long term system balance, unbundling the TO and SO activities has a negative effect since the TO has valuable information regarding the capital expenditures and operating expenditures of the transmission assets and the SO has valuable information regarding the benefits of any transmission asset, thereby creating valuable synergies in the planning of new transmission assets (Pollitt, 2008).

Take for example the connection of a new transmission asset which facilitates the evacuation of offshore wind energy. By connecting this OWF production facility, the SO must contract primary reserves to accommodate this production in case of a failure of the transmission assets and the need to maintain the system balance and system frequency (ACM, 2011). However the TO does not have information regarding the availability and costs associated with the contracting of the primary reserves, which could lead to inefficiencies in the planning of new construction assets.

For the short term system balance, by unbundling TO and SO activities, Pollitt (2012) argues that powerful incentives to reduce congestion are less effective and more costly. These synergies are underlined by Lieb-Doczy & McKenzie (2008), as they identify six interface issues regarding the TO & SO activities. These issues are assumed to be accentuated when TO & SO activities go through further unbundling. The following issues are identified:

1) The incentives of SO and TO are not aligned, as the SO wants to optimize flows, whereas the TO wants to maintain a high quality of its assets to guarantee availability in the short and long run.
2) Possibility of lower efficient transfer of information which is necessary to maintain system balance.
3) Efficiency of maintenance planning and planning of new investments, as SO & TO are interdependent on these activities
4) Problems regarding the roles and authority in emergency situations, as these need to be clearly defined and adhered to.
5) When disputes arise between unbundled SO & TO, an appropriate protocol needs to be in place to resolve these disputes.
6) An appropriate incentive system needs to be created that can incentivize efficiency in activities while not overloading the burdens on both the SO & TO. Especially creating an appropriate incentive scheme for SO activities tends to be difficult, as also underlined by Pollitt (Pollitt, 2012).

4.2.5 Interim conclusion

This section has provided an overview of the different governance options regarding the operation of transmission systems and the degree of unbundling, concluding in a selection of options which can be used for a MOG. This selection will subsequently be used to address and construct the design space in chapter 5. Moreover, this chapter not only provided input for the design space, the choice for a specific operator model implies certain consequences that will ultimately influence the performance of the governance model for a MOG in general. These findings will therefore be used to assess the expected performance of alternative governance models and thereby these findings will provide valuable input for chapter 7.

4.3 Case studies: governance models and regulation in practice

The previous sections have provided a theoretical frame through which practical implementations of regulatory and political choices can be viewed upon. Within this sub-section, two case studies will be presented of the most dominant governance models regarding the ownership and operation of radial grid connection systems for OWFs: the Dutch TSO-model and the UK OFTO-model. These governance models were selected as they are able to represent the two remaining institutional choices: long-term contracts (Franchise Bidding) and vertical integration (regulation).

In general the differences in governance models are caused by the different regulatory frameworks by which these assets are governed, depending primarily on the transposition of EU DIRECTIVE 2009/72/EC into national legislation regarding the definition of the grid connection system, which can be defined as part of the OWF, or as part of the offshore grid. If it is defined as part of the OWF, then the OWF developer is still allowed to own the grid connection system. Contrastingly, if it is defined as part of the offshore grid, ownership must be unbundled from the production facility (European Commission, 2010). As EU member states are allowed to define their own interpretation of the Directive, the specification of the grid connection point is therefore varying across the EU.

Furthermore, there is little overarching European legislation that specifically addresses the issue of how to regulate the development of offshore electricity transmission and how to allocate responsibilities across the Transmission System Operator (TSO), offshore wind farm developers and other infrastructure investors. This lack of overarching European legislation provides EU Member States the policy freedom to design their own governance models regarding the development of offshore electricity transmission. This is evidenced by the fact that different governance models have been implemented across EU member states, two of which will be described in more detail through the case studies.

The case studies and governance models are currently applied on simple configurations of grid connection systems, known as a radial offshore grid connection system. By describing these governance models in the subsequent sections and assessing their performance in section 4.3.5, it enables a performance estimation of the governance models which can be applied on a MOG.

Before this section will describe the two separate cases, this section will first provide some technological background of offshore electricity transmission projects and the risks associated with this type of projects.

Furthermore, as section 4.1 and 4.2 identified the institutional choices and unbundling options for electricity grid activities and related concepts. The following characteristics of the governance models will therefore be described:

- Policy choices (regulation, Franchise Bidding or hybrid)

- Revenue stream
- Unbundling choice
- Planning of transmission investments
- Transaction costs
- Risk allocation

4.3.1 Technological system boundaries

As the definition of the grid connection system is varying within the two case studies, the technical system boundaries will be defined prior to the description of the two case studies. As discussed previously, the case studies in this chapter are based on a radial grid connection system. However, the individual components which are present in a radial offshore grid connection system, as illustrated in figure 18, will also be present in a MOG.

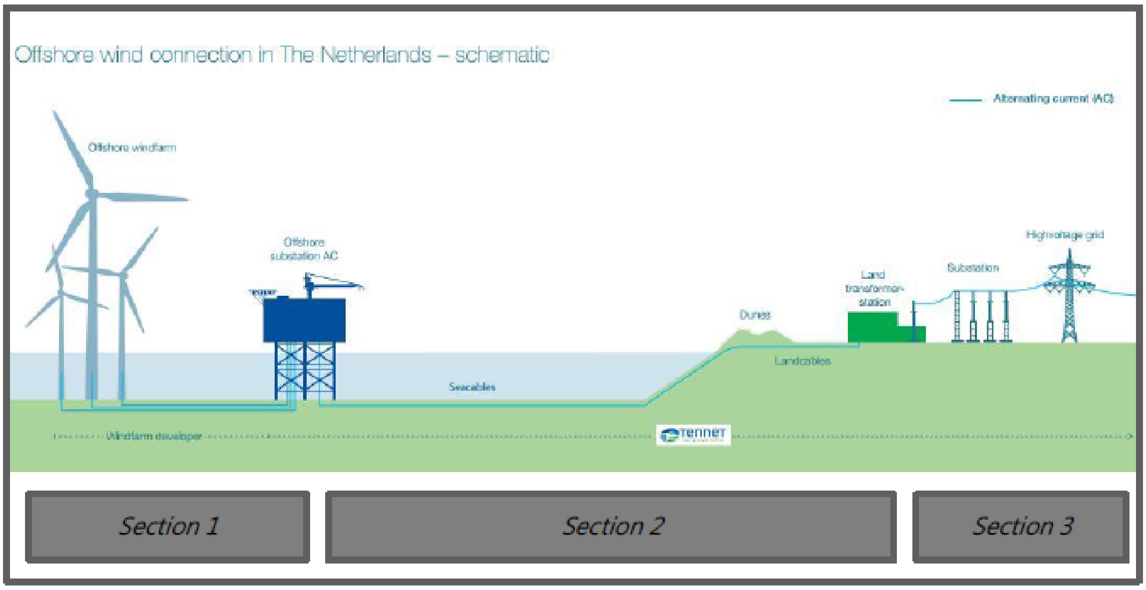


Figure 18: Illustration of OWF grid connection

4.3.1.1 Section 1

Section 1 consists of the offshore windfarm, including inter-array cables which connect the offshore wind turbines to the offshore substation. The interface of this section with section 2 is on the offshore substation, where the inter-array cables are connected with the offshore substation.

4.3.1.2 Section 2

Section 2 consists of the offshore substation, the export cables/lines connecting the offshore substation to the onshore substation. The interface of this section is two-folded. The interface of this section with section 1 is located where the inter-array cables are connected with the offshore substation, as previously described, whereas the interface of this section with section 3 is located where the export cables/lines are connected with the onshore substation.

4.3.1.3 Section 3

Section 3 consists of the entire onshore grid of the responsible TSO. The interface of this section with section 2 is at the onshore substation where the export cables are connected to the onshore substation, as previously described.

4.3.2 Risks in electricity transmission system projects

With large infrastructure projects, such as a MOG, a wide variety of risks can occur in the initiation phase of the project, the construction phase of the project and the operating phase of the project. These risks are of a different nature (technical &/or economical) and ultimately impact either the revenues or expenditures of a project, which will therefore impact the attractiveness of the project business case as the risks create uncertainty regarding the final profits of the project.

With regard to the risks in a MOG, it will be important to address the allocation of risks and the forthcoming liabilities. Depending on the allocation of the risk, the applied governance model and the specific regulatory framework, risk management and anticipatory provisions will differ accordingly. These variations will be made explicit in the specific case studies, which will follow in section 4.3.3 & 4.3.4. The level of risks in an investment will ultimately determine the cost of capital that is required by an investor.

In order to dissect the main risks in an infrastructure project, the risks will described through the main categories:

4.3.2.1 Construction risks

These are the losses incurred through events or circumstances that were not initially accounted for in the planning phase of a construction project. These losses can be both of financial nature (additional costs) or planning nature (delays). Within an offshore transmission project, a wide variety of risks can be identified that can significantly impact the initial cost projections and cause budget overruns. These budget overruns vary from additional cable installation costs when the seabed is less suitable then expected to underestimating costs for offshore substations because of unexpected market developments that limit competitive pressure when the offshore substation is tendered in the market. Additionally, public resistance or supply chain issues can delay the project accordingly. Appendix B shows a more complete overview of possible risks that can occur in the construction phase of a transmission system project.

The impact of the aforementioned risks firing can be very high, as studies show that typical cost overruns in the construction phase of a transmission system projects on average account for 8% of the initial budget and construction project delays are 7.5% over initially projected planning (Sovacool, Gilbert, & Nugent, 2014).

4.3.2.2 Commissioning risk

Closely related to the construction risk, is the commissioning risk within an offshore transmission project. Especially in a MOG, when OWFs depend on the offshore transmission assets to be online according to the planning. When the construction project incurs any delays, the wider system effects can be significant as this would implicate that the OWF is unable to sell its electricity on the connected electricity market.

4.3.2.3 Operating risks

During the operating phase risks can significantly impact the operating expenditures through an operating failure within the transmission system or a deviation of the operating requirements of the transmission system. The firing of a risk can then trigger unplanned maintenance which leads to both additional operating expenditures and potentially a loss of income. The loss of income can have two causes: 1) Transmission Owners can be punished by not achieving the availability target (this will be explained more in-depth in section 4.3.4) and, 2) a loss of income for OWF developers as they are not able to sell their electricity on the electricity markets, similar to the consequences of the commissioning risk.

4.3.2.4 Stranded asset risk

Inherent with more coordinated planning of investments while being dependent on developments which are decided upon elsewhere, the risk for stranded assets is increased. Specifically to offshore transmission system assets and the necessary onshore grid reinforcements, investment decisions must be made prior to the actual development of new production facilities (in this case the development of OWFs). The stranded asset risk is therefore the risk that certain assets will lose their demand when forecasted generation developments are terminated.

Take for example the development of OWFs in the Netherlands, where investment decisions and financial commitments for the necessary offshore transmission system are preceding the investment decisions and commitments by the OWFs. Thereby the possibility exists that the offshore transmission system is constructed while the demand for these assets is decreased because of a terminated project by the OWF developer. It must be noted that the risk for stranded assets in the Netherlands is addressed by imposing a financial penalty on the OWF developer when it is lacking to fulfil its obligations as approved upon in a contractual agreement with the TSO (RVO, 2016).

Ultimately, the entities who are underwriting the investments are liable for the stranded asset risk.

4.3.2.5 General technological risks

Technologically, a MOG will probably include less conventional offshore transmission grid technologies such as meshed High Voltage Direct Current (HVDC) to connect both OWFs and interconnect electricity markets. Where HVDC point-to-point connections are considered as state-of-the-art technology (Flourentzou, Agelidis, & Demetriades, 2009), multi-terminal HVDC connections (as of 2017) still need to be developed and are therefore less conventional. Moreover, a MOG will probably also require additional innovative solutions regarding grid protection mechanisms and system operation (PROMOTioN, 2016). While risks associated with conventional High Voltage Alternating Current (HVAC) technologies are known and have decreased through decennia of experience, newly developed technologies will inherently be more risky.

4.3.3 Case study 1: The Dutch TSO-model

The TSO model is currently the most dominant governance model to connect OWFs in the North(ern) Sea(s), as this governance model is deployed in Germany, France, Denmark and The Netherlands. Moreover, Belgium is looking into the possibility to build an offshore substation which will function as the connection point and will thereby move towards the TSO model in which the national TSO is responsible for the GCS.

It has to be noted that the different countries deviate in specific elements of the application of the model. This is mostly depending on the planning responsibility of the OWF location and the details of the regulatory framework in general, which stipulate aspects such as the risk distribution, liability and the allowed revenues depending on operating and capital related costs, as described in section 4.1.2 (incentive regulation).

Within the Dutch TSO model, the scope of the TSO is extended beyond a single grid connection system for an OWF. In the Netherlands, the TSO is made responsible for five offshore connection points, each having 700 MW of transmission capacity, which facilitate the connection of 10 OWFs (RVO, 2015). Historically, most offshore transmission system concepts deployed were unique in size, which logically follow from the fact that the OWFs were varying in size. However, in the Netherlands a structured roll-out of OWFs with identical size have enabled the possibility to standardize the offshore transmission system concept (TenneT, 2016). By using a standardized approach, cost reductions can be anticipated on through economies of scale. As stated, this necessitates very strong coordination on a governmental level, since the OWFs need to be identical in size and follow a specific planning.

Another characteristic of the TSO model is that the planning of OWFs is centralized and coordinated by the government to facilitate the coordination between the OWF developer and the TSO. In the TSO model the OWFs can acquire the right to build and own an OWF on a specific site through a tender. Prior to this tender, all potential bidding parties are provided with sufficient information, such as wind data and oceanography in order to participate in the tender (PROMOTioN, 2017a). Additionally, potential bidders are provided specifications of the interface at the connection point of the OWF and the availability of the infrastructure in general, which influences their business case.

While the specific regulatory framework may differ per EU member state, the conceptual model is identical in the sense that the TSO is responsible for the grid connection of the OWF in the planning phase, construction phase and operational phase of the grid connection.

4.3.3.1 Policy choices

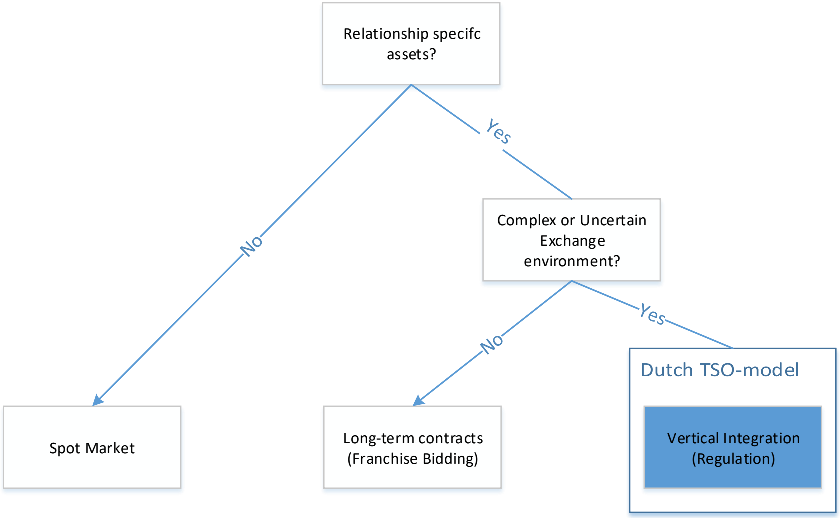


Figure 19: Institutional choice in TSO model

Within the Dutch regime, policy makers decided that the connection of offshore wind should be a responsibility of the TSO, consequently the Dutch onshore TSO is appointed as the offshore TSO by law. Thereby the allocation of ownership is decided upon centrally, creating a natural monopoly which needs to be regulated. As such, the institutional organization is defined as Vertical Integration through the Crocker & Masten framework presented in figure 19.

In the TSO model, the TSO leads the initiation phase of a transmission expansion project to connect the OWF to the onshore grid. In essence, the TSO expands the onshore grid through an offshore transmission system (section 2) creating an offshore connection point to which the OWFs can connect, thus enabling the OWF to evacuate the offshore wind energy to the onshore load centre. In the initiation phase of such projects, the TSO will therefore decide where the onshore connection point is going to be and is responsible for the offshore and onshore surveys as well as acquiring all the necessary permits and licenses to finally construct the offshore transmission system. Figure 20 provides a conceptual illustration of how the grid connection is developed.

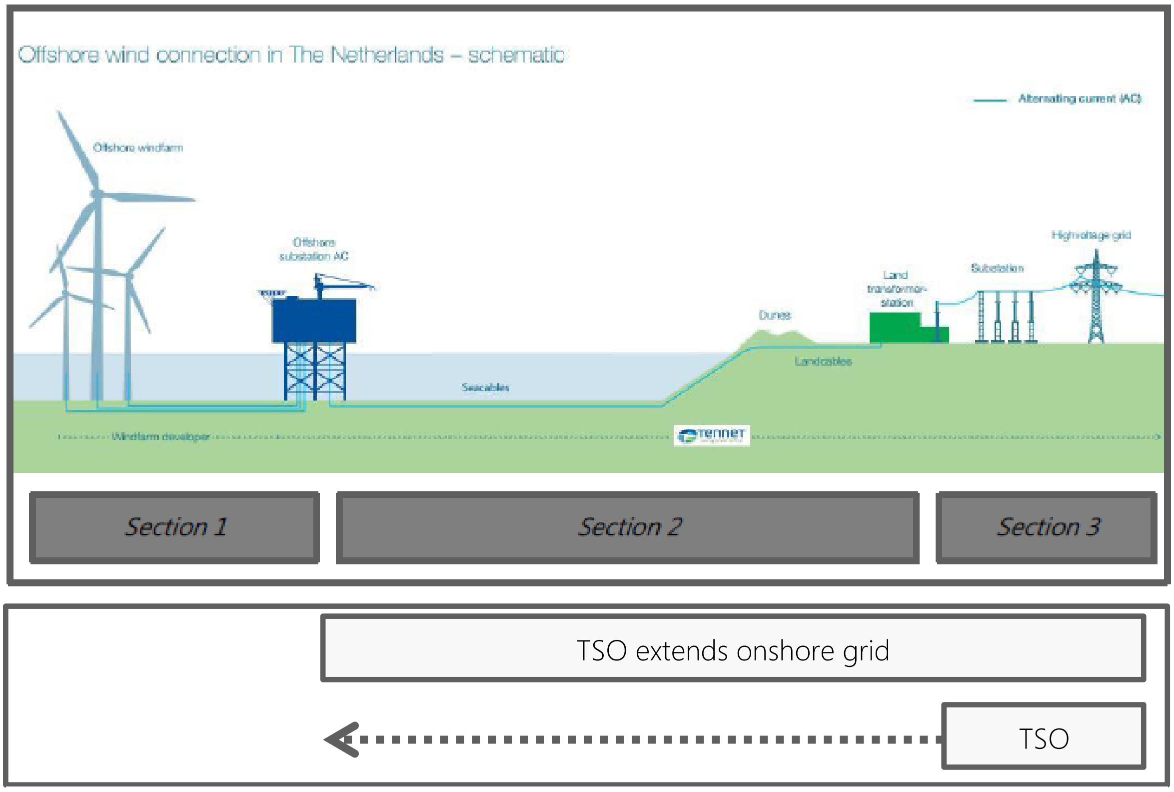


Figure 20: Illustration of grid connection TSO model

4.3.3.2 Revenue stream TSO model (regulated asset base approach)

In the Dutch TSO model, the revenues of the TSO depend on the capital expenditures and operational expenditures related to their responsibilities as a TSO (transmission and system operation), all under regulation of the NRA. The NRA in the Netherlands uses a combination of incentive regulation, as described in section 4.1.2 (benchmarking and revenue-cap). As for the OPEX, the NRA determines a revenue cap based which is a function of the initial CAPEX. The remuneration of investment costs (based on the CAPEX), is organized differently, since the NRA determines the appropriate return and therefore needs to estimate the cost of capital and efficient CAPEX to determine the regulated revenues. The efficient capital expenditures are then allowed to be included in the regulated asset base, this method is known as the regulated asset base (RAB) approach (Joskow, 2007). Consequently, the final regulated revenues of a TSO include the OPEX, depreciation of the owned assets and the overall cost of capital (figure 21).

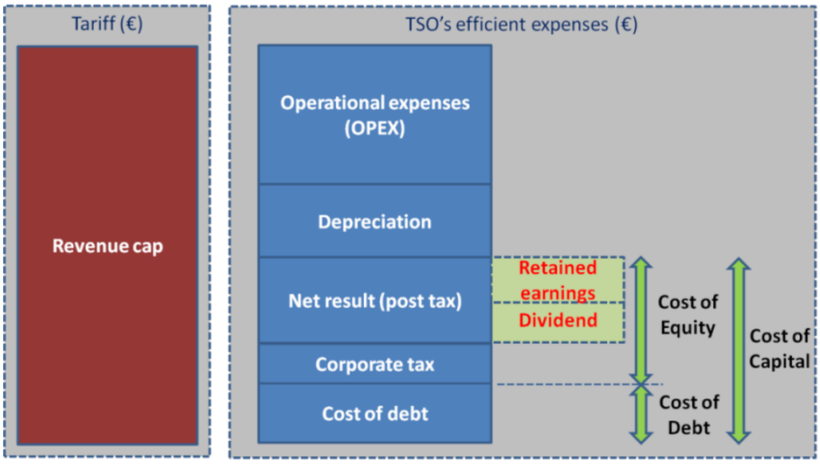


Figure 21: Elements that determine revenue cap

In a TSO model the transmission assets are separated from the production assets and the revenue model of a TSO is therefore not relying on the fluctuating revenue stream associated with the fluctuating electricity production, which eliminates the demand risk for the TSO. In contrast to a fluctuating revenue stream, in a TSO model the revenue stream is regulated by the NRA and underwritten by the users of the transmission grid. In the Dutch TSO model, the allowed revenues are not recovered through the transmission tariffs, as policy makers chose to retrieve the allowed revenues for TSO through a tax-mechanism, Subsidie Duurzame Energie+(SDE+) for the medium and small consumers. The RAB approach is a very stable and provides a predictable revenue stream which enables low financing costs for the TSO.

Specific to the Dutch offshore regulatory framework and the regulation of the allowed revenue, the Dutch NRA uses a mixture of revenue cap regulation and benchmarking to decide on the allowed revenue stream for the offshore transmission assets and thus uses incentive regulation to simulate a competitive market. The following parameters are therefore estimated to decide on the final regulated revenues:

- Regulated Asset Value (RAV)

Which is the approved asset value of the GCS by the regulator and is approved on a case by case analysis by determining the efficient costs. The specific assets that form the grid connection system (offshore substation, high voltage equipment and cabling) are procured through a competitive tendering to ensure that competitive prices are obtained. Additionally, the NRA uses ex-post benchmark regulation to determine the efficiency in the capital expenditures which are allowed to be included in the regulated asset base.

- Depreciation time (DT)

Which is the expected depreciation time of the assets. For the Dutch offshore grid, the depreciation time is estimated at 20 years (ACM, 2016b). Consequently the annual depreciation costs are a function of the regulated asset value and the depreciation time.

- Cost-of-capital

Which is the estimated cost of capital, known as the weighted average cost of capital (WACC), derived from the estimated cost of equity, the cost of debt, the gearing level, corporate taxes and inflation (ACM, 2016b). For the period 2017 -2021, the WACC for the Dutch offshore grid is estimated at 3,0% (ACM, 2016a). This estimation is a function of the return on equity, cost of debt, the gearing ratio and the corporate tax. While the corporate tax is derived from actual values, the return on equity, cost of debt and gearing ratio are determined by the regulator.

The following formula is used to estimate the WACC:

$$WACC = g * Rd + ((1 - g) * \frac{Re}{1 - Tc})$$

With:

Re = Return on Equity

Rd = Debt interest rate

g = Gearing (ratio between debt and equity)

Tc = corporate tax rate

- Operating Expenditures (OPEX)

Which is an estimation of the operating costs, and for the Dutch offshore grid these costs are estimated at 1% of the initial regulated asset value (ACM, 2016b).

Financing implications

The financial burden of raising capital to finance the investment costs is allocated solely to the TSO in the TSO model. As explained, the current revenues of the TSO reflect the historical investments of the TSO. However, as future investments far outweigh the historical investments, given the developments in the energy transition, the cash-flow of the TSO might be unsustainable in the sense that it can lead to a "vicious circle" where the TSO needs to attract debt capital with higher rates, which will translate into higher transmission tariffs for the consumer (ENTSO-E, 2014). This can be solved by equity injections by the owner of the TSO (in many cases a public entity), putting a significant financial burden on the owners of TSOs.

Looking at the future developments for offshore wind energy and therefore looking at the necessary investments in offshore transmission assets, this would implicate that governments either need to provide large amounts of equity injections for TSOs or new ways of financing must be sought for to carry this finance burden. Recent developments in the Dutch TSO model do suggest that the government is willing to provide equity injections to realize the necessary investments.

4.3.3.3 Unbundling choice

Moreover, this governance model assumes that ownership and operational responsibilities of the onshore grid, section 3, is allocated with to same TSO (figure 22). The final operational responsibility of the offshore transmission system (section 2) is allocated with the TSO in the TSO model, making the TSO responsible for operating the offshore transmission system and maintaining the offshore transmission system. The operating model can therefore be defined as an Integrated Transmission System Operator, where both TO activities and SO activities are integrated in one organization.

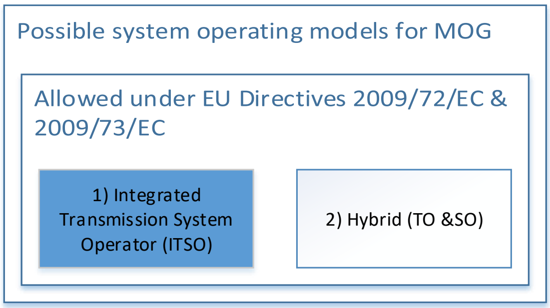


Figure 22: Unbundling choice in TSO model

4.3.3.4 Grid planning capabilities

In the TSO model, the TSO is able to optimize the grid connection in such a way that the costs for onshore grid reinforcements are as little as possible, because the TSO has the most accurate information regarding current and future grid constraints. This translates to lower overall system costs to integrate an OWF.

During the grid planning phase of the GCS, the Dutch ministry is involved in the decision making regarding the planning of the GCS is going to be and gives the final approval for the investment plans. Thereby trying to scrutinize investment plans that are not in line with public interest, and limiting the conflicts of interest of the TSO to propose unnecessary investments which can increase their revenues.

4.3.3.5 Transaction costs

Another characteristic of the TSO model is that by providing all necessary information to bid in the tender for a specific OWF site, including the availability of the offshore transmission system to evacuate the produced electricity, the potential OWF developer has little transaction costs, such as search and information costs, prior to the tender for the OWF site. This characteristic enables fair competition for the tender of the OWF site and should therefore increase social welfare when the subsidy feed-in premium price for the OWF site is determined

4.3.3.6 Risk allocation

By allocating ownership and responsibility at the national TSO, the availability responsibility of the offshore transmission asset is positioned at the TSO as well. Therefore the risk of non-availability is transferred from the OWF developer to the national TSO, thereby removing this risk from the business case of the OWF developer. By removing these negative impacts, the OWF developer will not account for this risk in his tender bid, hence the premium in the bid to account for these risks will not directly be paid by the consumer through its payments for electricity.

To ensure that the TSO is incentivized to deliver the assets on time and provide the available capacity to evacuate the offshore wind energy, the TSO cannot go over the maximum non-availability target of 5 days. When the TSO does not meet this target, it is penalized by paying a significant penalty.

4.3.4 Case study 2: Generator-led OFTO model

The second case study is a description of a third-party model to govern the ownership and operational responsibilities of offshore transmission assets which was recently introduced in the UK. In 2009, The UK government and Ofgem (the NRA in the UK) introduced a new governance model was initiated and implemented to integrate elements of competition and regulation and enabling entrance for new market participants (CEPA, 2016). What makes this governance model unique is that it consists of two different phases in which ownership or responsibility of the offshore assets is allocated to different parties. These phases consist of a planning and construction phase and an operating and owning phase. In this model, the generator is responsible for the planning and construction phase and the OWF developer is therefore still responsible for the offshore and onshore surveys as well as acquiring the necessary permits and licenses to construct the offshore transmission system. After commissioning of the offshore transmission system, however, the ownership of the offshore transmission assets in the operating and owning phase is allocated to a so-called OFTO.

4.3.4.1 Policy choices

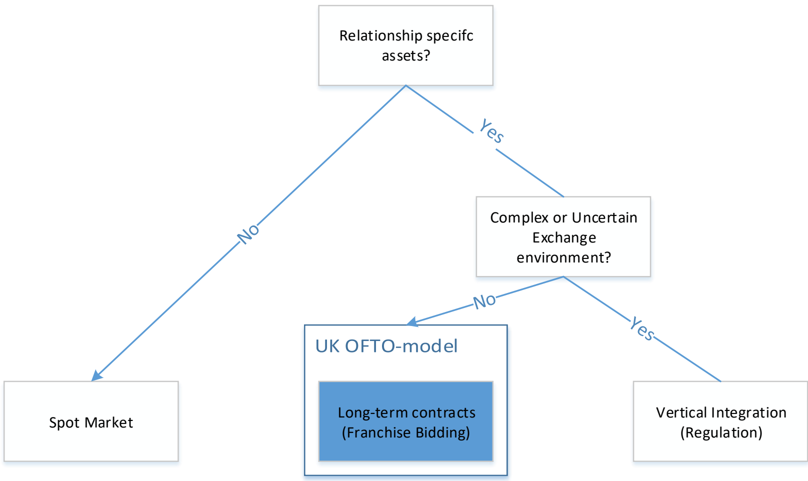


Figure 23: Institutional choice UK OFTO model

By introducing this type of governance model, the UK government and the NRA have chosen to introduce competition for the market, thereby applying the Franchise Bidding approach, shown in figure 23. Through the Franchise Bidding approach, the natural monopoly is allocated through an auction instead of centrally allocating the natural monopoly with one specific owner, as in the TSO model.

The institutional choice to use a Franchise Bidding approach, however, does not remove the information asymmetry which is present when a NRA needs to estimate the efficient costs associated with the grid connection system, as will be explained later in this sub-section. It must be noted that in order to apply a Franchise Bidding approach, initial setup-costs and bidding costs are incurred by the regulator and the potential OFTOs, these can be seen as initial transaction costs (CEPA, 2016).

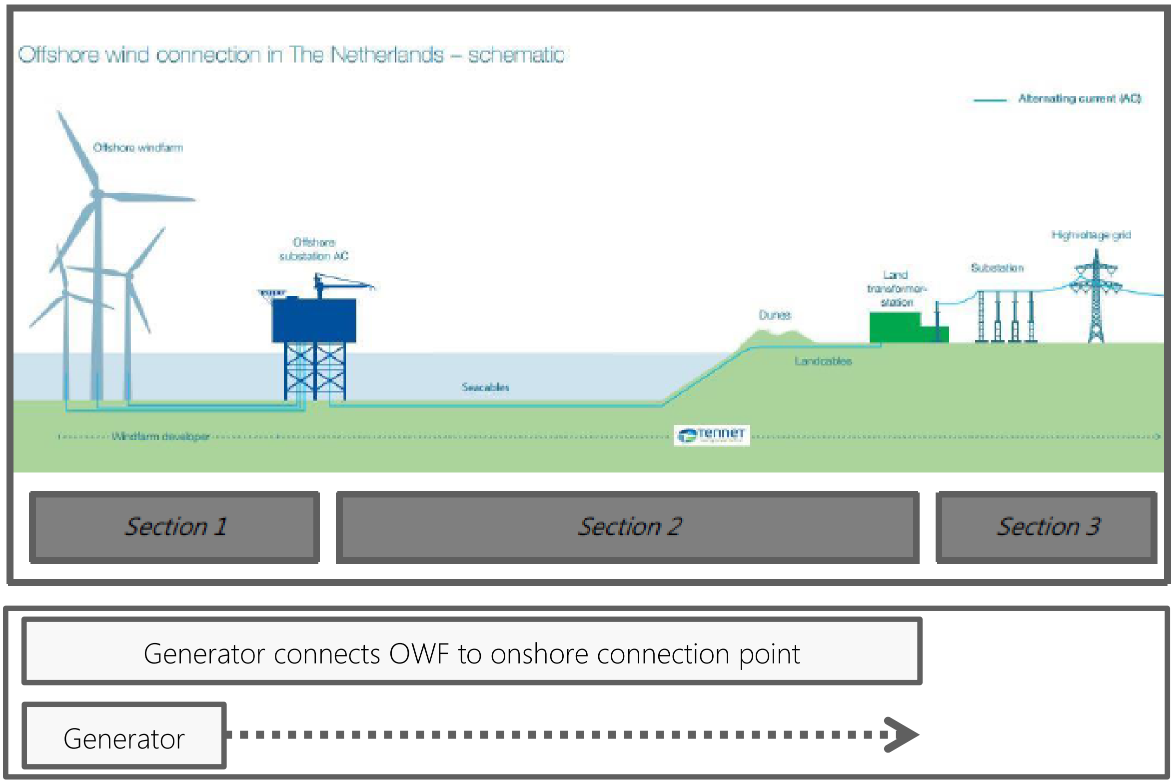


Figure 24: Illustration of grid connection UK OFTO model

As shown in figure 24, in the first phase the generator is responsible for connecting the OWF, however in the second phase section 2, the offshore transmission system, is separated from section 1. Section 2, the offshore transmission system, is subsequently put up for tender through a reverse auction in which potential OFTOs can bid for a fixed revenue stream for 20 years, called a Tendered Revenue Stream (TRS). This annual revenue stream should then cover all the annual expenses for the OFTO for 20 years, since the ownership is transferred to Ofgem after this period. Ofgem ultimately decides on the preferred bidder, which is the bidder who requires the lowest TRS for the 20 years in which he owns the transmission system.

When the OWF developer needs to sell off its offshore transmission system, it is allowed to offer an operating & maintenance package to the OFTO and thereby retain control over the maintenance responsibility of the offshore transmission system when the OFTO decides to accept the offer of the OWF developer.

Figure 25: Illustration of expenditure elements in Tendered Revenue Stream

As shown in figure 25, the largest part of the TRS is made up out of financing costs (80%), whereas the remaining costs are related to all operational tasks. The financing costs are incurred by the acquisition of the offshore transmission assets from the OWF developer. The OWF developer then receives a so-called Final Transfer Value (FTV) from the winning party in the tender.

This FTV consists of the expenditures incurred by the OWF developer related to the offshore transmission assets up until the commissioning of these assets, an example is shown in Appendix D. The FTV is ultimately determined and regulated by the NRA, which is Ofgem in the UK, which implies that there is an additional risk that the regulator will not approve all the expenditures incurred by the OWF developer. The OWF developer will therefore incur a loss on these assets, as the OWF developer will not remunerate all of the capital expenditures up until the commissioning of the offshore transmission assets.

Given the previously discussed properties of the Franchise Bidding approach, the UK OFTO-model can be defined as a Finance-Own-Operate-Transfer PPP structure, as the preferred bidder merely finances the FTV and operates the assets to provide the required transmission capacity. These services are relatively straightforward, and the required service through the lifetime of the license can be described in detail, which enables a level playing field for competition to come to competitive prices.

By creating a structured PPP, in which the private party finances and operates the transmission assets, these private parties have succeeded in providing new financing options and competitive operating expenditures, which resulted in both financing cost savings and operating cost savings (CEPA, 2016). These savings were calculated by comparing the actual revenues streams of the winning bids of various OFTO tenders with counterfactual approaches, such as the UK regulatory counterfactual which uses the onshore price control mechanisms that rely on incentive regulation. Both financing savings and operating savings each account for approximately 50% of the absolute cost savings, Appendix C provides an overview of these cost savings. These cost savings cannot be separated from specific characteristics of the OFTO model, as it is noted that financing cost savings materialized because of a very structured asset in which operational and regulatory risks can be determined prior to the tender and the construction risk was carried by the OWF developer. This created a very interesting investment opportunity for a wide variety of institutional investors (KPMG, 2012)

Additionally, the transmission assets are highly separable in the sense that the transmission assets are not part of an integrated network and therefore the maintenance planning can be optimized towards the costs incurred for the actual maintenance, consequently enabling more competitive operating and maintenance costs. In an integrated network, inefficient maintenance planning which is aimed at optimizing operating and maintenance costs for the specific assets and not taking into account wider network impacts, can lead to transmission constraints and congestion, which results in expensive re-dispatching (Brunekreeft et al., 2004).

While the observed cost savings in the CEPA report (2016) were calculated based on the UK counterfactual (using UK price control parameters), this report will perform a comparable analysis in section 4.3.4 which uses Dutch offshore price control parameters.

4.3.4.2 Revenue stream generator-led OFTO model (Tendered Revenue Stream)

As previously discussed, the offshore transmission assets of an OWF are acquired through a competitive tender, therefore the OFTO is essentially bidding for its revenue stream. Hence, the final TRS of the winning bid are the annual revenues, with specific annual adjustments depending on the performance of the OFTO (Ofgem, 2016a). The TRS is ultimately paid by the National Electricity Transmission System Operator (NETSO); in the UK this TSO is National Grid Electricity Transmission (NGET). The TRS is collected through both consumer transmission tariffs and producer transmission tariffs. Focusing on an OWF which is connected on the national High Voltage grid, the OWF developer is ultimately paying most of the TRS through the producer transmission tariffs (NationalGrid, 2013).

Regarding the cost of capital for the eventual OFTO, the OFTO is free to choose its financial structure. Given the highly dependable revenues stream paid out by an institution which is considered highly credible within the market (CEPA, 2016), the business case of this structured asset is very stable and dependable, enabling very low cost of capital through low cost of debt and high gearing financial structure. These low cost of capital are evidenced through the first 3 tender rounds for OFTO licenses in the UK (CEPA, 2016).

Financing implications

As financing responsibilities of the offshore transmission system are allocated at the OFTO, the OFTO is therefore responsible for attracting the necessary debt and equity to finance the investments. By doing so, the financial burden is shifted to the market and the market required return on this investment is decided by the market accordingly, thereby eliminating the finance problem when TSO owners are unwilling to provide the necessary equity injections.

4.3.4.3 Unbundling choice

Within the OFTO model, the OFTO is responsible for financing the FTV and operating the transmission assets. However, these operating activities are not to be confused with the operating activities performed by the System Operator as the national TSO (National Grid) is ultimately responsible for controlling the offshore transmission system by determining when the offshore transmission system is on- or offline (PROMOTioN, 2017c). The detailed responsibilities of the OFTO are specified in the network code "System Operator-Transmission Owner Code" (STC) (National Grid, 2016).

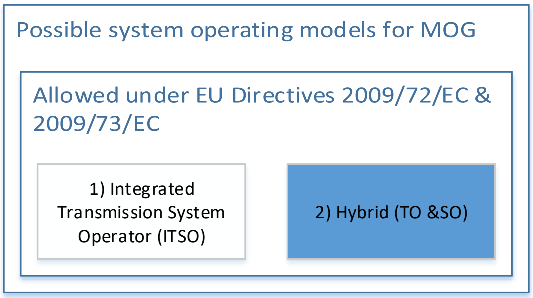


Figure 26: Unbundling choice in UK OFTO model

Technical limitations of the individual offshore transmission system prevent the OFTO to perform SO activities since the individual offshore windfarm provides intermittent electricity generation and current OFTOs do not have control over balancing plants to perform balancing activities. Therefore the UK OFTO-model is essentially a transmission system in which the transmission services are further unbundled, as explained in section 4.2. This is defined as a hybrid model in which both TO and SO activities are individually unbundled from the rest of the electricity system (figure 26). Regarding the downsides of unbundling of TO and SO, as described in section 4.2.4, a radial GCS provides less issues because it is not part of the onshore grid or a meshed offshore grid, thereby little system balancing activities are performed and congestion can only be managed through the curtailment of the connected OWF.

4.3.4.4 Grid planning capabilities

Focusing on the grid planning capabilities, within the generator-led OFTO model, the OWF developer is still responsible for acquiring the onshore connection point. Considering the cost efficiency of planning and designing the grid connection system, the overall incentive for an OWF developer is to optimize the offshore transmission system by focusing on the specific OWF. Given the fact that the OWF developer is paying a transmission tariff based on the TRS value, the OWF developer has the incentive that CAPEX are optimized.

Within the UK, a price signal is given to efficiently manage the onshore connection through a zonal price for requested capacity connection. In doing so, the OWF developer is incentivized to connect to a specific onshore substation which would require the least onshore grid constraints. However, the effect of this price signal can be negligible compared to the added offshore transmission system costs that are incurred by the OWF when it needs to connect to an onshore substation which is further away from the OWF. Accordingly, the overall costs to connect the

OWF to the onshore grid are not optimized when additional grid reinforcements are necessary, which could have been avoided if a total system perspective was applied to plan and design the grid connection system cost efficiently.

4.3.4.5 Transaction costs

Within the generator-led OFTO model, we can address two specific elements in which transaction costs are incurred. The first element is identical as the transaction costs incurred in the generator model in the sense that the OWF developer needs to perform all the necessary investigations in order to determine the business case for a specific location in which the OWF will be developed, including the offshore transmission system. Therefore, these search and information costs ultimately need to be included in the business case prior to the request for a specific subsidy and can thereby increase the price for the produced electricity. For example a competitive allocation can potentially force OWF developers not to include these transaction costs, which can discourage future OWF investments.

The second element is related to the transferring of ownership after commissioning of the offshore transmission assets. These are so-called bidding costs that are incurred due to the bidding process and are significantly impacting the overall costs (CEPA, 2016). This type of transaction costs are only incurred in this specific governance model, since the Dutch TSO model does not go through a transferring of ownership after commissioning of the assets.

4.3.4.6 Risk allocation

Within the generator-led OFTO model, the risks of the offshore transmission system are transferred away from the OWF developer. In essence the overall responsibility of the performance of the offshore transmission system is allocated at the OFTO. However, as the availability target for an OFTO is set at 98%, there is still a remaining risk for the OWF developer that the produced electricity is not evacuated which results a loss of income for the OWF developer. When the availability of the system drops below the 98% threshold, the OWF developer is partly compensated by the loss of income, because the transmission tariff for the offshore transmission system will be lowered.

Additionally, National Grid (NG) is still able to influence the availability performance of an OFTO, by forcing the offshore transmission system to be on or off. NG is also liable to compensate the OWF developer for lost income when the offshore transmission system fails, however if the OFTO is responsible for this system failure, NGET needs to be compensated for these costs by the OFTO (Ofgem, 2016a). Compensation costs related to these outages can be passed through to the consumer by an adjustment in the allowed pass-through items (Ofgem, 2016a).

The construction risk and associated commissioning risk are, however, still allocated to the OWF developer, as the OWF developer is responsible for the construction of the grid connection system. The OWF developer therefore needs to include this risk in its business case, thereby increasing the overall risk of the project which influences the necessary subsidy level for the OWF developer to have a viable business case.

4.3.5 Comparative analysis of two case studies

In the previous sub-section, two case studies of governance models have been introduced. These governance models both fulfil the same function, as they govern the responsibilities regarding the planning, construction and operation of offshore transmission assets to enable the evacuation of offshore wind energy.

Where the Dutch TSO model relies on the institutional choice of vertical integration and uses a hybrid form of incentive regulation to determine the allowed revenues, the UK OFTO model uses a Franchise Bidding approach to determine the allowed revenues and thereby reliefs the NRA of the burden to estimate financial parameters and operating expenditures.

4.3.5.1 Background of NPV (of costs) analysis

In section 4.1 the value for money principle was introduced, which is a CBA method to determine which policy choice delivers the most benefits to the ones who underwrite the allowed revenues in a grid connection system. To determine which governance model brings the most value for money, a comparative analysis needs to be performed which compares the allowed revenues in the UK OFTO model with the allowed revenues in a Dutch TSO model, as these allowed revenues are ultimately paid and underwritten by the consumers.

A cash flow model will be used to perform this quantitative analysis, as this enables the calculation of a Net Present Value (NPV) of the different governance models. The cash flows are specific for both types of governance models, consistent with the institutional choice to either regulate the firm or introduce ex-ante competition for the market through Franchise Bidding. Figure 27 illustrates the different cash flows that result in specific NPVs of the costs.

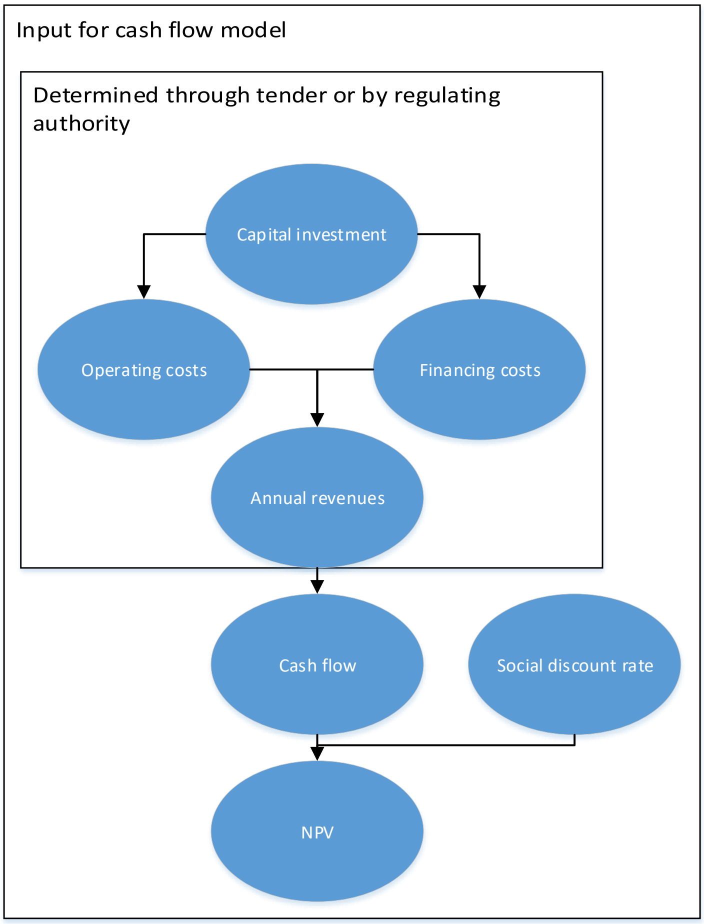


Figure 27: Factors that determine NPV of costs

4.3.5.2 Model & data use

In order to calculate the NPV, the model uses input data from both the designated UK regulatory authority (Ofgem) and the Dutch regulatory authority (ACM). Figure 28 shows the data which is used in the cash flow model. The FTV, which is used as an input, is decided upon by Ofgem and the TRS is the value of the winning tender bid, representing the fixed annual revenue stream of the OFTO.

It must be noted that these costs are the costs presented to the consumer and not the actual costs incurred by the OFTO or TSO. By using the costs presented to the consumer a comparison between the two governance models is possible through the comparison of the NPV for the specific cases. Additionally, it is assumed that the arranged incentives in both governance models have the desired outcome, in the sense that the owners of the transmission assets achieve their availability targets. This will need to be monitored throughout the lifetime of the assets to verify this assumption.

Case	FTV		TRS	
Walney 1	£	105.000.000,00	£	11.558.000,00
Barrow	£	33.600.000,00	£	4.991.000,00
Gunfleet Sands	£	49.500.000,00	£	6.106.000,00
Robin Rigg	£	65.500.000,00	£	6.533.000,00
Ormonde	£	103.900.000,00	£	10.603.000,00
Walney 2	£	109.800.000,00	£	12.466.000,00
London Array	£	458.900.000,00	£	34.936.000,00
Sheringham Shoal	£	193.100.000,00	£	19.128.000,00
Greater Gabbard	£	317.000.000,00	£	26.793.000,00
Lincs	£	307.700.000,00	£	24.635.000,00
Thanet	£	164.000.000,00	£	16.874.000,00
Gwynt y Mor	£	352.000.000,00	£	25.152.000,00
West of Duddon Sands	£	269.000.000,00	£	19.700.000,00

Figure 28: Data use in cash flow model

For the UK cash flows, annual TRS determined through the competitive tender are used for a twelve different cases. The data of these cases is based on reports of Ofgem regarding the individual costs assessment of the offshore transmission systems that conclude in a FTV and the most recent report on the TRS (Ofgem, 2016b).

More specifically the following equation is used to determine the NPV of the UK cases:

$$NPV_{UK} = \frac{\sum_{t=1}^{T} TRS_t}{(1+\mathrm{r})^t} \qquad (1)$$

With:

TRS: the Tender Revenue Stream of the specific case, determined through the competitive tender

T: the regulated lifetime of the "fixed" revenue stream, 20 years

r: the social discount rate (set at 3,5%), as advised by the UK government (HM Treasury, 2008)

The Dutch counterfactual cash flows, using the RAB principle, necessitates the initial regulated asset value as an input. The RAV is therefore derived from approved investment costs of the UK cases, the Final Transfer Value, which in the TSO cash flow calculation will be used as the replacing RAV. The data regarding the operating costs and the financing costs for offshore grid infrastructure is derived from several ACM sources. By combining the UK capital investment costs and the aforementioned Dutch counterfactual parameters, the following equation then leads to the calculation of the NPV for the Dutch counterfactual:

$$NPV_{NL} = \frac{\sum_{t=1}^{T} Regulated\ Revenue_t}{(1+\mathrm{r})^t} \qquad (2)$$

With:

r: the social discount rate

T: the years the revenues can be expected, the depreciation time, 20 years

Regulated Revenue:

$$Regulated\ Revenue_t = \frac{RAV_t}{DT} + RAV_t * WACC + OPEX \qquad (3)$$

With:

RAV: the final transfer value of the specific case

DT: Depreciation Time, 20 years

WACC: the weighted average cost of capital, 3,6%

OPEX: Operating Expenditures, 1%*RAV

Finally, the NPV of the UK OFTO-model are compared with the NPV of the Dutch counterfactual on a like-for-like basis. This comparison will result in a NPV delta, which is the difference in the NPV of both governance models for a specific case. The following equation is used to determine the NPV delta:

$$NPV\ delta = NPV_{UK} - NPV_{NL} \qquad (4)$$

The NPV delta will express the difference in the value for money of the two governance models and thus provide an insight into which governance model is able to provide more value for money for consumers in a specific case.

4.3.5.3 Results

The final results of the comparative analysis are shown in figure 28. Provided equation (4), a positive value indicates that the Dutch TSO-model counterfactual would have had a better NPV compared to the UK-OFTO model, while a negative value would indicate that the UK-OFTO model has a better NPV than the Dutch counterfactual.

Case	FTV	NPV delta
Walney 1	£ 105.000.000,00	£ 49.100.000
Barrow	£ 33.600.000,00	£ 38.900.000
Gunfleet Sands	£ 49.500.000,00	£ 35.500.000
Robin Rigg	£ 65.500.000,00	£ 20.600.000
Ormonde	£ 103.900.000,00	£ 34.900.000
Walney 2	£ 109.800.000,00	£ 57.400.000
London Array	£ 458.900.000,00	-£ 50.600.000
Sheringham Shoal	£ 193.100.000,00	£ 53.000.000
Greater Gabbard	£ 317.000.000,00	£ 9.600.000
Lincs	£ 307.700.000,00	-£ 13.100.000
Thanet	£ 164.000.000,00	£ 55.700.000
Gwynt y Mor	£ 352.000.000,00	-£ 65.100.000
West of Duddon Sands	£ 269.000.000,00	-£ 41.200.000

Figure 29: Aggregation of input data and model results

Moreover, the results of the comparative cash flow analysis shows that there are four cases (highlighted in figure 29) which show that the OFTO-model presents more value for money to consumers. Overall, by looking at the cumulative NPV delta, projected cost saving of £184 million could have been achieved if the Dutch TSO-model would have been applied on the offshore transmission assets, which have a cumulative regulated asset value of £2,53 billion.

4.3.5.4 Discussion of the results

While the overall projected cost savings, based on the cumulative asset value of £2,53, suggests that the TSO-model would provide cost savings for the consumers. However, it is not necessarily true that in any given offshore transmission case the TSO model would provide this cost saving, which is evidenced by the fact that four distinct cases provided no cost savings when the Dutch TSO parameters were applied on the FTV.

A possible explanation for the results is the effectiveness of incentive regulation in the TSO model, combined with lacking transaction costs associated with setup-costs for the OFTO tender. The trend that larger FTVs cause a higher value for money for the OFTO model is in line with this explanation, as the setup-costs are more or less equal in every OFTO tender, while economies of scale can contribute to relative lower financing costs and maintenance expenditures when assets increase in size and economic value.

Uncertainties

Several aspects could, however, change the outcome of the results which were presented in the previous sub-section.

Take for example the WACC parameters of the Dutch TSO model which are used in this analysis. These WACC parameters are subject to periodic review and history has shown that it is likely that these parameters will change in the future, either upwards or downwards. Sensitivity analysis (Appendix E) shows that the cumulative NPV deltas of the twelve cases are sensitive to adjustments, with ranging cost saving projections between £116-253 million when the Dutch TSO model parameters would have been used. Moreover, sensitivity analysis shows that the same four cases would provide a more value for money in the OFTO model.

Moreover, while the competitive bidding should reveal true costs for financing and operating the offshore transmission assets (CEPA, 2016), OWF developers are able to offer O&M solutions to the bidding firms for the offshore transmission system, as described in the OFTO case study. Therefore, there is a possibility that these O&M solutions do not reveal true prices when OWF developers offer O&M solutions below actual costs[5].

Another important element of the NPV analysis is that it uses a social discount rate to calculate the present value of the cash flows. The value of the social discount rate is continuously debated upon in the literature and hence there is no consensus on the value of the social discount rate. Within this analysis the social discount rate is set at 3,5%, as advised by the UK ministry (HM Treasury, 2008). Sensitivity analysis (Appendix E) shows that the cumulative value for money is

[5] It is possible for OWF developer to offer O&M packages below actual costs, since they will be paying fort he costs of O&M through their transmission tariffs which are based on the winning TRS bid.

sensitive to adjustments. However, similar to the results of section 4.3.5.3, four cases remain to have more value for money when the OFTO model is applied.

Finally, this analysis focusses on the costs, associated with radial connections to evacuate the offshore wind, that need to be paid by the consumer. However the impact of the governance models transcends the sole costs associated with the radial connections as it is physically and institutionally interfaced with the OWF and the onshore grid. For example, by removing construction risk and permitting delays of the grid connection system from the OWF developer, a more effective competitive bidding can be achieved for the required amount of subsidy to develop a OWF (IEA-RETD, 2017), through the removal of the aforementioned transaction costs.

The overall impact of the chosen governance model on the costs presented to the final consumer of electricity can be greater that the analysed impact in this article. Additional research is therefore necessary to analyse the impact of a governance model, for a radial offshore windfarm connection, on the total costs (including costs and benefits of the OWFs) which are paid by the consumer.

4.3.6 Interim conclusion

The primary conclusion of this analysis is therefore that the Dutch NRA is able to simulate a competitive market, regarding the financial parameters and operating expenditures for an offshore grid connection. Analysing section 4.3, it is evident that the results do not show the full picture of the impact of a chosen governance model on the actual value for money for the consumers of electricity when the OWF scope and the onshore grid reinforcements are included. However, by disregarding these two factors, a quantitative comparison between the two governance models, applied on radial grid connections, can be made by looking at the cash flows of the different models for specific cases.

By aggregating all of the results (NPV deltas), we can see that the Dutch TSO model, in which the regulator sets the allowed revenues, the consumer who underwrites the revenues would receive a higher value for money compared to the UK OFTO model. While the actual performance of the governance models can only be determined at the end of the assets lifetime, by forecasting the cash flows it is possible to conclude that there is no conclusive evidence that the OFTO model is superior to regulation, as the Dutch TSO model proves that it can provide higher value for money in all but three of the analysed cases.

Regarding the CAPEX, the NPV analysis cannot provide any relevant conclusions on whether these are efficient or not, as the analysis regards the allowed capital expenditures (to be put up for tender or allowed in the regulated asset base) as a given. It is however very likely that in a case where the OFTO would also be responsible for the construction of the offshore grid connection system, it would require a larger risk premium as the construction risk is then added to the business case for a potential OFTO. Thus, the required TRS is likely to increase accordingly.

Another valuable conclusion is that the value for money in an OFTO model increases when the FTV increases. This conclusion is in line with requirements for a successful PPP arrangement, as one of the requirements is that the investment should be significantly large. More specifically, a trend of increasing value for money with larger FTVs is observable, the NPV of the costs show that large radial grid connections (with a large FTV) are better off with an OFTO model and thus provide more value for money than a TSO model.

5 Evaluation & design space of governance models for MOG development

The previous chapter introduced the institutional choices regarding the ownership of transmission assets and the possible operating models which is related to the degree of unbundling of the electricity sector and more specifically to the degree of unbundling in the electricity transmission sector.

This chapter consists of four sections and will first describe the general objectives of a governance model for a MOG (section 5.1). Secondly, through section 5.2, the design space is contracted by providing argumentation why a merchant governance model is not economically feasible and desirable in a MOG context.

Thirdly, this chapter will integrate the most important findings in such a way that the conceptual design space for governance models regarding the ownership and operation of a MOG is shaped (section 5.3). A step-by-step approach is used, delineating from the highest level design space, to the most detailed level design space through a synthesis of the arguments introduced in the previous sub-section. The step-by-step approach subsequently provides the necessary input for chapter 6 to design alternative governance models.

Finally, this chapter will integrate the findings of chapter 4 to provide a foundation on which the designed governance can be assessed upon (section 5.4).

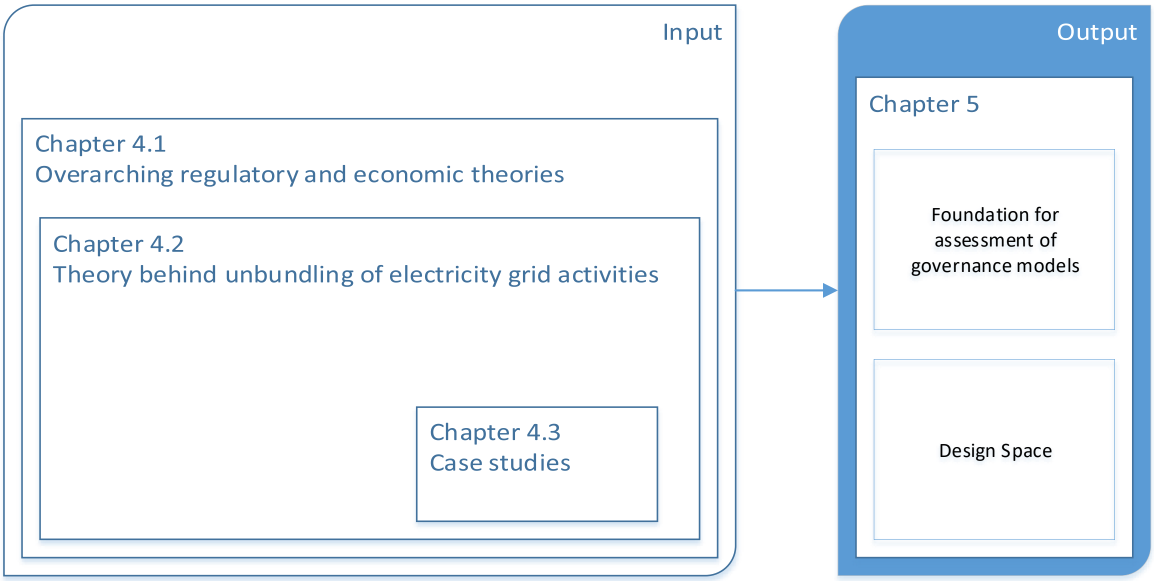


Figure 30: Input-Output diagram

5.1 The objectives of a governance model

In order to assess the alternative governance models, which will be described in chapter 6, a clear set of objectives needs to be constructed by which the alternative governance models for a

MOG can be assessed. Therefore, the described objectives of this sub-section will provide the necessary input for chapter 7. These objectives are derived from the literature and overall objectives of a regulatory framework (ACM, 2017) and a transmission system in general. The following objectives will subsequently be explained:

- Optimize investment planning
  - Ability to evolve in larger offshore grid
  - Efficient onshore grid connection
- Optimize allowed revenues
- Facilitate efficient operation of the system
- Optimize financial viability of investments

5.1.1 Optimize investment planning

Section 4.2.2 was already clear on the importance of investment planning in general and therefore the importance of investment planning for a MOG. However, there are significant differences in the investment planning approach for a MOG, as the development of a MOG in the North(ern) Sea(s) can be considered a greenfield situation. Given the enormous scale of investments to realize the necessary infrastructure to connect the OWFs in the coming decades, it is more likely that the development of a MOG will be incremental instead of a Big-Bang in which a full-blown MOG will be developed from the start.

Additionally, while the development of a MOG can be considered a greenfield situation, there are still onshore grid restrictions as to the congestion on the onshore grid created by the necessary integration of the offshore transmission assets and the accompanied evacuation of offshore wind energy to the onshore load centres. The objective to have efficient investment planning can thus be separated into two different sub-objectives:

5.1.1.1 Ability to evolve in larger offshore grid

Because of the likeliness that a MOG will develop gradually, the governance model for a MOG should therefore enable the flexibility needed to accommodate this gradual development. Practically, this would imply that for example transmission assets can be used for interconnection first, after which one or several OWFs are connected to this transmission asset, or vice versa. Thereby creating a hybrid transmission asset in which the interconnection function is combined with the grid connection of an OWF to evacuate offshore wind energy, which is considered the first step in a MOG development.

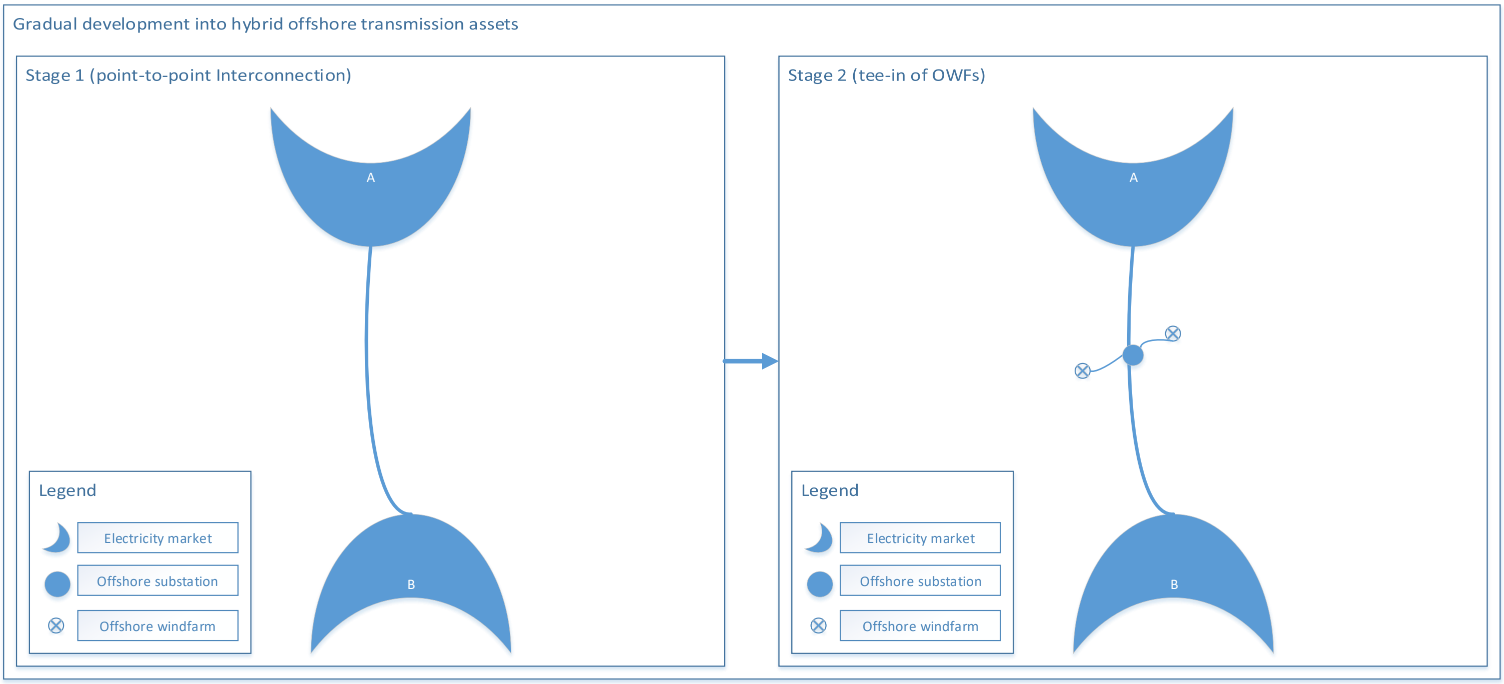


Figure 31: Possible gradual development of offshore transmission assets

Currently, one interconnection cable is already suitable for this development, the COBRA-cable, which initially is an offshore interconnection transmission asset which interconnects the Danish and Dutch electricity markets. However, this offshore interconnection transmission asset is designed in such a way that it could potentially tee-in an OWF in the future if there is demand for this tee-in[6] (European Commission, 2013), as shown in figure 31. Similar to the tee-in of OWFs, it is also possible that different radial offshore transmission assets are interconnected within the lifetime of these assets, several options are illustrated in Appendix F.

5.1.1.2 Efficient onshore grid connection

By planning large scale OWF electricity production, the produced electricity must be evacuated to the onshore grid in order to reach the onshore load centres, thereby influencing the onshore electricity flows and potentially creating congestion if the onshore grid does not have enough transport capacity to accommodate the offshore production. Consequently, if the offshore transmission assets are planned to be connected to onshore areas which are not able to provide the necessary transport capacity, these onshore grid areas need to be reinforced, thereby necessitating additional capital expenditures to avoid costly re-dispatching.

[6] A tee-in is defined as connecting an OWF to an already existing offshore transmission cable.

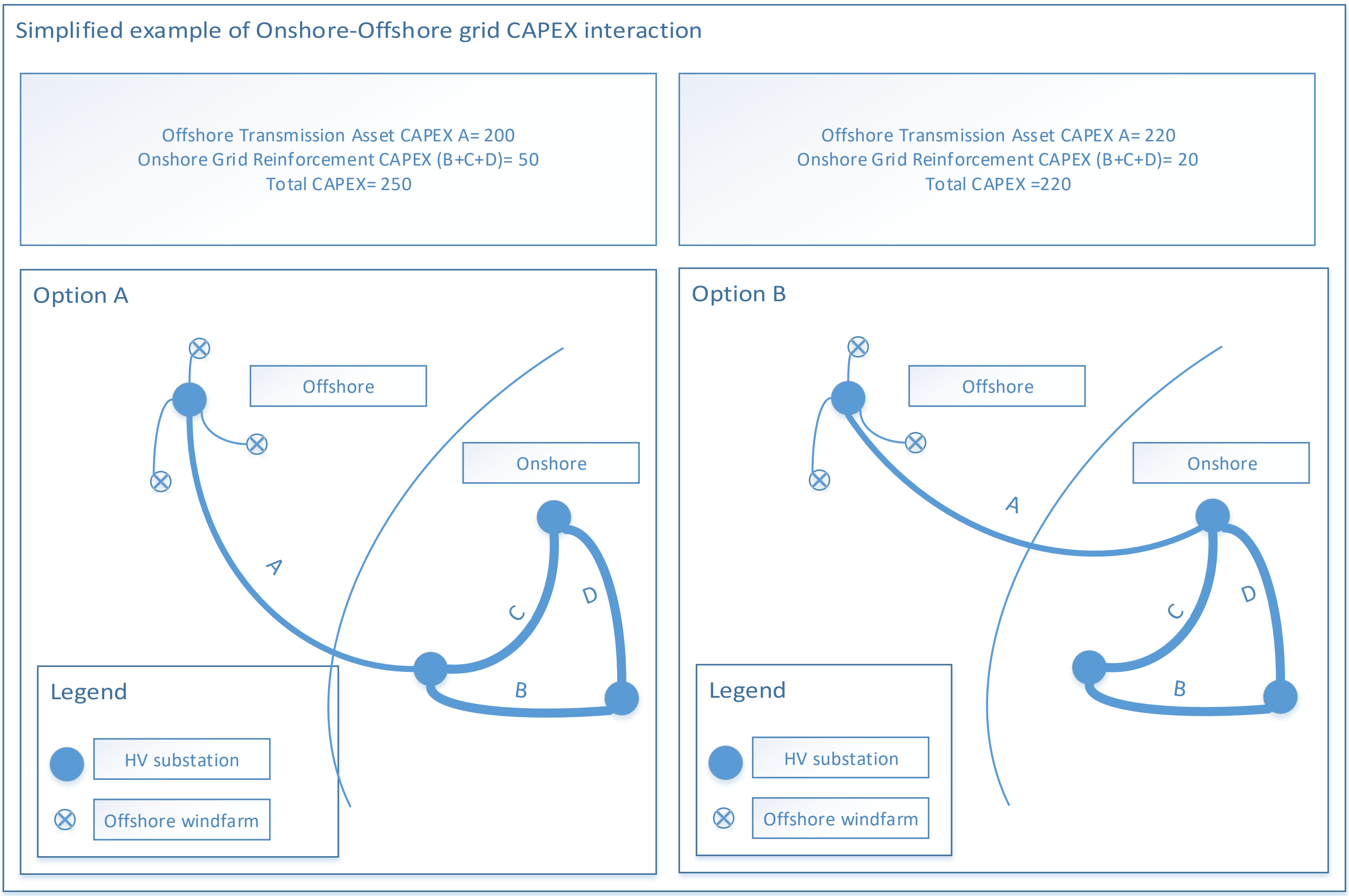


Figure 32: Possible onshore grid connection choices

Because of this wider system effect of integrating offshore wind energy, a governance model should enable efficient onshore grid connection in the sense that it should use total system perspective[7] when considering the costs and benefits of connecting the offshore transmission assets to the onshore grid. It could for example be possible that additional investments (or different timing of the investment) for the offshore transmission system will avoid higher investments in the onshore grid, thereby legitimizing these offshore investments when a total system perspective is used, as illustrated in the simplified example of figure 32.

5.1.2 Optimize allowed revenues for delivering transmission grid services

5.1.2.1 TO services

The TO services that are provided through the offshore transmission assets, of which a MOG consists of, are considered a natural monopoly, additionally the allowed revenues are ultimately underwritten by consumers since a merchant revenue model is considered economically

[7] A total system perspective includes potential onshore grid reinforcements to accommodate the offshore grid developments, while also taking into account the optimization of system operation.

inefficient, which will be explained in section 5.2. Thereby, the ownership of these assets and the related operating activities needs to be managed in such a way that the provider of TO services is not able to charge tariffs (obtain revenues) that are not proportionate to the costs these provider of the TO services incur. In order achieve this, the governance model for a MOG should therefore aim to set the allowed revenues as if it these revenues were obtained in a competitive market.

Moreover, as the NRAs and national ministries are ultimately responsible for safeguarding the interests of the consumers who will underwrite the investments, these institutions should therefore safeguard the interest of these consumers. In general this would mean that the governance model should aim to, 1) avoid inefficient allocation of services and 2) safeguard proportionate remuneration of these services.

Specifically to the MOG development, the avoidance of inefficient allocation of services implies that the governance model should enable efficient capital expenditures of the offshore transmission investments and thus eliminate investments which do not contribute to social welfare, contrastingly the governance model should support and push for offshore transmission investments that contribute to an increase of social welfare.

The safeguarding of proportionate remuneration subsequently implies that the provider of TO services receives an appropriate return on its investment and additional expenditures. By providing an appropriate return, a stable revenue stream is created for these providers that take into account the applicable cost of capital and overall operating expenditures.

5.1.2.2 SO services

Similar to an appropriate remuneration for TO services, the SO services must also be remunerated appropriately. While SO services are considered not-for-profit, section 4.2.4 showed that it is necessary to incentivize the SO to operate economically efficient.

5.1.3 Facilitate Operating Efficiency

Separately, the aim of a governance model should be in line with the overall objective of the technical system, thereby the aim of a governance model should be to maintain and facilitate operational efficiency. More specific to the governance model for a MOG, this would entail efficient coordination and communication between the System Operator and Transmission Owner to safeguard short term and long term reliability of the transmission system.

5.1.4 Optimize financial viability of investments

The financial viability of the investments is the objective which relates to the amount of investments and the necessary debt and equity capital to realize these investments. In any case, a governance model for a MOG should require that planned investments, which contribute to an increase in social welfare, are viable from a financing perspective. Hence, when a specific governance model restrains the development of a MOG, this governance model should be adapted to enable the development of the MOG and thereby enable the development of the offshore transmission assets that form the MOG.

5.2 Merchant transmission investment (spot market)

Merchant transmission investment is market driven investment, based on the revenues that can arise out of the price differential between electricity markets or, as in the US, price differential between nodes (Wu et al., 2006). Private investors will initiate or participate in merchant transmission investments when the revenues, or congestion rent, can be derived from the market by building transmission assets between the two price-zones and additionally these revenues outweigh the costs of building the transmission assets. Looking at figure 33, this type of investment comes closest to the spot market determinant as categorized by Crocker & Masten (1996).

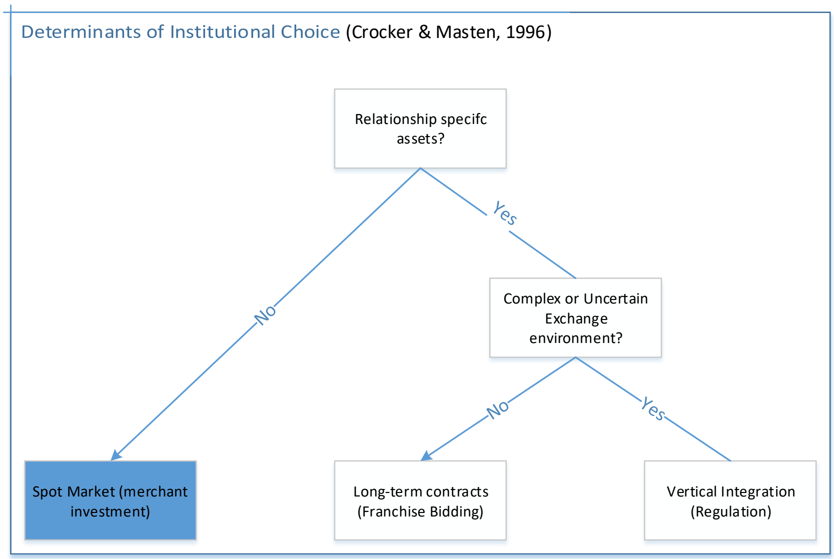


Figure 33: Institutional choice Merchant Investment

5.2.1 Pros and cons of merchant transmission investments

While congestion rents can be derived by the owner of the transmission assets in a merchant investment, investment in transmission assets should look to create overall social welfare. Thereby the added transmission asset should not only be based on the derivation of congestion rent for the owner, but also look at the changing consumer and producer surplus. Hogan (Hogan, 2011) argues that using the merchant investment approach, under a specific set of requirements, competition can be created in the market and thereby limiting the socialization of investment costs. Investment planning, which involves the capacity, location, timing and overall design of the transmission investment would be decided upon in a competitive environment by private investors, thereby alleviating this burden from the SO and policy makers and let the market allocate the appropriate resources. One of the requirements for merchant investment is the unbundling of SO, TO and generation activities, as the integration of these activities could lead to conflicts of interest and thereby the abuse of market power when revenues are depending on the congestion rent (Hogan, 2011; Van Koten, 2011). The implications of further unbundling were already described in sub-section 4.2.

On the downside, merchant transmission investment will only materialize when private investors are confident of their profit levels. Because of this, it is possible that a merchant investment model will cause underinvestment as incumbent merchant transmission owners are reluctant to create additional merchant transmission capacity between markets in which they already own merchant transmission capacity, since the creation of additional transmission capacity could "cannibalize" the congestion rent of the initial merchant transmission line. Moreover, when for example TSOs own merchant interconnection assets, the concept of merchant investments can potentially provide barriers for the development of a MOG as TSOs can have a conflict of interest when additional (regulated) interconnection capacity is optimal from a social welfare perspective, but, sub-optimal from the TSOs business perspective. A situation can arise that additional interconnection capacity (within a MOG configuration) can increase social welfare, while decreasing profits for the TSO as the additional interconnection capacity can decrease the congestion rents which it receives through the merchant interconnectors.

Literature indicates that a combination of regulated and merchant transmission investment is possible, as introduced by Hogan, Rosellón, & Vogelsang (2010), which is integrating studies of transmission pricing based on performance based regulation (Vogelsang, 2006) and merchant investments (Hogan, 2011). These studies did not include MOG options, which are characterized by the function of evacuating intermittent offshore wind energy, which will be addressed in the following sub-section.

5.2.2 Application of merchant investment in a MOG

While the theoretical literature is mostly focusing on point-to-point transmission assets, a MOG however includes the possibility that a generating unit, the OWF, is situated between the two nodes which have a price differential. Specifically for a European MOG case, a merchant investment would likely include an interconnection transmission asset, which connects two or more distinct bidding-zones. Additionally, current market design and subsidy schemes for OWFs require the OWF to bid into its own local electricity market.

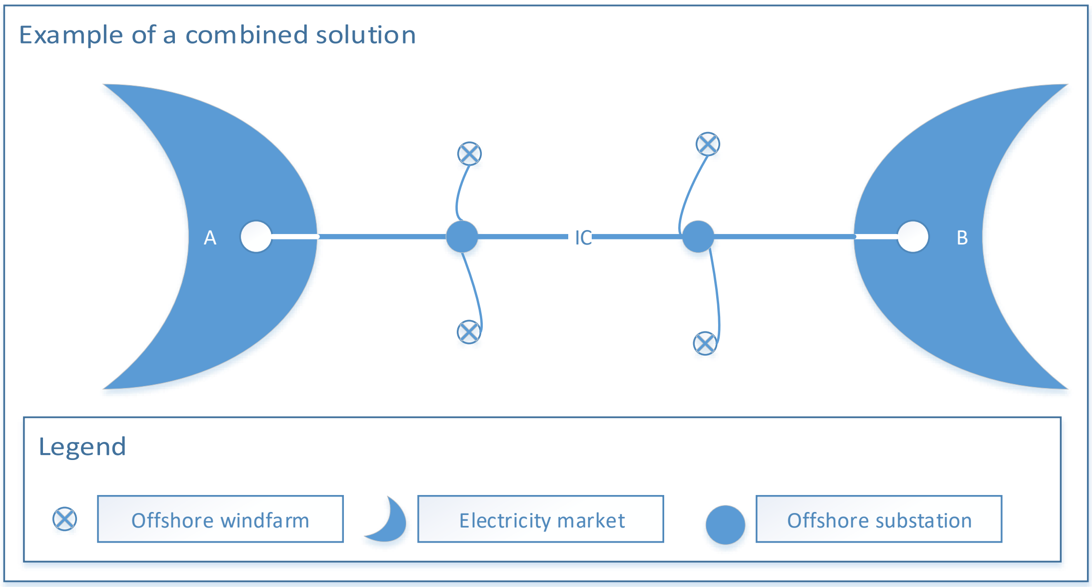


Figure 34: Example of hybrid transmission asset

Combining these characteristics, the revenues that can be derived from transmission assets are therefore more volatile as the congestion rent is depending on the production of the OWF(s). This situation can be explained by an example in which an interconnection (IC) asset is constructed between two OWFs (figure 34). Using this example, the available capacity to provide interconnection between the two countries is depending on the real-time production of the OWF(s) and therefore the remaining capacity (net-of-wind capacity) can be used to derive congestion rents, as shown in figure 35.

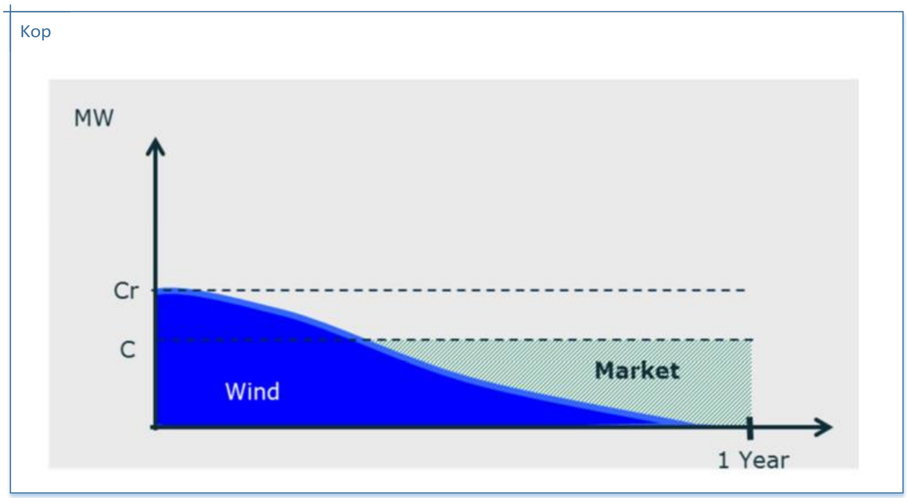


Figure 35: Capacity allocation in hybrid transmission asset (Energinet DK, 2015)

Based on the above implications of a MOG on the possible congestion rents that can be derived from the market and the downward effect of wind generation on the marginal electricity prices, which will lower price-differentials across Europe according to Egerer, Kunz, & Hirschhausen, (2013), merchant transmission investment will not provide sufficient transmission capacity to facilitate an offshore grid (Egerer et al., 2013). Finally, one of the main objectives of the EC is the convergence electricity prices across the continent and a MOG is a part of the solution, making it more likely that price differentials would continue to decrease across Europe. These converging prices thereby remove the incentive for private merchant investors to participate, hence will not facilitate the development of a MOG.

5.2.3 Interim conclusion

Concluding, the main benefits of merchant transmission investment are obvious, as it reliefs policymakers and system operators from allocating resources. Making policy makers and system operators, instead of the market, responsible for allocating resources can lead to an inefficient allocation thereof, which can decrease social welfare. Moreover, if appropriate structures are in place, such as the unbundling of system operating activities and transmission owning activities, it can remove the conflicts of interest in regulated transmission investment that could potentially lead to overinvestment. On the other hand, this section showed that a merchant investment approach can also lead to underinvestment.

The presented overall technological and economic implications of a MOG, however, suggests that a merchant model for the investment in a MOG is not sustainable and will therefore not attract enough investment for a MOG to evolve.

In the subsequent sections of this report, the merchant investment model will therefore not be included in the design space of section 5.3 and the following assessment of the alternative governance models for a MOG.

5.3 Design space for the governance model of a MOG

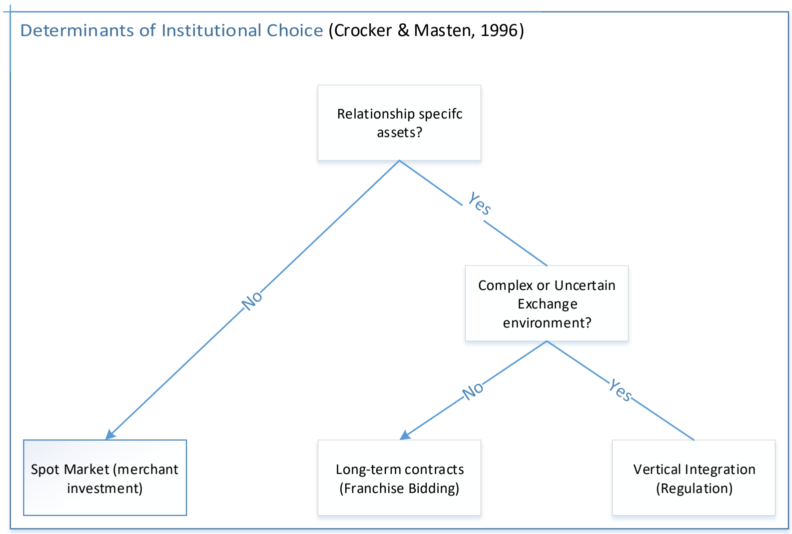


Figure 36: Institutional choice as first level design space

5.3.1 First level design space

The highest, or 1st-level design space are the determinants of institutional choice as defined in figure 35 by Crocker & Masten (1996). Through this framework, three potential ownership models can be defined: 1) a Merchant model, 2) a Franchise Bidding model and a Vertical Integration model.

Based on a variety of arguments, as described in section 5.2, the merchant model is no longer considered as an ownership model that can be applied on a MOG. By removing this option, the ownership models that remain are the Franchise Bidding model which is relying on competition for the market and Vertical Integration which is relying on regulation to simulate a competitive market.

5.3.2 Second level design space

The 2nd-level design space is related to the governance of electricity grid activities and the technological context which is applicable on a MOG. As the technological context, which is described in section 4.2, has shown us that electricity grid activities can be separated in two main services: Transmission Ownership activities and System Operating activities. These services can be distributed among different entities through ownership or legal bundling/unbundling.

Figure 37 first shows the possible operating models in general and subsequently highlights the operating models that are allowed to be applied on a MOG, based on the analysis in section 4.2. It is therefore possible to conclude that a MOG can be operated through two distinct models: 1) an integrated TSO which provides both TO activities and SO activities, and 2) a hybrid TO & SO model in which TO activities and SO activities are unbundled.

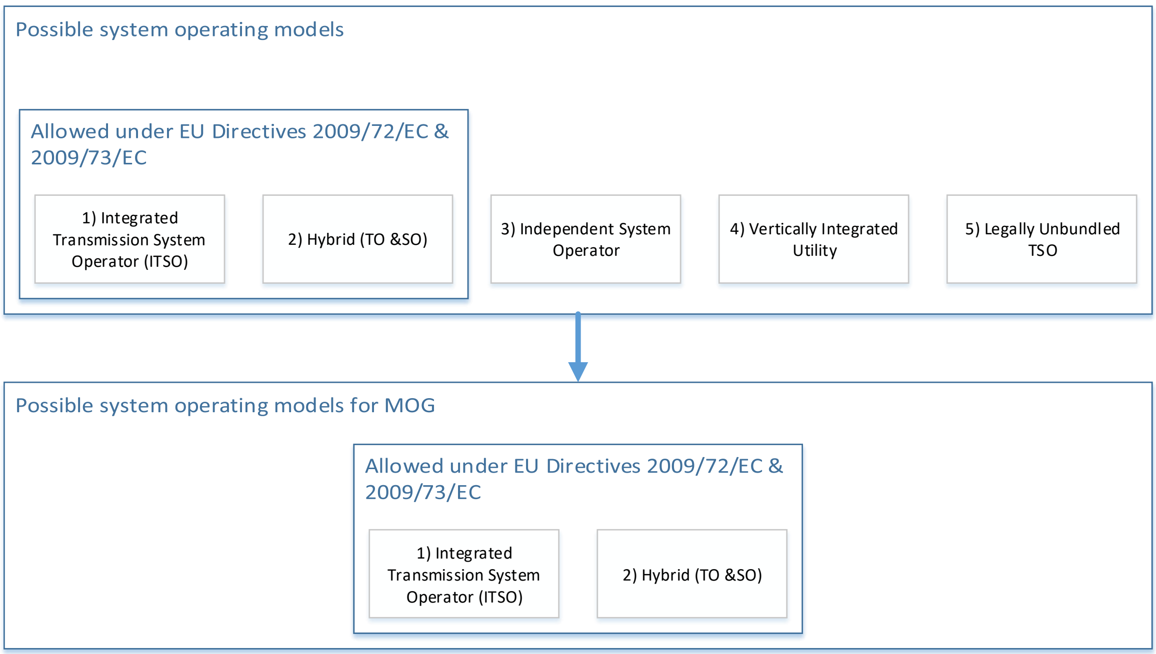


Figure 37: Unbundling choice as second level design space

Additionally, interdependency exists between the institutional choice (1st-level design space) and the possible operating models. While it is possible to competitively tender TO activities and services, the UK OFTO case study has shown that SO activities are then to be separated from the TO and the SO has ultimate responsibility over the transmission assets (PROMOTioN, 2017c).

Hence, when competitive tendering for the transmission assets is applied through the institutional choice of Franchise Bidding, an ITSO model is no longer possible.

Therefore the implication of Franchise Bidding is the necessity of unbundling TO and SO activities.

5.3.3 Third level design space

The 3rd-level design space is exclusively applicable to the Franchise Bidding institutional choice, as there are two distinct types of PPP structures that can be applied on a Franchise Bidding approach:

1) BOOT

   In a Build-Own-Operate-Transfer PPP structure the competitively tendered party is not only responsible for financing and maintaining the electricity transmission assets, but in a BOOT structure the party is additionally made responsible for the construction of the assets.

2) FOOT

   In a Finance-Own-Operate-Transfer PPP structure the competitively tendered party merely finances the electricity transmission assets and is responsible for previously defined operational tasks, such as maintenance. While the BOOT PPP structure is merely relying on the high-level conceptual design of the transmission assets, the FOOT PPP structure is relying on other parties to construct the transmission assets. Hence, the construction risks are incurred by a party other than the eventual TO.

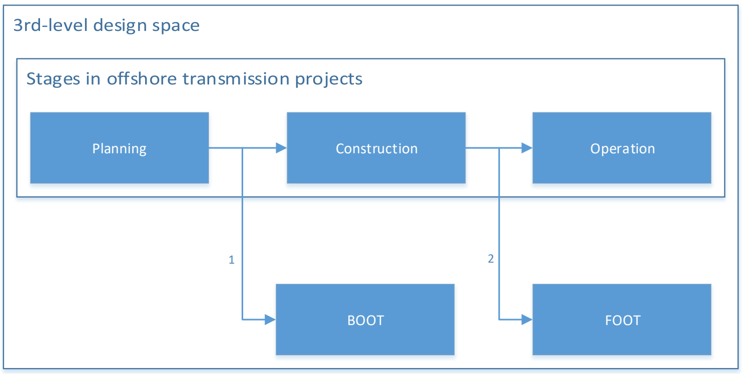


Figure 38: PPP choice as third level design space

As explained in the analytical framework in section 4.2.2, electricity transmission projects can be separated into three different stages: Planning, Construction and Operation. Combining these stages with the possible PPP structures (BOOT & FOOT) implicate that the Franchise Bidding approach is applied either after the planning stage of the transmission assets (BOOT) or applied after the construction phase of the transmission assets and the private party merely has to finance-own-operate the transmission assets (FOOT). These implications are illustrated in figure 38.

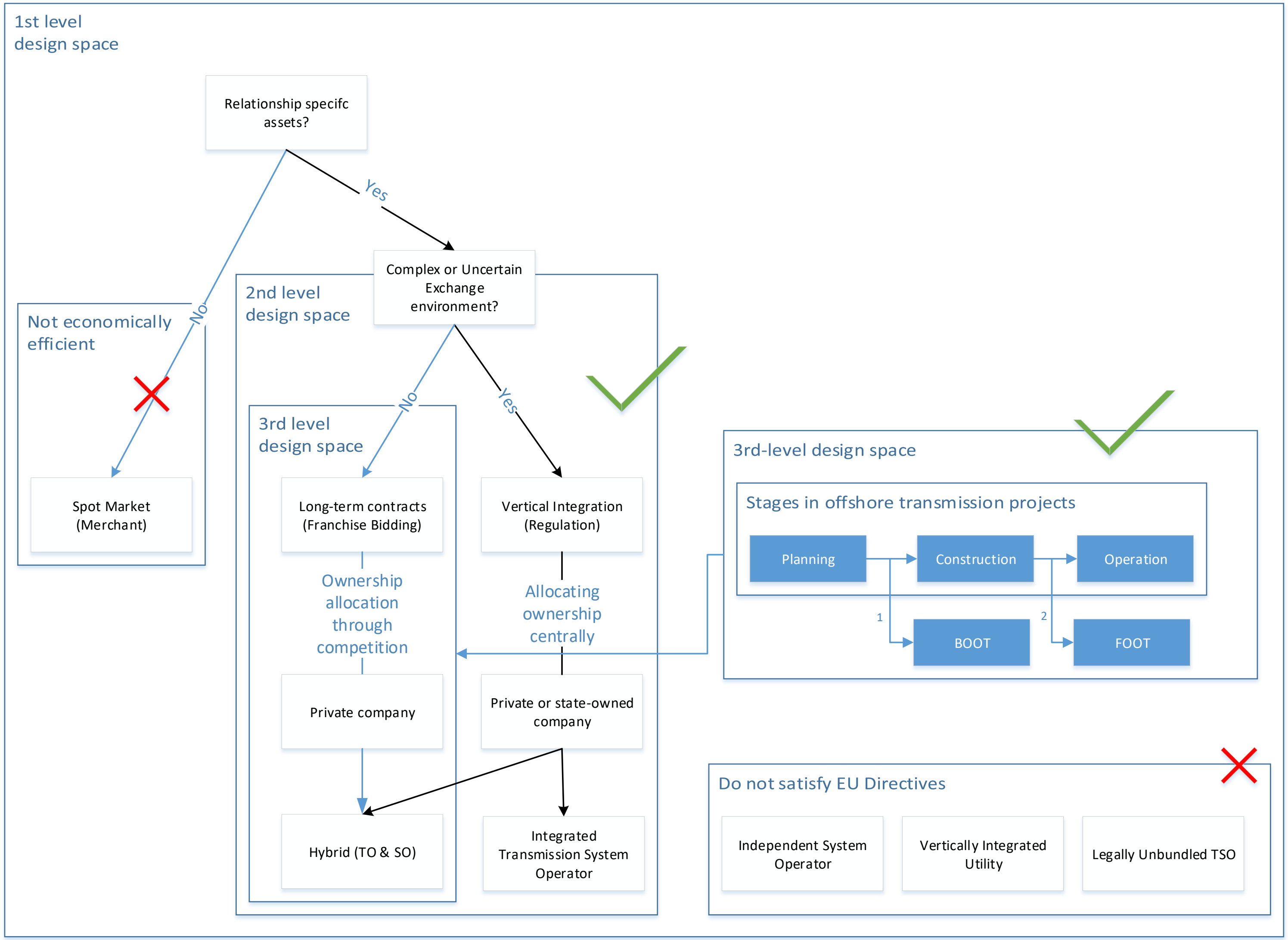
Moreover, different actors can be involved in the different stages of the transmission projects. The following parties can be involved in the planning stage of the project:

- National Ministries
- National Regulatory Authorities
- OWF developers
- Onshore TSOs and ISOs
- OFTOs

Regarding the allocation of responsibilities, the national ministries and NRAs can have responsibility in the planning stage of an electricity transmission project.

5.3.4 Design Space visualization

By combining the previously described levels of design space, a design space can be introduced by adapting the Crocker & Masten institutional choice framework through the addition of the technological context of a MOG. In the overview of the design space, the three levels of design are integrated through the Crocker & Masten framework. By using the degrees of freedom within this design space we can subsequently combine the distinct elements to design a governance model for a MOG. While it is possible to make a wide variety of governance models, this report will limit the possible governance models by, one, extending current regulatory regimes and, two, using configurations that could practically be implemented and realize benefits compared to the extended regimes. This will be addressed in more detail through the description of the governance models in chapter 6.



5.4 Expected performance of design levels

Not only did chapter 4 provide the degrees of freedom for the design of a governance model, it also provided arguments and substantiation which enables the analysis of the expected performance of the designed governance models. This sub-section will summarize the main findings within the analytical framework that contribute to this exercise. First the implications of bundling an unbundling will be described, after which the expected transactions costs of the governance models will be delineated and finally the performance of PPP structures is addressed.

These three aspects relate to the three design levels which were introduced in section 5.3. The following sub-section will therefore provide an assessment for each design level.

5.4.1 Transaction costs (1st level design space)

By looking at the different design levels and focusing on the first level design space, an important institutional choice is to be decided upon. Policy makers will need to decide whether it will introduce competition in a transmission service market which is generally considered a natural monopoly and therefore competition within the market is not feasible. However, as this report has shown through the literature and the UK case-study, competition for the market can be implemented through the creation of long-term contracts, thereby removing the necessity of the NRA to estimate parameters which determine the cost level of the regulated firm and simulate a competitive environment for the natural monopolist. However, as the literature has shown, by introducing competition for the market through long-term contracts, the contractor will receive contractual rights and can subsequently exercise these rights when circumstances cause the contractual rights to be amended, ultimately causing transaction costs in future negotiations, as observed by Williamson (1976).

When Franchise Bidding is the institutional choice, it is necessary to identify circumstances that could potentially lead to the revision of the initial contract, and thereby cause transaction costs in future negotiations with the contractor. Ultimately, these potential transaction costs will need to be compared with the potential benefits of creating competition for the market.

While the previous argument was focusing on future transaction costs, the initial setup-costs and bidding-costs are not to be neglected, as described in the UK case study. These are the initial transaction costs that are guaranteed to be incurred when a Franchise Bidding approach is used to allocate the ownership responsibility for the offshore transmission assets.

Moreover, while it can be convenient to focus on the efficiency of the transmission assets, it is not only important to consider the impact of the governance models on the value for money achieved on the transmission system. The impact of the choice of a governance model is also impacting the amount of transaction costs which are incurred by OWF developers and thereby their required subsidy tariff, as analysed in section 3.3. This report will therefore additionally consider the transaction costs imposed on the interfacing systems, when the alternatives are assessed.

Concluding, the incurred and potential transaction costs are different depending on the design of the governance model, when analysing the designed governance models, the applicable transaction costs of the specific governance model will be highlighted and will provide the basis of the analysis of the governance models in determining their expected performance.

5.4.2 Unbundling or bundling of transmission services

Another important aspect regarding the performance of a governance model is the impact of either unbundling or bundling the transmission services (TO & SO). Sub-section 4.2.4 revealed that by unbundling transmission services, potential synergies would be lost.

The potential synergies include more efficient investment and maintenance planning in an integrated network, thereby limiting the possible costs for congestion either through coordinating maintenance schedules of different transmission assets or through planning new transmission investments adequately. Another important aspect is the flow of information when TO and SO services are bundled, which is assumed to be more efficient compared with the unbundled TO and SO services.

Moreover, when unbundling the TO and SO services, it becomes more difficult to provide incentives for the SO to become more efficient in its operation as strong incentives or punishments can' t be enforced as the SO typically has a not-for-profit structure with limited revenues, thereby any economic punishment could jeopardize the ongoing tasks of the SO to provide security of supply.

Concluding, the potential synergies between TO and SO services, as described, make scholars argue that the theoretical optimal model for governing TO and SO services is to integrate these services into an ITSO.

5.4.3 PPP requirements to achieve value for money

One of the main questions for policymakers is whether Franchise Bidding delivers additional benefits and therefore provides value for money for the consumers of electricity who are ultimately paying for the investments and overall expenditures. Section 4.1 provided valuable input to determine whether a PPP will be successful, thus highlighting the following requirements for a successful PPP:

- Significantly large investment
- Private sector expertise to design and implement complex projects
- Possibility of detailed service description to put into a contract
- Clear definition of risk allocation between contractor and procurer
- Life-cycle costs estimation must be possible
- Stable technology

6 Alternatives for a MOG governance model

Chapter 6 will provide four conceptual designed governance models regarding the ownership and operation of a MOG by making use of the design space as illustrated in section 5.3. Thus the alternatives of governance models are a combination of the introduced degrees of freedom and the responsible and involved actors through the various stages (planning, construction, operation) of an offshore transmission projects in general and a MOG in particular.

Section 5.3 additionally explained the rationale behind the designed alternatives: alternative 1, 2 and 4 being extensions of currently applied governance models for radial offshore transmission assets and alternative 3 being a combination within the design space that could potentially achieve benefits compared to the other governance models, as will be explained in detail. Subsequently, this chapter will elaborate on the specifics and characteristics of the designed governance models.

6.1 Alternative 1 (OWF developer-led OFTO model)

The first alternative is an extension of the UK developer-led OFTO model, which is described in the case study. This model is characterized by the early involvement of the OWF-developer(s) regarding the planning and construction of the transmission assets, a so-called developer led approach in which the OWF developer(s) are made responsible for overall responsibilities that are inherent with transmission expansion planning, such as the timing, the capacity, the location and the overall design of the transmission assets. Within this alternative it is assumed that OWF developers continue to have the right to require a connection on the onshore grid, which is currently an obligation of the onshore TSO.

More specifically, the OWF developer(s) are responsible for not only planning the grid connection; they are additionally responsible for the planning of the interconnection assets, which combined form into a MOG.

Moreover, the OWF developers are made responsible for the construction phase of the offshore transmission system. Therefore, in order for a MOG to be constructed, strong coordination and agreement is necessary between the various OWF developers, who will be using the transmission assets to evacuate their offshore wind energy to the onshore load centres. Moreover, the OWF developers will need to finance the transmission assets, including the specific interconnection assets. These costs are therefore to be included and shared among the subsidy tariffs of the participating OWF developers, necessitating additional incentives for OWF developers to build transmission assets which do not directly benefit their own business case.

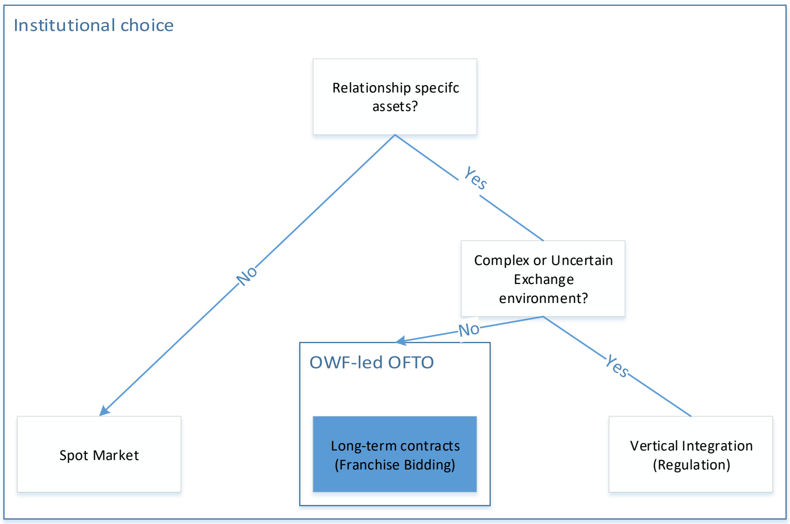


Figure 39: Institutional choice in Alternative1

When the transmission assets are constructed and commissioned, the offshore transmission assets will be carved out from the offshore windfarm, thereby creating separable transmission assets which can be put up for tender using the Franchise Bidding approach (figure 39). In order to have a level playing field for potential Transmission Owners and thus creating effective competition for the market, the potential OFTOs are competing for a Tendered Revenue Stream (TRS). This TRS is identical to the UK-OFTO model setup and consists of a "fixed" revenue stream for a specific time horizon, depending on the lifetime of these assets. In return for the TRS, the OFTO will need to pay a Final Transfer Value (which is determined by the NRA) to the OWF developers and provide a predetermined level of availability of the transmission assets, this therefore constitutes as a FOOT PPP (figure 40). This alternative is thereby relying on private parties to come up with innovative financing solutions to optimize the cost of capital and additionally incentivizes the optimization of operating expenditures to increase the profits for the OFTO.

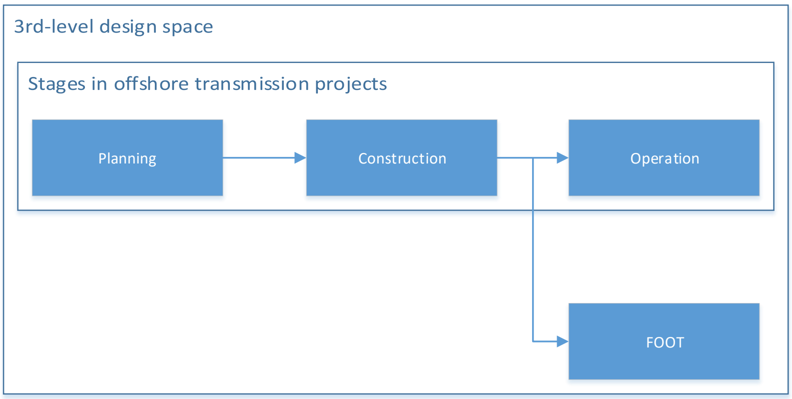


Figure 40: PPP choice in Alternative1

By this means, the OFTO is essentially agreeing upon a long-term contract with the NRA, in which the revenues are underwritten by the consumer and the OFTO is not dependent on the business case and revenue stream of the OWF developer. The underwriting of the investment by the consumers de-risks the business case of the OFTO, making the OFTO merely responsible for the maintenance and availability of the transmission assets, identical to the UK-OFTO regime. The responsibilities and rights of the OFTO are thus specified in a long-term contract, creating contractual rights. The detailed specifications of the rights and obligations must therefore be determined ex-ante, prior to the competitive tender taking place.

By using the Franchise Bidding approach, the NRA is relieved from the issue of determining the fundamental parameters which determine the cost level of a natural monopolist. However, the NRA still needs to determine the FTV of the transmission assets, the efficient capital expenditures, and thereby the NRA still has an important role to fulfil. Moreover, the NRA can decide whether to put the newly constructed and commissioned MOG up for tender as a whole, or split the MOG in separable transmission assets, which can be put up for tender separately. The institutional choice to enable competition for the market, taking place on the 1st-level design space, creates implications for the 2nd-level design space, which follows from the analysis in sub-section 5.3.2. This analysis showed that SO services need to be unbundled from TO services when a Franchise Bidding approach is used to allocate transmission ownership. This unbundling of activities creates a governance model in which SO and TO services are performed by different entities (figure 41).

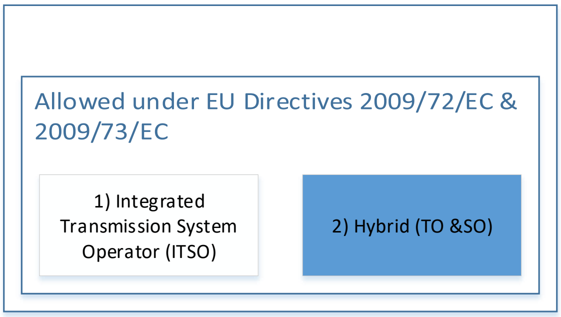


Figure 41: Unbundling choice in Alternative 1

Specifically to this alternative, TO services can be provided by one or more OFTOs, depending on the decision of the NRA to put the newly constructed transmission assets up for tender as whole or split them up into separable transmission systems. SO services are consequently performed by the connected onshore TSOs or ISOs. Because of this, the operating expenditures for the OFTO are mostly related to organizing the ownership services and maintenance activities and the SO services are therefore not included in the operating expenditures allocated to the OFTO.

Coordination between TO service providers and SO service providers therefore need to be made explicit in contracts and agreements between these entities, similar to the STC arrangements which are currently in place between OFTOs in the UK and National Grid (as described in sub-section 4.3.3).

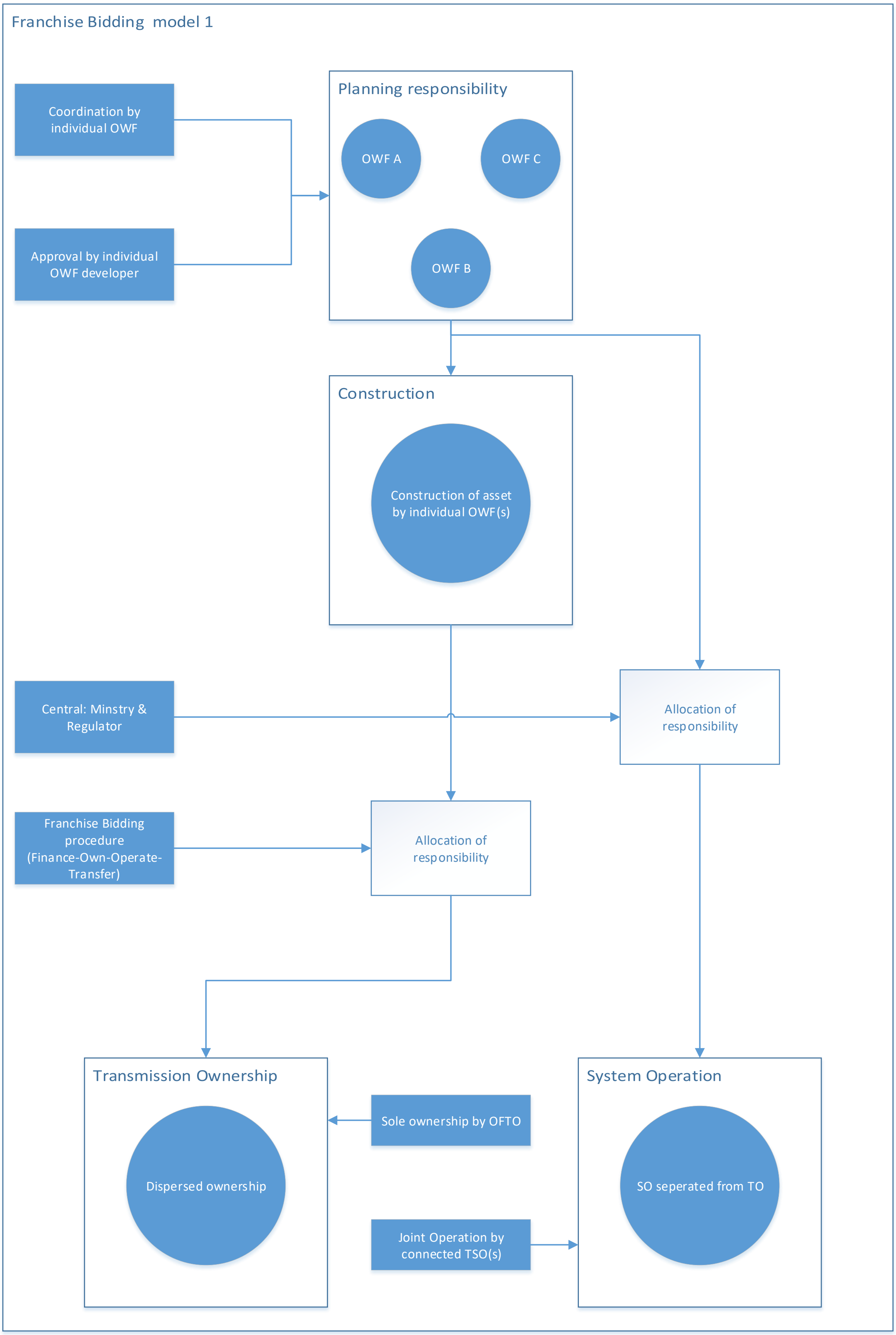


Figure 42: Overview of Alternative 1

6.2 Alternative 2 (full OFTO model)

The second alternative is based on the arrangements which are in place to facilitate an OFTO-build model in the UK for the creation of offshore transmission assets. Within these arrangements, potential OFTOs are allowed by the OWF developer to compete for a TRS to build-own-operate-transfer the transmission assets to connect OWFs to the onshore grid. Moreover, within the UK, this model is also currently in the process of being applied on onshore transmission assets through the Competitively Appointed Transmission Owners (CATO) and thereby enabling onshore competition for the market for electricity transmission systems.

The institutional choice within this alternative is to use Franchise Bidding and therefore relies on a long-term contract to specify obligations, responsibilities and rights (figure 43). This alternative is driven by the argument that PPP can bring additional value for money, compared to the other alternatives, when the PPP is responsible for construction. By making the PPP responsible for the construction phase as well, the PPP is incentivized (through competition and possible profits) to come up with innovative solutions that can potentially decrease capital expenditures and thereby creating additional value for money for the procuring authority and thereby the ones paying for the transmission assets.

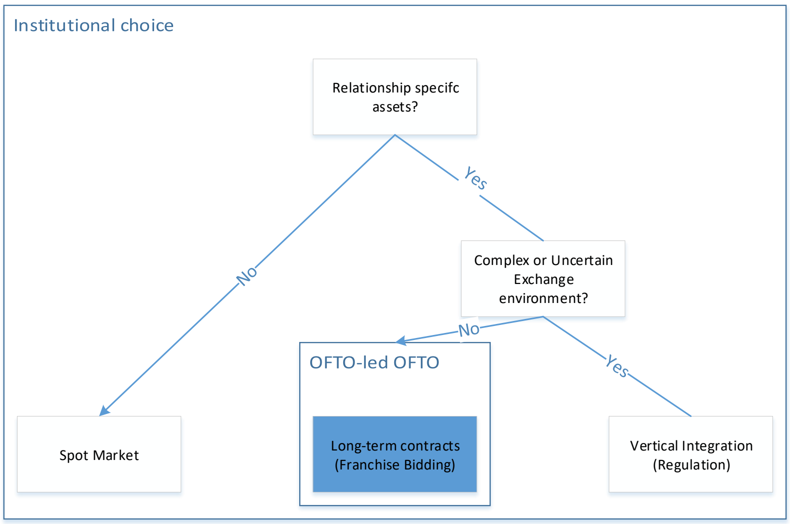


Figure 43: Institutional choice in Alternative 2

Within this alternative, the onshore TSOs or ISOs are planning the transmission assets and are thereby responsible for the capacity, the location, the timing and the high-over design of the transmission assets that will form into a MOG, thus consisting of both grid connection assets and interconnection assets. Using this approach by making the onshore TSOs and ISOs responsible for the planning of the transmission assets, implicates that the location, timing, size and grid connection of the OWF is decided upon centrally. Moreover, as the constructed assets will be underwritten by consumers, both NRAs and national Ministries will be involved in the decision making process by scrutinizing the investment plans of TSOs and ISOs. In doing so, these institutions will look to safeguard the interest of the consumers who will be paying for these transmission assets through their electricity bills.

Before the planned transmission assets are constructed, the NRA uses the investment plans as input for a competitive tender which allocates responsibility of the construction and operating stage of the transmission asset through a Franchise Bidding approach. Comparable to alternative 1, the NRA can decide to split up separable transmission assets, thereby enabling several transmission systems to be tendered.

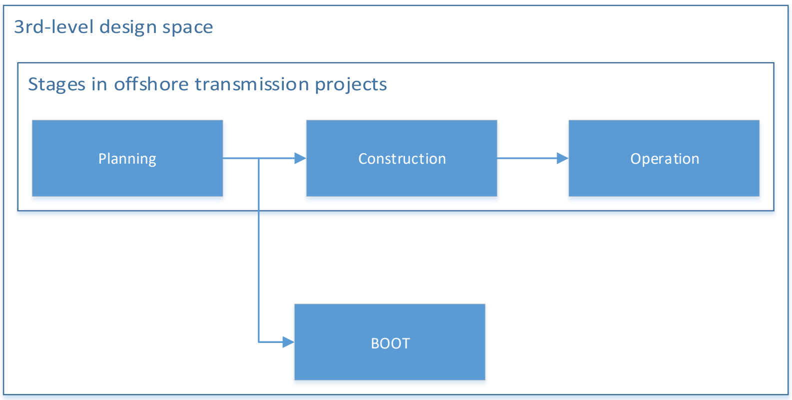


Figure 44: PPP choice in Alternative 2

Potential OFTOs will consequently compete for a TRS, identical with Alternative 1, however, the TRS will additionally need to cover the construction risk as the OFTO is responsible for the construction of the transmission assets. Alternative 2 can therefore be regarded as a BOOT PPP structure, in which the private party is responsible for building, owning, operating the transmission assets (figure 44). Depending on the TRS time horizon, which is related to the lifetime of the assets and the demand for these assets, the assets are transferred to the applicable NRA(s). An important aspect is that the obligations, responsibilities and contractual rights are therefore to be specified in long-term contracts, of which the details need to be specified ex-ante, prior to the competitive tender.

Identical to alternative 1, the institutional choice to use Franchise Bidding as a mechanism to allocate ownership responsibilities of the offshore transmission assets, implicates that TO and SO services are to be unbundled from one another.

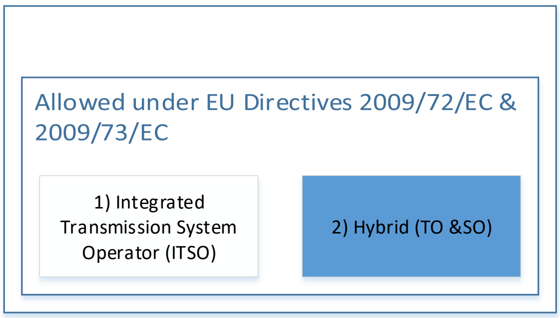


Figure 45: Unbundling choice in Alternative 2

By unbundling these transmission services, the responsibility for SO services is allocated at the onshore TSOs or ISOs. TO services are subsequently allocated at the OFTO(s) (figure 45).

Identical to alternative 1, the coordination between TO service providers and SO service providers therefore need to be made explicit in contracts and agreements between these entities, similar to the STC arrangements which are currently in place between OFTOs in the UK and National Grid (as described in sub-section 4.3.3).

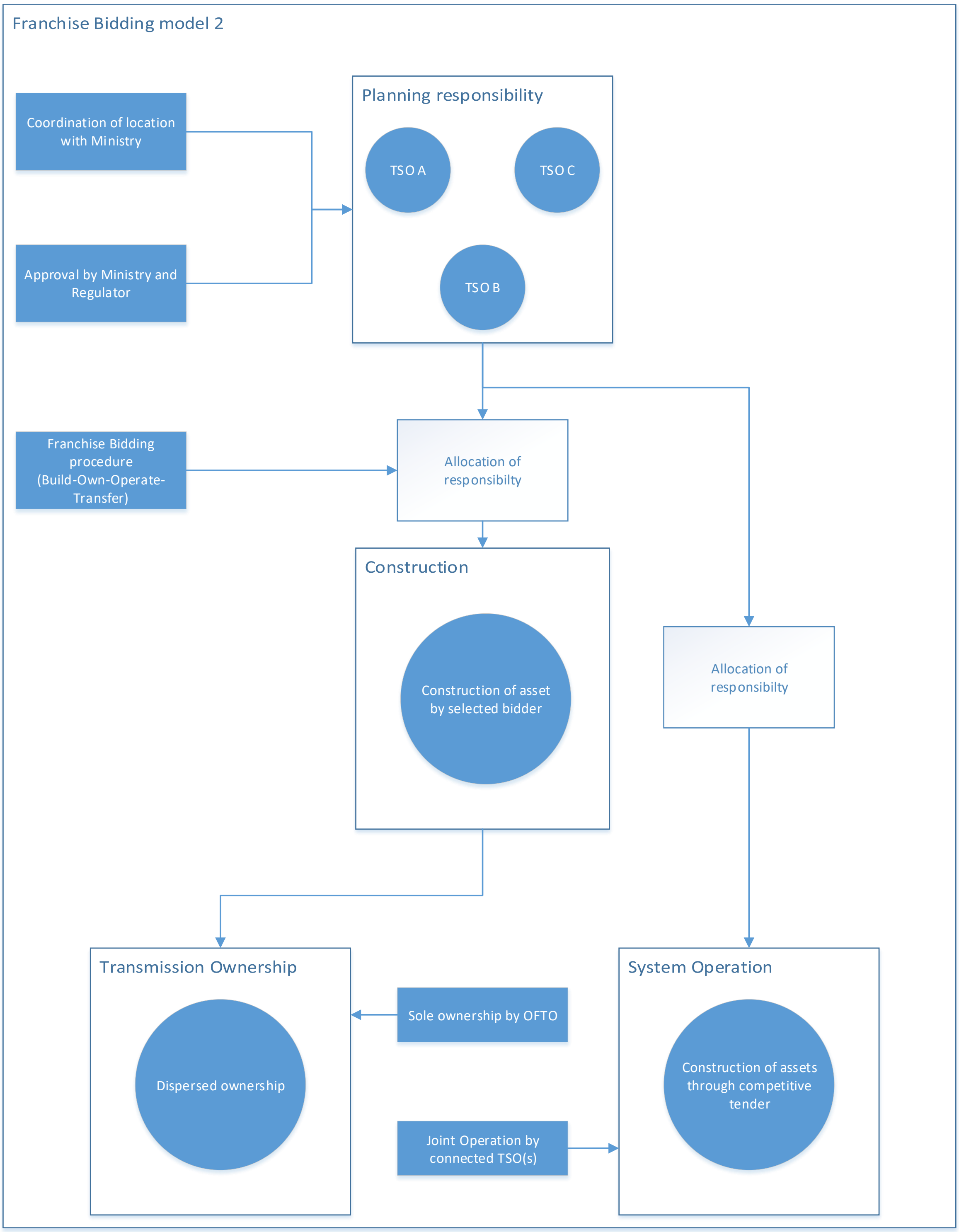


Figure 46: Overview of Alternative 2

6.3 Alternative 3 (TSO-model)

The third alternative is an extension of the current TSO-model, which is a widely used governance model in the EU to plan, coordinate, construct and operate offshore transmission assets. Within the TSO-model the relevant onshore TSOs or ISOs are responsible for planning the offshore transmission assets and are therefore responsible for the timing, location, capacity and the high-over design of the transmission assets.

In essence, this model can be seen as a joint-venture between the TSOs who will be connected through the hybrid transmission assets. In theory, the hybrid assets can therefore be connecting all of the North Sea surrounding countries.

Moreover, to coordinate with OWF developments, national ministries are involved in the decision-making and together with the NRAs are ultimately approving the investment plans which are initiated by TSOs and ISOs. Because of this, the relevant NRAs and ministries will try to scrutinize these investment plans in order to safeguard consumers interest who will underwrite these investment plans.

Within the third alternative, the institutional choice (figure 47) is to vertically integrate the services and this alternative will therefore primarily rely on incentive regulation as a driving force to incentivize the natural monopolist to be efficient. The NRAs will therefore be responsible for estimating financial parameters, operating expenditures and simulating a competitive environment to safeguard consumer interests. As explained in detail in section 4.1.2, incentive regulation is the most effective form of regulation and therefore this alternative will be built upon these findings, thereby using incentive regulation to simulate a competitive environment which is similar to the Dutch case study.

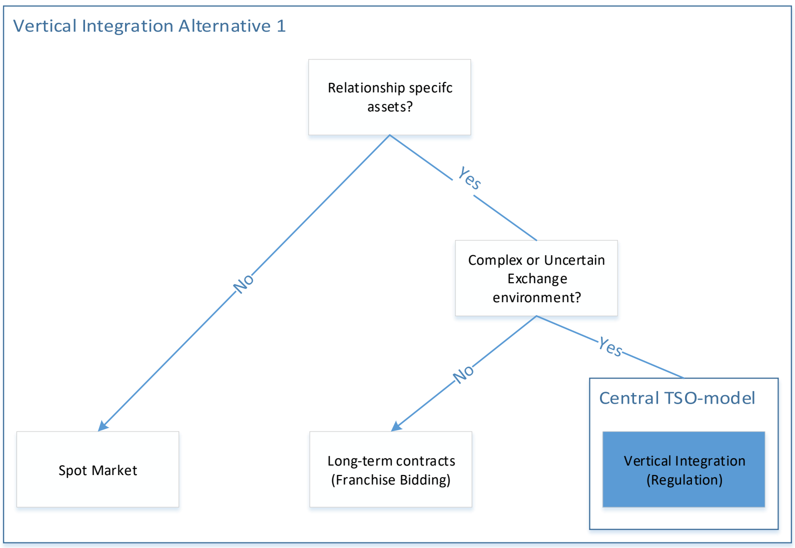


Figure 47: Institutional choice Alternative 3

When the investment plans are approved by the relevant NRAs and national ministries, responsibility for the construction of the offshore transmission assets is centrally allocated at the onshore TSOs. In order to limit the possibilities of inefficient investments (capital expenditures) and thus safeguard consumer interests, procurement of individual components of transmission assets (offshore substations, cables, high-voltage equipment) should be performed through competitive tendering of the components. This procurement method is considered the standard method of procurement of current TSOs in the EU.

Ultimately, the revenue stream for the TSOs will include the revenues related to the capital expenditures and operating expenditures incurred through the construction and operation of the offshore transmission assets. Consequently, NRAs will use a Regulatory Asset Base (RAB) method, as explained in section 4.1.2 to determine the allowed revenues for the TSOs and will therefore determine efficient capital expenditures ex-post. Furthermore, as explained in section 4.1.2, the NRAs are responsible for estimating the necessary financial and operating parameters.

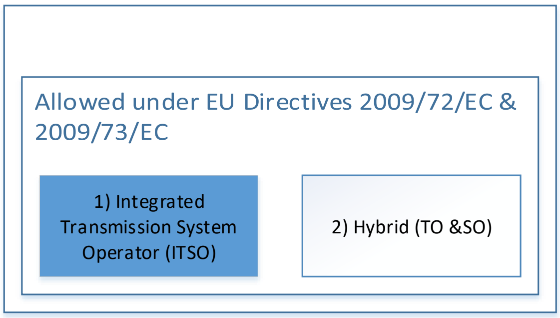


Figure 48: Unbundling choice Alternative 3

The third alternative is characterized by the institutional choice of vertical integration and therefore the possibility remains to integrate both SO and TO services (figure 48). The central TSO model is therefore applying this Integrated Transmission System Operator model. It is however important to note that the onshore TSOs (or ISOs) will be responsible for operating specific transmission assets and its connected OWFs, as it is unfitting to have two entities operating the same transmission assets.

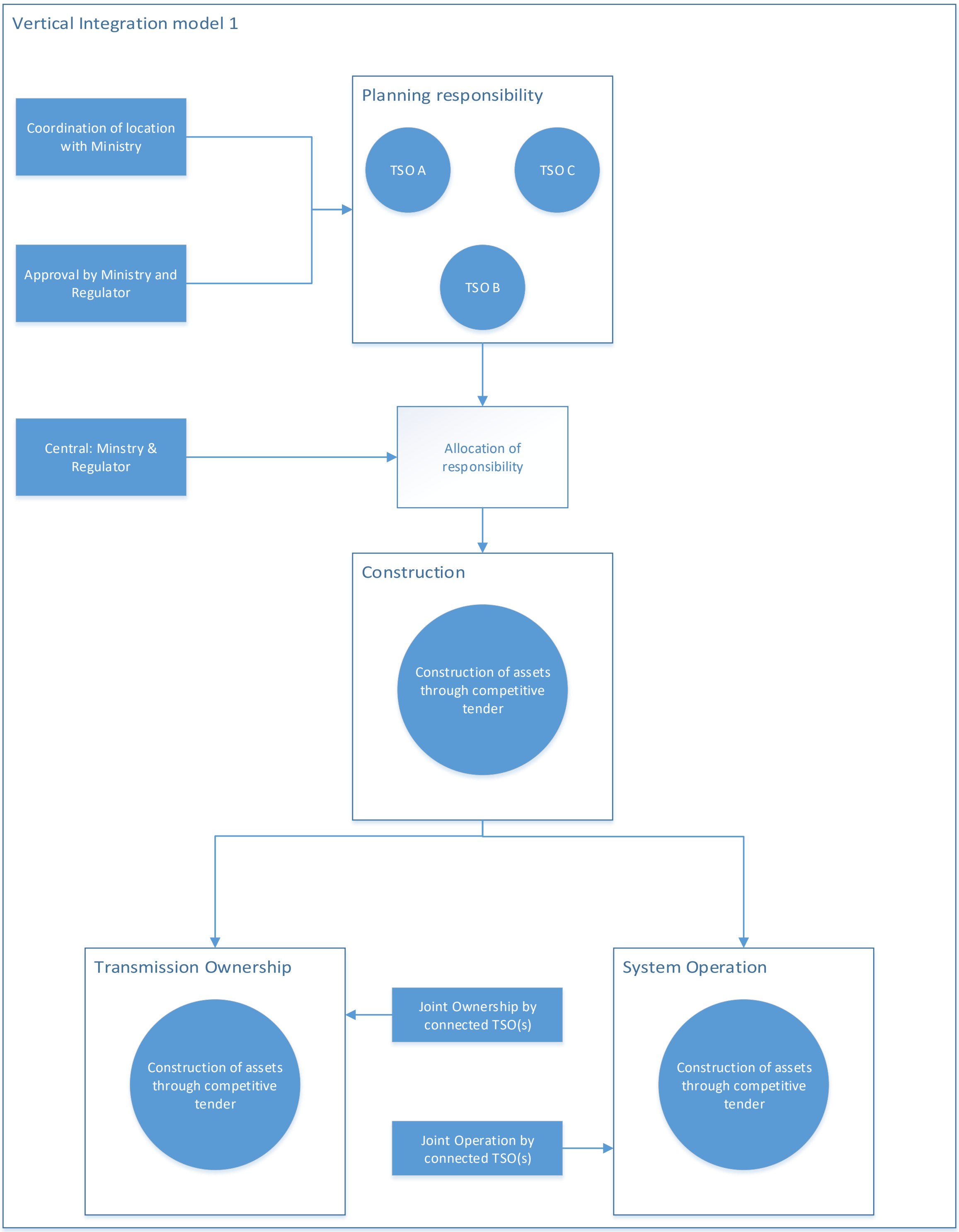


Figure 49: Overview of Alternative 3

6.4 Alternative 4 (TSO-led OFTO model)

The fourth and final alternative is a TSO-led OFTO model which is a newly designed concept of governing offshore transmission assets and is essentially a hybrid version of the central TSO model (Alternative 3) and the developer led OFTO-model (Alternative 1). This model is conceptually designed through the created design space of section 5.3. The institutional choice within this model is franchise-bidding, thereby creating competition for the market in the allocation of ownership responsibility (figure 50).

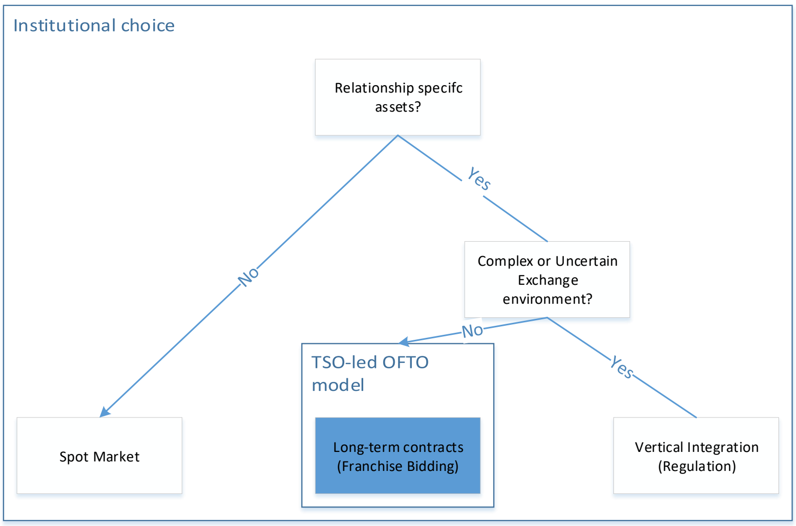


Figure 50: Institutional choice Alternative 4

Within the TSO-led OFTO model, the involved onshore TSOs or ISOs are jointly responsible for planning the transmission assets, thus deciding on the capacity, location, timing and high-over design of the transmission assets. In order for the plans to correspond to the development of the OWFs, considering the timing, capacity and location, the national ministries are involved in the coordination of these aspects. Moreover, the final approval of the investment plans is the responsibility of the national ministries and regulators; thereby the responsibility of scrutinizing the investment plans is allocated at these institutions accordingly.

When the investment plans are approved, the onshore TSOs or ISOs are subsequently jointly responsible for the construction of the transmission assets that will form the initial infrastructure of a MOG. However, when construction is finalized and the transmission assets are commissioned, the newly constructed transmission assets will be carved out, thereby creating separable assets which can successively be put up for tender. To ensure that capital expenditures are made efficiently, individual components of transmission assets (cables, substation, High-Voltage equipment) need to be procured through competitive tendering of these assets, which is compliant with the current procurement standards of these assets for TSOs in the EU.

This process is similar to the current UK OFTO-model with one significant difference however, as the initial construction responsibility was allocated with the onshore TSOs or ISOs and thus not with the OWF developers. Potential OFTOs are, similar to the UK OFTO-model, competing for a "fixed" TRS for a specific time and are incentivized to maintain a certain level of availability through incentives and penalties. Obligations, responsibilities and contractual rights are therefore to be specified in long-term contracts, of which the details need to be specified ex-ante, prior to the competitive tender.

By designing this governance model in such a way, a FOOT PPP structure is created (figure 51) enabling institutional investors to privately finance the infrastructure. This model is therefore relying on private parties to create innovative financing solutions and operating strategies than optimizes the cost of capital and operating expenditures, thereby potentially creating value for money for consumers. In creating competition for the market of commissioned transmission assets, NRAs are additionally relieved of the pressure to estimate financial parameters and operating expenditures to simulate a competitive environment and estimate cost levels of the natural monopoly.

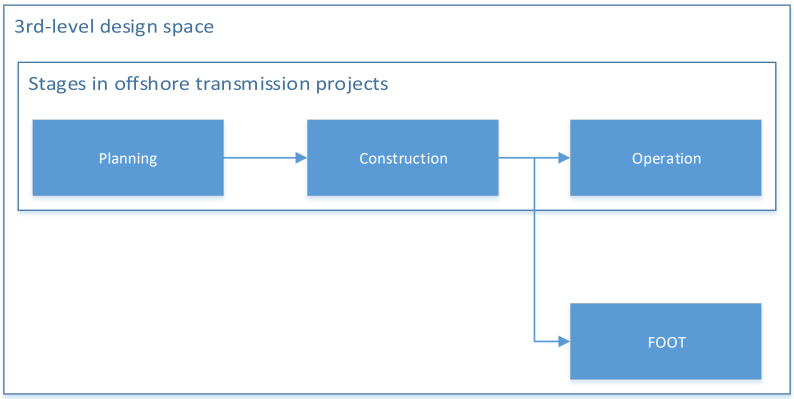


Figure 51: PPP choice in Alternative 4

While the NRAs are relieved of the regulator pressure to estimate certain parameters, the still need to determine efficient costs by determining the Final Transfer Value, or efficient capital expenditures, of the transmission assets which need to be paid by the winning OFTO bidder to the onshore TSOs. Furthermore, similar to alternative 1, the NRA can decide on putting the newly constructed transmission assets up for tender separately, thereby creating multiple separable transmission assets with multiple OFTOs. Contrastingly, the NRA can also decide to put the transmission assets up for tender jointly, the newly constructed transmission assets will therefore have one OFTO.

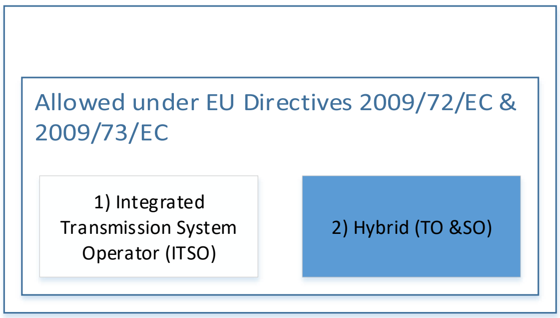


Figure 52: Unbundling choice Alternative 4

Similar to alternative 1 and 2, the institutional choice to use Franchise Bidding to allocate ownership responsibility for the transmission assets, implicates that the TO and SO services are to be unbundled, as analysed in section 5.3.2. Specifically for this alternative, the SO services are thus allocated at the onshore connected TSOs or ISOs creating a hybrid operator model (figure 52). Coordination between TO service providers and SO service providers therefore needs to be made explicit in contracts and agreements between these entities.

Identical to alternative 1 and 2, coordination between TO service providers and SO service providers therefore need to be made explicit in contracts and agreements between these entities, similar to the STC arrangements which are currently in place between OFTOs in the UK and National Grid (as described in section 4.3.3).

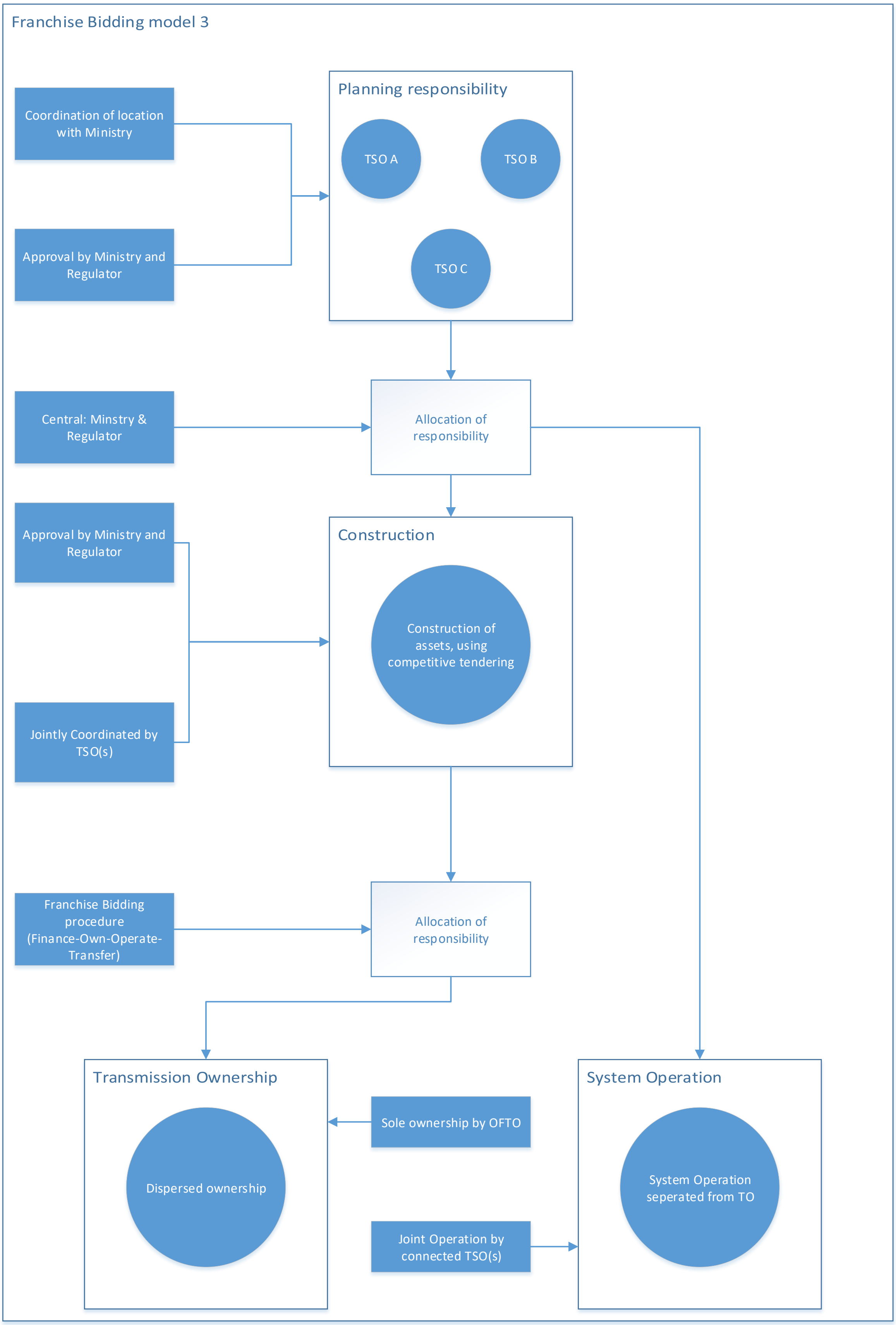


Figure 53: Overview of Alternative 4

7 Analysis and assessment of designed governance models

The previous chapter has provided four detailed descriptions of alternative governance models that can be applied for a MOG. Section 5.4 provided the expected performance of design variables and institutional choices which need to be addressed in a governance model for a MOG, which is derived from the literature and case studies as provided in chapter 4. Furthermore, section 5.1 provided the objectives of a governance model for a MOG.

This chapter will subsequently analyse and assess the alternative governance models of chapter 5 through the expectations for the performance and the objectives of chapter 5. While describing the performance in the forthcoming alternatives, there is significant overlap within the different alternatives because of identical design choices. When describing the different alternatives, reference to the alternative will be made which has an overlapping expected performance.

7.1 Alternative 1 (developer-led OFTO model)

Provided the description of alternative 1 in chapter 6, alternative 1 is characterized by having a high level of self-organization of the OWF developers that should result into the construction of hybrid transmission assets.

7.1.1 Efficient investment planning

In general we can assess the investment planning to be inefficient in a developer-led OFTO model, as it will become increasingly difficult to come up with efficient investment solutions when different OWF developers need to coordinate and collaborate to plan and construct hybrid transmission assets. While these coordination and collaboration issues in theory can be addressed through the setup of incentives within subsidy properties, in practice the alignment of these incentives across EU MS will be a very complex exercise due to the amount of stakeholders when the alignment of OWF developer incentives are included.

Apart from the coordination and collaboration issues, which are specific issues in alternative 1 for the planning and construction of a MOG, this alternative has several other properties related to the specific design choices and thereby impacting the performance on the objective of a governance model to enable the evolution into a larger offshore grid. Looking at the design choice to have a FOOT PPP structure, and thereby using a Franchise Bidding approach, ex-ante specification of the contract is necessary to provide a level-playing field when potential OFTOs want to compete for the ownership of the constructed transmission assets. To enable the future evolution into a larger offshore grid, policy makers have two options when determining the specification of the long-term contract of a PPP. The first option is that policymakers can opt to include flexibility into the PPP contract, this flexibility would entail that OFTOs need to facilitate the connection of other OFTOs to their transmission assets, which could potentially lead to additional risks for the OFTO, as it is possible that the performance of their assets might be affected through this connection. To include this flexibility, will therefore likely increase the risk perception of the assets prior to the competitive tender, thereby increasing the required cost of capital of the bidders in the tender.

The second option for policymakers is to incur future transaction costs when PPP contracts need to be broken up to accommodate the evolution of the initial transmission assets into a larger offshore grid. By not including flexibility in the PPP contract, OFTOs will enforce their contractual rights when these rights need to adapted, thus requiring compensation for their loss incurred by the adaption of the initial contract rights. This could potentially hamper the evolution of a larger MOG through the additional transaction costs.

Moreover, as OWF developers are able to require a connection with the onshore grid, it is possible that a sub-optimal connection is realized, as grid reinforcements are out of the initial scope of the OWF developers. As such, taking a total system perspective, inefficiencies in the onshore grid connection, from an economical perspective, are to be expected.

7.1.2 Competitive allowed revenues for delivering transmission grid services

Associated with the institutional choice to apply a Franchise Bidding approach, the NRA is relieved from the regulator burden to determine the cost of capital and operating costs. Hence the issue of information asymmetry between the NRA and the regulated firm is removed through the application of competitive forces inherent with the Franchise Bidding approach. Because of the fact that the offshore transmission assets are built before they are being put up for tender, it is conceivable that efficient competition can take place as evidenced by the case study of the UK OFTO-model. Still, the NRAs are responsible for determining the FTV of the constructed assets, thereby applying the mandatory provision derived from the case study. Because of this, the NRA is not relieved from the task to determine the efficiency of capital expenditures.

However, as the offshore transmission assets are included in the scope of the OWF developer, the transaction costs associated with the inclusion of these assets into the scope of the OWF developer will thereby probably require a higher subsidy premium. This argument is substantiated by the current subsidy levels required by the OWFs in the UK, as these subsidies include the offshore transmission system scope. Including the offshore transmission system scope with hybrid assets will possibly require a higher subsidy premium, provided the additional risks in a MOG on top of the construction and commissioning risk of offshore transmission assets.

While the previously mentioned characteristic is not promoting this alternative, there is one significant benefit when applying alternative 1: a partial allocation of resources through the market. As the investment planning and construction of the offshore transmission assets is the responsibility of the OWF developer, the risk of stranded assets, and thereby an inefficient allocation of resources, is significantly decreased as the OWF developer will only build these assets according to its own demand for these assets.

Another important element, which relates to the unbundling of TO and SO services, is the fact that it becomes more difficult to incentivize a SO (as it has no assets and therefore has limited revenues) to reduce operating expenditures associated with system balancing activities such as congestion management.

7.1.3 Operating Efficiency

The objective to facilitate the operating efficiency is related to the institutional choice and thereby the degree of unbundling related to the SO and TO functions. Through section 5.3 the implication of the institutional choice was made explicit, as the SO and TO function are to be unbundled when a Franchise Bidding approach is used to determine the allocation of ownership responsibilities. Thereby, this alternative is moving away from the theoretical optimum: an ITSO. Additional contracts to safeguard efficient operation are therefore to be constructed to optimize the short term economic efficiency of the system, through efficient congestion management and coordinated maintenance planning.

This alternative is thereby implicating a loss of potential synergies between SO and TO functions, while additionally incurring transaction cost associated with the necessary contracts to safeguard the security of supply.

7.1.4 Financial viability of investments

Another benefit of the developer-led OFTO model is the financial viability of the investments, as the assets are completely financed by private parties and a competitive market will determine the required revenues to make the financing of these assets possible.

7.2 Alternative 2 (full OFTO model)

The full OFTO model is characterized by the amount of responsibilities allocated at a private party (OFTO) through a PPP structure. As the OFTO is not only responsible for financing the offshore transmission assets, the OFTO is additionally made responsible for the construction of the offshore transmission assets.

7.2.1 Efficient investment planning

As explained in section 6.2, the investment planning responsibility is allocated with the TSOs and coordinated and approved by the relevant national ministries. Because of the design choice to centrally allocated resources and investments for the offshore transmission assets, the risk for stranded assets is increased as the development of the offshore transmission assets can only partly be integrated with the development of the OWFs. Moreover, by including NRAs and ministries in the investment plans, it is possible to scrutinize investment plans initiated by the TSOs. Moreover, financial incentives should be designed to incentivize OWFs developers to build the OWFs and safeguarding the demand for the offshore transmission assets.

In general, onshore grid connection can be considered efficient as TSOs are responsible for planning the capacity, location, timing and overall design. As the TSOs are also responsible for the development of the onshore grid, this alternative uses a total system perspective to calculate the costs for connecting the offshore transmission assets.

Considering the ability of initial offshore transmission assets to facilitate an evolutionary development into a larger offshore grid, the characteristics and performances are similar to alternative 1. Alternative 2 similarly necessitates the specification of the contracted service prior to the competitive tender to appoint the private party. Thereby the PPP long-term contract specifications must be constructed ex-ante. Enabling the flexibility to evolve in a larger offshore grid will therefore require either to include this flexibility in the initial contract, thus increasing the required revenue stream, or incur future transaction costs and thereby potentially hampering the evolution of the initial transmission assets into a larger offshore grid.

7.2.2 Competitive allowed revenues for delivering transmission grid services

Specifically for this alternative, the NRAs are relieved from the regulatory burden to estimate parameters regarding the cost of capital and operating expenditures, similar to alternative 1. However, as the competitively appointed OFTO is also responsible for constructing the offshore transmission assets, the NRAs are additionally relieved from the burden to determine the efficiency of the investment costs. However, still no evidence is present whether a BOOT PPP structure would provide additional benefits, contrary to alternative 1 in which a FOOT PPP structure is used. By including the construction risk within the business case of the OFTO and its required revenues stream, it is conceivable that the cost of capital will increase when comparing these with the cost of capital in a FOOT PPP structure.

By allocating the responsibility for the planning responsibility with the TSOs, NRAs and national ministries and the construction of the offshore transmission assets with a competitively appointed OFTO, the OWF developer is relieved from the transaction costs associated with the development of the offshore transmission assets, as described in section 3.3. By relieving the OWF developer from these transaction costs prior to its subsidy level bid, the OWF developer is able to bid more competitively as there is a greater level playing field.

Similar to alternative 1, the SO and TO services are unbundled, which therefore complicates incentive mechanisms for SO services to optimize their expenditures, which are related to efficient maintenance planning and congestion management.

7.2.3 Operating Efficiency

These are identical to Alternative 1, as the institutional choice to franchise bid implicates the necessity of unbundling TO and SO activities.

7.2.4 Financial viability of investments

Identical with Alternative 1, the benefit of the OFTO-led OFTO model is the financial viability of the investments. Accordingly, the investments are completely financed by private parties in which the required revenues to make it financially attractive is determined through competitive forces inherent with a Franchise Bidding approach.

7.3 Alternative 3 (TSO model)

The TSO model is characterized by the central allocation of responsibilities, as the TSOs are jointly responsible for the investment planning, construction and operation of the offshore transmission assets.

7.3.1 Efficient investment planning

Within alternative 3, the investment planning responsibility is allocated with the applicable TSOs with the NRAs and ministries coordinating and approving the final investment plans, making them responsible for scrutinizing the investments. By allocating this responsibility with these entities, and not with the OWF developer, the risk of stranded assets is increased, similar to alternative 2. A joint responsibility is therefore allocated with the TSOs, NRAs and national ministries to limit this stranded asset risk, through the design of incentives which drive the OWFs to construct the OWFs and thus decrease the stranded asset risk.

In general the TSO-model is enabling efficient onshore grid connection, as the TSOs can apply a total system perspective when optimizing the overall costs when connecting the offshore transmission assets to the onshore grid.

Moreover, the third alternative is best situated when the expected performance to evolve in a larger grid is assessed. The TSO-model is not relying on Franchise Bidding to allocate the responsibility for the ownership and operation of offshore transmission assets; thereby this governance model is not relying upon long-term contracts to specify contractual rights and obligations. Instead, vertical integration is relying upon regulation which enables the adaptation of the regulatory framework periodically. Because of this, the evolution of initial offshore transmission assets into a larger offshore grid can be facilitated without incurring transaction costs.

7.3.2 Competitive allowed revenues for delivering transmission grid services

Regarding the regulatory burden, the TSO-model is a governance model which relies on incentive regulation by the NRA. Through this institutional choice, the NRAs are responsible for simulating a competitive market and thus estimating parameters such as the cost of capital and operating expenditures. Provided the quantitative comparison of the two case-studies in section 4.3, it is to be expected that NRAs are able to simulate a competitive market, which safeguards consumers that competitive allowed revenues are determined for delivering transmission grid services. The case studies have shown that NRAs is able to estimate parameters comparable to competitive environment.

Similar to alternative 2, the allocation of investment planning and construction responsibility with the TSOs enables more competitive bids as the removal of transaction costs for the OWF creates a greater level playing field. This can possibly facilitate lower required subsidy levels for the OWFs.

Regarding the competitive allowed revenues for SO services, the TSO model enables strong incentives for the SO to optimize its expenditures, given the fact that TO and SO services are integrated.

7.3.3 Operating efficiency

As explained in the description of alternative 3, the operating model is an ITSO and thereby the TO and SO services are integrated which is considered the theoretical optimum. Synergies regarding the planning and operation of the offshore transmission assets can be achieved, which enables efficient coordination regarding maintenance planning and congestion management.

7.3.4 Financial viability of investments

A potential downside of the TSO is the fact that the financial viability of the investment plans is depending on the owner of the TSOs. Contrastingly with the Franchise Bidding approach, the financial viability is depending on the available equity within the TSOs. Especially given the huge amount of investments which are necessary to accommodate future offshore wind developments, this can potentially be a problem as it depends on the owner's willingness to provide equity injections or raise equity through other sources.

7.4 Alternative 4 (TSO-led OFTO model)

Alternative 4 (TSO-led OFTO model) is characterized by having a hybrid approach, as it combines both central decision making and Franchise Bidding. Therefore, this model is essentially a combination of alternative 1 and 3, the description of this alternative will subsequently include an identical description of certain elements of the alternative.

7.4.1 Efficient investment planning

Within alternative 4, the investment planning responsibility is allocated with the applicable TSOs with the NRAs and ministries are coordinating and approving the final investment plans, making them responsible for scrutinizing the investments. By allocating this responsibility with these entities, and not with the OWF developer, the risk of stranded assets is increased, similar to alternative 2. A joint responsibility is therefore allocated with the TSOs, NRAs and national ministries to limit this stranded asset risk, through the design of incentives which drive the OWFs to construct the OWFs and thus decrease the stranded asset risk.

In general the TSO-model is enabling efficient onshore grid connection, as the TSOs can apply a total system perspective when optimizing the overall costs when connecting the offshore transmission assets to the onshore grid.

Similar to alternative 2, looking at the design choice to have a FOOT PPP structure, and thereby using a Franchise Bidding approach, ex-ante specification of the contract is necessary to provide a level-playing field when potential OFTOs want to compete for the ownership of the constructed transmission assets. To enable the future evolution into a larger offshore grid, policy makers have two options as for the specification of the long-term contract that a PPP requires.

The first option is that policymakers can opt to include flexibility into the PPP contract, this flexibility would entail that OFTOs need to facilitate the connection of other OFTOs to their transmission assets, which could potentially lead to additional risks for the OFTO, as it is possible that the performance of their assets might be affected through this connection. To include this flexibility, will therefore likely increase the risk perception of the assets prior to the competitive tender, thereby increasing the required cost of capital of the bidders in the tender.

The second option for policymakers is to incur future transaction costs when PPP contracts need to be broken up to accommodate the evolution of the initial transmission assets into a larger offshore grid. By not including flexibility in the PPP contract, OFTOs will enforce their contractual rights when these rights need to adapted, thus requiring compensation for their loss incurred by the adaption of the initial contract rights. This could potentially hamper the evolution of a larger MOG through the additional transaction costs.

7.4.2 Competitive allowed revenues for delivering transmission grid services

Associated with the institutional choice to apply a Franchise Bidding approach, the NRA is relieved from the regulator burden to determine the cost of capital and operating costs. Hence the issue of information asymmetry between the NRA and the regulated firm is removed through the application of competitive forces inherent with the Franchise Bidding approach. Because of the fact that the offshore transmission assets are built before they are being put up for tender, it is conceivable that efficient competition can take place as evidenced by the case study of the UK OFTO-model.

Still the NRAs are responsible for determining the FTV of the constructed assets, thereby applying the mandatory provision derived from the case study. Because of this, the NRA is not relieved from the task to determine the efficiency of capital expenditures.

By allocating the responsibility for the planning responsibility with the TSOs, NRAs and national ministries and the construction of the offshore transmission assets with a competitively appointed OFTO, the OWF developer is relieved from the transaction costs associated with the development of the offshore transmission assets, as described in section 3.3. By relieving the OWF developer from these transaction costs prior to its subsidy level bid, the OWF developer is able to bid more competitively as there is a greater level playing field.

Similar to alternative 1, the SO and TO services are unbundled, which therefore complicates incentive mechanisms for SO services to optimize their expenditures, which are related to efficient maintenance planning and congestion management.

7.4.3 Operating efficiency

These are identical to Alternative 1, as the institutional choice to franchise bid implicates the necessity of unbundling TO and SO activities.

7.4.4 Financial viability of investments

Within the TSO-led OFTO model the financial viability of the investments is higher compared with the TSO-model, as the TSOs are merely responsible for initially financing the offshore transmission assets. As described, when the offshore transmission assets are commissioned, the TSOs are remunerated their investments through the payment of the FTV by the OFTO. This characteristic relieves the TSOs from a significant part of the financing burden

There is however one downside regarding the financial viability, as the NRAs will ultimately determine the FTV based on efficient capital expenditures. When the efficient capital expenditures do not align with the financial investments of the TSOs, TSOs will probably be hesitant to take on this task. This would therefore need additional measures to cope with this issue, as for example additional involvement of the NRAs in the execution of investment plans.

8 Conclusion & Recommendations

This chapter will provide the conclusions and recommendations through answering the sub-questions and main research question that were described in chapter 2. Where applicable, the conclusions will refer to the appropriate section in which these conclusions were obtained. Moreover, section 8.2 will provide recommendations by looking at the implications of the conclusions.

8.1 Conclusions

The objective of this research is to contribute to the overall lacking knowledge regarding the content of a regulatory framework regarding governance models that allocate responsibilities of ownership and operation of a MOG. To obtain the aforementioned knowledge gap, the following main research question was constructed:

8.1.1 Main research question and answer

What should the governance model be, in terms of the allocation of responsibilities regarding the ownership of offshore assets and system operation, for a Meshed Offshore Grid to be deployed efficiently?

Based on several assumptions, as will be explained in the answers of the sub-questions, this research concludes that the TSO model (alternative 3) is the most appropriate governance model that can facilitate an efficient deployment of a MOG. While this research showed that there is no ideal governance model in practice, the TSO model can be considered the preferable alternative regarding the allocation of responsibilities and regarding offshore grid transmission assets that connect OWFs to the grid and interconnect electricity markets.

8.1.2 Sub-questions and answers

As explained in chapter 2, five sub-questions were constructed that contribute to answering the main research question. The answers to the following sub-questions will thereby provide the necessary context and assumptions on which the answer to the main research question relies.

1. *What are the main characteristics of a MOG?*

Provided the description of a MOG in chapter 3, the main characteristics of a MOG are the functional and economical aspects. Consequently, this research concluded that a MOG fulfils two separate functions: connecting OWFs to the onshore grid and interconnecting electricity markets. These two functions simultaneously enable a MOG to derive revenues through arbitrage and through additional (regulated) charges to remunerate the total costs to provide the transmission services.

2. *What theoretical concepts apply to the governance models for the ownership and operation of electricity transmission assets?*

Regarding the application of governance models for electricity transmission assets, this research has shown that it is possible to have three determinants of institutional choice (figure 54): 1) market, 2) long-term contract (Franchise Bidding) and 3) vertical integration (regulation). These institutional choices are related to the method of ownership allocations across economic agents and how ownership needs to be managed. While all of these institutional choices are possible in theory and practice, the characteristics of the industry ultimately decide which institutional choice is most appropriate. The framework of Crocker & Masten (1996), which identified the three institutional choices is therefore used to provide a reference framework throughout this research.

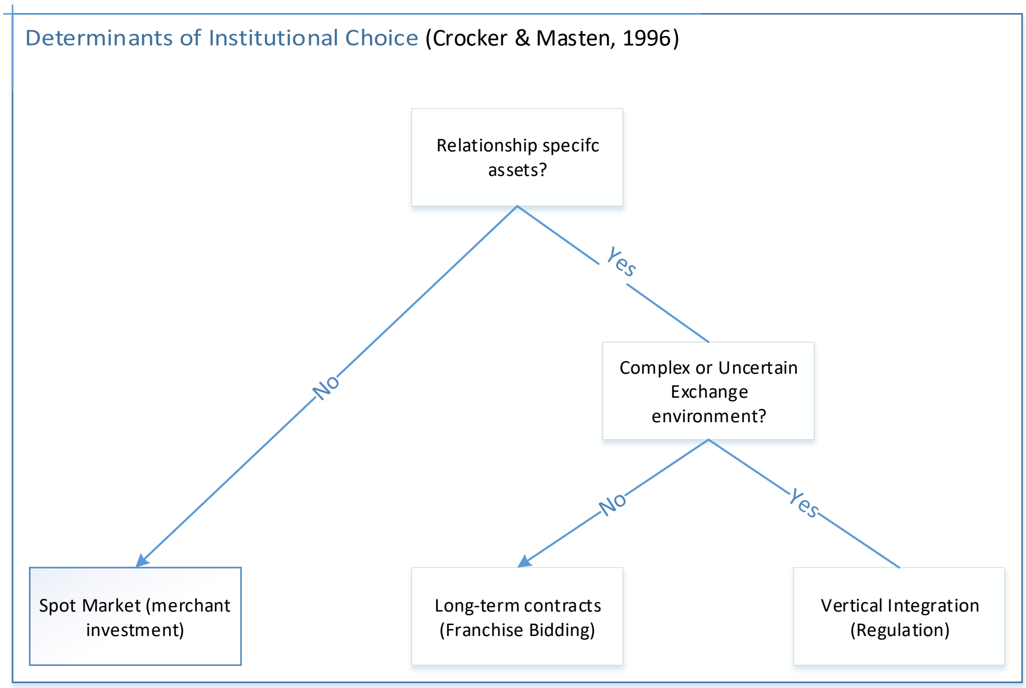


Figure 54: Institutional choices

Specifically for vertical integration, chapter 4 showed that several types of regulation can be applied on a natural monopoly, with incentive regulation being the most efficient according to the literature.

Regarding the operation of electricity transmission systems, with several models are distinguished in the literature (figure 55), as described in section 4.2. These operating models are varying through the degree of unbundling. With a vertically integrated utility (model 5) being the least unbundled operator model, as it integrates not only all electricity grid activities, it also integrates generation, distribution and supply. On the other hand, a fully unbundled operator model is a model in which also the system operating services and transmission services are unbundled (model 1).

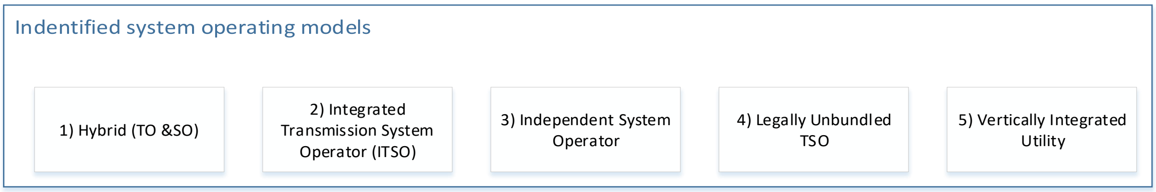


Figure 55: Unbundling option in electricity grid activities

Section 4.2 not only identified system operating models, it also provided the specific responsibilities that these different operating models include through the planning stage, the construction stage and the operating stage. This provided a valuable insight into which different entities should be involved at these specific stages.

3. *What is the current practice in governance models for radial OWF grid connections?*

While MOG solutions are not yet constructed and therefore cannot be reviewed through case studies, this research did provide case studies which analysed governance models applied on simpler offshore transmission assets: radial offshore grid connection system. Subsequently a quantitative comparative analysis between two distinctly different governance models was performed which determined the value for money for the consumers. The UK OFTO model and the Dutch TSO model were selected for these case studies, as these governance models have different institutional choices.

The main conclusion from this quantitative comparison is that the Dutch NRA is able to simulate a competitive market, regarding the financial and operating parameters of a TSO.

4. *Which alternative governance model can be designed to allocate ownership and operating responsibilities in a MOG?*

While the case studies provided valuable insights on the performance of governance models for radial offshore grid connection systems, a MOG is more complex and has certain implications on the possible MOG governance models. Provided the characteristic of a MOG, in which the interconnection function is combined with a grid connection of an OWF, the EU directives constrain certain operator models. Because of this, only a hybrid operator model (which unbundles TO & SO services) and an ITSO model (which integrates TO & SO services) are possible to apply on a MOG. In addition, section 5.2 provided valuable insight as to why the revenues should ultimately be underwritten by the consumers of electricity, as merchant transmission investments are not considered economically efficient in a MOG solution.

Through the synthesis of the analytical framework (chapter 5), a design space was constructed with three different levels, taking into account the implications of the characteristics of a MOG, as described in the previous paragraph.

The first level is the institutional choice, Franchise Bidding or vertical integration. The second level is the allocation of transmission system services and the degree of unbundling thereof (TO and SO) and the third level design space is the type of PPP structure, which can be either a Finance-Own-Operate-Transfer (FOOT) or a Build-Own-Operate-Transfer (BOOT).

Through the different design space levels, four distinct governance models were designed:

- The OWF develop-led OFTO model (Alternative 1)
- The full OFTO model (Alternative 2)
- The TSO model (Alternative 3)
- The TSO-led OFTO model (Alternative 4)

The combination of the different elements was selected through extending current governance models for radial offshore grid connection systems and combining elements that could potentially provide additional benefits.

5. *What is the most appropriate governance model for a MOG?*

Provided the variety of the effects which determine and influence the appropriateness for a MOG, a conclusive answer to this question cannot be given be given. Following the assessment of the different governance models through the objectives of a MOG governance model, it is evident that every specific governance model has its advantages and disadvantages.

However, the most important element that distinguishes the four governance models is the institutional choice on the allocation of ownership responsibilities. As this determines whether the relationship between the consumers (who underwrite the investment) and transmission service providers is formalized in a long-term contract or governed through regulation.

One of the main benefits of the Franchise Bidding approach is that competitive forces ultimately determine the appropriate revenues, thereby removing the information asymmetry between NRAs and the regulated firm. However, the case studies provided some examples that, while information asymmetry exists, a NRA can be able to simulate a competitive market effectively through a combination of incentive regulation methods.

By considering the previous two paragraphs, and looking at the future offshore wind developments in the North(ern) Sea(s), it is important that policy makers (one) chose a governance model that provides flexibility for future, more complex, MOG solutions. And (two) as offshore transmission system solutions become more complex, it is conceivable that efficient operation of the electricity system becomes more of an issue and the applied governance model should therefore entail as little communication and coordination problems as possible.

Provided the previous two policy choice considerations, combined with the findings from the case studies, the estimated benefits for a TSO model are probably more significant compared with the estimated benefits of the various Franchise Bidding approaches.

This does rely on one important assumption, that current owners of TSOs who will become joint owners of the offshore transmission assets are able to provide the necessary capital and thus provide sufficient equity to finance the investment plans.

8.2 Recommendations

Provided the conclusions in section 8.1, several policy recommendations are to be presented, while this research also provides remaining knowledge gaps which are to be addressed.

8.2.1 Policy recommendations

Within the different EU Member States surrounding the North(ern) Sea(s) views on the regulation or governance of a natural monopoly are dissimilar. Combining these dissimilar views with a lacking overarching regulatory framework subsequently provide a situation in which different EU Member States are able to construct different regulatory regimes regarding the development of offshore transmission systems which facilitate the interconnection of electricity markets and the grid connection of OWFs. The following policy recommendations are to be addressed:

1. Harmonize regulatory framework regarding ownership and operation of (hybrid) offshore transmission assets
2. Eliminate potential conflicts of interest at current TSOs
3. Increase capacity of NRAs and Ministries to efficiently scrutinize investment plans

These policy recommendations are described below:

1. Harmonize regulatory framework

The primary policy recommendation that can be derived from this research is to align the regulatory frameworks regarding the ownership and operation of a MOG. A first attempt should be made to harmonize the regulatory regimes towards a more centrally planned development, of which the TSO model has the first priority. This can be done through either EU legislation or harmonization of the current national regimes.

2. Eliminate potential conflicts of interest at current TSOs

Additionally, current economic barriers can and should be removed to enable the development of hybrid transmission assets. Provided the argumentation in section 5.2, which described the potential conflict of interest that TSOs can face. TSOs can be hesitant to plan and invest in interconnection capacity if they are also owners of merchant transmission investments. The consequence of this is that (current) merchant interconnectors in the North(ern) Sea(s) should either be fully unbundled (divested) from TSOs or fully regulated and thereby including these assets in the RAB of the applicable TSOs.

3. Increase capacity of NRAs and Ministries to efficiently scrutinize investment plans

First, while the research also highlighted the weaknesses of the TSO model, policies and regulatory measures should be made to eliminate or decrease these weaknesses. For example, NRAs and national ministries should be more involved in the planning stage of offshore transmission assets. Therefore, expertise and tacit-knowledge regarding offshore transmission assets within NRAs and national ministries should be comparable with TSOs to safeguard that scrutinizing of the investment plans is done adequately.

8.2.2 Remaining knowledge gaps

This research focusses on MOG solutions and the necessary regulatory framework to develop the hybrid transmission assets. However, it is not evident that hybrid transmission assets are by definition better suited to provide transmission services, compared with point-to-point interconnection and radial grid connection systems of OWFs. Ultimately, the creation of MOG solutions should never be a goal in itself but rather a means. Any creation thereof, should accordingly provide a higher increase of social welfare compared to the individual development of offshore transmission assets. It is therefore important to perform a quantitative comparative analysis of the costs and benefits of hybrid transmission assets, or the evolution thereof, and the costs and benefits regarding the individual development of point-to-point interconnection and radial grid connection systems of OWFs.

Secondly, another important knowledge gap is related to the assumption which is highlighted in the final section of the conclusion: the financial commitment and abilities of the current owners of TSOs. Performing a survey, which involves the owners of TSOs, should therefore focus on their willingness and requirements to provide the necessary (equity) capital, in order to finance the offshore transmission assets. This survey should therefore provide the necessary information whether the TSO model is financially feasible.

Thirdly, more research should be executed on the potential transaction costs which will be incurred when ownership of offshore transmission assets are developed based on a Franchise Bidding approach (alternatives 1, 2 & 4) and the flexibility of the gradual evolution into a larger offshore grid is to be facilitated. Stakeholder consultations, regarding these potential transaction costs can contribute to the knowledge regarding these transaction costs. Finally, parallel to the additional information regarding the transaction costs, potential cost savings which can be achieved through competition (which can simultaneously drive innovation) in alternatives 1,2 & 4 are to be investigated and an effort is to be made to quantify these cost savings.

By addressing the previously described knowledge gaps, the conclusions from this research can be scrutinized with more quantitative data, thereby quantitatively validating or falsifying the results and conclusions which are presented in this report.

9 Reflection

This chapter will serve as a reflection on the performed research by elaborating on the initial research objective, methods and structure.

Social relevance

By providing additional knowledge regarding the appropriate governance model for a MOG, this research was able to provide relevant conclusions that can ultimately contribute to the development of a MOG when MOG solutions are beneficial for society as a whole. Thus providing content for the construction of an overarching regulatory framework, which is considered one of the primary barriers for the development of a North Sea Offshore Grid.

However, as this research is only one part of the overall lacking knowledge regarding the current barriers for a MOG to come to fruition. Several other barriers still need to be resolved to fully pave the way for a MOG to be developed. As explained in section 1.4, the sharing of costs and benefits of the affected countries needs to be researched more closely. Creating a method to determine the costs and benefits of specific MOG topologies and subsequently determining the costs and benefits for each country will be a remaining knowledge gap to be addressed. Currently, the PROMOTioN project, funded by the European Commission, tries to tackle this remaining knowledge gap. Moreover, getting involved countries to accept subsequent cross-border cost allocation to enable the "beneficiary pays" principle, based on the costs and benefits of each country, will be another incremental step towards an accelerated deployment of a MOG.

Scientific relevance

This research contributes to the scientific knowledge regarding the possible options for a governance model and the applicable design space for a governance model of a MOG. Through this research, it is found that a merchant approach is economically inefficient on the long term to facilitate the development of a MOG. By eliminating this option, the design space for a governance model is reduced. Another important finding within this research is the conclusion that a (Dutch) NRA is able to simulate a competitive market, regarding the financial parameters and operating expenditures that determine the overall costs for a transmission owner.

Research methods

The dominant research methods within this report are desk research and literature review. By using this research method, it is therefore possible that relevant literature and previous research was left untouched. The relevant literature within the theoretical domains for this research is in abundance, because of its societal value. However, to analyse all the relevant materials regarding the theoretical domains that apply to this research was impossible given the amount of time which was available to perform this research. An attempt to limit the impact of this issue, was to select the most relevant scientific literature.

Additionally, a quantitative method was applied in this report: a value for money assessment through a cash flow model. This research method is widely regarded as a suitable research method to assess whether a Private Public Partnership contract can provide value for money for the procurer. However, the limitations regarding the amount of cases to be analysed determine that only general conclusions can be made, specific to these cases. Because of this the value in predicting future cases or generalizing conclusions is limited.

Research approach

The approach of this research question was to consider the current national regulatory frameworks, regarding the governance models for a MOG, a greenfield situation. Because of this approach, the current situation in the countries surround the North(ern) Sea(s) was not used as a starting point of this research and policy recommendations will therefore be more difficult to implement.

Take for example the current developments of OWFs in the UK, which rely on a developer-led governance model, it will become extremely difficult to harmonize the regulatory framework of the UK with that of continental Europe. The approved licenses that enable OWF developers to rightfully develop OWF zones individually, will need to be rescinded when conclusions of this report are to be implemented. Moreover, the UK is currently looking to extend the competitively appointed transmission owner approach onshore (Ofgem, 2016c), thus moving further away from the integrated TSO model as individual TOs will own transmission infrastructure which is owned by a different SO.

Research process

As the structure and planning of the research were set-out in detail prior to the start of the research, gradually the understanding unfolded that the literature review and desk research demanded additional time to fully understand all the factors that impact the performance of the different governance models, the elements of which a governance model consists of and its implications on the overall design space for alternative governance models.

Reference List

ACM. Systeemcode Elektriciteit (2011).

ACM. (2015). Bestuurlijke reactie conceptrapporten InvesteringenTenneT in Nederlands hoogspanningsnet en Aankoop Duits hoogspanningsnet door TenneT.

ACM. (2016a). *Bijlage 2 bij het methodebesluit netbeheerder van het net op zee TenneT 2017-2021*. Den Haag.

ACM. (2016b). *METHODEBESLUIT NETBEHEERDER VAN HET NET OP ZEE TENNET 2017 – 2021*. Den Haag.

ACM. (2017). *Incentive Regulation of the gas and electricity networks in the Netherlands*.

Alexander, I., & Irwin, T. (1996). Price Caps, Rate-of-Return Regulation, and the Cost of Capital. *The World Bank Group: Public Policy for the Private Sector*, *September*(87), 1–4.

Averch, H., & Johnson, L. L. (1962). Behavior of the firm under regulatory constraint. *American Economic Review*. Retrieved from http://pascal.iseg.utl.pt/~carlosfr/ses/averch_johnson.pdf

Brunekreeft, G., Neuhoff, K., & Newbery, D. (2004). An Overview of the Current Debate. *Cambridge Working Papers in Economics CWPE 0463*. Retrieved from https://www.repository.cam.ac.uk/bitstream/handle/1810/131563/ep60.pdf?s

CEPA. (2014). *Contestability in Network Industries*.

CEPA. (2016). Evaluation of OFTO tender round 2 and 3 benefits. *Cambridge Economic Policy Associates*, (March).

Cowan, S. (2002). Price-cap regulation. *Swedish Economic Policy Review*, *9*, 167–188. Retrieved from https://www.researchgate.net/profile/Simon_Cowan/publication/265423229_Price-cap_regulation/links/54d37f810cf250179182301b.pdf

Crocker, K. J., & Masten, S. E. (1996). Regulation and administrated contracts revised: lessons from transaction-cost economics for public untility regualtion. *Journal of Regulatory Economics*, *9*, n. *1*, 5–39. https://doi.org/10.1007/BF00134817

Deloitte. (2006). Closing the Infrastructure Gap : The Role of Public-Private Partnerships.

Demsetz, H. (1968). Why Regulate Utilities? *The Journal of Law and Economics*, *11*(1), 55. https://doi.org/10.1086/466643

Dnes, A. W. (1995). Franchising and Privatization. *Public Policy for the Private Sector*, *March 1995*(40), 1–4.

Ecofys. (2017a). Adopting a sustainable 2050 vision for North Seas infrastructure to define a way forward. Brussel.

Ecofys. (2017b). *Translate COP21 2045 outlook and implications for offshore wind in the North Seas Translate COP21 2045 outlook and implications for offshore wind in the*.

Egerer, J., Kunz, F., & Hirschhausen, C. von. (2013). Development scenarios for the North and Baltic Seas Grid - A welfare economic analysis. *Utilities Policy*, *27*, 123–134. https://doi.org/10.1016/j.jup.2013.10.002

EIB, E. I. B. (2015). Value for Money Analysis. Retrieved August 14, 2017, from http://www.eib.org/epec/g2g/i-project-identification/12/124/

Energinet DK. (2015). *Market and Technical framework for the Danish Kriegers Flak offshore wind park*. Fredericia. Retrieved from https://ens.dk/sites/ens.dk/files/Vindenergi/market_framework_for_kriegers_flak_off-shore_wind_turbine_park_.pdf

ENTSO-E. (2014). Fostering Electricity transmission investments to achieve Europe´s energy goals : Towards a future-looking regulation ENTSO-E Working Group Economic Framework.

European Commission. (2010). *INTERPRETATIVE NOTE ON DIRECTIVE 2009/72/EC CONCERNING COMMON RULES FOR THE INTERNAL MARKET IN ELECTRICITY AND DIRECTIVE 2009/73/EC CONCERNING COMMON RULES FOR THE INTERNAL MARKET IN NATURAL GAS THE UNBUNDLING REGIME*. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/2010_01_21_the_unbundling_regime.pdf

European Commission. (2013). *Cobra cable*. Retrieved from http://ec.europa.eu/energy/eepr/projects/files/offshore-wind-energy/cobra-cable_en.pdf

European Commission. (2015). Achieving the 10% electricity interconnection target, 1–16. https://doi.org/COM(2015) 82 final

European Commission. (2017). Energy Strategy and Energy Union - European Commission. Retrieved September 11, 2017, from http://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union

Flourentzou, N., Agelidis, V. G., & Demetriades, G. D. (2009). VSC-Based HVDC Power Transmission Systems: An Overview. *IEEE Transactions on Power Electronics*, *24*(3), 592–602. https://doi.org/10.1109/TPEL.2008.2008441

Flynn, B. (2016). Marine wind energy and the North Sea Offshore Grid Initiative: A Multi-Level Perspective on a stalled technology transition? *Chemical Physics Letters*, *22*, 36–51. https://doi.org/10.1016/j.erss.2016.08.009

Flynn, D. B. (2016). Marine wind energy and the North Sea Offshore Grid Initiative: A Multi-Level Perspective on a stalled technology transition? *Energy Research & Social Science*, *22*, 36–51. https://doi.org/10.1016/j.erss.2016.08.009

Froud, J. (2003). The Private Finance Initiative: risk, uncertainty and the state. *Accounting, Organizations & Society*, *28*(6), 567–589.

Glachant, J.-M., & Pignon, V. (2002). *Nordic electricity congestion's arrangement as a model for Europe: Physical constraints or operators' opportunism? "Nordic electricity congestion's arrangement as a model for Europe: Physical constraints or operators' opportunism?"* Retrieved from www.grjm.net

González, J. S., & Lacal-Arántegui, R. (2016). A review of regulatory framework for wind energy in European Union countries: Current state and expected developments. *Renewable and Sustainable Energy Reviews*, *56*(January), 588–602. https://doi.org/10.1016/j.rser.2015.11.091

Harstad, R. M., & Crew, M. A. (1999a). Franchise-Bidding-Without-Holdups-Utility-Regulation-with-Efficient-Pricing-and-Choice-of-Provider.pdf. *Journal of Regulatory Economics*, *15*, 141–163.

Harstad, R. M., & Crew, M. A. (1999b). Franchise Bidding Without Holdups: Utility Regulation with Efficient Pricing and Choice of Provider. *Journal of Regulatory Economics*. https://doi.org/10.1023/A:1008077710419

HM Treasury. (2006). *Value for Money Assessment Guidance*. Retrieved from http://webarchive.nationalarchives.gov.uk/20130123214702/http://www.hm-treasury.gov.uk/d/vfm_assessmentguidance061006opt.pdf

HM Treasury. (2008). Intergenerational wealth transfers and social discounting: Supplementary Green Book guidance. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/193938/Green_Book_supplementary_guidance_intergenerational_wealth_transfers_and_social_discounting.pdf

Hogan, W. (2011). Transmission benefits and cost allocation, 1–30. Retrieved from http://www.hks.harvard.edu/hepg/Papers/2011/Hogan_Trans_Cost_053111.pdf

Hogan, W., Rosellón, J., & Vogelsang, I. (2010). *Toward a combined merchant-regulatory mechanism for electricity transmission expansion*. *Journal of Regulatory Economics* (Vol. 38). https://doi.org/10.1007/s11149-010-9123-2

IABR. (2017). 2050- An Energetic Odyssey. Retrieved September 20, 2017, from https://www.iabr.nl/en/projectatelier/atelier2050

IEA-RETD. (2017). Comparative Analysis of International Offshore Wind Energy Development, (March).

Joskow, P. (2007). Chapter 16 Regulation of Natural Monopoly. *Handbook of Law and Economics*, *2*(7), 1227–1348. https://doi.org/10.1016/S1574-0730(07)02016-6

Joskow, P., & Tirole, J. (2003). Merchant Transmission Investment. *Cambridge Working Papers in Economics CWPE 0324*. Retrieved from https://www.repository.cam.ac.uk/bitstream/handle/1810/356/EP24.pdf?sequence=1

Klip, D. (2015). *The North Seas Offshore Grid*. The Hague.

KPMG. (2012). Offshore Transmission: An Investor Perspective - Prepared for The Electricity and Gas Markets Authority, (December). Retrieved from https://www.ofgem.gov.uk/ofgem-publications/79347/ofto-aninvestorperspective.pdf

Lieb-Doczy, E., & McKenzie, I. (2008). Unbundling ownership and control: international experience of independent system operators. *International Journal of*. Retrieved from http://www.inderscienceonline.com/doi/abs/10.1504/IJGEI.2008.016345

Liston, C. (1993). Price-cap versus rate-of-return regulation. *Journal of Regulatory Economics*,

5(1), 25–48. https://doi.org/10.1007/BF01066312
Mathios, A. D., & Rogers, R. P. (1989). The Impact of Alternative Forms of State Regulation of AT&T on. *Directdial, Long-Distance Telephone Rates' , RAND Journal of Economics*, *20*(3), 437–53.
Morallos, D., & Amekudzi, A. (2008). The State of the Practice of Value for Money Analysis in Comparing Public Private Partnerships to Traditional Procurements. *Public Works Management & Policy*. https://doi.org/10.1177/1087724X08326176
Müller, H. K. (2015). *Developing a legal framework for a transnational offshore grid in the North Sea PhD thesis*. Rijksuniversiteit Groningen.
National Grid. (2016). System Operator Transmission Owner Code (STC), 376. Retrieved from http://www2.nationalgrid.com/UK/Industry?information/Electricity?codes/System?Operator?Transmission?Owner?Code
NationalGrid. (2013). Guidance Notes for Generator Offshore Local TNUoS Charges Radial Connections January 2013 (Version 1 . 1 - Amended to take out security factor in substation tariff formulae . Security Factor is only applicable to circuit tariffs) What TNUoS charges do I, *1*(January).
NORTHSEAGRID. (2015). *Offshore Electricity Grid Implementation in the North Sea*. Ioannis Konstantelos. Retrieved from http://northseagrid.info/sites/default/files/NorthSeaGrid_Final_Report.pdf
NSCOGI. (2014). The North Seas Countries' Offshore Grid initiative (NSCOGI) -Cost allocation for hybrid infrastructures - Deliverable 3 – Final version Working Group 2 – Market and Regulatory issues. Retrieved from http://www.benelux.int/files/8414/0923/4156/cost_allocation_paper_final_version_28_July_2014.pdf
NSOGI. (2014). Study of the Benefits of a Meshed Offshore Grid in Northern Seas Region. *European Commission*. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/2014_nsog_report.pdf
Offshore Wind Programe Board. (2016). Transmission Costs for Offshore Wind- Final Report, (April).
Ofgem. (2010). Electricity interconnector policy Team: European Strategy. Retrieved from http://ec.europa.eu/energy/gas_electricity/doc/forum_florence_electricity/meeting_1
Ofgem. (2013). Offshore Transmission: Cost Assessment for the London Array transmission assets. Retrieved from https://www.ofgem.gov.uk/sites/default/files/docs/2013/09/london_array_cost_assessment_report.pdf
Ofgem. (2014). OFTO Build : Providing additional flexibility through an extended framework Updated policy proposals.
Ofgem. (2016a). Guidance on the offshore transmission owner licence for Tender Round 4 (TR4). Retrieved from https://www.ofgem.gov.uk/ofgem-publications/99968

Ofgem. (2016b). *Offshore Transmission Owner Revenue Report*. Retrieved from http://www.thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy/offshore-wind-electricity-map/

Ofgem. (2016c). Quick Guide to the CATO Regime – November 2016, (November).

Oren, S., Gross, G., & Alvarado, F. (2002). *Alternative Business Models for Transmission Investment and Operation*. Retrieved from https://emp.lbl.gov/sites/all/files/alt-models-for-transmission.pdf

Pérez-Arriaga, I. J. (2014). *Regulation of the Power Sector 2014 - Annex A and B.pdf*.

Pollitt, M. (2008). The arguments for and against ownership unbundling of energy transmission networks. *Energy Policy*, *36*(2), 704–713. https://doi.org/10.1016/j.enpol.2007.10.011

Pollitt, M. (2012). Lessons from the history of independent system operators in the energy sector. *Energy Policy*, *47*, 32–48. https://doi.org/10.1016/j.enpol.2012.04.007

Posner, R. (1969). Natural Monopoly and its Regulation. *Stanford Law Review*, *21*(3), 548–643. https://doi.org/10.2307/1227483

PROMOTioN. (2016). *Deliverable 1 . 3 : Synthesis of available studies on offshore meshed HVDC grids*.

PROMOTioN. (2017a). *Economic framework for offshore grid planning*. Retrieved from https://www.promotion-offshore.net/fileadmin/PDFs/D7.3_-_Economic_framework_for_offshore_grid_planning.pdf

PROMOTioN. (2017b). Intermediate report : Financing framework for meshed offshore grid investments.

PROMOTioN. (2017c). *Legal framework and legal barriers to an offshore HVDC electricity grid in the North Sea*. Retrieved from https://www.promotion-offshore.net/fileadmin/PDFs/D7.1_-_Legal_framework_and_legal_barriers_to_an_offshore_HVDC_electricity_grid_in_the_North_Sea.pdf

Rekenkamer, A. (2015). Investeringen TenneT in Nederlands hoogspanningsnet Investeringen TenneT in Nederlands hoogspanningsnet Toezicht van het Rijk op het publieke belang.

RVO. (2015). *Offshore wind energy in the Netherlands*.

RVO. (2016). *Vragen en Antwoorden Windenergiegebied Borssele kavels III & IV*. Retrieved from https://www.rvo.nl/sites/default/files/2016/09/Vragen en antwoorden windenergiegebied Borssele kavels III en IV.pdf

Sovacool, B. K., Gilbert, A., & Nugent, D. (2014). An international comparative assessment of construction cost overruns for electricity infrastructure. *Energy Research and Social Science*, *3*(C), 152–160. https://doi.org/10.1016/j.erss.2014.07.016

Stigler, G. J. (1974). Free Riders and Collective Action: An Appendix to Theories of Economic Regulation. *The Bell Journal of Economics*, *Vol 5*(2), 359–365.

TenneT. (2016). Kwaliteits-en Capaciteitsdocument Net op Zee. Retrieved from

https://www.tennet.eu/fileadmin/user_upload/Company/Publications/Technical_Publications/Dutch/TP_KCD2016_net_op_zee.pdf
Van Koten, S. (2011). Merchant interconnector projects by generators in the EU: Profitability and allocation of capacity. *Energy Policy*, *41*, 748–758. https://doi.org/10.1016/j.enpol.2011.11.042
Vogelsang, I. (2005). *ELECTRICITY TRANSMISSION PRICING AND PERFORMANCE-BASED REGULATION*.
Vogelsang, I. (2006). Electricity transmission pricing and performance based regulation. *The Energy Journal*, *27*(4), 97–127.
Williamson, O. (1976). Franchise Bidding for Natural Monopolies-in General and with Respect to CATV. *The Bell Journal of Economics*, *7*(1), 73–104. https://doi.org/10.2307/3003191
Wind Europe. (2017). WindEurope Working Group: Offshore Wind.
Wind Power Offshore. (2017). Dong and EnBW win German auction with zero-subsidy bids | Windpower Offshore. Retrieved October 14, 2017, from https://www.windpoweroffshore.com/article/1430702/dong-enbw-win-german-auction-zero-subsidy-bids
Wu, F. F., Zheng, F. L., & Wen, F. S. (2006). Transmission investment and expansion planning in a restructured electricity market. https://doi.org/10.1016/j.energy.2005.03.001

Appendix A Allocation of responsibilities per country

Possible interconnection governance models

As for the assets for the interconnection (IC) of electricity markets, or ''interconnectors'', two distinct owners can have final responsibility of the transmission assets: a regulated model, in which the two TSOs of the interconnected markets are responsible for ownership and operation or a merchant model where private-parties are owner of these assets and have the right to derive revenues from these assets (Ofgem, 2010).

In the regulated model, the owner of the asset is essentially receiving a regulated return on its investment, based on the initial investment of the infrastructure and the operational expenditures during the lifetime of the infrastructure. Revenues, which are derived from the interconnector itself through the selling of interconnection capacity (arbitrage) for market participants, will be to the benefit of electricity consumers who pay transmission tariffs.

Contrastingly, in a merchant model, the owner of the infrastructure will pay for the infrastructure and will subsequently derive revenues from the users of the infrastructure through arbitraging between the interconnect electricity markets.

A purely regulated model and a purely merchant model are considered as the two main governance models on opposite sides of the spectrum when considering the ownership of the interconnection infrastructure. Hybrid version of both the regulated and the merchant investment models can be considered as well, depending on the share of underwritten revenues by the users of the transmission system (Ofgem, 2010). Below (figure 56) is an overview of the policy options.

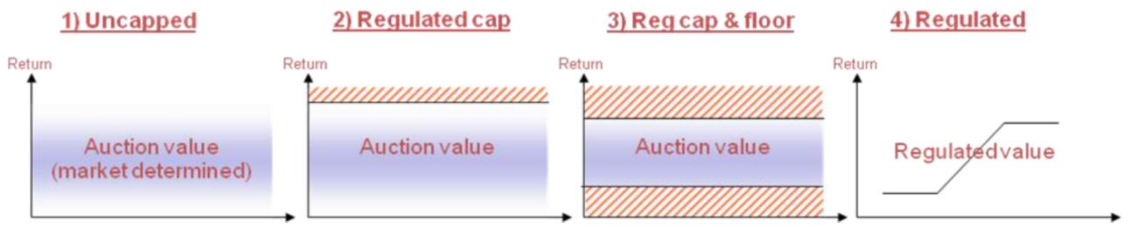


Figure 56: Interconnector policy options (Ofgem, 2010)

1) Uncapped

The first option is an uncapped approach, which is considered a full merchant approach in which the developer of the asset is responsible for the overall planning, timing, capacity and high over design of the transmission assets. Within the current interconnection EU regulatory framework, such an approach would require an exemption of Regulation (EC) No 1228/2003, which addresses the use of revenues, third-party access etc.

2) Regulated cap

Similar to the uncapped merchant model, the revenues of the interconnector owner are fully derived from the market by arbitraging between the electricity markets. However, to prevent merchant interconnector owners to obtain extraordinary profits, the allowed revenues are capped and revenues that exceed this cap will be returned to the users of the transmission infrastructure. This height of the cap is decided upon by the regulator. Depending on specific policy choices, the revenues that exceed the cap can be distributed among consumers and producers of the interconnected electricity markets.

3) Regulated cap & floor

Identical to option two, the third option also includes a revenue cap, thereby limiting the potential profits of the owner of the interconnector. However, the third regulatory option also includes a regulated revenue floor. Through this revenue floor a part of the revenues are underwritten by the consumers of the infrastructure, thereby guaranteeing a part of the revenues for the owner of the interconnector. By guaranteeing a part of the revenues, investors' appetite might increase due to the decreasing uncertainty regarding the potential revenues across the lifetime of the asset. The revenues that are derived from the market through arbitraging, can therefore remain a significant share of the potential revenues.

4) Regulated

The fourth option is a fully regulated option, essentially this fourth option means that both the cap and the floor are intersecting with each other and all of the revenues are underwritten by consumers. Subsequently, all of the revenues that are derived from the market through arbitrage, will be returned to the same consumers.

Appendix B Risks in offshore transmission system projects

The table bellows shows a wide variety of risks that can occur in an offshore transmission project. Each of the risks below has the potential to cause additional costs, compared with the initial budget. The risk register below includes 43 risk descriptions, categorized through the different main components of an offshore transmission system, as described in section 4.3.1. The risks below were obtained through an expert-interview of TenneT TSO b.v., which is a company that has extended experience in the construction of offshore transmission systems.

The risk description shows the amount of uncertainties within an offshore transmission system construction project. The impact of the different risks is varying from below 1% of the initial budget to 10-15% of the initial budget and can therefore significantly impact the final CAPEX of an offshore transmission system project.

Nr.	Risk Discription	Section	Nr.	Risk Discription	Section
1	Harmonic filters necessary Land Station	Land station	23	Unclarity in contracts leads to awarded claims	Platform
2	Harmonic filters necessary on platform	Platform	24	Divergent conditions (soil, UXO's, fauna etc.) leads to awarded claims and variation orders	Platform
3	Cable corridor changes	Cables	25	Misalignment interfaces leads to awarded claims	Platform
4	Problems with cable installation Westerschelde (UXO's, burial depth)	Cables	26	Equipment failure leads to awarded claims	Platform
5	Scour protection has to be applied	Platform	27	FIDIC 17.3 leads to awarded claims and variation orders	Platform
6	Financial uncertainties land management (incl. compensation, planological damage and other damages)	General	28	Auxilary delays caused by employer (management, cooperation, land management) lead to awarded claims	Platform
7	Shared use state property for cable zone	General	29	Residual weather and installation risk (incl. guard vessels) Employer (provisional sums in contracts) leads to awarded claims	Platform
8	Shared use state property for ZRO zone	General	30	Changing standards lead to awarded claims and variation orders	Platform
9	Market restrictions and risks contractor (production, transportation and weather) lead tot high prices cables	Cables	31	Free issued item not delivered on time for installation in top side	Platform
10	Tender result higher than cost estimate: - Market consultation prices were too low - Transportation and installation risks contractor lead to higher prices	Platform	32	Unclarity in contracts leads to awarded claims	Land station
11	Weather risk contractor leads to higher price in tender	Platform	33	Misalignment interfaces leads to awarded claims	Land station
12	Delays and restrictions in permits leads to awarded claims and variation orders	General	34	Equipment failure leads to awarded claims	Land station
13	Equipment failure leads to awarded claims	Cables	35	FIDIC 17.3 leads to awarded claims and variation orders	Land station
14	Delay connection to grid lead to awarded claims	Cables	36	Divergent conditions (soil, UXO's, fauna etc.) lead to awarded claims and variation orders	Land station
15	FIDIC 17.3 leads to awarded claims and variation orders	Cables	37	Auxilary delays caused by employer (management, cooperation, land management) lead to awarded claims	Land station
16	Divergent conditions (soil, UXO's, fauna etc.) lead to awarded claims and variation orders	Cables	38	Changing standards lead to awarded claims and variation orders	Land station
17	Auxilary delays caused by employer (management, cooperation, land management) lead to awarded claims	Cables	39	Misalignment interfaces leads to awarded claims	Land station
18	Residual weather and installation risk (incl. guard vessels) Employer (provisional sums in contracts) leads to awarded claims	Cables	40	Delay connection to grid leads to awarded claims	General
19	Changing standards lead to awarded claims and variation orders	Cables	41	Financial impact of delays Project Initiation on time dependant costs	General
20	Public resistance leads to variation orders	Cables	42	Financial impact of delays Realisation on time dependant costs	General
21	Unclarity in contracts leads to awarded claims	Cables	43	Larger project organisation needed	General
22	Misalignment interfaces leads to awarded claims	Cables			

Appendix C OFTO savings

Figure 57 shows the cost savings of the OFTO model, compared with the constructed counterfactuals. The cost savings show that the calculated cost savings in Tender Round 2 varies from £326-£595 million. Regarding Tender Round 3, cost savings varies from £102-£154 million (figure 58).

The source of cost savings are divided in different groups: financing cost savings, operating costs and bid costs. Cost savings in both financing costs and operating costs are a consequence of the level of competition compared with the OFTO model. Additionally the bid costs show that significant transaction costs are associated with setting-up an OFTO tender.

Source of saving	Counterfactual 1 Merchant generator project	Counterfactual 2 Merchant sale and lease back	Counterfactual 3 Regulated network – RIIO-T1	Counterfactual 4 Regulated network – specific control	Counterfactual 5 Regulated network – offshore zone licence
Financing costs	501	347	225	145	232
Operating costs	-	-	201-391	201-391	152-295
Bid costs	-21	-21	-21	-21	-
Total (EXC tax)	**480**	**326**	**406-595**	**326-515**	**384-527**

Figure 57: Calculated savings in Tender Round 2 by OFTO regime

Source of saving	Counterfactual 1 Merchant generator project	Counterfactual 2 Merchant sale and lease back	Counterfactual 3 Regulated network – RIIO-T1	Counterfactual 4 Regulated network – specific control	Counterfactual 5 Regulated network – offshore zone licence
Financing costs	149	113	82	64	85
Operating costs	-	-	45-79	45-79	34-59
Bid costs	-7	-7	-7	-7	-
Total (EXC tax)	**143**	**106**	**120-154**	**102-136**	**119-144**

Figure 58: Calculated savings in Tender Round 3 by OFTO regime

Appendix D FTV example

Figure 59 provides an example of the determined Final Transfer Value of a specific offshore transmission system which is subsequently put up for tender, as explained in the UK case study. The example is the London Array offshore transmission system, which is also used as a case in the comparative analysis of section 4.3.4. The FTV is divided into four different categories: CAPEX, Development costs (DEVEX), Interest During Construction and Transaction costs.

To provide potential OFTOs with relevant preliminary information, before the commissioning of the transmission assets, an indicative transfer value is calculated. This enables potential OFTOs to prepare for their bids, however, when the offshore transmission assets are commissioned, Ofgem finally decides upon the FTV. This FTV can defer from the initial transfer value if Ofgem can determine whether certain costs were inappropriate.

Category	**Initial Transfer Value: November 2010 (£m)**	**Indicative transfer value: November 2011 (£m)**	**Assessed costs (£m)**	**Reasons for change between Indicative transfer value and assessed costs**
CAPEX	374.9	345.4	343.9	Increases of: £12.1m for standby vessel costs associated with cable supply delays. £5.5m for variations to the original contract value for export cable jointing, terminations and independent cable survey. £1.8m for contractor project management costs due to cable installation delays. £1.1m for costs associated with onshore substation repairs. Offset by decreases of: £3.6m to reflect removal of assets as result of changes to the offshore boundary point. £0.7m due to a correction to the onshore transformer cost. £0.6m for miscellaneous changes in contract costs. Note there is also a net reallocation from CAPEX to development costs of £17.2m.
Development Costs	31.9	31.2	48.8	Increase of: £10.6m for project management costs due to project delays. £0.8m for miscellaneous property and consent costs. Offset by decreases of: £5.3m for removal of insurance costs. £3.2m for the change in the transmission asset allocation percentage. £2.5m for the sale of unused land at Cleve Hill farm and Graveney Farm. Note there is also a net reallocation from CAPEX to development costs of £17.2m.
IDC	68.9	51.8	66.5	The IDC amount has increased as a result of a longer construction period, and an increase in development costs.
Transaction	0	0	2.4	Transaction costs have been added as they are assessed at the end of the cost assessment process.
Total (Assessed costs)	**475.7**	**428.4**	**461.6**	
Capital allowances	0	0	-2.7	The developer has confirmed that the OFTO will not be able to obtain the full benefit of all available capital allowances; therefore, a reduction of £2.7m has been made.
Total (Final transfer value)	**475.7**	**428.4**	**458.9**	

Figure 59: Example of determining FTV by Ofgem (Ofgem, 2013)

Appendix E Sensitivity analysis comparative analysis

To analyse the sensitivity of the results in the comparative analysis, this appendix provides the quantitative results of the sensitivity analysis. The sensitivity analysis is performed based on the base case results (figure 60).

Case	FTV	NPV delta
Walney 1	£ 105.000.000,00	£ 49.100.000
Barrow	£ 33.600.000,00	£ 38.900.000
Gunfleet Sands	£ 49.500.000,00	£ 35.500.000
Robin Rigg	£ 65.500.000,00	£ 20.600.000
Ormonde	£ 103.900.000,00	£ 34.900.000
Walney 2	£ 109.800.000,00	£ 57.400.000
London Array	£ 458.900.000,00	-£ 50.600.000
Sheringham Shoal	£ 193.100.000,00	£ 53.000.000
Greater Gabbard	£ 317.000.000,00	£ 9.600.000
Lincs	£ 307.700.000,00	-£ 13.100.000
Thanet	£ 164.000.000,00	£ 55.700.000
Gwynt y Mor	£ 352.000.000,00	-£ 65.100.000
West of Duddon Sands	£ 269.000.000,00	-£ 41.200.000

Figure 60: Base case results

Within the sensitivity analysis, the input parameters are adjusted according to the figures shown in figure 61. The input parameter adjustments are defined as low and high.

Sensitivity Analysis		
	Low	**High**
WACC	2,7%	3,3%
Discount rate	2,5%	4,5%
Inflation	1,0%	2,0%

Figure 61: Input parameter adjustments

The next sub-sections will describe the sensitivities of the different parameters by comparing the results of the adjusted input parameters with the base case results.

Weighted Average Cost of Capital (WACC)

Regarding the WACC, the base case result is based on a WACC of 3%. The cumulative value for money, for the base case, is calculated to be £184 million. Similar to the base case, the sensitivity analysis for the WACC shows that there are four specific case which would provide more value for money when the UK OFTO model is applied. Moreover, the results do not show a difference in sensitivity when the WACC is decreased or increased.

WACC	Low 2,7%		High 3,3%	
Walney 1	£	52.000.000,00	£	46.300.000,00
Barrow	£	39.800.000,00	£	38.000.000,00
Gunfleet Sands	£	36.800.000,00	£	34.100.000,00
Robin Rigg	£	22.400.000,00	£	18.900.000,00
Ormonde	£	37.800.000,00	£	32.100.000,00
Walney 2	£	60.400.000,00	£	54.500.000,00
London Array	-£	38.200.000,00	-£	63.000.000,00
Sheringham Shoal	£	58.200.000,00	£	47.800.000,00
Greater Gabbard	£	18.100.000,00	£	1.000.000,00
Lincs	-£	4.800.000,00	-£	21.400.000,00
Thanet	£	60.200.000,00	£	51.300.000,00
Gwynt y Mor	-£	55.600.000,00	-£	74.600.000,00
West of Duddon Sands	-£	33.900.000,00	-£	48.500.000,00
Sum	£	253.200.000,00	£	116.500.000,00

Figure 62: WACC sensitivity

The sensitivity analysis shows that the cumulative value when using the adjusted input parameters is calculated to be between £116-253 million (figure 62). As can be expected, a higher WACC leads to a higher NPV for the Dutch TSO model, as an increase immediately affects the cash flow of the TSO. Inversely, a lower WACC leads to a lower NPV for the Dutch TSO model.

It must be noted that the Dutch WACC historically had a higher value than the 3.3%. However, this analysis used the current value as a starting point, which in turn determines the value of the adjusted parameters.

Discount rate

For the calculation of the base case NPVs of the cash flows, this report uses a discount rate of 3,5%, as advised by the UK government (HM Treasury, 2008). However, this value is arbitrary, as the discount rate is usually a parameter which is debated upon when cost and benefit analysis is performed. The value of the discount rate is depending on the time value of money for society. In essence, it described the social preference of receiving (or paying) money in the present rather than in the future.

Discount rate	Low 2,5%		High 4,5%	
Walney 1	£	54.800.000,00	£	44.200.000,00
Barrow	£	42.900.000,00	£	35.400.000,00
Gunfleet Sands	£	39.200.000,00	£	32.200.000,00
Robin Rigg	£	23.000.000,00	£	18.600.000,00
Ormonde	£	39.100.000,00	£	31.300.000,00
Walney 2	£	64.000.000,00	£	51.800.000,00
London Array	-£	52.100.000,00	-£	49.000.000,00
Sheringham Shoal	£	59.800.000,00	£	47.200.000,00
Greater Gabbard	£	13.000.000,00	£	6.700.000,00
Lincs	-£	12.100.000,00	-£	13.900.000,00
Thanet	£	62.600.000,00	£	49.900.000,00
Gwynt y Mor	-£	69.000.000,00	-£	61.500.000,00
West of Duddon Sands	-£	43.400.000,00	-£	39.200.000,00
Sum	£	221.900.000,00	£	153.700.000,00

Figure 63: Discount rate sensitivity

Similar to the WACC sensitivity, the changing parameters do not show a significant change when looking at how many cases would provide more value for money had the Dutch TSO parameters been applied. There is, however, a difference in the cumulative value for money when the discount rate is adjusted, as shown in figure 63. When the discount rate is lowered, the TSO model has increased value for money: £221,9 million compared with £184 million in the base case. Inversely, when the discount rate is increased the TSO model shows a decreased value for money: £153,7 million compared with £184 million in the base case.

Appendix F possible development of MOG

Figure 64 shows another possible development of a MOG, conceptually similar with the example in section 5.1.1. Stage 1 is regarded as the initial stage of a MOG in this example. It is shown that stage 1 already consists of hybrid offshore transmission assets, thus combining both the OWF grid connection and the interconnection of electricity markets. Stage 2-A and Stage 2-B are consequently two options that can gradually develop from the initial stage. Stage 2-A shows the possibility that the two offshore substations are connected with a third offshore substation. Stage 2-B shows the possibility the third offshore substation is teed-in the offshore transmission cable that connects the initial two offshore substations.

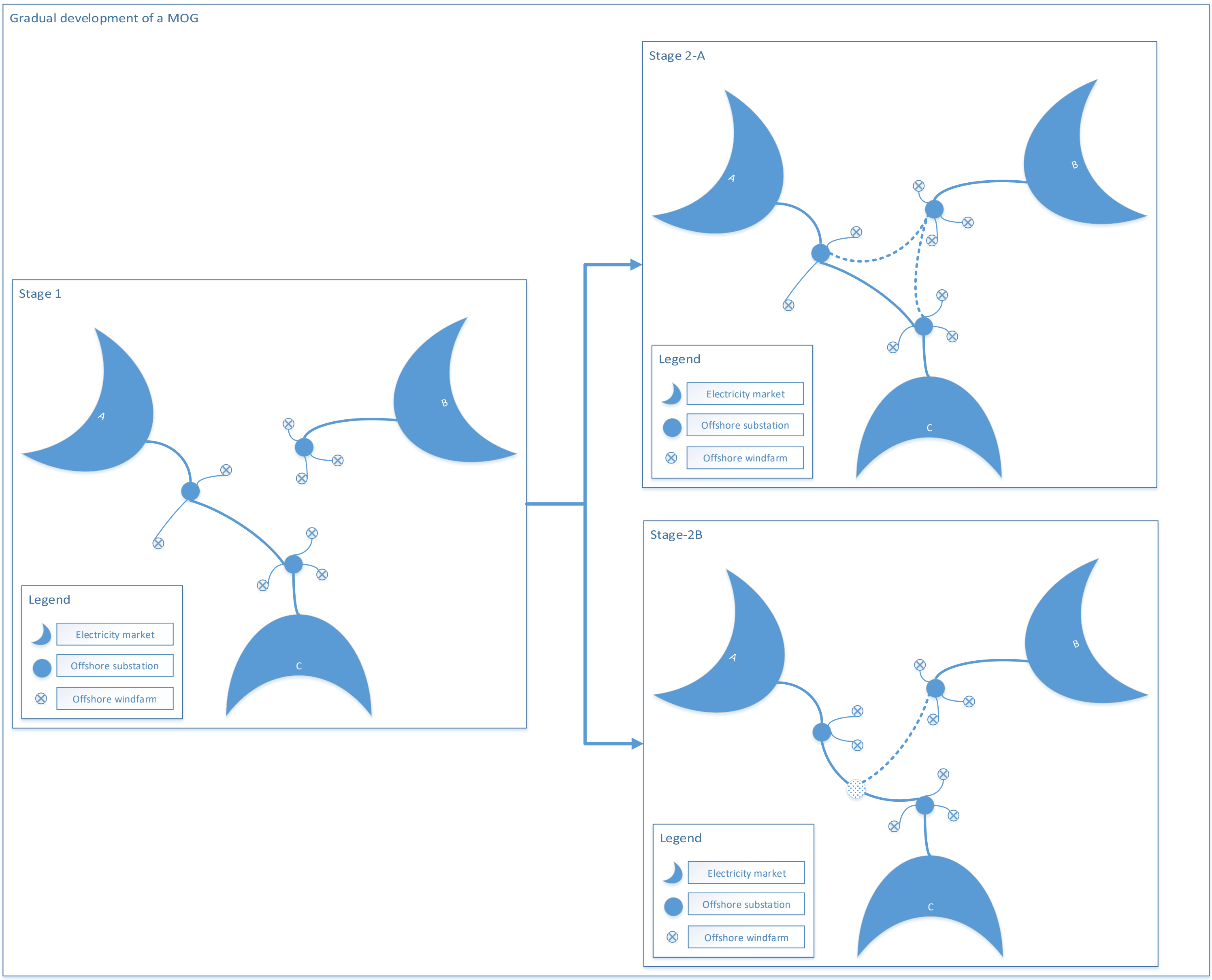


Figure 64: Possible gradual development of Meshed Offshore Grid