The regulation of radial grid connection systems for offshore windfarms

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ABSTRACT

In order to meet climate goals, offshore wind energy is regarded as one of the main technologies that can contribute to low-carbon future and to reach the agreements set out in the Paris climate agreement (COP21), 230 GW of offshore wind is projected to be necessary in 2050. This will require electricity grid infrastructure to be developed in the North(ern) Sea(s). Currently, two dominant governance models are applied in the North Sea region to govern ownership responsibilities, the TSO model (most of continental Europe) and the OFTO model (in the United Kingdom). While the OFTO model relies on competitive forces to determine the allowed revenues for the transmission owner, a TSO model relies on regulatory forces to determine appropriate revenues for the transmission owner. While previous studies showed that the OFTO model provided value for money for the consumers of electricity, this article examines the potential benefits that the OFTO model could bring for Dutch consumers, thereby comparing the UK OFTO model with the Dutch TSO model. This comparison enables the assessment to determine whether a Dutch regulator is able to simulate a competitive market and thereby provide value for money for the consumers. A quantitative analysis showed that the UK OFTO model is not superior to the Dutch model and we can therefore conclude that the Dutch regulator is able to simulate competitive forces to determine appropriate revenues for the transmission owner of offshore electricity grid infrastructure.

1. Introduction

Current national climate goals are pushing European Union (EU) member states to increase their share of sustainable electricity production [1]. While different technologies are capable of achieving these climate goals, offshore wind is regarded as one of the main technologies to contribute to the energy transition [2]. As of 2017, already 12,6 Giga Watt (GW) of offshore wind is installed in EU member states [3] and studies show 230 GW of offshore wind power is necessary to be installed in 2050 to reach the goals set out in the Paris climate agreement [4].

In order to evacuate the offshore wind energy to the onshore load centres, electricity transmission infrastructure needs to be developed to provide the necessary grid connection. Moreover, from an economic perspective, electricity transmission is considered a natural monopoly and therefore it needs to be regulated so that consumers can be protected against the abuse of monopoly power.

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 (OWF) 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. A distinction can be made of three (existing) governance models: the TSO-model, the Offshore Transmission Owner (OFTO)-model and the generator-model[5]. The policy choice for a specific governance model is not trivial, as it is impacting financing costs, transaction costs and additional costs associated with transmission investments[6], thereby impacting the value for money for the agents who are paying for the grid connections of OWFs. The, previously introduced governance models will be explained more in-depth in Chapter 3.

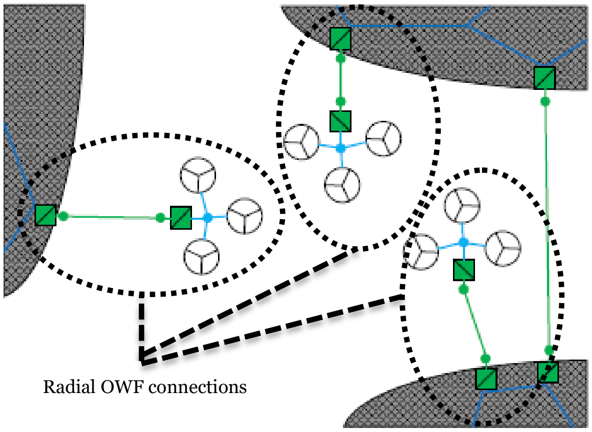

Figure 1: Conceptual radial OWF connection

Future offshore wind developments could provide the feeding ground for combined or even meshed offshore grid (MOG) solutions [7][8], in which the grid connection system (GCS) connects not only one or more OWFs but also interconnects two or more electricity markets. However, current grid connection systems in operation provide the sole function of connecting the OWF to the onshore grid, known as a radial grid connection system [7], thereby enabling the evacuation of the produced electricity to the onshore load centres, as shown in figure 1.

This article attempts to increase the understanding of the currently applied governance models regarding the allocation of grid connection responsibility and, consequently, the allocation of radial grid connection costs. . Moreover, this article will take a consumer-perspective in doing so.

Allocation of grid connection responsibility and costs

With respect to the allocation of grid connection responsibility and costs for offshore windfarms, literature is not conclusive on the question which governance model is most efficient. Weißensteiner et. al [9] have made an effort to address this question, as they argue that this should be the responsibility of the incumbent TSO. Their argument is that by allocating the responsibility of the grid connection system with the incumbent TSO instead of the OWF developer, it would realize significant transfer cost savings due to two main reasons: 1) lower producer rents and 2) lower financing costs. The lower financing costs cannot be disputed, as the OWF developer do have significant higher financial risk as their business case is more risky, due to the volatility of the electricity prices and weather dependent production capacity, compared with the regulated TSO in which the revenues are underwritten by the consumers. However, the producer rents, as defined in the article of Weißensteiner et. al, is a consequence of non-differentiated feed-in tariffs where the long run marginal costs of the marginal OWF is used to determine the feed-in tariff for all OWF's. This logic does not hold when the feed-in tariff is differentiated over the different OWF's and therefore each OWF has its own feed-in tariff based on the specific (cost) characteristics. Subsequently, the lower producer rents can be achieved not only by transferring the responsibility of the grid connection to the TSO but also through a differentiated feed-in tariff per OWF.

Moreover, a comparison is lacking between other applied governance models, such as the OFTO-model which is introduced in the UK. While previous quantitative analysis indicated that the OFTO-model provided significant value for money, with savings in the range of £672 million -£1218 million compared to other governance models[6]. These savings are calculated by comparing UK counterfactual, which uses financial parameters and operating expenditures based as determined by the UK regulator (Ofgem). It would therefore be valuable to calculate whether there are also savings achievable in a country such as the Netherlands. Thereby essentially assessing the effectiveness of the regulator to simulate a competitive market.

Research question

To what extent would an OFTO-model lead to more value-for money for Dutch consumers, in case of a pure radial grid connection system?

The following structure will be used to come to a substantiated answering of the research question:

Chapter 2 of this article will briefly explain the methods used in this article, followed by chapter 3 in which the theories behind the governance models are explained. Moreover, chapter 3 will also include a detailed description of the two case-studies that will be compared in the comparative quantitative analysis. Chapter 4 will describe the model structure and the equations, added with the data which are used as input to perform a cash flow analysis. Chapter 5 will subsequently present the results derived from the quantitative analysis, followed by a discussion of the results in chapter 6. Concluding, chapter 7 will provide a nuanced answer on the research question, based on the discussion points and results of this research.

2. Method

In order to answer the research question, a general overview of current regulatory options to regulate a natural monopoly will be provided. This will set the scene for two case studies, in which the regulatory regime, regarding the connection of OWF's, in both the UK and the Netherlands will be described. Subsequently, in order to answer the research question, quantitative analysis will be performed in which the value for money, from a consumer perspective, will be determined through the cash flow analysis of two different governance models which are currently applied to provide the radial GCS for the evacuation of offshore wind.

The value for money principle is essentially a Cost Benefit Analysis (CBA) method which is a commonly used method to determine the added value of a different procurement method or policy implementation[10][11]. Concluding, this report will use a predetermined set of cases and the cash flows of every specific case will then be discounted to calculate the Net Present Value of the costs of each case.

3. Theory

Within the literature we can distinguish three types of natural monopoly regulation that can be applied: rate-of-return (ROR), incentive regulation (IR) and franchise bidding (FB). Where ROR and IR assume an single ex post supply as the starting point, FB 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 possible competition within the market[12], which is the primary characteristic of a natural monopoly. These regulatory approaches are presented through the framework of Crocker & Masten [13], shown in figure 2.

In practice, hybrid forms of the previous three types of regulation approaches, or institutional arrangements, are applied to accommodate the specific costs associated with the variety of natural monopolies and its cost functions. The following section will describe the regulatory approaches through the applicable literature.

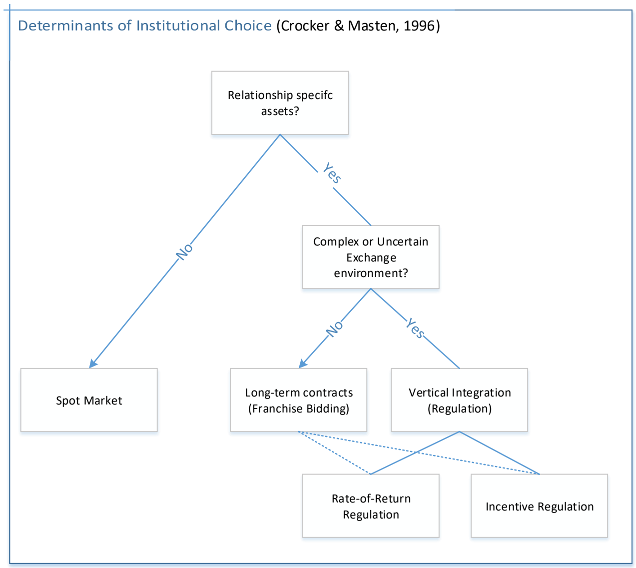

Figure 2: Determinants of Institutional Choice

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 a specific year[14][15][16]. These total costs of service or allowed revenues usually consist of several elements:

1. Operating costs
2. Capital related costs
    a. Depreciation costs
    b. Cost of debt and equity
    c. Income tax
3. Other costs

These allowed revenues are subsequently the input on which the tariffs are designed which will ultimately form the price approved or set by the regulator [15][17]. This type of regulation prevents the monopolist to abuse their monopoly power by charging monopoly prices, however it fails to incentivize the monopolist to operate efficiently [18].

Incentive regulation

As ROR 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 totally new concept of regulation, but more of an addition to rate-of-return regulation [15][19][17][20].

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 incentive based regulatory approaches.

1) Price-cap regulation, in which the regulating authority sets the price which the monopolist can maximally charge the consumers[14]. 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. By setting a revenue-cap the regulated firm is relieved from the volume risk, which subsequently de-risks the business[21].

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 [15][21]. Essentially making the firms compete against each other.

Franchise bidding

Franchise bidding is a type of regulation which was initially introduced as a problem solving institutional concept that would solve the issue of how to regulate a natural monopoly. Demsetz argued that competition for the market would remove the regulation necessity of a natural monopoly with a single ex post supplier[12].

In Franchise Bidding, potential bidders compete for the market and the bidder who offers the most value for money (lowest required net revenue) to the consumer will obtain the franchise rights to be the single ex post supplier of the market[22][23].

Franchise bidding can therefore be seen as a Public Private Partnership in which the natural monopoly is privatized and the consumers of the product will underwrite the required revenues which are set by the winner of the bid[24][25].

Hybrid Regulation

While the previous section described the three possibilities, a forth option is also possible, as technology or market specific costs need to be accounted for to optimize the regulation of a natural monopoly[15], therefore there is not a one-size fits all regulation.

Hybrid regulation is therefore a combination of the previously discussed regulations and therefore a wide variety of options are possible. This will also be illustrated by the case studies which will be described in this article.

Regulation in practice

As previously stated, within the EU three categories of governance models are currently applied, all distinguishing in the allocation of responsibilities within the development of the GCS.

A typical GCS consists of the following high level components: (1) an onshore substation, (2) an offshore substation and (3) the cables between the onshore and offshore substation, as shown in figure 3.

While it would also be useful to compare the OFTO-model and the TSO-model with the value for money which is achieved by the generator-model, disaggregated data to perform a comparative analysis of the cash flows presented to the consumer is not available. In general, as also presented by Weißensteiner et. al [9], financing costs of the OWF-developer are significantly higher than that of a TSO. Additionally, with regards to the grid connection costs of OWF's in the Netherlands, a quantitative analysis has shown that the TSO is better positioned to deliver the grid connection of OWF's [26]. The generator model will consequently be dismissed within this research, provided the findings of previous research, that conclude that the generator model has higher financing costs [9] [26].
Furthermore, to provide an answer to the research question, it is useful to provide a detailed description of both the TSO-model and the OFTO-model. This detailed description will clarify the key input parameters which will be used to determine the NPV through the cash flow analysis of the two governance models.

Dutch TSO-model

In the TSO model, the national TSO has the overall responsibility of the grid connection system used to evacuate the offshore wind energy within the country's Economic Exclusive Zone. Essentially the onshore grid connection responsibility (third party access) is extended to the offshore territory [27]. Through this extended responsibility, an offshore connection point is developed to facilitate the offshore generator to evacuate the produced electricity to the onshore load centres. The allocation of the grid connection system implicates that the domestic TSO will plan, built and operate & maintain the grid connection system, while also incurring the associated investment and operating costs. The TSO is then allowed to recover its costs through the regulated revenues.

Additionally, the onshore system operating responsibilities are similarly extended onto the offshore GCS. Thereby having the responsibility to decide whether the GCS, and thereby the OWF, is on or offline.

With regards to the revenue stream, the Dutch regulator uses a combination of ROR regulation and

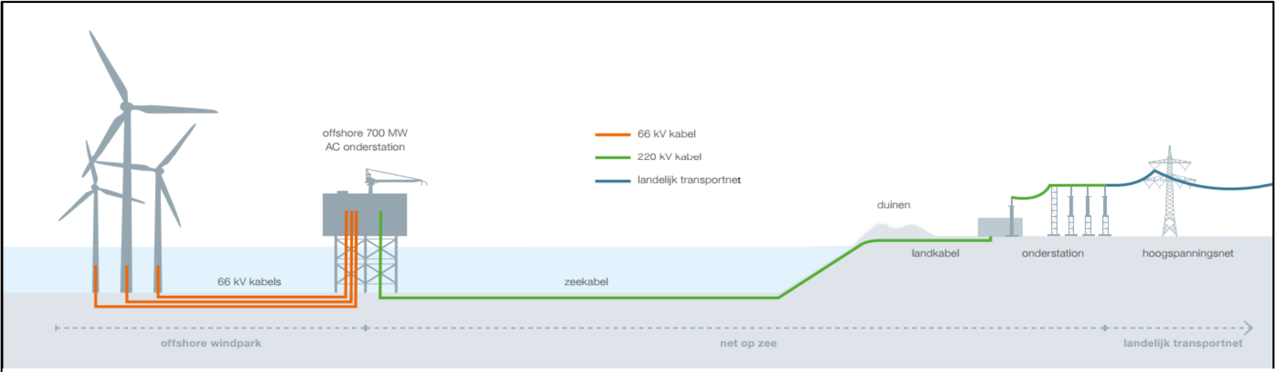

Figure 3: Typical radial OWF connection

incentive regulation to determine the regulated revenue stream.

In order to determine the regulated revenue stream for a specific offshore transmission investment, the regulator determines the efficient costs of the capital investment which can then be included in the regulated asset base of the TSO, which is known as the regulated asset base (RAB) approach[15][28]. Ultimately, these revenues are underwritten by consumers. In the Netherlands policy makers opted to relief large consumers from these costs, thus making small and medium consumers responsible to pay for the allowed revenues of the TSO. The annual revenues of the TSO of a single GCS can be approximated based on the following parameters:

- **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.

- **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[29].

- **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[29]. For the period 2017 -2021, the WACC for the Dutch offshore grid is estimated at 3,0%[30]. The WACC is determined through incentive regulation (benchmarking)

- **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 regulated asset value[29]. The OPEX are determine through incentive regulation (revenue cap).

UK OFTO- model

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 [31]. The OFTO-model is a governance model that is characterized by the grid connection system to be either bought or built by the offshore transmission owner following a competitive tender which selects the offshore transmission owner based on the annual revenue it requires to buy/build and operate[31] [32][33]. In the UK, the OWF developer ultimately decides whether the OFTO buys or builds the GCS [33].

Currently, all projects to date are realized under the generator-build option. In this option the OWF developer plans and constructs the offshore transmission assets. When the OWF and the offshore transmission system are commissioned, the offshore transmission assets are transferred to the OFTO[34]. The OFTO is determined through a competitive tender, in which the bidder who bids the lowest required Tendered Revenue Stream (TRS) acquires the rights to buy the offshore transmission assets for a predetermined Final Transfer Value (FTV). This FTV is determined by Ofgem through an assessment of which costs are regarded as efficient. In return for buying the offshore transmission assets, the OFTO is guaranteed the TRS which it bid in the competitive tender. This TRS is effectively a “fixed” annual revenue stream for 20 years, after which the OFTO license expires. Ultimately, the TRS is underwritten by the consumers, as the TRS is paid by the consumer through the tariffs collected upon by National Grid, which is the national electricity TSO in the UK. By underwriting the TRS, the OFTO is secured of having a stable revenue stream throughout the lifetime of the offshore transmission assets.

Furthermore, the OFTO's annual revenue is depending on the performance of the OFTO as it is incentivized to deliver a certain availability of the transport capacity throughout the year. These incentives consist of a bonus on the base level annual revenue when it outperforms the target availability and malus when the OFTO underperforms the target availability.

By combining the TRS system with ex-ante competition for the field, Ofgem essentially implemented a hybrid regulation by combining incentive regulation with franchise bidding.

4. Model & Data

In order answer the research question, a comparative analysis needs to be performed between the UK OFTO-model model and the Dutch TSO-model. As already mentioned in the method section, a cash flow analysis is performed. The cash flow model will calculate the Net Present Value (NPV) of the cash flows (figure 4). The cash flows will depend on the regulated revenues in the TSO model and the required annual revenue stream in the UK OFTO-model.

While a normal CBA analyses both Costs and Benefits in time to calculate the NPV, the quantitative analysis within this research calculates the NPV of the costs that are presented to consumers.

This quantitative analysis assumes that the GCS is already built, moreover, the description of the case studies provided the information that in both governance models the allowed revenues are ultimately underwritten by consumers. Provided these assumptions, by analysing the cash flows, a NPV of the costs for consumers can be determined, thereby analysing the value for money of the two distinct governance models.

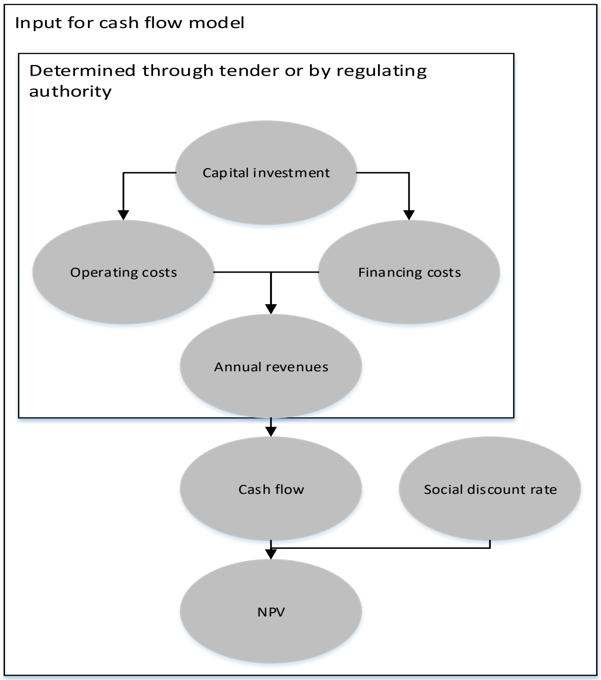

Figure 4: NPV input

In order to calculate the NPV, as shown in figure 4, the model uses input data from both the designated UK regulatory authority (Ofgem) and the Dutch regulatory authority (ACM). Table 1 shows the data which is used in the cash flow model. In which the FTV is decided upon by Ofgem and the TRS is the ultimate value of the winning 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.

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

Table 1: FTV and TRS values per case

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.

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 ministry [35]

With regards to the Dutch counterfactual cash flows, using the RAB principle, the investment costs are derived from approved capital 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 to 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:

$$Regulated\ Revenue_t = \frac{RAV_t}{DT} + RAV_t * WACC + \mathrm{OPEX}$$

With:

RAV: the final transfer value (FTV) 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, whereby a comparative analysis is performed for the 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:

$$NPV\ delta = NPV_{UK} - NPV_{NL} \qquad (3)$$

5. Results

The final results of the comparative analysis is shown in table xxx. Provided equation (3), 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

Table 2: NPV delta per case

Moreover, the results of the comparative cash flow analysis shows that there are four cases (highlighted in Table 2) which show that the OFTO-model presents more value for money.

Overall, by looking at the cumulative NPV delta, a projected cost saving of £184 million could have been achieved if the Dutch TSO-model (with its distinct regulated parameters) would have been applied on the offshore transmission assets, which have a cumulative asset value of £2,53 billion.

6. Discussion

Possible explanations of the results

While the overall projected cost savings, based on the cumulative asset value of £2,53 billion, suggests that the TSO-model would provide cost savings for the consumers, it is not necessarily true that in any given offshore transmission case the TSO model would provide these 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. In this light, several aspects could change the outcome of the results which were presented in the previous sub-chapter.

In general the results show that a TSO model would provide a lower NPV of the costs which are presented to the consumers. A possible explanation for these result is the effectiveness of incentive regulation, as both OPEX and cost of capital are determined through incentive regulation by the applicable NRA. Furthermore, the lacking transaction costs, associated with setting up competitive tenders in the UK OFTO model, can add to the cost effectiveness of the regulated TSO model. This would subsequently explain the four cases in which the UK OFTO model is more beneficial than the Dutch TSO model, as the relative share of the transaction costs decreases, thereby increasing the cost effectiveness in relative terms.

Furthermore, the results show that a trend can be discovered in the results: the larger the FTV the more beneficial the UK OFTO regime becomes. This trend can be explained by the possibility that institutional investors are more willing to participate in larger investments, thus increasing the competition for the market and increasing the value for money of the UK OFTO governance model.

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 A) 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 [31], 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.

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 [35]. Sensitivity analysis (Appendix A) shows that the cumulative value for money is sensitive to adjustments. However, similar to the results of chapter 5, 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 [36], 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.

7. Conclusions

The primary conclusion of this analysis is that the Dutch NRA is able to simulate a competitive market, regarding the financial parameters and operating expenditures for an offshore grid connection.

By aggregating all of the results, 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 four of the analysed cases.

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 separating these two interfaces, a quantitative comparison between the two governance models can be made by looking at the cash flows of the different models for specific cases.

Regarding the capital expenditures, the NPV analysis cannot provide any relevant conclusions 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.

Appendix A

Sensitivity 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, which are the results presented in chapter 5 (table 3).

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

Table 3: Base case results

Within the sensitivity analysis, the input parameters are adjusted according to the figures shown in table 4. 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%

Table 4: 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

Table 5: WACC sensitivity

The sensitivity analysis shows that the cumulative value when using the adjusted input parameters is calculated to be between £116-253 million (table 5). 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 [35]. 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

Table 6: 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 table 6). 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.

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