International Journal of Sustainable Energy Planning and Management Vol. 25 2020 33–44

International Journal of
Sustainable Energy Planning and Management

Investing in Meshed Offshore Grids in the Baltic Sea: Catching up with the Regulatory Gap

Bergaentzlé, Claire-Marie'[a]*; Pade, Lise-Lotte[a]; Truels Larsen, Lauge[a]

[a] *Technical University of Denmark (DTU), Energy Economics and Regulation. Building 424, Room 117, 2800 Kongens Lyngby, Danmark*

ABSTRACT

The connection of cables from offshore wind parks to interconnection lines is receiving growing attention in Europe. Although important technical breakthroughs are enabling transmission system operators (TSOs) to engage in such hybrid forms of architecture, substantial regulatory challenges are preventing progress.

Anchored in current European legal frameworks and targets, this paper reviews the national framework conditions that treat the development of transmission grids as regulated assets, focusing on the distribution of connection costs, the access grid tariff and the investment incentives faced by TSOs. The paper develops an ideal regulatory framework and compares it to the current regulations in countries around the Baltic Sea in order to assess their suitability for supporting Meshed Offshore Grids (MOGs).

The results of this paper highlight the heterogeneity of national regulatory frameworks and the deviations from our recommendations. It is found that Germany lives up to the recommendations best, followed by Denmark, which suggests they have the regulatory potential to pioneer a MOG project in the Baltic Sea region. This is followed by consideration of two clusters of countries defined by their proximity to the ideal framework, assuming a three-step development of MOGs, and following ever more progressive regulatory adjustments.

Keywords:

Meshed Offshore Grid;
Transmission System Operator;
Regulation;
Offshore Wind Energy;
Baltic Sea;

URL: http://doi.org/10.5278/ijsepm.3372

1. Introduction

Offshore Wind (OW) energy is expected to play a central role in decarbonising future energy systems. 25 GW of cumulated OW capacity will be connected to European grids by 2020 [1], [2], supported by technological improvements and cost reductions in manufacturing wind turbines [3]. In the Baltic Sea, simulations show that total installed OW capacity will be multiplied nine-fold between 2016 and 2030 [2] in response to favourable wind energy conditions, shallow waters, low tides and wave height. With respect to the European transmission grid, overall investment costs are expected to reach EUR 125-140 billion by 2030 and up to 420 billion by 2050 if European decarbonisation targets are to be met [4].

Advanced infrastructure solutions using the complementarity between subsea interconnectors and offshore wind farms (OWF), such as Meshed Offshore Grids (MOGs), have been examined to address the investment challenge in a context of decarbonisation. A MOG is a hybrid infrastructure combining OW farms connected to the transmission system with cross-border interconnections, as opposed to radial connection to a single country's market and interconnectors.

The main argument in favour of MOGs is that they increase the value of both the interconnector and the

*Corresponding author - e-mail: clberg@dtu.dk

wind park, benefiting from the synergies from the dual-purpose infrastructure. MOG architecture reduces OW park connection costs significantly and improves grid utilisation rates. Connection costs in a radial connection line account for between 10% and 30% of the total project cost, depending on distance to the shore, and are only in use 40% of the time, which corresponds to the average load factor of OW energy [5], [6]. In the Kriegers Flak project, which connects several OWFs to an interconnector linking Denmark, Germany and initially Sweden, the feasibility study showed that this combined solution increases cable use from 36% up to 79% [7]. The latest pre-feasibility study for integrated offshore grids in the Baltic Sea also stresses the great economic potential of hybrid solutions in a context of high offshore wind development [8]. Recent innovations in HVDC technologies also support hybrid architecture [9]. Ultimately, social dynamics provide an additional driver for MOG as current acceptability issues push OW projects further away from shore [2].

In spite of these benefits, the development of hybrid forms of architecture is still being significantly undermined by regulatory barriers. It is therefore critical to identify these barriers and lift them prior to engaging in future development [10]. The objective of this paper is to assess qualitatively the gap between current regulation and MOG-friendly regulation in the Baltic Sea Region (BSR) countries of Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden. While past studies have reviewed the perception of risks or the supportive regulatory set ups for wind developers [12]–[16], or the regulatory barriers to system operation or the administrative and legal processes associated with hybrid networks or offshore wind farms [17]–[22], this study focuses on the regulatory framework affecting investments in MOG for TSOs.

In the North Sea context, [23] estimate that the cost allocation of the new infrastructure involves a critical risk for project development. The first large scale project investigating new regulatory frameworks for hybrid offshore infrastructure in Europe, NSCOGI, identified the main incompatibilities in regulatory frameworks [20], [24]. They include misalignments in the distribution of roles and responsibilities among the different actors and the coexistence of different technical rules affecting project coordination in the planning, financing and construction phases. The financing and the construction phase are particularly affected by the set of rules that frame the regulated recovery of grid expenses across countries and the potentially uneven financial risks faced by the TSOs involved in a joint project.

Building on past research, this study identifies three key regulatory factors that affect joint investment in network infrastructure in a MOG context, namely the connection cost distribution, the generation grid tariff and the investment incentives for grid development. In anchoring our analysis into current European targets for competitive and sustainable energy systems, this study qualitatively reviews the regulatory factors to define good practices. The good practices constitute an ideal framework that the regulatory set-up existing in the countries of the BSR is compared to. The outcome of the study provides indications on how to adjust current regulation and draws a stepwise approach to future MOG in the Baltic Sea using a policy and regulatory viewpoint.

This paper advocates using a super shallow methodology in the construction of the offshore infrastructure and argues for a grid access charge that only reflects the operating costs derived from the generator's use of system (energy charge). Regarding the investment incentives, a MOG-friendly incentive package should at least address investment incentives for innovation and R&D specifically. Thus, encouraging innovative CAPEX while also incentivising least-cost spending on controllable investment projects, and coupling the TSO's profit to the expected MOG benefits.

Section 2 describes the regulatory framework conditions that support regional investment in MOGs. Section 3 sets out an ideal regulatory framework and compares it to existing regulations in the BSR in order to assess the extent to which country regulations support MOG development. Section 4 discusses the policy implications of our findings, and Section 5 offers conclusions.

2. Key regulatory barriers

Current regulatory set ups are not meant to provide the TSOs incentives to invest in MOGs [25]. Far from claiming that the regulatory challenges are the only factors hampering MOG, this lack of adapted framework contributes to slowing down the path of development. To obtain a more accurate picture, other criteria such as the business potential for OW investment have to be included too. In a recent feasibility study assessing the costs and benefits for two distinct cases of MOG in the BSR [21], shows that the economic benefits of this solution outperform the total cost of a traditional infrastructure scenario if sufficient generation capacity is connected. This optimization study assumes no regulatory barriers hamper the project and indicates the higher end of the benefit potentials that can be unlocked when a MOG-friendly regulation applies in the given wind development conditions.

Taking its point of departure in a number of existing studies [20], [23], [26]–[28], this paper pinpoints three key aspects of the regulation that constitutes critical barriers to MOG development.

- **Distribution of connection costs**;
- **Grid access charges**;
- **The set of incentive instruments for recovering grid costs.** While the incentive instruments have been studied within the context of the developing European electricity market [29], this paper argues that a similar approach can be used in the case of MOGs.

2.1. Distribution of connection costs

MOGs combine cross-border interconnectors, which are paid for by TSOs pursuant to Directive 2009/72/EC, with connection infrastructure, where the rules for cost distributions between TSOs and OW developers are specific to each country. In the case of renewables, and in particular OW, these costs are significantly higher than those for connecting traditional power plants because of their resource-dependency [31]. Accordingly, the rules that apply regarding how connection costs are distributed between TSO and OW developer will directly affect the commercial viability of OW projects.

The methodology for sharing the costs of a new connection line distinguishes three broad approaches: super-shallow, shallow or deep. The full responsibility for bearing the expansion and reinforcement costs goes from the TSO in the supper-shallow case to the wind developer in the deep case and is shared in the shallow case.

The shallow and deep approaches give a locational signal in linking the connection costs to the physical expansion of the network. These approaches drive cost efficiencies from a system-planning perspective, but they also create significant system access difficulties for resource-dependent power plants [32], potentially resulting in a trade-off between the least-cost location in terms of network development and the optimal location in terms of wind conditions.

From a pure market perspective, the OW developers should pay for the extra costs they incur to the transmission system. Accordingly, a shallow method should apply where the system is not stressed, while a deep approach should be used at congested nodes [33]. From a more practical perspective, the investment risks associated with the connection costs create a strong disincentive for project developers to invest, questioning the relevance of the pure market-based approach in a context of transition [34].

Besides, deep and shallow approaches raise several concerns in hybrid architecture involving interconnectors [35]. The deep approach adds a layer of complexity across countries, raising an issue with the requirements for transparency set out in the RES Directive [36]. This approach is also inconsistent with Electricity Market Regulation (EC) No. 714/2009 [38] specifying TSOs as the only responsible entity for investments in cross-border interconnections, and further emphasising the importance of the legal definition given to the hybrid infrastructure. In the case of shallow cost sharing, the legal question to address is where the interconnection and the OWF connection cable start and terminate, which is likely to give rise to differences in interpretation and to dampen the completion of hybrid projects. The connection methodology used in MOGs should be identical regardless of the transmission system's owner in order to avoid discrimination.

2.2. Grid access charges for generators

The European Agency for the Cooperation of Energy Regulators (ACER) identified greater harmonisation of grid access tariff design across national regulations as an additional step towards integrated electricity markets, provided that transmission tariff designs promote economic efficiency [39], [40]. In the case of MOGs, the legal definition of the infrastructure itself and the diversity of the economic signals sent by the national grid access tariffs are two important limitations.

The tariff must comply with non-discriminatory criteria [30] and must take into account the restrictions arising from the legal definition of the grid infrastructure (connection cable and interconnector) in the hybrid architecture. According to Regulation 714/2009 and Commission Regulation (EU) No. 838/2010 [41], applying an access fee to a European interconnector is contrary to the law. The access tariff for OW parks in a MOG is therefore limited to the connection to the interconnector through a connection cable.

Since each utility presents different regulated asset bases, depreciation rates and grid development plans, implementing a common fixed charge is poorly relevant. Harmonisation should consequently be sought on the tariff design rather than the tariff level. The grid access tariff is made to recoup the investment (capital) costs and the utilisation (operating) costs of the grid infrastructure. It is usually represented as a two-part tariff, including a fixed charge and an energy charge that is paid as a function of the energy consumed or produced. It is set by the National Regulatory Agencies (NRAs) and varies between the different European countries [42], [43], resulting in as many different signals [44] that impact on OW investors' perceptions of risk and profit [45] . At the MOG, this situation may influence location choice based on whose TSO offers the most advantageous grid use conditions. Ultimately, un-harmonised tariff designs in a MOG may discriminate against some operators and, even more so, differentiate grid utilisation between the different users.

Regulation (EU) No. 838/2010 [41] took the first step towards a convergence in tariff designs, since it sets a cap on the energy component within the tariff of between 0 and 0.5 EUR/MWh, approximating to the real value of the operating costs l. However, many disparities across countries remain, for example, regarding whom the tariff should apply to: the consumers only, or both consumers and producers? The tariff designs also differ widely. While some countries use only an energy-based cost component to cover the grid costs (Denmark), others use multi-part tariffs combining the energy component with capacity-based cost components (Belgium, France) or send locational (congestion) signals (Sweden).

2.3. Investment incentives

As pointed out in the promotion project, 'A meshed offshore grid will be achieved by the joint investment in transmission lines, as is the case for interconnectors nowadays' [28].

Investments in electricity networks are made by TSOs in response to binding legal obligations (e.g. to achieve interconnection targets or connect renewable energies) and to a set of regulatory incentives. The incentives consist of instruments and mechanisms that constitute the regulatory package used by NRAs to review and monitor the TSO's expenses and to incentivise good practices. A MOG-friendly incentive instrument package should be designed taking the characteristics of such investments into account, which can be summarised as being:

- Capital-intensive: covering the investment risk should be prioritised while keeping overall expenditure low;
- Innovative: limited information will be available to both parties;
- Capable of unlocking large efficiency gains at the system level (eg. reduced back-up, limited price volatility, accelerate CO_2 reductions etc.).

Cost plus regulation is the basis of rate-making. This regime allows the expenses registered in the regulated asset base (RAB) to be fully covered by the tariff while granting the operator a 'fair' rate of return (RoR) as profit [46]. The main characteristic of this regime is that it secures revenue adequacy while being criticised for its over-investment effect [47].

Current regulatory regimes were developed in response to over-capacity in infrastructure, their main objective being to achieve efficiency gains. The main incentive instruments they introduce, namely price and revenue caps and performance-based regulation (PBR), have been aimed primarily at limiting moral hazard and increasing productive efficiency and quality of service while attempting to enhance allocative efficiency in introducing rent-sharing mechanisms [46]–[53]. The combination of these instruments is theoretically appropriate for driving costs down and maintaining a high quality of service. However, the practical implementations of the incentive package may deviate from effectively bringing costs down, especially the capital costs, and from supporting innovative solutions, making it poorly suited to triggering MOG investments as developed hereinafter.

Empirically it can be observed that the incentive instrument (also known as the efficiency or X-factor) usually only applies to the controllable operation expenditures (OPEX), leaving the capital expenditures (CAPEX) out of the incentive mechanism. The CAPEX continue to be regulated following a cost-plus scheme and continue to generate profit. This has three main implications. The financial risk associated with capital investment is minimised, which supports large investments, including in MOGs. Nevertheless, without any specific driver to appropriately reward the extra risk incurred by new technical and organisational solutions, the TSOs will tend to favour business as usual investments. For example, the higher financial risk associated with CAPEX in MOG is due to the project's novelty and the limited information leading to a higher risk of cost overruns and inaccurate *ex-ante* cost estimates. Besides, leaving all CAPEX, including the routine expansion and reinforcement activities out of the incentive mechanism in a context of a network investment boom is likely to result in a substantial rise in the tariff paid by the rate-payers. The simple socialisation of CAPEX should accordingly be completed by introducing additional incentive mechanisms directed at both limiting the uncontrolled rise of spending, and supporting innovative investment choices in distinguishing between controllable and non-controllable CAPEX and using different RoRs [54], [55]. The financial risk should be reflected in the remuneration of these specific assets using a specific reward (e.g. increased Weighted Average Capital Cost (WACC) or premium) without resulting in an increase in other categories of CAPEX that are deemed controllable.

As regulated firms, network operators may have little incentive to conduct R&D activities, and empirical studies show a decline in research spending since the unbundling reforms [56], [57]. As with CAPEX, R&D costs should be authorised and targeted [58].

The PBR instruments that apply to OPEX target short-term reliability targets such as the reduction of outages and only capture the benefits expected from MOGs to a limited extent. Developing new performance-based indicators [59] that couple profit-making to MOG benefits would encourage investments in meshed architecture. In California, for example, incentive mechanisms were developed to support investments in smart grids and demand flexibility [60]. Similar performance-based indicators could be constructed to associate MOG benefits with TSOs' profits.

3. The ideal regulatory framework and the Baltic Sea countries

This section compares the current regulations of the Baltic Sea countries with the ideal framework and identifies regulatory gaps.

3.1. Criteria for evaluation

A regulatory framework is considered a driver to MOG when it facilitates the deployment of decarbonized energy sources in internalizing the investment risks associated with their resource-dependency nature, while limiting market distortions in the region across technologies and actors. Especially, a supportive set of rules must be established in accordance with the European legal framework, should give the right incentive to develop future decarbonised networks and be non-discriminatory. It should also be easily implementable without requiring heavy bureaucratic adjustments from the NRAs. Accordingly, the super-shallow approach is preferred, since it avoids the risks and complexities associated with the legal definition of the assets, and because of its lower financial risks from the OW development perspective. OW-friendly tariff designs for all generators regardless of their point of connection should apply an energy component only, complying with European requirements set forth in [41]. The generators would thereby pay for their own grid utilisation costs. Locational signals should be avoided in the tariff to avoid locational distortions, and the remaining fixed costs should be entirely socialised to the end-users. Finally, a MOG-friendly incentive package should at least address investment incentives for innovation and R&D, thus encouraging innovative CAPEX while also incentivising least-cost spending on controllable investment projects, and coupling the TSO's profit to the expected MOG benefits.

3.2. Empirical analysis

Most Baltic Sea countries, including all the Baltic States and Sweden, use a deep methodology for radial connection where the OW developer pays all the **connection and reinforcement costs** [61]. Sweden is currently developing an agreement to shift all or part of the connection costs from the OW developers to the Swedish TSO, but the final framework is still under discussion [62]. Poland and Finland use a shallow approach. Currently the export cable from the OWF to the grid connection node is not considered a transmission system in Poland and the OW developer is responsible for this part. Current the division of responsibility is such that the investor builds the export cable including a substation if needed, the export infrastructure is connected to a grid connection point owned by the TSO. If necessary, the onshore grid and the grid connection station are reinforced by the TSO. In Finland, the OW developer bears the costs for the construction of its own power cable and any additional structures needed to enable the connection to the network. If another connection is constructed to the same switchyard during the following ten years, the connection fee paid by the wind power developer is partly reimbursed. The shallow approach also applies in Denmark for open-door procedures and near-shore projects. Only in the Kriegers Flak and Horns Rev 3 projects (tendered projects), a super-shallow approach is used where Energinet.dk bears the costs of grid connection to the offshore connection point. The super-shallow approach is also used by the two German TSOs having access to the coastline (Tennet and 50Hertz). The German regulatory framework (Energiewende) is particularly favourable to the development of wind energy since it provides that in the context of tendering, the OW developer receives compensation when no connection is available at the time of commissioning. Given the legal obligations, TSOs have demanded a framework (laid out in the O-NEP and the Bundesfachplan Offshore) for long-term OW planning and connection that facilitates their connection activities and mitigate the potential excess cost due to low coordination.

Grid access tariffs for generators in the BSR only apply in the three Scandinavian countries [43]. In the other countries, producers do not pay for using the grid. Different signals therefore apply between the group of countries using a tariff and the others, and different signals also apply between the Scandinavian countries, since they all use different tariff levels (relative share paid by the consumer and the generators) and tariff designs (Table 1). As for the tariff level, the relative share of the cost of network access paid by the Danish producers amount to 3% (against 97% paid by the end-users). In Finland and Sweden, this distribution is 19% and 36%, respectively paid by the producers and the rest socialized to the consumers. The tariff design in Denmark is entirely based on an energy component. For each unit of energy fed into the network, the producers pay a fixed fee to the TSO. In Finland and Sweden a capacity charge also applies. Finland has a point-of-connection approach, but price signals are not locational and only account for seasonal changes. In Sweden, the capacity charge is dominant and is complemented with a locational component that supports connections to the least stressed networks. For feed-ins, charges are higher in the northernmost location, whereas for consumption the converse applies: that is, the charges are the highest in the southernmost part of the country. In addition, all the Scandinavian countries receive exemptions from Regulation (EU) No. 838/2010 [41] (see 2.2) and can apply an energy charge of up to 1.2 EUR/MWh.

Finally, all eight countries in this study use different **incentive packages**. Estonia and Poland use a cost-plus regulation in which all authorised Total (OPEX+CAPEX) Expenditures (TOTEX), including those for research, are passed through in the tariffs, no cost-efficiency requirement applies to the CAPEX, and no separate treatment applies to the different items of expenditure. Performance instruments are absent from the Estonian regulation, while the Polish regulator decided to remove its performance targets in 2017.

Latvia and Finland both also authorise the passing through of CAPEX in the tariffs and use a hybrid regulation aimed at supporting capital investments and the modernisation of specific quality-related assets respectively. The Latvian regulator linked the TSO's revenue to a financial penalty of 10% from the previous year's net turnover if the latter fails to match grid development forecasts, especially concerning new connections. Latvia also uses a set of performance incentives directed at reducing interruptions of supply [63]. The Finnish regulation incentivises improvements in quality of service in using a 0% X-factor applying to OPEX (thereby removing the incentive for cost reductions) and in

Table 1: TSO tariff characteristics in the BSR

	Sharing of network operator charges			Tariff structure (%)	
	producer	consumer	Locational signal	capacity	energy
Denmark	3%	97%	no	0	100
Estonia	0%	100%	n/r	n/r	n/r
Finland	19%	81%	no	7	93
Germany	0%	100%	no	n/r	n/r
Latvia	0%	100%	n/r	n/r	n/r
Lithuania	0%	100%	n/r	n/r	n/r
Poland	0%	100%	n/r	n/r	n/r
Sweden	36%	64%	yes	74	26

Source: [43]. Note: the split between the energy and capacity cost components reflects a base case computed by Entso-e for purposes of comparison. n/r = not relevant

Table 2: Country overview of framework conditions

Regulatory framework condition	Good practices	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Sweden
Connection cost methodology	Super shallow cost recovery	+	–	o	+	–	–	o	–
Grid access tariff	Energy-based tariff / no access fee for producers	+	+	o	+	+	+	+	–
	Full recovery of R&D costs	+	+	+	+	+	+	+	+
	Clear R&D incentive	–	–	+	+	–	–	–	–
MOG-friendly investment incentive	Limits the financial risk on CAPEX	+	+	+	+	+	+	+	+
	Specifically supports CAPEX	–	–	o	+	+	+	–	–
	Limits CAPEX overspending	o	–	–	+	–	–	–	–
	Incentive on OPEX/PBR	–	–	o	o	o	o	–	o

authorising the continuation of depreciation for the early replacement of strategic assets for quality. Finland also uses a dedicated innovation incentive granting up to 1% of the total annual turnover in R&D activities, encompassing new technologies, knowledge or operating methods [63].

Sweden and Lithuania fully cover all CAPEX and use an incentive regulation with a 1% X-factor on controllable OPEX.[1] In both countries financial incentives are used to improve the quality of delivery. Lithuania in particular significantly increased its capital spending (+67% between 2013 and 2014 [64]), while the NRA supports future investments for grid expansion, reconstruction and reinforcement [65].

Denmark uses a cost-plus regulation on its TOTEX and applies a return on capital based on the inflation rate [54], meaning that the TSO's profit is not coupled to its regulated asset base, and leaving market conditions to drive the TSO's investment choices. The authorised TOTEX are entirely passed through in the tariff without explicit regulation of the quality of supply, nor any specific cost-efficiency or performance requirements [63]. Research, demonstration and development activities are currently funded through the network Public Service Obligation (PSO) charge. However, the PSO is expected to be fully phased out by 2022 and to be replaced by tax-based funding. It is unclear how this change will affect the TSOs' activities.

Finally, Germany uses a revenue cap regulation in which the efficiency incentive applies to all controllable TOTEX. Germany therefore applies a distinction between controllable and non-controllable CAPEX, the latter being considered strategic to the Energiewende (e.g. cost for interconnection, for renewables plant connection and R&D) and being entirely passed on through the tariff. The TSOs' eligible expenses must comply with several efficiency factors to receive a full return on equity. A common X-factor applies to the controllable TOTEX regardless of the operator, and an individual efficiency requirement set by international efficiency benchmarking tailors the efficiency objectives at each TSO level. Short-term quality performance objectives complete the mechanism.

Table 2 summarises our ideal regulatory framework and shows the results of the different country benchmarks. (+) indicates that the regulatory framework in a country is in line with our recommendations. (o) indicates that the regulatory framework needs to be slightly improved. Finally (-) indicates that the regulatory framework is a barrier to investing in MOGs.

The above comparison stresses the heterogeneity of the framework conditions among the Baltic Sea countries and shows that some countries are closer than others to having a MOG-friendly regulatory set-up.

[1] Lithuania uses a special hybrid incentive cap scheme with a 50/50 price/revenue cap.

4. Discussion

It is important to note that, because the different measures are not ranked, the discussion is limited to how far or close the Baltic Sea countries are to having a consistent, pro-MOG regulation.

Currently, only Germany lives up to the recommendations in this paper. German's regulatory framework offers low risk for OW developers, minimizes market distortions, and supports location choices based on wind conditions, rather than least cost for the system. Looking at the grid connection and tariff only, Denmark also has suitable regulatory arrangements for connection and access fees. Efforts should therefore concentrate on implementing specific regulatory drivers to incentivise hybrid investments as developed hereafter. The connection and grid access conditions that apply in the rest of the BSR suggest that Poland and Finland need only minor adjustments to prioritise changes in their respective connection cost allocation methods, whereas the remaining countries, Sweden, Lithuania, Latvia and Estonia, are lagging behind and will need to take greater steps to create homogeneous connection signals supporting MOGs.

Alignment in connection frameworks will require strong ex-ante coordination mechanisms to be laid down at the regional level to offset the potential impact of the super-shallow approach on system costs. One possible way of addressing this is to set up a regional task force involving all relevant stakeholders: the NRAs, maritime spatial planners, TSOs and representatives of the wind sector with the role of identifying and selecting future OW park locations, network corridors and hubs based on available maritime lands, wind conditions and economics parameters for off- and onshore network investments.

The significant differences in different countries' grid access tariffs suggest discrepancies among the TSOs, as well as a failure to create a level playing field at the regional level. This conclusion is not only valid in the BSR but also extends to all European countries.

Regarding the investment incentive package set out in the TSOs' cost recovery framework, the incentives for R&D spending and CAPEX are secured in all the countries, the main differences arising from specific drivers and, more rarely, from over-investment brakes on CAPEX. Most countries dedicate a certain budget to R&D activities, fixed as a certain level of the TSO's turnover (usually 0.5%% to 1%). Only Germany and Finland apply a regulation that actively supports R&D. Germany, Lithuania and Latvia specifically support CAPEX, as they encourage grid expansions for interconnection and renewable energy sources connection. This situation also hides differences in how the expenditure items are treated and socialised. Finally, the regulatory schemes associated with OPEX, if any, are limited to duration and frequency interruption indicators and would require new indicators to be elaborated.

During the planning, development and operational phases, the transparent dissemination of good practices will be particularly critical in reducing information asymmetry for NRAs and supporting successful projects. Appropriate platforms should be introduced to share information in a transparent, reliable and unambiguous way. Pooling key competences and sharing expertise would also alleviate NRAs' differences in terms of their respective human and financial resources. This would also support the compilation of harmonised data sets across countries, upon which new performance indicators adapted to MOG can be designed.

Other approaches to improving regional cooperation include increasing centralisation, for example, through the implementation of a regional Independent System Operator (ISO) [6] or a supra-national TSO [66], as well as setting up a strong European regulatory body [67]. The centralised option also has the advantage of limiting the prevalence of national interests in network expansion and is likely to assess competing alternatives more objectively. However, it also questions the notion of countries' sovereignty. In either case, the alignment of regulatory frameworks assumes a strong commitment by NRAs, and beyond that by policy-makers, to use a regional scope that can potentially conflict with national interests [68], raising new questions regarding the binding power of European regulatory frameworks.

5. Conclusions and policy recommendations

This study has aimed to highlight the existence of regulatory barriers and to provide initial policy recommendations for how to bridge the gap between existing regulations and the regulatory framework that best supports the development of MOGs in the Baltic Sea.

The ideal framework developed based on the qualitative analysis performed on the key regulatory frameworks affecting network investment, namely offshore wind connection, grid tariff design and transmission network incentive instruments were compared to the existing regulation in the countries of the BSR. This comparison allowed us to identify the regulatory gaps between the best theoretical practices and empirical observations and to make policy recommendations.

Departing from the assumption that OW promotion is consistent with achieving European targets and the Paris Agreement, and using a transmission grid development perspective, the recommendations in this paper stipulate a line of action combining i) least financial risk for OW developers with respect to network infrastructure, and ii) a high degree of coordination in the methodologies used to set the distribution of connection costs, access grid tariff designs and investment incentives for the TSOs.

Using a single set of approaches for infrastructure cost allocations and grid designs on the meshed grid scale and beyond, at the level of a whole country's territory, seems unavoidable in supporting unbiased development. Eventually, a coordinated set of investment incentives adapted to hybrid projects will lead to optimal techno-economic choices and to cost-cutting. High-level coordination on the regional scale, facilitated by European jurisdiction, is advocated to initiate convergence in the regulatory framework conditions of different countries.

The current lack of coordination in deciding the regulatory frameworks for network development between European countries arises from the latter's different energy policies, which are themselves based on the subsidiarity principle set out in the European legal framework. This results in heterogeneous signals that distort investment choices and hinder the creation of a level playing field across countries. Nonetheless this level playing field, which should be constructed upon economically sound signals, is critical to the prospect of efficiently developing and operating shared infrastructure.

The different layers of governance involved in shaping each of the three regulatory framework conditions are also likely to affect future adjustments. The grid access tariff signal is partially shaped by the European Regulation that gives a relatively common basis to all countries and is strongly influenced by political decisions before finally being designed and implemented by the NRAs. The connection methodologies reflect above all the political support given to variable renewable energy before their translation into national grid regulation. Lastly, the incentive instrument package is dominated by NRA decisions taken with limited political interference and with no common framework from the layer of European governance. The harmonisation of incentive instruments is considered the most challenging because of this decentralised degree of governance, and this is likely to require the implementation of transnational coordination platforms. In contrast, the alignment of grid access tariff signals may require the least effort, and the European countries' commitment to the Paris Agreement should further encourage policy-makers to put VRE-friendly connection frameworks on top of the energy policy agenda.

Confronting regulatory good practices with the various regulations in the countries around the Baltic Sea shows how suitable or restrictive current frameworks may be in supporting OW development and investment in MOGs, allowing us to suggest country-specific solutions. The comparison of regulatory frameworks also drives attention to similarities and discrepancies between the observed countries and highlights clusters of countries that share similar regulatory frameworks. Such groupings can be essential to successful hybrid projects, as they provide indications for which set of countries should be targeted first when initiating MOG projects, as well as insights to lay down adapted regulatory pathways for coordinated action. For example, Germany and Denmark have a supportive regulatory framework for MOGs and have rather similar regulatory arrangements, suggesting that the chances of success for a hybrid project are likely to be higher between these two countries, as the Kriegers Flak project already tends to suggest. Assuming that the timings of regulatory adjustments are identical regardless of the regulatory barrier, as the remaining countries Latvia, Lithuania and Finland would enter into a second wave of development at a later stage.

6. Acknowledgements

This article has been written as part of research within the Baltic InteGrid project (registration number: R1.255, project number: #R018), which received funding from the InterReg Baltic Sea Region Programme 2014–2020, part-financed by the European Regional Development Fund. The content of the article reflects the authors' views alone.

The authors also thank the partners from the Baltic InteGrid project for their valuable comments.

References

[1] P. Schwabe, S. Lensink, and M. Hand, "IEA Wind Task 26" *Wind Energy*, pp. 1–122, 2011.

[2] WindEurope, "Offshore wind in Europe: Key trends and statistics 2017". February 2018, 2017.

[3] DEA, "Technology Data for Energy Plants. Danish Energy Agency (DEA). August 2016, latest update June 2017.," 2017.

[4] Commission Expert Group, "Towards a sustainable and integrated Europe - Report of the Commission Expert Group on electricity interconnection targets". November 2017, p. 40, 2017.

[5] C. Obersteiner, T. Faber, G. Resch, H. Auer, and W. Pruggler, "Modelling Least-Cost RES-E Grid Integration under different Regulatory Conditions based on the Simulation Software GreenNet, GreenNet-EU27-project report," 2006.

[6] I. Konstantelos, R. Moreno, and G. Strbac, "Coordination and uncertainty in strategic network investment: Case on the North Seas Grid" *Energy Econ.*, vol. 64, pp. 131–148, 2017. https://doi.org/10.1016/j.eneco.2017.03.022

[7] 50Hertz; Energinet.dk; Svenska Kraftnät, "Kriegers Flak combined grid solution. Joint feasibility study" 24 February 2010, 2010.

[8] M. Wójcik, "Towards a Baltic Offshore Grid: connecting electricity markets through offshore wind farms: PreFeasibility Studies report for Polish-Swedish-Lithuanian and German-Swedish-Danish interconnectors integrated with offshore wind farms" Baltic InteGrid project report, 2018.

[9] T. Houghton, K. R. W. Bell, and M. Doquet, "Offshore transmission for wind: Comparing the economic benefits of different offshore network configurations," *Renew. Energy*, vol. 94, pp. 268–279, Aug. 2016. https://doi.org/10.1016/j.renene.2016.03.038

[10] S. A. Jay and H. M. Toonen, "The power of the offshore (super-) grid in advancing marine regionalization" *Ocean Coast. Manag.*, vol. 117, pp. 32–42, 2015. https://doi.org/10.1016/j.ocecoaman.2015.08.002

[11] J. K. Knudsen *et al.*, "Local perceptions of opportunities for engagement and procedural justice in electricity transmission grid projects in Norway and the UK," *Land use policy*, vol. 48, pp. 299–308, 2015. https://doi.org/10.1016/j.landusepol.2015.04.031

[12] L. Kitzing and C. Weber, "Support mechanisms for renewables: How risk exposure influences investment incentives" *Int. J. Sustain. Energy Plan. Manag.*, vol. 7, pp. 117–134, 2015. https://doi.org/10.5278/ijsepm.2015.7.9

[13] V. Maxwell, K. Sperling, and F. Hvelplund, "Electricity cost effects of expanding wind power and integrating energy sectors," *Int. J. Sustain. Energy Plan. Manag.*, vol. 6, pp. 31–48, 2015. https://doi.org/10.5278/ijsepm.2015.6.4

[14] D. Toke, "Renewable energy auctions and tenders: How good are they?" *Int. J. Sustain. Energy Plan. Manag.*, vol. 8, pp. 43–56, 2015. https://doi.org/10.5278/ijsepm.2015.8.5

[15] P. Varela-Vázquez, M. del C. Sánchez-Carreira, and Ó. Rodil-Marzábal, "A novel systemic approach for analysing offshore wind energy implementation" *J. Clean. Prod.*, vol. 212, pp. 1310–1318, Mar. 2019. https://doi.org/10.1016/j.jclepro.2018.12.079

[16] A. C. Marques, J. A. Fuinhas, and D. S. Pereira, "The dynamics of the short and long-run effects of public policies supporting renewable energy: A comparative study of installed capacity and electricity generation" *Econ. Anal. Policy*, vol. 63, pp. 188–206, Sep. 2019. https://doi.org/10.1016/j.eap.2019.06.004

[17] NSCOGI, "Cost allocation for hybrid infrastructures Deliverable 3 – Final version. The North Seas Countries' Offshore Grid Initiative (NSCOGI). July 2014.," 2014.

[18] European Commission, "Nordic countries demonstrate the potential of low-carbon energy policies Nordic countries demonstrate the potential of low-carbon energy policies," p. 2, 2017.

[19] C. Nieuwenhout, "WP7.1 Deliverable 1 Intermediate report for stakeholder review : Legal framework and legal barriers to an offshore HVDC electricity grid in the North Sea. PROMOTION Project. June 2017.," 2017.

[20] NSCOGI, "Regulatory Benchmark - Final Report Working Group 2. The North Seas Countries' Offshore Grid Initiative (NSCOGI). 13/01/2012," 2012.

[21] P. Ståhl and D. Belltheus Avdic, "Baltic InteGrid: towards a meshed offshore grid in the Baltic Sea. Final report. February 2019," 2019.

[22] A. Papakonstantinou, C. Bergaentzle, and L.-L. Pade, "Regional coordination in grid expansion with offshore wind: the case of the Baltic Sea Region.," *16th IEEE Int. Conf. Eur. Energy Mark.*, 2019.

[23] European Commission, "Study on regulatory matters concerning the development of the North Sea offshore energy potential. PwC; Tractebel Engineering; ECOFYS. Project No: 2016.3011. January, 2016.," 2016.

[24] NSCOGI, "Recommendations for guiding principles for the development of integrated offshore cross border infrastructure - Deliverable 2 - WG 2 – Market and Regulatory issues - Final report. 23/11/2012.," p. 11, 2012.

[25] H. K. Müller, "Can we build it? Yes we can: a legal analysis of how to enable a transnational offshore grid. In: M.M. ROGGENKAMP and C. BANET, eds, European Energy Law Report XI. Cambridge: Intersentia, pp. 145-164.," 2017.

[26] R. Lacal Arántegui and J. Serrano González, "2014 JRC wind status report. Technology, market and economic aspects of wind energy in Europe. Joint Research Centre (JRC), European Commission," p. 92, 2015. 10.2790/97044 (online)

[27] European Commission, "Political Declaration on energy cooperation between the North Seas Countries," p. 7, 2016.

[28] P. Bhagwat *et al.*, "Economic framework for offshore grid planning. WP7 Intermediate Deliverable. PROMOTioN Project – Progress on Meshed HVDC Offshore Transmission Networks. June 2017.," 2017.

[29] J.-M. Glachant, M. Saguan, V. Rious, and S. Douguet, "Incentives for investments: Comparing EU electricity TSO regulatory regimes". European University Institute. Robert Schuman Centre for Advanced Studies. December 2013," pp. 1–110, 2013. https://doi.org/10.2870/80768

[30] Directive 2009/72/EC, "Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, OJ L 211, 14.8.2009, p. 55–93."

[31] L. Weißensteiner, R. Haas, and H. Auer, "Offshore wind power grid connection — The impact of shallow versus super-shallow charging on the cost-effectiveness of public support" *Energy Policy*, vol. 39, no. 8, pp. 4631–4643, 2011. https://doi.org/10.1016/j.enpol.2011.05.006

[32] D. J. Swider *et al.*, "Conditions and costs for renewables electricity grid connection: Examples in Europe" *Renew. Energy*, vol. 33, pp. 1832–1842, 2008. https://doi.org/10.1016/j.renene.2007.11.005

[33] R. Barth, C. Weber, and D. J. Swider, "Distribution of costs induced by the integration of RES-E power" *Energy Policy*, vol. 36, pp. 3107–3115, 2008. https://doi.org/10.1016/j.enpol.2008.03.039

[34] H. Auer, C. Obersteiner, and W. Prüggler, "Comparing Different Cost Allocation Policies for Large-Scale Res-E Grid Integration in Europe" *Int. J. Distrib. Energy Resour.*, vol. 3, no. 1, pp. 7138–7138, 2007.

[35] S. Chatzivasileiadis, "Transmission Investments in Deregulated Electricity Markets". Technical Report. EEH-Power Systems Laboratory, ETH Zurich. May 8, 2012, pp. 1–10, 2012.

[36] Directive 2009/28/EC, "Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, OJ L 140, 5.6.2009, p. 16–62."

[37] Regulation (EC) No 714/2009, "of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003, OJ L 211, 14.8.2009, p. 15–35."

[38] European Commission, *COMMISSION REGULATION (EU) 2017/ 2195 - of 23 November 2017 - establishing a guideline on electricity balancing*, vol. 2017, no. November. 2017, pp. 6–53.

[39] CEPA, "Scoping Towards Potential Harmonisation Of Electricity Transmission Tariff Structures. Final Report. Agency For Cooperation Of Energy Regulators (ACER). August 2015.," 2015.

[40] ACER, "Opinion of the Agency for the Cooperation of energy Regulators No 09/2014 on the appropriate range of transmission charges paid by electricity producers on the appropriate range of transmission charges. ACER, Agency for the Cooperation of energy Regulator," p. 22, 2014.

[41] Commission Regulation (EU) No 838/2010, "of 23 September 2010 on laying down guidelines relating to the inter-transmission system operator compensation mechanism and a common regulatory approach to transmission charging, OJ L 250, 24.9.2010, p. 5–11.," *Off. J. Eur. Union EN L 250/5*.

[42] Eurelectric, "Network tariff structure for smart energy system" no. May, 2013.

[43] Entso-e, "ENTSO-E Overview of transmission tariffs in Europe: Synthesis 2017," 2017.

[44] S. Honkapuro and J. Tuunanen, 'Tariff scheme options for distribution system operators" 2012.

[45] EWEA, "EWEA position paper on network tariffs and grid connection regimes (revisited). European Wind Energy Association (EWEA). March 2016.," 2016.

[46] J. Laffont and J. Tirole, "A theory of incentives in Regulation and Procurement". MIT Press. Cambridge, 1993.

[47] H. Averch and L. L. . J. Johnson, "Behavior of the Firm Under Regulatory Constraint" *Am. Econ. Rev.*, vol. 52, no. 5, pp. 1052–1069, 1962.

[48] T. Jamasb and M. Pollitt, "Benchmarking and regulation: international electricity experience" *Util. Policy*, vol. 9, no. 3, pp. 107–130, 2000. https://doi.org/10.1016/S0957-1787(01)00010-8G

[49] E. Iossa and F. Stroffolini, "Price cap regulation, revenue sharing and information acquisition" *Inf. Econ. Policy*, vol. 17, no. 2, pp. 217–230, Mar. 2005. https://doi.org/10.1016/j.infoecopol.2004.06.001

[50] P. L. Joskow, "Transmission policy in the United States" *Util. Policy*, vol. 13, no. 2, pp. 95–115, Jun. 2005. https://doi.org/10.1016/j.jup.2004.12.005

[51] P. L. Joskow, "Incentive regulation in theory and practice: electricity distribution and transmission networks" Chapter in NBER book Economic Regulation and Its Reform: What Have We Learned? (2014), Nancy L. Rose, editor (p. 291 - 344), 2006.

[52] M. A. Jamison, "Regulation: price cap and revenue cap" *Encyclopedia of Energy Engineering*, vol. 1, no. October. S. Anwar and B. L. Capehart, pp. 1–18, 2007.

[53] A. Ter-Martirosyan and J. Kwoka, "Incentive regulation, service quality, and standards in U.S. electricity distribution,"

J. Regul. Econ., vol. 38, no. 3, pp. 258–273, 2010. https://doi.org/10.1007/s11149-010-9126-z

[54] European Commission, "Study on regulatory incentives for investments in electricity and gas infrastructure projects –Final Report. AF-Mercados EMI , Directorate-General for Energy (European Commission), REF-E," *Eur. Comm.*, pp. 1–126, 2014.

[55] IRG, "Regulatory Accounting Principles calculation February 2007 of Implementation and Practice for WACC Calculation. Public Consultation Summary. IRG/ERG Regulatory Accounting. Independent Regulator Group. February 2007," p. 50, 2007.

[56] T. P. Lyon and H. Huang, "Asymmetric Regulation and Incentives for Innovation" *Ind. Corp. Chang.*, vol. 4, no. 4, pp. 769–776, 1995. https://doi.org/10.1093/icc/4.4.769

[57] T. Jamasb and M. Pollitt, "Liberalisation and R&D in network industries: the case of the electricity industry" *Res. Policy*, vol. 37, no. 6/7, pp. 995–1008, 2008. https://doi.org/10.1016/j.respol.2008.04.010

[58] D. Bauknecht, "Incentive Regulation and Network Innovation". EUI Working Paper RSCAS 2011/02. February 2011, p. 31, 2011.

[59] R. Davis, "Acting on performance-based regulation," *Electr. J.*, vol. 13, no. 4, pp. 13–23, 2000. https://doi.org/10.1016/S1040-6190(00)00109-3

[60] CPUC, "Adopting metrics to measure the smart grid deployments of PG&E, SCE, and SDG&E. California Public Utilities Commission (CPUC). Decision 12-04-025. San Francisco, April 19," 2012.

[61] C. Bergaentzlé *et al.*, "Paving the way to a meshed offshore grid. Recommendations for an efficient policy and regulatory framework". Final report. February 2019, 2019.

[62] Svenska kraftnät, "Ramöverenskommelse mellan Socialdemokraterna, Moderaterna, Miljöpartiet de gröna, Centerpartiet och Kristdemokraterna om energi," pp. 1–7, 2016.

[63] CEER, "CEER Report on Investment Conditions in European Countries. Ref: C15-IRB-28-03. Council of European Energy Regulators (CEER). 14 March 2016," 2016.

[64] NCC, "Annual Report on Electricity and Natural Gas Markets of the Republic of Lithuania to the European Commission". National Commission for Energy Control and Prices (NCC). Vilnius, 2015, p. 98, 2015.

[65] Litgrid, "Development of the Lithuanian Electric Power System and Transmission Grids," 2015.

[66] K. Sunila, C. Bergaentzlé, B. Martin, and A. Ekroos, "A supra-national TSO to enhance offshore wind power development in the Baltic Sea? A legal and regulatory analysis," *Energy Policy*, vol. 128, pp. 775–782, May 2019. https://doi.org/10.1016/j.enpol.2019.01.047

[67] L. Kapff and J. Pelkmans, "Interconnector Investment for a Well-functioning Internal Market What EU regime of regulatory incentives?," *Bruges Eur. Econ. Res. Pap. BEER n° 18*, vol. 18, p. 41, 2010.

[68] H. K. Müller, "A Legal Framework for a Transnational Offshore Grid in the North Sea," in *Energy & Law Series Vol. 16*, Intersentia, 2015, p. 436.