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International Cooperation on the Expansion of Offshore Wind Generation Capacity

Potential Benefits and Pitfalls of Joint Projects from an Institutional Economic Perspective

September 2018

Interreg
Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

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Published by: Baltic InteGrid

www.baltic-integrid.eu

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1. Introduction

Offshore wind power (OWP) is a very promising technology for the decarbonisation of power systems.[1] Although drastic cost reductions have already been achieved over the last few years, the levelised costs of electricity (LCOE) of OWP plants typically still exceed those of onshore wind farms or PV installations at the most suitable locations. However, OWP is at a comparatively early stage of development and large experience curve effects are yet to be realised.[2] Moreover, OWP offers certain advantages over other intermittent RES-E (electricity from renewable energy sources) technologies that are not included in an LCOE comparison: Firstly, OWP plants have more stable production patterns. This is likely to go along with both an increased value of the electricity generated and lower costs for backup capacities. Secondly, the offshore location of OWP plants can help avoid land use conflicts and negative externalities that occur in connection with the expansion of onshore wind and PV capacity. The importance of these issues can be expected to further increase in Europe, as countries with high population densities are moving towards ambitions RES-E targets. For those reasons, OWP can play a main role in future European electricity systems and it seems vital to make use of all options that promise further cost savings.

Two important factors for driving down OWP costs are technological progress and experience gained in the course of building offshore wind farms. Besides that, cost savings could arise from international collaboration. In this research paper we focus on one specific way of cooperation: the joint planning and implementation of OWP projects by two or more national states (hereinafter "joint projects").[3] Such an approach generally allows for choosing the best-suited sites for OWP deployment irrespective of national

[1] This research paper was conceptualised by Albert Hoffrichter and Thorsten Beckers. Albert Hoffrichter, who primarily works as a research associate at Technische Universität Berlin – Workgroup for Infrastructure Policy (TU Berlin – WIP), was writing this working paper as a researcher at the Berlin-based Institute for Climate Protection, Energy and Mobility (IKEM). Thorsten Beckers is a researcher at TU Berlin – WIP and an honorary board member at IKEM. Ralf Ott supported the preparation of the research paper. He is a research associate at TU Berlin – WIP as well and was also working at IKEM at the time when the research paper was developed. The analysis presented in the research paper partly builds on previous research activities within the framework of the project "Effiziente Koordination in einem auf Erneuerbaren Energien basierenden europäischen Elektrizitätsversorgungssystem (EK-E4S)" carried out by TU Berlin – WIP which was funded by the German Federal Ministry for Economic Affairs and Energy (BMWi); Daniel Weber and Alexander Weber delivered substantial contributions in this context.

[2] Cf. IRENA (2018), "Renewable Power Generation Costs in 2017" and Karltorp (2016). "Challenges in Mobilising Financial Resources for Renewable Energy".

[3] Cf. IRENA (2018), "Renewable Power Generation Costs in 2017" and Karltorp (2016). "Challenges in Mobilising Financial Resources for Renewable Energy".

borders. Compared to an approach in which each state carries out its own projects in its own territory, the cooperative solution offers a potential to decrease the LCOE. Furthermore, there are synergies with respect to offshore grid and interconnector planning, investment and operation. However, joint projects can go along with complex effects regarding the distribution of costs and benefits between the cooperating parties. In some cases the initial rent distribution might be unfavourable for some of the actors involved. Besides, building OWP plants abroad instead of domestically can alter the environmental implications, as the OWP production might replace the production of different plants with different CO_2 emissions. It might, in principle, be possible to effectively tackle the problems described by adding further contractual arrangements. Yet it is important to recognise that such provisions go along with transaction costs[4] which might offset the achievable gains from cooperation.

This research paper takes a detailed look at potential benefits and pitfalls associated with joint OWP projects. The central research questions can be summarised as follows: Which effects might arise from joint OWP projects for the participating countries? Which hurdles exist for the realisation of joint projects? Under which circumstances do international cooperations on the development and funding of OWP projects make sense? Which measures might help to facilitate the realisation of joint OWP projects?

The analysis in this research paper is based on qualitative economic considerations. This includes the application of insights from (New) Institutional economics, Industrial economics and Welfare economics as well as Finance theory and Game theory. Among those, different theories from the realm of New institutional economics – namely Transaction cost theory, Contract theory and Principal-agent theory – can be considered the centrepiece of the theoretical foundation. The aim of the analysis is to demonstrate elementary causal connections and expected effects in the context of joint OWP projects. For the evaluation of different solutions, we assume two objectives: the limitation of costs, which includes welfare and distributional effects, and environmental protection; regarding the latter one we limit the discussion to impacts on CO_2 emissions. Furthermore, the analysis is kept abstract with respect to the research subject, which means that we do not examine any specific electricity system. Instead, we draw conclusions from observations made in a simplified industry model environment. The results can be applied to assist the assessment of joint OWP projects in practical cases.

[4] The term "transaction costs" describes the consumption of resources related to the determination, transfer and the enforcement of rights of disposal or further rights. Cf. Coase (1937), "The Nature of the Firm"; Coase (1960), "The Problem of Social Cost"; Williamson (1975), "Markets and Hierarchies, Analysis and Antitrust Implications".

The section following this introductory segment presents some basic economic considerations on which the analysis is built. Besides, it contains an assessment of the analysis' scope. In section 3 we carry out the model-based examination of jointly developed and financed OWP projects. This step includes the investigation of selected issues regarding the grid connection and the extension of interconnector capacities. A major aim of the section is to identify hurdles for the realisation of potentially beneficial joint projects. Section 4 deals with the role of supranational institutions. In this context, we touch upon measures that could be taken in a union of states in order to facilitate cooperation projects. The research paper concludes with a summary of the main findings in section 5.

2. Basic considerations and scope of the analysis

Joint OWP projects as one form of collaboration in interlinked electricity systems

In interconnected power systems, like the European one, international coordination is of great importance. The deployment of RES-E plants can be regarded as one of several areas in which collaboration offers benefits. Numerous studies find that a coordinated expansion of intermittent RES-E generation capacities in Europe can substantially decrease the costs.[5] In line with this proposition, the European Commission has been increasing its promotion of cross-border cooperation on the development of new RES-E plants. In the OWP segment the question of international collaboration arises more or less logically, as the potential plant locations are often situated along national borders.

In general, international collaboration on the development of OWP capacities is conceivable in many forms. Cooperation initiatives can vary with respect to several dimensions, amongst others:

- Array of assets concerned: Collaborative projects can either be limited to the wind farms or also include offshore grid assets used for the transportation of generated electricity.
- Extent of cooperation: Cooperation can reach from a mere coordination of national OWP expansion plans to commonly funded and operated OWP projects.
- The number of participants: Some initiatives might be bilateral agreements between only two states, whereas others might include multiple countries.

As stated in the introduction, our analysis focusses on joint OWP projects. Under the term "joint project" we understand that two or more national states engage in the common development and financing of an OWP project. This implies that we assume a greatly simplified setting in which public actors (hereinafter usually referred to as "countries" or "states") develop OWP projects in order to reach certain national expansion targets. Afterwards, private generators built and operate the wind farms on behalf of the national regulators.[6] The offshore wind farms concerned are located in the territory of one of the

[5] Cf. for instance Fürsch et al. (2010), "European RES-E Policy Analysis"; Booz & Company et al. (2013), "Benefits of an Integrated European Energy Market"; Unteutsch / Lindenberger (2014), "Promotion of Electricity from Renewable Energy in Europe Post 2020 - The Economic Benefits of Cooperation"; Schröder et al. (2012), "Joint Support and Efficient Offshore Investment: Market and Transmission Connection Barriers and Solutions".

[6] In practice, private actors might also play important roles in early development stages of OWP projects including the initiation of cross-border collaborations. However, the simplification seems appropriate, because most of the essential interdependencies presented in the research paper are directly transferable to settings with private actors.

states involved. In this research paper this means, by definition, that at least one of the states is funding OWP capacity which is not located in its own territory (as opposed to the conventional approach in which projects are completely financed by the host country).[7] For simplicity, we examine only bilateral cooperation initiatives throughout most parts of the analysis. However, the scope is extended to multilateral agreements later on.

Alternative measures to foster international collaboration on OWP projects like statistic transfers[8] or joint support schemes are not considered in this research paper.

Inclusion of grid-related issues

The coordination of national grid infrastructure plans, in general, represents an important source of efficiency gains. In this research paper we only focus on certain aspects of this topic which are closely related to joint OWP projects. Currently, it is the exception rather than the rule that new OWP capacity can rely on existing grid infrastructure. Hence, an expansion of OWP capacities must usually be accompanied by corresponding grid extension measures. Since the offshore location of the plants often imply production sites along national borders, the question arises as to which national electricity systems the wind farms should be connected. A connection of wind farms to more than one electricity system usually functions as an interconnector. In some cases, it can prove beneficial to combine OWP grid connection measures with the extension of interconnection capacities. Potential reasons for this can be found in cost savings through a more efficient usage of grid capacities or a higher value of the electricity produced.[9] However, increases in interconnection capacities go along with a range of effects for the national electricity systems and sometimes the arguments against an extension of cross-border capacities prevail. This subject is discussed in detail in section 3.2.

Transaction costs as a hurdle for cooperation initiatives

As mentioned in the introduction, a main idea behind the concept of joint projects is to utilise the most suitable locations for offshore wind farms, irrespective of national

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[7] It is also conceivable that joint projects are situated around a national border, instead of being located in the territory of only one state. This aspect is not discussed in detail in the analysis, but the presented findings can be applied analogously.
[8] Cf. for a critical assessment of the instrument of statistical transfers Klessmann et al. (2010), “Design Options for Cooperation Mechanisms under the New European Renewable Energy Directive”
[9] Cf. NSCOGI (2014), “Cost Allocation for Hybrid Infrastructures”; Meeus (2014), “Offshore Grids for Renewables: Do We Need a Particular Regulatory Framework?”; Konstantelos et al. (2017), “Integrated North Sea Grids: The Costs, the Benefits and Their Distribution between Countries”; Flament et al. (2015), “NorthSeaGrid: Offshore Electricity Grid Implementation in the North Sea”.

territories. Theoretically, this approach promises substantial reductions in generation costs and therefore a welfare surplus. However, costs and benefits are likely to be distributed unequally among the participating countries. Some states might be even left worse off, if no further arrangements are put into place.[10] Such arrangements on the sharing of costs and benefits and further definitions regarding the rights and obligations of the contractual parties might often be generally useful. But it is not always easy to reach agreements. The transaction costs related to designing and negotiating contracts can (partly) offset the achievable benefits from cooperation.

From the perspective of a country willing to build new OWP plants, it can sometimes be difficult to assess the option of entering into a joint project. As mentioned above, executing a joint project instead of building plants in domestic territory can go along with a variety of complex effects which are often subject to high uncertainty (we will elaborate on these effects and the underlying mechanisms in more detail below). The occurrence of complex effects is particularly likely, if there are relevant transport restrictions to the grid capacities (especially with respect to interconnection lines). One important reason for this is that the new plants might predominantly affect the power supply in the national electricity system they are connected to. This means that plants abroad might not create the same value for a country's power system as domestically located plants. In some cases parallel extensions of interconnection capacities might reduce the problems, but – as mentioned above – such measures go along with distributional and environmental effects themselves.

Taking all these aspects into consideration, it is far from obvious that the realisation of every joint project which at first glance seems to offer efficiency gains turns out to be reasonable in the end. It is therefore essential to investigate on a case-by-case basis the benefits and drawbacks of joint projects as well as available means to overcome obstacles.

[10] Cf. Pade / Klinge Jacobsen / Skovsgaard Nielsen (2012), "Assessment of Cooperation Mechanism Options"; Pade / Klinge Jacobsen (2012), "Barriers and Critical Success Factors for the Implementation of Cooperation Mechanisms"; Klinge Jacobsen et al. (2014), "Cooperation Mechanisms to Achieve EU Renewable Targets"; Konstantelos et al. (2017), "Integrated North Sea Grids: The Costs, the Benefits and Their Distribution between Countries".

3. Model-based identification of potential cooperation effects

3.1 Examination of joint OWP project scenarios

3.1.1 Outline and basic model set-up

General assumptions

Section 3 deals with the description of effects that can result from developing new OWP capacity abroad instead of building the plants within domestic territory.

Apart from effects that are directly related to electricity supply, namely generation cost effects and environmental effects, we consider the need for coordination between the cooperating parties and implied transaction cost effects. Furthermore, we take a look at the distribution of rents between the countries concerned and between certain groups of actors within these countries (i.e., consumers and power generators). Any further effects that might arise in the context of joint projects such as job effects etc. are excluded from the scope of the analysis.[11]

The analysis is carried out on the basis of a simplified industry model. The basic model version is used in section 3.1.2 for the examination of three scenarios (which are outlined further below) and set up as follows:

- There are two neighbouring countries, "A" and "B". Further countries are not considered which means that countries A and B are assumed to form an autarchic electricity system. The primary goal of both states is to enhance domestic welfare (i.e., the aggregate consumer and producer rents in the respective country).
- The two national electricity systems are linked via power lines with a certain aggregate interconnection capacity. Also, the two national wholesale electricity markets, on which supply and demand side actors exchange volumes of electricity, are connected. The market connection is implemented in the form of "market coupling", for which the entire available interconnector capacity is made use of. This means that the countries' merit order curves are merged as far as the cross-

[11] In Klinge Jacobsen et al. (2014), "Cooperation Mechanisms to Achieve EU Renewable Targets", the authors suggest that such effects – to which they refer as "local benefits" – are of comparatively low importance for the overall assessment of OWP cooperations.

border grid capacity allows it.[12] As long as the interconnector is not congested, available plants abroad with lower marginal costs replace domestic plants with higher marginal costs to satisfy a local demand, and vice versa.[13]

The analysis is performed from country A's perspective, which is intending to expand its OWP capacity and thereby reach a certain increase in the annual OWP generation volume. For simplicity, we assume that it has decided to build a single new offshore wind farm. In this context, country A faces a decision upon the wind farm's location. It can opt between two alternatives:

1) The new wind farm is built in domestic country A territory. We regard this alternative as the baseline option (see Fig. 1 for a simplistic illustration).

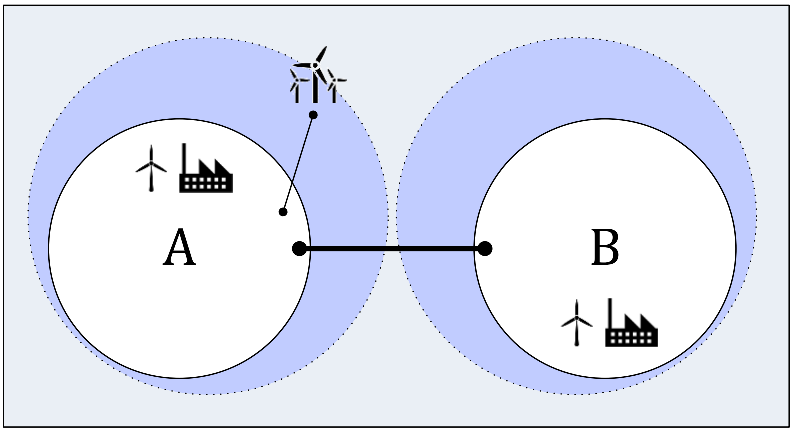

Figure 1: Wind farm built in domestic territory (baseline option).[14]

[12] The merit order curve represents a ranking of all available plants as a function of their marginal costs of generation. Leaving further aspects aside, the curve determines the sequence in which plants are efficiently dispatched to meet a given system load.

[13] In simple terms, this means that market coupling has the effect that offers made in one market also appear in the merit order curve of interconnected markets, as long as sufficient cross-border capacities are available. In this context, the national markets represent price zones (however, there can also be several price zones within one national market); price gaps between these zones potentially occur when the cross-border transport capacities are fully used. Cf. Hoffrichter / Beckers (2018), "Cross-Border Coordination as a Prerequisite for Efficient Sector Coupling in Interconnected Power Systems – Institutional Economic Considerations on Allocating Decision-Making Competencies in the European Union".

[14] All figures in this research paper present simplistic illustrations of the different joint project scenarios that we discuss. The solid circles which contain the letters A, B and C portray the respective countries. The plant symbols within those circles characterise the national generation fleets, indicating corresponding differences between the countries (a wind engine indicates low variable generation costs and low emissions, whereas a conventional plant indicates higher variable costs and higher emissions). The straight lines represent interconnection cables between the countries and connections cables to the

2) Country A is collaborating with country B on developing the project in B's territory, which is assumed to offer significantly more favourable conditions regarding the wind yield or other factors that lead to a decrease in the LCOE (e.g., the distance to the shore or water depth; see Fig. 2).[15] For this purpose the two countries enter into a long-term contract, which covers the wind farm's lifetime. Throughout section 3 we assume that a location in country B implies that the wind farm is also connected to country B's main grid.[16]

Initially, the funding of the OWP project is assumed to be country A's responsibility. However, considerations regarding the sharing of costs between the countries are an important topic of the analysis. Apart from that, we assume that the wind farm is ultimately built and operated by private generators on behalf of country A; similarly, we consider all existing generation assets in both countries to be owned by private investors (see section 2).[17] The remuneration of OWP generators is assumed to be cost-oriented, allowing for only moderate producer rents (for illustration purposes, a well-designed feed-in tariff approach can be imagined as the remuneration instrument in place).[18] This means that country A – and in particular its consumers – benefit from LCOE reductions, as they entail a decrease in the level of remuneration payments for produced electricity. In this context it is important to mention, that we refer to the measure of LCOE in order to evaluate differences in the aggregate cost from a welfare perspective and not consider

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offshore wind farm (which is portrayed by the corresponding symbol); transmission restrictions are indicated by a bottleneck road sign. The dashed circles mark the offshore territories of the two countries A and B, in which the new wind farm can be built.

[15] Other potential advantages related to the location of the wind farm in country B – which we will discuss below – could, in general, also represent the primary motivation for engaging in a joint project. This means that lower LCOE are not necessarily a precondition for achieving net benefits through the realisation of a joint project.

[16] In section 3.2 we will take a look at alternatives to this solution.

[17] In this way potential effects on the distribution of rents between producers and consumers appear more clearly. It is worth noting that the assumptions regarding the involvement of private actors are not relevant for most parts of the analysis. The majority of effects, which are described below, occur all the same or very similarly when plants are built, operated and owned by public companies from country A (instead of private investors from country A).

[18] For simplicity, we assume that the duration of the feed-in tariff contracts corresponds to the plants' economic lifetime. More detailed analyses demonstrate that feed-in tariffs can be considered a generally suitable instrument for the remuneration of OWP generators. Cf. Hoffrichter / Beckers / Ott (2018), "Institutional Framework for the Development of Offshore Wind Power Projects – Key Aspects for Instrument Choice and Design from an Institutional Economic Perspective", which was also developed within the framework of the project Baltic InteGrid. For an examination of OWP cooperations in the case of diverging national RES-E remuneration schemes, cf. Pade / Klinge Jacobsen (2012), "Barriers and Critical Success Factors for the Implementation of Cooperation Mechanisms".

factors such as fees, taxes or depreciation rules (which affect the LCOE from an investor perspective).

With respect to the interdependencies described, we assume throughout the analysis that the sizes of the new offshore wind farm and its connection cables are sufficiently large to produce relevant effects in the two power systems. When single OWP projects are considered in reality, the effects might sometimes be rather weak or even negligible. However, if the considerations are transferred to a broader context in which several OWP projects are concerned, the strength of effects increases.

The simplistic model layout implies further assumptions which are not outlined in detail. Similarly, due to the condensed form of presenting the underlying interdependencies in this research paper, the line of argumentation contains several implications.

Examined scenarios in the basic model set-up

As mentioned above, we will examine three different scenarios within the basic model set-up. In this way we are able to clearly distinguish observed effects and their causalties. The scenarios vary with respect to the availability of grid capacities (limited/unlimited) and with respect to the generation fleets in the two countries (identical/different):

- Scenario 1: No restriction of transport capacities over the entire contract period (this implies that assumptions about the generation fleets are irrelevant, as we will show below in detail).
- Scenario 2: Restricted grid capacities and identical national power plant fleets.
- Scenario 3: Restricted grid capacities and different national power plant fleets.

As far as scenario 1 is concerned, the causal relations and the resulting effects are described below in detail. The subsequent discussion of scenario 2 and scenario 3 focusses on additional effects that arise (i.e., differences to scenario 1). According to the above description of the analysis focus, in each section the discussion of effects is split into the three subsections “generation cost effects”, “distributional effects and transaction costs”, and “environmental aspects”.

Following the analysis of the three scenarios in the basic model, in section 3.1.3 we add a third country C to the model set-up in order to point out certain aspects related to the increased complexity in a (more realistic) multi-country setting.

3.1.2 Analysis of scenarios in the basic model with only two countries

3.1.2.1 Scenario 1: No restriction of transport capacities

In the first scenario, we assume that there are no relevant limitations to the transportation of electricity between the two countries (see Fig. 2). Under such circumstances, assumptions regarding the national generation fleets are irrelevant, because the dispatch of power plants is not subject to cross-border restrictions. This means that the plants in both countries are always part of one common merit order curve.

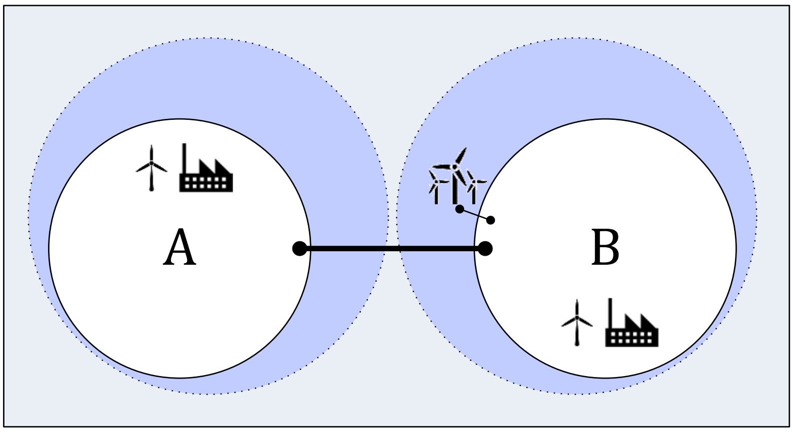

Figure 2: Joint project in scenario 1 (no cross-border restrictions).

Generation cost effects

Due to the more favourable conditions in country B the wind farm's LCOE decline. The corresponding decrease in generation costs represents the most obvious, but not necessarily the only effect on the total cost of the electricity system. Changing the offshore wind farm's location (from country A to country B) might induce further cost effects related to the correlation of RES-E production. Increased geographical concentration of RES-E plants usually leads to a higher correlation of production patterns. The higher the correlation of RES-E production, the higher (ceteris paribus) the need for flexible back-up capacities (including storage systems and demand response measures).[19] Whether the relocation of the OWP project to country B increases or decreases the correlation of RES-E infeed depends on the initial spatial distribution of RES-E plants across the two countries. Against this background, it is important to consider effects related to the spatial distribution of plants when assessing a joint project. Net benefits are only achievable, if positive LCOE effects are not offset by costs increases at other points of the supply system.

[19] Cf. for instance Peter / Wagner (2018), "Optimal Allocation of Variable Renewable Energy Considering Contributions to Security of Supply".

Distributional effects and transaction costs

In the assumed model setting, country B does not directly benefit from the decrease in OWP generation costs, because the wind farm is financed by country A.[20] On the other hand, providing the OWP site incurs costs in country B. Costs arise, for instance, in the form of opportunity costs (i.e., the forfeited option to use the site for other projects in the future) or negative local externalities. Against this background, country B can be expected to demand a compensation for allowing country A to build and operate the wind farm in its territory. In this context, the cooperating parties have to negotiate the sharing of costs and benefits.[21]

Agreements on sharing the costs and benefits require a calculation of all relevant values. Ideally, the calculation is carried out before the conclusion of the contract. In some cases, however, it is only possible to quantify effects sufficiently precise during the contract period. In this context, it is important to note that the calculation of costs and benefits can be a significant source of transaction costs itself. While measuring LCOE effects is typically fairly simple, this cannot generally be said with regards to many other effects. Determining the correlation of the wind farms' production with other RES-E production, for instance, requires forecasts of future RES-E capacity extensions in both systems. The quantification of opportunity costs and negative externalities incurred in country B might be even more complicated.

Another source of significant transaction costs is the occurrence of strategic or opportunistic behaviour. The wrangling over distributional issues might even be laborious, if both countries work constructively on reaching an agreement. If the countries apply self-seeking negotiation strategies, it is possible that they are not able to reach generally achievable solutions which would lead to improvements for both sides.[22] The situation is similar with respect to opportunistic behaviour. Real-world contracts are almost always quite incomplete, which often leaves room for opportunistic behaviour by

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[20] As stated in section 3.1.1, further potential benefits for the wind farm's host country such as positive job effects are excluded from the scope of our analysis.

[21] In line with the assumptions made here, in Ragwitz / del Río / Resch (2009), "Assessing the Advantages and Drawbacks of Government Trading of Guarantees of Origin for Renewable Electricity in Europe", the authors conclude that contracts regarding the distribution of costs and benefits from cross-border generation initiatives should rather be negotiated between states and not between the respective companies involved.

[22] For basic economic considerations on this topic cf. Nash, "The Bargaining Problem"; Myerson / Satterthwaite (1983), "Efficient Mechanisms for Bilateral Trading".

the respective counterparty (which is also referred to as "hold-up");[23] due to the very nature of long-term contracts on complex matters like joint OWP projects, the degree of incompleteness tends to be particularly high. To give an example, the wind farm's host country B could decide unilaterally during the contract period to impose a new tax on the operator's revenues in order to appropriate a larger share of the earnings.[24] If the risk of such opportunistic behaviour is to be considered significant, it may represent a major hurdle for implementing the joint project. Although additional contractual arrangements might prevent specific undesired actions, the vast variety of factors which potentially affect the outcomes of an OWP cooperation render it impractical to make contractual provisions for all conceivable contingencies (in other words, the related transaction costs are prohibitive).

Whether and to which extent the discussed problems appear depends on the prevailing circumstances of each application case. Apart from the amount of generally achievable cooperation gains, the transaction environment can be regarded as a particularly important factor. The chances for reaching agreements are comparatively high, if the cooperating countries have homogenous energy policy goals,[25] a profound experience of mutual interaction and a good transaction atmosphere as well as stable political conditions. Under such circumstances, a rough estimation of costs and benefits and a less accurate sharing method might be regarded as sufficient for entering into a contract; especially if the two countries are already involved in a larger number of collaborative initiatives which are regarded mutually beneficial overall. Similarly, the risk of opportunistic behaviour decreases, if the contracting parties have reason to trust on each other (which means that there is no need to include as many contingencies as possible into the contract).

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[23] Cf. Williamson (1985), "The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting"; Alchian / Woodward (1988), "The Firm Is Dead; Long Live the Firm: A Review of Oliver E. Williamson's The Economic Institutions of Capitalism"; Tirole (1999), "Incomplete Contracts: Where Do We Stand?"

[24] Such opportunistic actions are also referred to as "creeping expropriation". Cf. for instance, Steffen (2018), "The importance of project finance for renewable energy projects"; Sawant (2010), "The economics of large-scale infrastructure FDI: The case of project finance", which both stretch this topic in the course of assessing the role of project finance in international infrastructure projects. For real-world examples of retroactive policy changes in EU countries, which might be assessed as opportunistic regulatory actions against foreign investors cf. Fouquet / Nysten (2015), "Retroactive and Retrospective Changes and Moratoria to RES Support". Another example, which in some ways crosses the borders of the scenario examined here, would be that country B unilaterally reduces the available interconnection capacity between the two countries. As a result, the offshore wind farm's electricity production would not fully contribute to supply in country A anymore.

[25] Klinge Jacobsen et al. (2014), "Cooperation Mechanisms to Achieve EU Renewable Targets".

Environmental aspects

Since there are no grid restrictions in scenario 1, the impact on the dispatch is independent of the wind farm's location. New OWP production replaces the production of the exact same plants, no matter whether the wind farm is situated in country A or B.[26] Hence, the location of the new wind farm also has no impact on the CO_2 emissions.

3.1.2.2 Scenario 2: Restricted transport capacities and identical generation fleets

As described in the outline, from now on we assume significant restrictions to the transport of electricity between the two power systems.[27] This implies that national electricity market prices can diverge, whenever the import/export restrictions become relevant. The described effects are particularly obvious, if the transmission lines are congested in the initial situation and over large parts of the contract period. Yet, most arguments apply very similarly, if restrictions during the contract period cannot be completely ruled out at the time the contract is made. For simplicity reasons we assume that the congestion occurs at the interconnection cables, however, limited hinterland grid capacities might cause comparable effects, if the wind farm in country B is not situated very close to interconnectors. Furthermore, at this point of the analysis, we do not consider the possibility of linking the new OWP capacity built in country B territory exclusively to country A's power system (instead, this option is discussed in section 3.1.3).

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[26] This implicates the simplifying assumption that the wind farm produces energy in both locations at the exact same points in time. In case there should be any relevant differences in reality that can be forecasted with a reasonable precision, this aspect should be taken into account when evaluating the option of a joint project.

[27] Most of the interdependencies that we describe throughout the following sections apply similarly, if transport is only restricted in the direction from country B to country A. This could be the case, if country A usually imports electricity from country B.

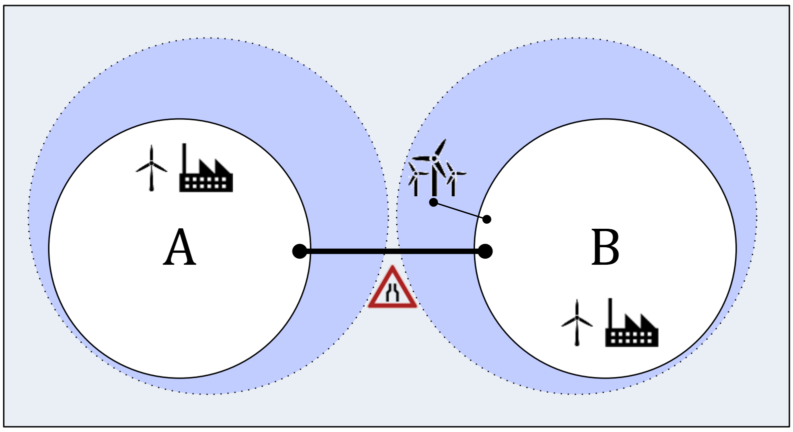

Figure 3: Joint project in scenario 2 (limited interconnection capacity, identical generation fleets).

In scenario 2 the generation fleets of both countries are assumed to be – apart from the new wind farm – completely identical over the entire contract period (see Fig. 3). This (unrealistic) assumption is made in order to highlight certain causal connections.

Generation cost effects

With two identical national generation fleets, the effects on the generation costs are basically the same as described in scenario 1. With short-run marginal costs near zero, available OWP production is normally used for supplying demand.[28] In this context, it virtually replaces the production of other plants which would operate, if the wind farm produced less or no electricity. This means that the aggregate variable costs of production decrease.[29] If the countries opt for the joint project solution, the wind farm's power generation replaces the production of plants in country B when the interconnector is congested. However, the plants concerned are exactly the same kind of plants that would have been replaced in country A, if the wind farm had been built there. Hence, the restriction of transport capacities does not cause additional generation cost effects.

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[28] Despite marginal costs near zero and no production-related emissions, it might sometimes be necessary to curtail intermittent RES-E plants (like OWP) when negative market prices occur; another reason can be found in grid bottlenecks. It seems imperative to make full use of all economically available flexibility options in order to keep the curtailments of intermittent RES-E production to a minimum. Whenever OWP plants are not (fully) available for production – for example due to a lack of wind or maintenance work – the marginal costs of increasing power generation are virtually prohibitive.

[29] In situations in which the production of existing RES-E plants (with marginal costs near zero) satisfies the entire demand already, the new OWP capacity does not induce further cost savings.

Additional distributional effects and transaction costs

Whenever the grid is congested, the offshore wind farm's generation mainly contributes to supply in the country of its location. Therefore, also the effect on market prices is greater in the plants' host country than in the other one. If the plants are built abroad, the average market price in country A is higher than in the case in which they are built in domestic territory.[30] This means, on the one hand, higher revenues for all generators that sell electricity on the wholesale market in country A. On the other hand, the consumer payments in country A increase as well. The reverse effects occur in country B. If country A has a preference for low domestic market prices, the occurrence of the described effects are, in general, detrimental to its willingness to engage in the cooperation; at least, it could be a further matter of negotiations between the two countries. If country A, for any reasons, prefers higher prices of electricity, it will appreciate the market price effects associated with building the wind farm abroad.[31]

Environmental aspects

As the OWP production replaces the same kind of plants in country B as it would have replaced in country A, the joint project does not affect the aggregate emissions in scenario 2. However, the emissions caused in country A increase, because a larger part of the abatement happens in country B. If country A had the goal of reducing domestic emissions, a joint project would always be detrimental to its interests. For simplicity, we assume for the remainder of our analysis that country A's goal is to reach a low aggregate emission level in the whole interconnected system or that it can, in some way, appropriate emission reductions realised in country B for its own national targets.

3.1.2.3 Scenario 3: Restricted transport capacities and different generation fleets

In the third scenario, the assumption of restricted transport capacities from scenario 2 remains unaltered. In contrast to the preceding section, we now assume that the two

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[30] Additional production units lower the wholesale prices for market volumes of electricity, because the new plants replace other plants with higher marginal costs. Due to the low marginal costs of OWP production, it is particularly likely that it replaces other production on a regular basis.

[31] One potential reason for a preference of high market prices could be related to the public acceptance of RES-E expansion. If RES-E generators receive remuneration payments in the form of feed-in tariffs, they are not affected by changes in wholesale market prices. If, however, a remuneration system other than feed-in tariffs is applied, market prices might affect the revenues of OWP (and other RES-E) investors/operators. In a system like the sliding premium scheme, in which regulatory payments complement market revenues, changes in market prices might matter, because they change the necessary size of the regulatory remuneration component. Sometimes the level of market premiums is publically regarded as the level of support to RES-E plants. Although there is good reason to consider such an interpretation as misleading, higher market prices could theoretically improve public acceptance of further RES-E expansion in such cases.

national power plant fleets differ considerably with regards to both the marginal generation costs of plants and the CO_2 intensity of production.

Additional generation cost effects

With different generation fleets and relevant grid constraints, the location of the new offshore wind farm affects the aggregate generation costs mainly in two ways. For one thing, the new generation capacity has location-specific effects on the dispatch of power plants. Secondly, the system integration costs (which we will describe below) might diverge between the two alternatives.

As explained in the previous section, the production of a wind farm located in country B replaces other generation in the host country, when the interconnector is congested. If the replaced plants in country B have higher production costs than the plants which would have been replaced in country A, the joint project allows for higher savings in variable costs. If country B plants, in the opposite case, have lower variable costs, the cooperation goes along with a relative increase in costs (this setting is portrayed in Fig. 4).[32]

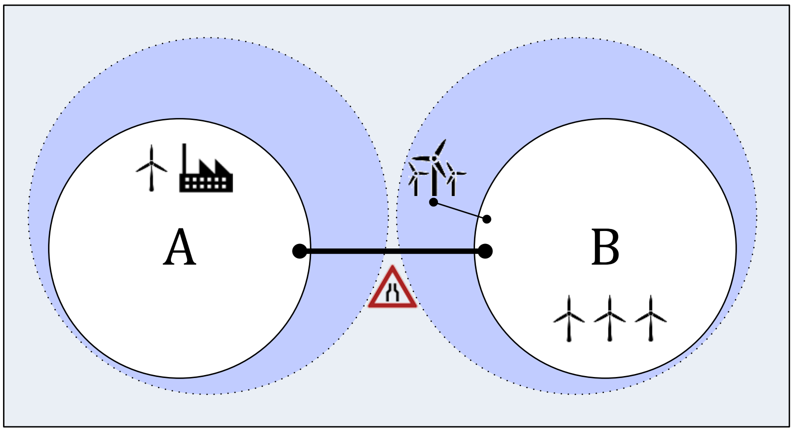

Figure 4: Joint project in scenario 3 (limited interconnection capacity, different generation fleets); case of higher variable costs and emissions in country A.

Apart from such short-term merit order effects, potential structural changes in the power plant fleets have to be taken into account. Since lower utilisation rates can virtually force existing plants into retirement, other costs such as fixed operating costs (but also opportunity costs) might be relevant for the cost comparison as well. Moreover, the

[32] Cf. Klinge Jacobsen et al. (2014), "Cooperation Mechanisms to Achieve EU Renewable Targets"; Schröder et al. (2012), "Joint Support and Efficient Offshore Investment: Market and Transmission Connection Barriers and Solutions".

addition of generation capacity can influence the needs for future investments and the costs of available options can also differ between the two countries.

Similar mechanisms apply with respect to the system integration costs, which are related to the intermittent production pattern of RES-E plants. Sufficient flexibility of backup plants for responding to sudden fluctuations of the RES-E infeed is an essential prerequisite for a successful RES-E integration. Besides, the capacity of the power grid must be adequate. If there are relevant limitations to the flexibility of the existing plant fleet or to grid capacities in one of the two countries, additional cost aspects have to be taken into consideration when assessing the joint project. To give an example, let us assume that the power system of country B already operates at the limits of its flexibility, whereas the system in country A still allows for the integration of further RES-E plants. Under such circumstances, the deployment of the offshore wind farm in country B might create a need for increasing the flexibility of the local power system (for instance, by building new flexible backup facilities or by retrofitting existing generation units in country B).[33]

However, for the estimation of cost implications it is not sufficient to simply look at the initial situations in the two countries. Instead, developments during the contract period and thereafter play an important role.[34] If, for instance, country B is planning to increase the flexibility of its power system anyway in the above example, the corresponding costs should not, or at least not fully, be attributed to the new OWP capacity. Similarly, the achievable savings in variable costs can change over the lifetime of the wind farm.

Additional distributional effects and transaction costs

When looking at a static situation, the distributional effects in scenario 3 basically correspond to those in scenario 2; only the size of market price effects might differ between the countries.

Taking dynamic developments into account, the assessment of costs, benefits and the resulting rent effects for different groups of actors can be difficult, because it requires forecasts of future developments in both power systems. A precise determination of effects in advance seems barely feasible in general. Even the preparation of reasonable estimates might be very demanding in scenario 3, because of complex underlying interdependencies. Besides, the room for opportunistic behaviour increases with the level of complexity. For these reasons, the preparation of contractual agreements on the sharing

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[33] In the opposite case (i.e., adaptive measures would only be necessary in country A), the system integration cost aspect strengthens the case for the joint project.

[34] Cf. Klinge Jacobsen et al. (2014), "Cooperation Mechanisms to Achieve EU Renewable Targets".

of costs and benefits as well as further contract related arrangements might involve considerable transaction costs.[35]

Environmental aspects

Unlike in the two previously examined scenarios, the location of the wind farm does matter in scenario 3 for the overall CO_2 emissions. Environmental effects, which arise from differences in the national generation fleets' emission intensity, are caused analogically to the generation cost effects related to differences in the variable costs. At each of the alternative locations, the OWP production will replace the production of certain other plants with specific CO_2 emissions. Which exact plants are replaced at a certain point in time, depends on the current situation in the respective power system. Yet, taking a long-term view, there is usually a group of plants, whose production is replaced particularly frequently. The average CO_2 emissions of the respective plants will usually differ between the countries. If the replaced plants in country B are more polluting than their counterparts in country A, the joint project is conducive to the environmental objective, and vice versa.[36] In comparison to distributional issues, it is significantly more difficult to overcome such environmental issues through contractual agreements.[37]

3.1.2.4 Main findings of the scenario analysis

Discussing the three scenarios, we showed that the assessment of costs and benefits which arise from joint OWP projects can be very challenging – even in a very simplistic model setting of only two countries. The same applies to negotiations on the sharing of costs and benefits between the contractual parties.

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[35] Similar considerations are presented in Busch (2017), "An efficient mechanism for cross-border support of renewable electricity in the European Union".

[36] One could argue that differences in emission abatement are irrelevant, if there are instruments in place which limit the overall emissions of the economy, like the EU Emission Trading System (ETS) in Europe. However, such reasoning neglects, among other things, the importance of dynamic effects on political decision-making (especially with respect to the level of ambition concerning future emission reduction targets). Cf. Gross et al. (2012), "On Picking Winners: The Need for Targeted Support for Renewable Energy"; Gawel / Strunz / Lehmann (2014), "A Public Choice View on the Climate and Energy Policy Mix in the EU – How Do the Emissions Trading Scheme and Support for Renewable Energies Interact?". Nevertheless, the existence of certain interdependencies between cap and trade mechanisms and the effectiveness of RES-E expansion with respect to emission abatement is undisputed. Since the current design of the ETS impedes the realisation of positive environmental effects, a reform of the mechanism seems advisable. Cf. Hoffrichter / Beckers (2018), "Cross-border coordination as a prerequisite for efficient sector coupling in interconnected power systems".

[37] As pointed out above, the option of connecting the wind farm in country B exclusively to the power system of country A is excluded throughout the current part of the analysis, but discussed below in section 3.2.

3.1.3 Increased complexity in a multi-country setting

General relevance of third countries and modification of the model set-up

In practice, it is very unusual that two countries form an autarchic electricity system. Instead, national power systems are often connected to the power systems of several neighbouring countries, which are in turn connected to further national systems. The electrical interconnections are often complemented by commercial linkages between the national markets. The complexity of assessing a joint OWP project under such circumstances can be substantially higher than in the two-country setting that we assumed above. The reason is that the initial situations and future developments in other countries can affect the nature, direction and magnitude of effects that arise from installing the wind farm abroad. In this context, it might also be worthwhile to involve further countries in the contractual agreements on the joint project.

For the purpose of demonstrating the most relevant differences in a multi-country setting, we complement the basic model set-up by a single additional country C which is physically and commercially connected to both other countries. This means that the examined autarchic electricity system now comprises the countries A, B and C. Apart from this, the assumptions of scenario 3 are maintained.

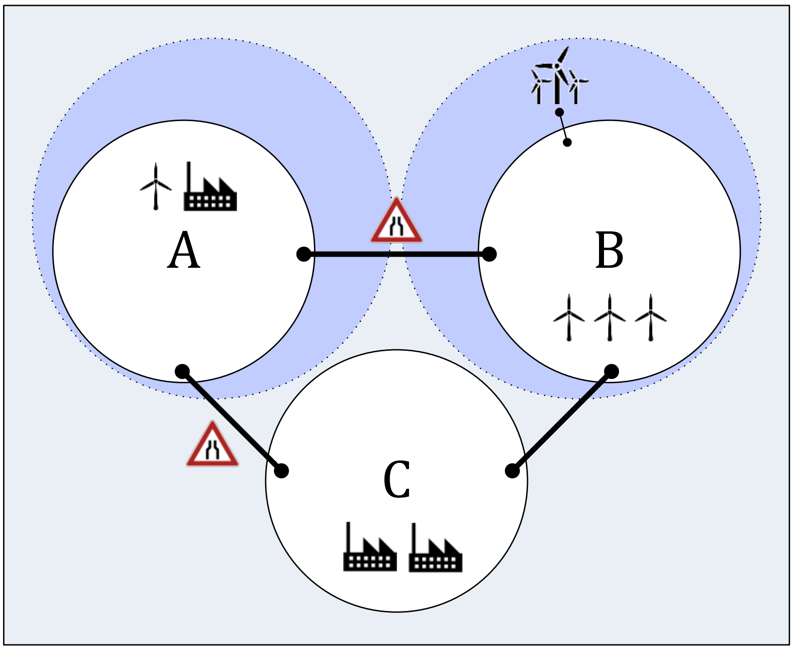

Figure 5: Joint project in a three-country setting with limited interconnection capacities at country A's borders and different national generation fleets.

Country C is not considered an active partner in the OWP collaboration, originally; it is neither a potential host country for the wind farm, nor is it initially involved in its funding. The relevance for the assessment of the joint project merely stems from the commercial connections between the countries. Firstly, electricity exchange with country C influences the prices in the other two national power markets and thus the size of potential benefits of a joint project. Secondly, this also has implications for the CO_2 emissions.

Differences regarding potential cost effects and environmental effects

For illustration purposes, let us recall the particular set-up of scenario 3, in which the electricity production in country B goes along with lower marginal production costs and with lower emissions than in country A (see Fig. 4). This means that we assume a setting in which the beneficial LCOE effects might be outweighed by adverse effects related to the dispatch of power plants. Now we add country C to the model and assume that the interconnector between countries A and C is considerably congested (just like the interconnector between the countries A and B), while there are no transport restrictions between the countries B and C. Furthermore, the generation fleet in country C is assumed to have the highest marginal production costs and emissions among the three countries (this set-up is portrayed in Fig. 5).

In contrast to the two-country setting, both the variable costs and emissions might decrease, if the wind farm is located in country B. The reason is that the OWP production now often replaces very expensive and highly polluting production in country C, which – due to the transport restrictions – is not possible to the same extent, if the wind farm is situated in country A.[38]

As far as the difficulty of determining the effects associated with the joint project option is concerned, the nature of the task does not substantially change, if a static situation is examined (like in our example). If, however, the dynamics of electricity systems are taken into consideration, the complexity can be expected to increase significantly. The situation in country C's power system is likely to change over time such as the situations in the two other countries. This also means that investment decisions made in country C during the contract period of the joint project might essentially influence the dispatch of plants across national power systems. As a result, market prices, emission levels and rent distributions in the countries A and B and thus the corresponding potential benefits of the cooperation initiative can be dependent on the developments in the third country C.

Involvement of third countries in the joint project contract

If country C cannot actively influence certain developments in its power system, they represent additional sources of uncertainty for the joint project's success. By contrast, if the developments are directly connected to country C's actions, it could make sense to involve country C in the contractual agreements. In this way the two original contracting

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[38] If, by contrast, electricity production in country C goes along with lower marginal costs and lower emissions than in country A, the situation does not substantially differ from the two-country setting.

parties can ensure, that country C's decisions do not undermine the aspired goals of the joint project. However, the involvement of further parties usually increases the transaction costs of contractual negotiations. Against this background, this option seems to be particularly worth considering, if the actions of country C appear to be pivotal for the success of the collaboration between A and B (as an example within the context discussed, country C could unilaterally constrain the interconnection capacity to country B). If country C does not benefit from the joint project directly, it can be expected to request a compensation for agreeing to contractual terms which limit its future scope of action or even require modifications to its original plans.

Another reason for including country C in the contractual negotiations could be that a large share of the joint project's benefits falls to country C. In this case the involvement could aim at a redistribution of benefits or a participation of country C in the project's funding. If country C, by contrast, incurs costs through the realisation of the joint project (which could be regarded as negative externalities), there could be reasons to compensate it; for example, in order to maintain a good relationship. However, as decisions on the deployment of plants affect the neighbouring countries in an interconnected power system on a regular basis, it seems reasonable to evaluate the necessity of such measures in a larger context.

Summary

The complexity of effects associated with a joint OWP project increases in a multi-country setting. This goes along with higher transaction costs related to the investigation of effects which are potentially relevant for the achievability of a net benefit. There might be, in general, various rationales to involve other countries in the cooperation. However, this will usually be accompanied by a rise in transaction costs, too.

3.2 Alternative grid connection concepts and combination of joint OWP projects with grid extension measures

Relevance of the grid connection and discussed options

Up until now, new OWP capacity can usually not rely on existing transmission grid infrastructure. Offshore cables which are already in operation or under construction are normally designed and laid out for specific purposes: they either link the electricity systems of two countries or connect certain offshore wind farms to the main grid. Combining submarine cables to meshed offshore grids is not yet a common practice. There is a small number of “combined projects” which are grid extension measures that involve “hybrid grid components” with the purpose of both interlinking national power systems and connecting OWP plants to the main grid.[39] Nevertheless, most OWP connections are still planned as separate lines, leading to largely radial grid structures with potential portfolio effects not being realised.[40] Connecting new cables to existing grid infrastructure is impractical, if this option was not already intended in the assets’ initial design. For these reasons, offshore wind projects usually have to be accompanied by the construction of new connections to the main grid.

The planning of offshore grid connections is a key matter for the overall costs of OWP. Among the wide range of generally important topics, our analysis focusses on implications of grid connection design choices for the examined effects that might arise from joint projects. As was explained in section 3, it is relevant to which country’s power system a new offshore wind farm is connected, if cross-border capacities are limited. Throughout the previous parts of the analysis we assumed a connection to the host country’s power grid (i.e., in the case of a joint project a connection to country B), but several other options are conceivable. In the following subsections we take a look at two simple variations of the grid connections for joint projects: first, a direct link from the wind farm to country A’s main grid and, second, grid connections to both countries. For demonstrating the implications of such solutions, we use the basic model set-up (with only two countries) and the set of assumptions from scenario 3.

Model variation 1: Cable landing point in the funding country

The idea to connect the wind farm in country B exclusively to the main grid of country A (see Fig. 6) could be based on various motives. The most obvious rationale appears to be that a connection to country A is – for any reasons – less costly than a connection to the host country B. If the grid costs, by contrast, are higher, this option is worth considering only under the following circumstances:

1) The LCOE savings at the location in country B are fairly large.

[39] The term “combined projects” denotes grid extension measures that involve “hybrid grid components” with the purpose of both interlinking national power systems and connecting RES-E plants to the main grid. Cf. NSCOGI (2014), “Cost Allocation for Hybrid Infrastructures”; Meeus (2014), “Offshore Grids for Renewables”.

[40] It is generally possible to reduce the cost of electricity transportation by using meshed grids instead of connecting each generation unit (or load unit) via separate cables. Another important advantage of the meshed solution is that redundancies significantly improve security of supply.

2) The connection of the wind farm to country B would go along with highly undesirable dispatch-related effects which cannot be overcome through contractual agreements between the countries.

3) The additional costs of a connection to country A instead of one to country B are on a moderate level.

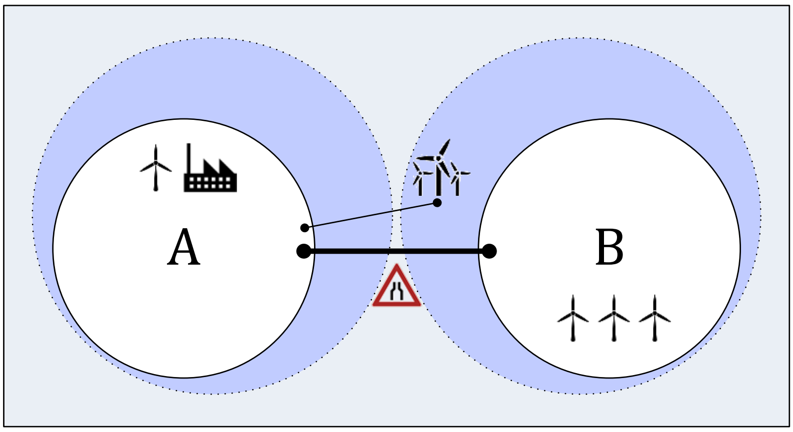

Figure 6: Joint project with a direct link from the wind farm to country A, which leads to higher savings in generation costs and emissions.

This means that connecting the wind farm to the main grid of country A could be considered a viable solution for avoiding persistent problems associated with a grid connection to country B; this assumes that the additional costs of the grid connection and the transaction costs of the joint project do not exceed the achievable LCOE savings.[41] Especially adverse generation cost effects, environmental effects or distributional effects can be eliminated (Fig. 6, as an example, depicts a situation in which a connection to country A leads to lower domestic market prices, larger savings in variable costs and lower emissions); the same applies to the relevance of uncertainty about such effects. If, however, generally complicated negotiations between the countries regarding the sharing of costs and benefits or potential "hold-ups" represent the main problem, a connection of the wind farm to country A might not solve any problems.

Model variation 2: Grid connections to both countries and interconnector extensions

Sometimes it might be worthwhile to consider grid connections from the wind farm to both countries. This rather includes cases in which the selected production site in

[41] This normally rules out joint projects located very remote from the border to country A.

country B is located somewhat between the two countries (if it is very far from the border, the costs of an additional link to country A will usually exceed the achievable benefits).

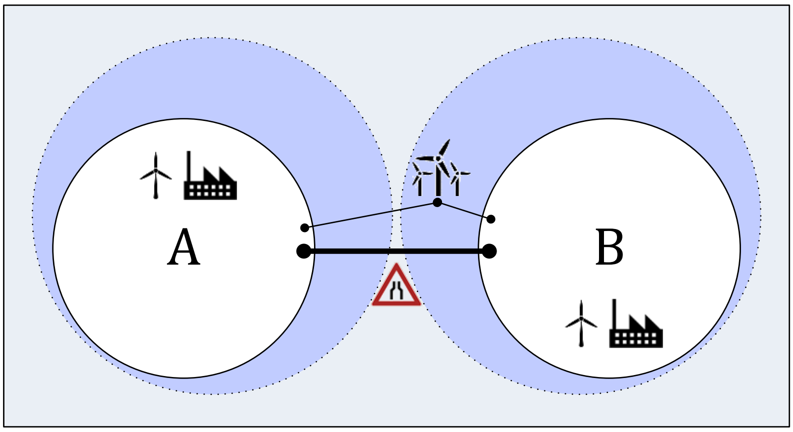

Figure 7: Joint project with a grid connection to both countries.

With connections to both countries, the production of the wind farm always replaces the generation of the highest marginal costs in any of the two systems. This can be a clear advantage, if the marginal costs are sometimes higher in one country and sometimes in the other (this setting is depicted in Fig. 7). As the marginal costs and the emission intensity of production are not perfectly correlated, the direction of the environmental effect is uncertain. This means that in some cases the increased savings in variable costs might come at the cost of lower emission reductions.[42]

Besides, building connection lines to both countries might sometimes serve as a pragmatic approach to sharing the project's benefits. If, for example, each of the cooperating parties expects net benefits from additional OWP capacity connected to its respective power system (e.g., in the form of lower market prices), the countries could theoretically be willing to forego detailed assessments and negotiations. Hence, the corresponding

[42] To give an example, coal and lignite plants currently often rank before natural gas plants in the merit-orders of European electricity markets (mostly because natural gas currently has the highest market price among these fuels). However, electricity production from coal and lignite usually goes along with even higher emissions than electricity production from natural gas. Assuming these circumstances in our model could result in the following outcomes: If country B would use only natural gas plants while country A only uses lignite and coal, an additional connection to country A would lead to higher savings in variable costs on the one hand, but lower emission reductions on the other hand. If country B, by contrast, would only use hydropower (with low marginal costs), an additional connection to country A would lead to higher savings in both variable costs and emissions.

transaction costs could be avoided. A very conducive transaction atmosphere between the two countries seems to be a precondition for engaging in such agreements.[43]

When discussing the option of connecting the wind farm to both countries, it is important to note that, besides delivering the wind farm's electricity output to the main land, the new lines can also be used for regular electricity exchange. They virtually function as an interconnector and therefore increase the available cross-border capacity, whenever the wind farm does not operate at full load.[44] The joint project might therefore affect the dispatch of plants across the two systems, even when the wind farm does not produce any electricity itself. This involves further effects with regard to the generation costs, the emission level and market prices. Against this background, the decision on connecting the wind farm to both countries requires a careful evaluation, since the impact of an increase in cross-border capacities may have far-reaching consequences.[45] If the countries have evaluated the extension of interconnector capacities already prior to the joint project initiative, the decision is made significantly easier.[46]

If the cooperating parties consider an increase of the interconnection capacity desirable, they should ensure that a two-sided wind farm connection represents the most efficient solution for achieving this aim. An alternative would be to and build a separate interconnection cable (and connect the wind farm only to country B).

[43] Agreements seem especially feasible, if the maximisation of net gains from the particular joint project does not represent the primary goal of any collaboration partner (see section 3.1.2.1).

[44] This implies that the capacity of the connection lines is calculated in order to just allow for the transportation of the wind farm's maximum production in both directions. If the capacity is larger, the new connection lines can also transport electricity produced in other plants, when the wind farm operates at full load. Furthermore, our considerations are based on the assumption that all available interconnection capacity is used for electricity exchange (see section 3.1.1). In general, it would also be conceivable to limit the purpose of the connection lines to transporting the output of the new wind farm. In this case, many of the aspects discussed would become irrelevant.

[45] As described in section 3.1.1, we assume throughout the analysis that offshore wind farms and their connection cables have sufficiently large sizes to produce significant effects. The interdependencies become more obvious, if more than one offshore wind farm project is considered.

[46] Cf. Konstantelos et al. (2017), "Integrated North Sea Grids: The Costs, the Benefits and Their Distribution between Countries"; Flament et al. (2015), "NorthSeaGrid: Offshore Electricity Grid Implementation in the North Sea".

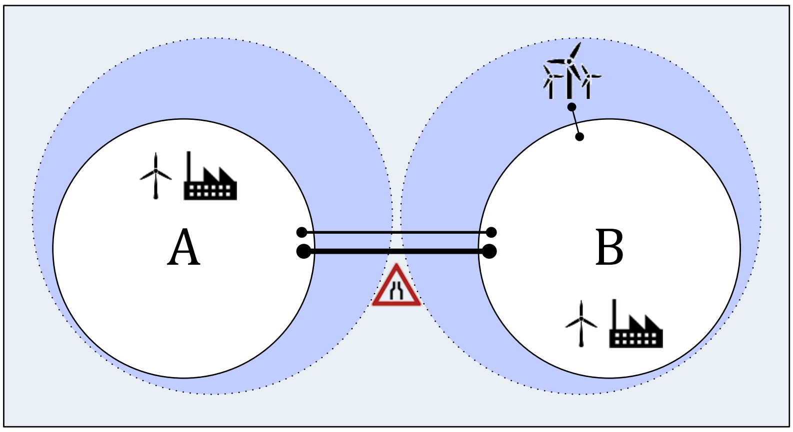

Figure 8: Joint project accompanied by an additional interconnector extension.

This option basically has the same effects on the dispatch, if there are no relevant hinterland grid capacity restrictions.[47] In such cases, the ranking of the two alternatives can be determined by a cost comparison of the measures. If the wind farm's location in country B is far from the border (as depicted in Fig. 8), a separate interconnection extension will usually be superior to a two-sided wind farm connection.[48]

Summary

If countries implement a joint OWP project, there are sometimes good reasons for connecting the wind farm to the financing country or to both countries instead of only to the host country's main grid. Concerning the evaluation of two-sided wind farm connections, further dispatch-related effects have to be taken into account. Apart from the selected aspects discussed in this section, which directly affect our considerations about joint projects, a wide range of further grid planning related topics are highly relevant for the cost of OWP. Among other things, the common usage of grid connection infrastructure such as offshore converter stations or connection cables by several wind farms promises substantial cost savings. The same generally applies to combined projects and meshed offshore grid solutions. The institutional framework for grid planning and grid regulation plays an important role in this context.[49] Since the grid planning approach also affects the

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[47] If there are relevant hinterland grid restrictions, the cooperation partners have to assess which alternative leads to more preferable effects.

[48] For a more detailed examination of potential benefits and challenges, cf. Konstantelos et al. (2017), "Integrated North Sea Grids: The Costs, the Benefits and Their Distribution between Countries".

[49] Cf. Meeus (2014), "Offshore Grids for Renewables".

lead time available for planning offshore wind projects, it might be directly relevant with respect to the feasibility of joint OWP projects as well.[50]

3.3 Interpretation of the findings

In our qualitative model-based analysis we demonstrated that engaging in a joint offshore wind project might go along with a wide range of effects for a country. Accordingly, it is seems necessary to take several further factors beyond potential LCOE savings into account, when evaluating this option.

Among the scenarios discussed, scenario 3 – with its limited interconnection capacities and different national power plant fleets – is most likely to roughly represent a typical situation in real-world power systems (although in certain cases interconnection capacities are in fact virtually unlimited). Under such circumstances, the involved countries have to consider dispatch-related effects, if the wind farm feeds into the host country's power system. These effects include further generation cost effects (i.e., cost effects apart from the wind farm's reduced LCOE) and emission effects as well as market price effects with distributional implications.

The first general problem in this context is that the effects result from a large variety of more or less complex interdependencies within the power systems which continuously change over the project's lifetime. The determination, or rather forecast, of effects is often a difficult task. As a consequence, sufficiently thorough analyses might entail significant transaction costs, but still leave the contracting parties with considerable uncertainty. The second potential problem is that the dispatch-related effects might be regarded as undesirable from the perspective of one or both countries. Redistributing the costs and benefits might solve the problem, if the initial effects leave only one country worse off, while there is a positive overall welfare effect (i.e., the net loss of the one country is outweighed by the other country's net benefit which implies that a Pareto improvement is generally achievable). However, real-life contracts are incomplete and their arrangement, implementation, management and supervision go along with further transaction costs. These costs might sometimes exceed the achievable net benefit and thus be prohibitive (or, if the parties neglect or underestimate the transaction cost aspect, it can also lead to a negative overall welfare effect of realised joint projects).

To sum up, forecasting the effects that arise from joint projects is, on the one hand, important in order to reduce uncertainy. On the other hand, it usually causes considerable transaction costs. The same applies to the negotiation and management of the cooperation

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[50] Cf. Hoffrichter / Beckers / Ott (2018), "Institutional Framework for the Development of Offshore Wind Power Projects".

contract. For this reason, the successful implementation of a joint project is most likely, if, firstly, the LCOE savings are sufficiently high and, secondly, the transaction costs are moderate. The existence of a conducive transaction atmosphere between the countries increases the probability that the latter condition is fulfilled.

4. The role of supranational institutions: Measures to facilitate the implementation of cooperation projects

As pointed out in the previous sections, transaction costs can impede the realisation of otherwise beneficial joint projects. This leads to the question as to which measures are available for improving the conditions for cooperation. Apart from contributions by the contracting parties themselves, supranational institutions can play an important role in overcoming transaction cost related obstacles in a union of states. However, it is important that measures implemented at the supranational level are compatible with the objectives of the countries concerned. In the following two subsections we will present an assessment of conceivable measures intended to foster cooperation with respect to their actual suitability regarding the reduction of costs for joint projects. The assessment is based on more fundamental research work on this topic which is not presented in this research paper in detail. [51] Afterwards, in a brief excursus, we will compare the results of our assessment with the current situation in the European Union.

Potentially constructive measures

The following supranational measures have the potential to decrease the costs of joint OWP projects and thus improve their viability:

- **Provision of a general framework for international cooperation**: Supranational institutions can provide plattforms and a framework of rules for the cooperation of associated countries. This reduces the costs of individual transactions, since general standards can be applied. Moreover, if countries, on this basis, engage in a large variety of cooperative activities, the necessity to obtain net benefits from each individual project (which is considered to have a positive overall welfare effect) might vanish. This does not directly imply that assessing the dispatch-related effects of joint OWP projects becomes unnecessary under such circumstances. However, it seems logical that at least the amount of effort in determining distributional effects can be reduced.
- **Support of emerging OWP collaboration initiatives**: Besides a general promotion of cooperative actions, a supranational institution can directly involve

[51] Cf. for a more fundamental examination of this topic Hoffrichter / Beckers (2018), “Cross-border coordination as a prerequisite for efficient sector coupling in interconnected power systems”.

itself in offshore wind cooperation initiatives. It might be able to provide useful support, for instance, in the form of assisting the determination of effects or helping the countries to reach agreements.

- **Assignment of ruling-competencies to supranational institutions**: If the cooperating parties can rely on a neutral institution to resolve conflicts which arise during the contract period, the transaction costs related to the design, negotiation and reinforcement of cooperation contracts might be significantly lower.
- **Optional or mandatory standard procedures for the determination and distribution of costs and benefits**: In order to avoid laborious negotiations on the sharing mechanism, the supranational institution could establish standard procedures.[52] The limitation of the scope of action in negotiations potentially reduces the transaction costs and facilitates the achievement of agreements. On the other hand, such limitations also carry the risk of excluding reasonable distributions and thus preventing the realisation of beneficial joint projects. If the occurrence of such problems is likely, non-binding standards might appear preferable.
- **Financial support for positively assessed cooperation projects**: The provision of grants out of centralised funds for joint projects which are considered to increase overall welfare could be yet another way to encourage potential cooperators. By raising the achievable net gains for the countries involved, this measure can be expected to lower the barriers to engaging in international projects; potentially it reduces the transaction costs. A precondition for the implementation of such an instrument is that its distributional effects are not considered undesirable; this might constitute a problem, if not all countries that contribute to the centralised funds also plan to invest in (joint) OWP projects. Furthermore, there might be concerns with respect to the effect on competition in generation investment and operation. A possible solution for these problems could be to support generation projects across several technological segments in a way

[52] In Konstantelos et al. (2017), "Integrated North Sea Grids: The Costs, the Benefits and Their Distribution between Countries" the authors suggest the so-called "positive net benefit differential" (PNBD) method for the distribution of costs and benefits. For further considerations regarding methods for the identification and sharing of costs and benefits in the context of OWP collaborations – however, primarily with respect to grid investment – cf. Flament et al. (2015), "NorthSeaGrid: Offshore Electricity Grid Implementation in the North Sea" and Busch (2017), "An efficient mechanism for cross-border support of renewable electricity in the European Union" which is discussing this topic with respect to RES-E in general.

that appropriately benefits all contributors. However, creating a suitable design for such an instrument might turn out to be extremely challenging. A possible alternative to grants can be seen in central funding for positively assessed joint projects in the form of (low-priced) loans.[53] Since loans are sometimes regarded as a more subtle form of support, this option might be considered more compatible with the competitiveness goals within a union of states. Besides overcoming possible financing gaps, the provision of investment loans is, similar to grants, likely to improve the overall financing conditions of projects and thus lower the costs of capital.[54]

Questionable measures

As far as binding requirements for countries to engage in collaborative projects are concerned, the disadvantages seem to often outweigh the advantages. This particularly applies to the following measures:

- **Obligations to realise OWP projects in cooperation:** Forcing countries into agreements could lead to the realisation of joint projects which are unfavourable from the perspective of some of the actors involved or even unfavourable overall. It generally seems advantageous to leave the final decision whether or not to realise a joint project up the countries concerned.
- **Obligations to extent interconnection capacities:** Very similar problems appear – even more obviously – if decisions about the extension of cross-border capacities are centralised at the supranational level. The distributional effects which go along with such extensions might leave some of the countries affected by the measure worse off (see section 3.2). Besides, larger interconnection capacities restrict a country's power to decide upon the usage of generation technologies; forced expansions therefore neglect national preferences. Moreover, the measure increases the probability of security of supply issues spreading across national borders. This seems particularly questionable, if there are no mechanisms in place

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[53] The two options (investment grants and loans), however, do not rule each other out, but they can also be combined. In fact, there are generally good reasons for providing public funding, if private generators receive payments for building and operating certain power plants. Cf. Hoffrichter / Beckers / Ott (2018), "Institutional Framework for the Development of Offshore Wind Power Projects".

[54] Cf. Beckers / Gehrt / Klatt (2010), "Rationales for the (Limited) Use of Private Finance in Public-Private Partnerships" for a general discussion on the role of public (and private) funding in the context public investment decisions which are (partly) implemented by private actors and Geddes / Schmidt / Steffen (2018), "The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany" which deals with rationales for the involvement of public investment banks in the development of power plant projects.

which guarantee an equal burden sharing with regard to the costs of maintaining security of supply. In sum, there are good reasons for decentralised decision making processes when it comes to the extension of interconnector capacities between countries.

- **Binding requirements to adopt certain RES-E support schemes:** For simplicity, we assumed in our model that the private investors who are involved in building and operating the wind farm receive payments from country A, irrespective of the plants' location. In reality there are several other conceivable options, including solutions in which the investors are remunerated according to the host country's national RES-E support scheme. In this context, diverging national RES-E support schemes can be identified as a possible problem for international OWP cooperations. For one thing, the support schemes might influence the evaluation of the alternatives and thus distort the assessment;[55] for another, different support schemes might go along with additional transaction costs for the investors and operators.[56] The convergence of institutional frameworks can potentially facilitate collaborations. It should therefore be considered by countries which plan to comprehensively engage in bilateral or multilateral cooperation on the provision of power plants. However, there are very good reasons against mandatory requirements to adapt national mechanisms in order to comply with certain "blueprints" established on the supranational level, because they might neglect national preferences and prevent competition between different institutional approaches.[57]

Excursus: Current situation in the European Union

As stated in section 2, the analysis presented in this research paper is generally kept abstract with respect to the research subject. It does not aim at providing a comprehensive overview or even an evaluation of the current situation in a certain existing power system. However, concerning the practical relevance of the analysis it is worth noting that several of the supranational measures described in this section can also be found in the

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[55] It is, however, worth mentioning that typically a large variety of country-specific regulations matter for real-life OWP projects. As a consequence, the harmonisation of RES-E support schemes does by no means lead to the achievement of a "level-playing-field" (which is a liberalistic ideal of a competitive environment). Cf. Hoffrichter / Beckers / Ott (2018), "Institutional Framework for the Development of Offshore Wind Power Projects".

[56] Cf. Genoese (2014), "The Role of Support Schemes for Renewables in Creating a Meshed Offshore Grid".

[57] Cf. Hoffrichter / Beckers (2018), "Cross-border coordination as a prerequisite for efficient sector coupling in interconnected power systems".

institutional framework of the European Union. This includes instruments that we consider as generally suitable as well as policies that resemble practices which we have evaluated negatively.

The European Union does, for instance, provide a general framework for international cooperation; in fact, this is one, if not the most important, of its core ideas. Moreover, there are European institutions with ruling competencies in place, which could help resolve conflicts that arise during the contract period of a joint OWP project. EU institutions also specifically offer support to collaboration initiatives which arise on a decentralised level.[58] Regarding the financial support of projects in the electricity sector, there is a variety of programmes. The rationale for the selection of projects which receive direct financial support varies between the areas of grid and generation. Grid extension measures are, for instance, supported, if they are considered to go along with large positive effects on the interconnected power system; this condition is especially often assumed to be met in the case of cooperative cross-border projects.[59] Generation projects, by contrast, only receive direct payments from centralised funds in special cases, involving a particularly innovative character of the individual project.[60] This approach is generally in line with the fact that the grid infrastructure is typically regarded as a natural monopoly, whereas the restraint in funding generation projects is reflecting the EU's competitiveness goals with respect to power generation.[61] This means that the EU policy toolbox does currently not include instruments which would provide grants to "regular" joint OWP projects that can be expected to go along with net benefits from an overall perspective. Instruments that are

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[58] There are several examples of (more or less directly) offshore wind related collaboration projects supported by EU institutions which originated at a member states level, including the High Level Group on Baltic Interconnections which delivered the Baltic Energy Market Interconnection Plan (BEMIP) in 2009, the Pentalateral Energy Forum and the North seas energy cooperation. The North Sea Wind Power Hub is an example for a TSO-driven initiative.

[59] National or multinational grid extension measures which are included in the list of so-called Projects of common interest (PCIs) by the European Commission may apply for funding provided within the framework of the Connecting Europe Facility (CEF) programme (a common point of concern arises from the perception that the project selection process is rather based on political motives than on the amount of benefits for the system). Further support to grid extension measures is provided by instruments of the European Structural and Investment Funds (ESIF) and of the European Fund for Strategic Investment (EFSI).

[60] Up until now, several OWP generation projects have received funds within the framework of the European Energy Programme for Recovery (EEPR) or from the NER 300 programme. Apart from that, the programme Horizon 2020, which aims at supporting activities in the areas of transportation and energy, is funding OWP research and innovation activities on a comparatively small scale.

[61] In this research paper we do not address the question whether the EU's current strategy to achieve a common market in the area of power generation is reasonable with respect to its overarching policy objectives. For critical reflections on this topic cf. Hoffrichter / Beckers (2018), "Cross-border coordination as a prerequisite for efficient sector coupling in interconnected power systems".

available for OWP projects − and which indeed play a significant role for their implementation − are loans and other financial instruments provided by the European Investment Bank (EIB). Along with the engagement in financing investments, the EIB also advises the administration and development of offshore wind projects.

Up until now, there are no obligations for EU countries to implement joint generation projects. The EU however urges its member states to open national RES-E support schemes to plants which are located beyond national borders. Moreover, the EU calls on the member states to modify their national support schemes in order to comply with certain centrally established standards which aim at enhancing competition within the EU.

5. Conclusion

International cooperation offers a great potential to reduce the cost of OWP installations. Collaboration measures that might, in principle, allow countries to reach their national expansion targets at lower costs include the development of joint projects, which means that wind farms are built at more favourable sites within the territory of other countries. Whereas the theoretical potential of such arrangements to lower the cost of new OWP installations cannot be disputed, they go along with a wide range of further effects which have to be taken into account as well. For one thing, a grid connection point in the wind farm's host country changes the impact on the dispatch of power plants, if the interconnector capacity between the countries is limited. This has implications for both overall generation costs and the level of greenhouse gas emissions. In some cases the effects can be assumed to be beneficial. In other cases they might (partly) offset the cost savings from more favourable OWP conditions in the host country. Similarly, the resulting effects on the distribution of rents can be desirable or not. Furthermore, the determination of effects goes along with transaction costs which adversely affect the joint project's economic viability. The same applies to negotiations between the cooperating parties on the sharing of costs and benefits. The topic of the offshore wind farms' grid connections further increases the complexity of the issue. However, in some cases suitable connection concepts may also help avoid undesirable effects. Since transaction costs can be a main obstacle for the realisation of joint projects and the volume of costs highly depends on the transaction environment, it seems imperative to use all available measures to improve the conditions for international cooperation. In cases in which joint projects in an interconnected power system of associated states are considered to be beneficial from an overall system perspective, supporting instruments on a supranational level could be part of the solution. However, not all conceivable measures seem generally suitable or compatible with overarching energy policy goals. In particular, binding requirements that force associated countries into cooperative projects might have counterproductive effects. Taking all these aspects into consideration leads to the conclusion that not each joint OWP project which promises lower costs at first sight stands up to a comprehensive assessment and for this reason a thorough evaluation seems necessary in any case.

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