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Stellungnahme zum Offshore-Netzentwicklungsplan 2025: Internationale Anbindung von Offshore-Windparks in Deutschland

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Zusammenfassung

Der Offshore-Netzentwicklungsplan beschreibt die zukünftige Anbindung der deutschen Offshore-Windparks. Bisher wird in der Planung nur berücksichtigt, wie eine Anbindung nach Deutschland erfolgen kann. Verschiedene Vorteile würden sich ergeben, wenn in der Zukunft einzelne Offshore-Anbindungen ins Ausland erfolgen (z.B. nach Norwegen). Dadurch steigen zwar die Investitionskosten der Offshore-Anbindung, unsere Analysen zeigen aber, dass diese Mehrkosten durch höhere Erlöse kompensiert werden. Insgesamt ergeben sich für das deutsche Stromsystem einige Vorteile:

a) Langfristig steigen die Merit-Order-Effekte in Deutschland. Eine Anbindung ans Ausland ermöglicht also in der Zukunft, dass der Strom einen höheren Wert bekommt, weil der Strom immer in den Markt verkauft werden kann, in dem die Preise am höchsten sind.

b) Wenn der Wind nicht weht, können die Offshore-Kabel für den Stromhandel genutzt werden. Durch diesen Stromtransport können zusätzliche Erlöse realisiert werden, die die höheren Investitionen kompensieren.

c) Außerdem kann das innerdeutsche Netz entlastet werden. Bisher erreichen die Offshore-Windparks nur eine Auslastung von bis zu 50%. Wenn bei hoher Offshorewind-Produktion Strom nach Norwegen exportiert wird und bei niedriger Stromproduktion die Kabel für einen Strom-Import aus Norwegen genutzt werden können, ergibt sich ein Profil, das einer „Grundlasteinspeisung“ ähnelt. Dies reduziert langfristig die Kosten für den Ausbaubedarf des innerdeutschen Netzes.

Vor diesem Hintergrund wird vorgeschlagen, dass der Offshore-Netzentwicklungsplan zukünftig auch die teilweise Anbindung von Offshore-Windparks ans Ausland untersuchen möge. Dabei wären zum einen die zusätzlichen Kosten der Anbindung für einzelne Länder zu vergleichen, zum anderen wäre zu analysieren ob und in welcher Höhe zusätzliche Erlöse erzielt werden können. Insbesondere bei den Erlösen sind die sich im Zeitverlauf verändernden Rahmenbedingungen zu berücksichtigen (z.B. der Merit-Order-Effekt in Deutschland und Ausstrahlungseffekte auf Nachbarländer).

Um die einzelnen Komponenten zu analysieren, wurde eine vereinfachte, illustrierende Analyse basierend auf historischen Daten für das Jahr 2012 durchgeführt (historische Strompreise für Deutschland und Norwegen; historisches Offshore-Einspeisungsprofil). Es wurde unterstellt, dass Strom immer in Richtung des Marktes mit den höheren Preisen fließt. Außerdem wurde eine „Interkonnektoren-Rente“ anhand der historischen Preisunterschiede im Jahr 2012 bestimmt. Insgesamt sind gegenläufige Effekte zu beobachten. Im Jahr 2012 waren die Strompreise in Norwegen niedriger als in Deutschland, so dass die Erlöse für den Offshore-Strom insgesamt etwas niedriger sind, wenn man Offshore-Windparks teilweise nach Norwegen angeschlossen hätte. Dies wird aber durch die Interkonnektoren-Rente überkompensiert. Die Analysen zeigen, dass die höheren Kosten für den Kabelanschluss bis nach Norwegen durch höhere Erlöse ausgeglichen werden können. Gleichzeitig sind weitere Analysen sinnvoll, weil sich das Strompreisgefüge in Zukunft verändern wird.

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1. Introduction

Germany has formulated a goal to install 6.5 GW of offshore windfarms until 2020. The grid connection for these windparks is planned in the 'Netzentwicklungsplan Offshore' (ÜNB, 2015a). In the long term various stakeholders have formulated the vision of an offshore-grid (European Wind Energy Association, 2013; Airtricity, 2006). The integration of electricity networks between Germany and its neighbouring countries represents an opportunity to increase the deployment of renewables by both overcoming intermittency issues and improving the financial viability of renewables via the trading of electricity (Agora Energiewende, 2015).

An important first step towards the long term version of an offshore-grid can be to use grid connections of offshore wind-farms. The new interconnection between the Danish region of Zealand and the German region of Mecklenburg-Western Pomerania, referred to as the 'Combined Grid Solution', will have a capacity of 400 megawatts (MW) and is expected to commence operation by the end of 2018 (Energinet.dk & 50Hertz, 2015). The economic rationale for establishing such an interconnection, as opposed to a conventional radial or national connection, depends upon increasing the utilisation rate of renewable energy deployment and trading any excess capacity on the spot market.

Apart from the common grid solution in the Baltic sea, no projects have currently been started in Germany to use offshore windpark connections to increase the interconnection with neighboring countries. The on-going consultation for the network development plan presents an opportunity to consider how best to use the growing offshore wind resources available off the north coast of Germany. The aim of this working paper is to therefore compare the potential profitability of a standard offshore-grid connection (as currently envisaged by the 'Netzentwicklungsplan Offshore') with an offshore-grid connection to Norway based upon a modelling exercise using empirical data on electricity spot market prices. The hypothesis of the analysis is that the additional revenues generated from such an interconnection will offset the additional investment costs and be more financially viable than a conventional radial or national connection. The reasons underpinning this hypothesis are two-fold:

(1) The connection to Norway can be profitable when electricity prices in Norway are higher than in Germany and the generated electricity from the offshore turbines can be sold at a higher revenue compared to Germany;

(2) The connection to Norway can also be used to sell electricity from Norway to Germany in times when German offshore wind production is low.

In order to demonstrate the financial viability of an interconnection between German offshore wind resources and Norway, two illustrative scenarios (i.e. a reference case with three national connections and an alternative case with two national connections and an interconnection) will be outlined in Section 2 that are both associated with the same overall capacity but different levels of investment. The approach and data to be used in the modelling exercise will be briefly described in Section 3, which will highlight the intermittency of offshore wind generation and the differences in electricity price profiles between Germany and Norway. The analysis of load flows and the revenue generated under both scenarios will then be presented in Section 4 and 5 and will then be followed by concluding remarks (Section 6).

2. Scenario development

The grid connections in the North Sea are built by the system operator Tennet. The grid connections in the Baltic Sea are built by the system operator 50-Hertz. Grid connections in the North Sea are technically more complex and are built with 'Gleichstromtechnologie'. By 2020 Tennet will have an installed connection capacity of about 8 GW in the North Sea.[1]

Figure 1 German offshore wind farm clusters

Source: http://www.tennet.eu/nl/grid-projects/international-projects/nordlink.html

Currently offshore windparks are connected with hvdc-connections with a capacity of 0.9 GW each. The NordLink cable that is currently built between Norway and Germany has a length of 623 km.[2] The length of the Sylwin 2 project is 205 km.[3] Thus connecting the Sylwin cluster to Norway would require a cable with a length of about 417 km. Thus the additional cable length would be about 213 km, leading to additional annual capital costs of 42 €/kW.[4]

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[1] http://www.tennet.eu/de/index.php?id=128&L=2

[2] http://www.tennet.eu/nl/grid-projects/international-projects/nordlink.html

[3] In future offshore connections will be longer, as network nodes further inland are required for the connection. For example the Borwin 5 cable is 260 km long (HGÜ-Verbindung NOR-7-1, S. 116 des Anhangs zum O-NEP). Thus an additional cable length of about 220 km could also be used for the Borwin cluster.

[4] Assuming costs of 2 million €/km (ÜNB, 2015a) and an additional length of 217 km leads to additional investment costs of 426 million € for a cable with a capacity of 900 MW. Scaled to 1000 MW the investment costs would be 473

Based upon the differentials in investment costs, the profitability of the following two scenarios will be considered:

(1) **Reference scenario (three national hvdc-connections)**: Three national hvdc-connections established between a German offshore wind farm and the mainland with a total capacity of 3 GW.

(2) **Alternative scenario (two national hvdc-connections and an interconnector)**: Two national hvdc-connections established between a German offshore wind farm and the mainland with one interconnector between a German offshore wind farm and Norway with a total capacity of 3 GW with additional annual costs of € 42 million. It is assumed that the hvdc substations are connected by AC-cables (BET 2012).[5]

The key question is, if and under which conditions, it would be profitable to spend these additional investment costs? This working paper will present evidence for the financial viability of establishing an interconnection between the German offshore wind farm and Norway that justifies the higher initial investment costs compared to the reference scenario.

3. Modelling approach

In order to estimate the additional revenue that could be achieved from the establishment of an interconnection from a German offshore wind farm to Norway, it was necessary to compare a reference scenario that assumed 3 GW of hvdc-connections only to Germany with an alternative scenario that assumed 2 GW of hvdc-connections to Germany and a 1 GW interconnection to Norway. A simple modelling exercise was taken performed on historic data for the year 2012.

In the reference scenario, the electricity from a German offshore wind farm (with a capacity of 3 GW in 2012) is only transported to the German mainland via 3 GW of hvdc-connections. The historic production profile of the offshore wind farm is shown in Figure 2 for the year 2012. The seasonal variation in electricity output from German offshore wind resources means that the offshore hvdc-connections are only utilised for 49 % of the year. Given this low utilisation rate it is expected that the alternative scenario will result in a higher rate of usage and therefore be more financially viable.

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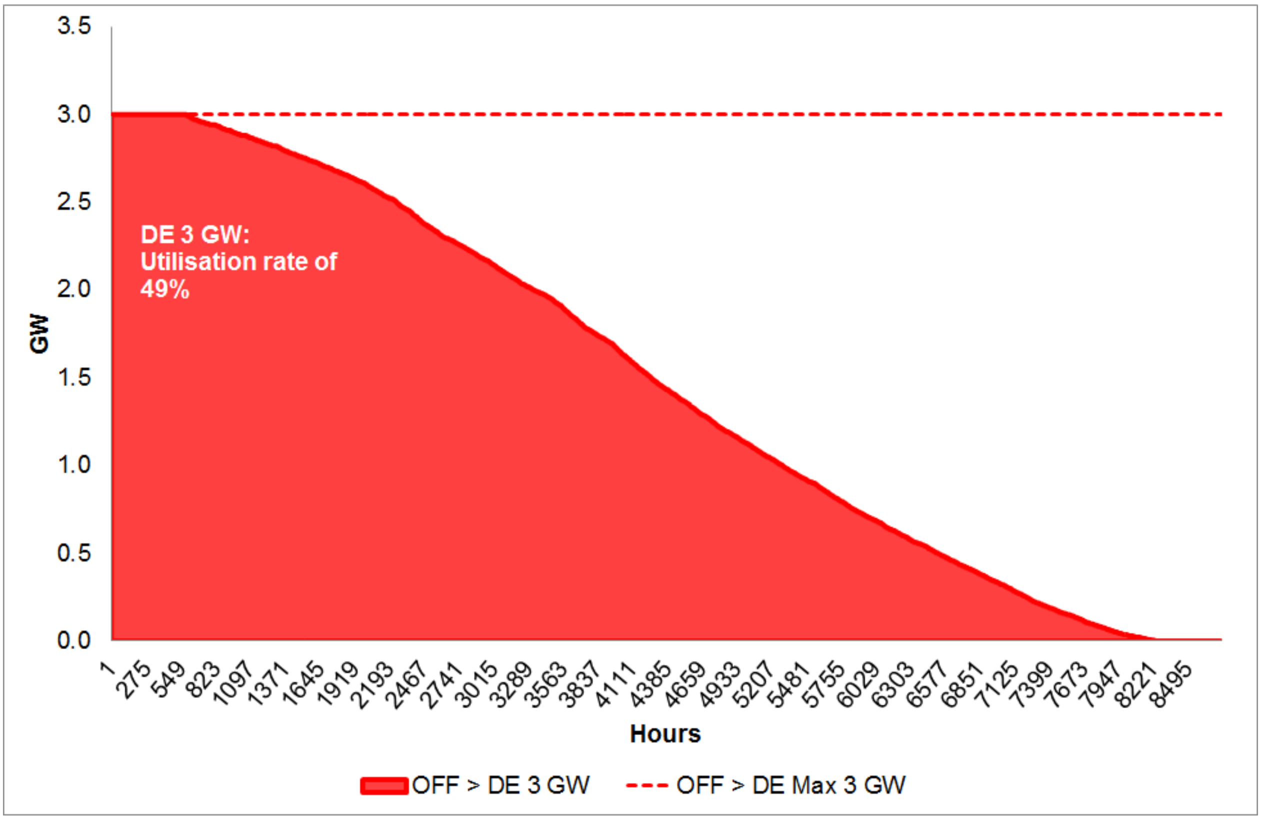
million €. Assuming an interest rate of 6% and a depreciation period of 20 years leads to additional annual costs of 42 million €.

[5] No additional costs were taken into account for these AC connections.

Figure 2 **Load duration curve of a 3 GW German offshore wind farm in 2012**



Source: Scaled based on 2012 data from Tennet

In the alternative scenario it was assumed that the electricity production from the offshore wind farm was sold to the market (i.e. Germany or Norway) with the higher electricity price. Historic electricity prices for the year 2012 were applied for both Germany and Norway (Figure 3) in order to determine the flow of electricity from German offshore wind resources.[6] For example, if the price of electricity was higher in Germany than in Norway then electricity from the offshore wind farm would flow to Germany. However, if the amount of electricity exceeded the 2 GW capacity of the connection to Germany the excess electricity could be exported to Norway.[7] In addition, the alternative scenario also accounted for further revenues from congestion rents (i.e. the profits earned via trading of electricity by the organisation responsible for the operation and maintenance of the hvdc-connections). This occurs when the German offshore wind farm is only generating low amounts of electricity allowing for this unused connection capacity to be made available for electricity trading between Germany and Norway.

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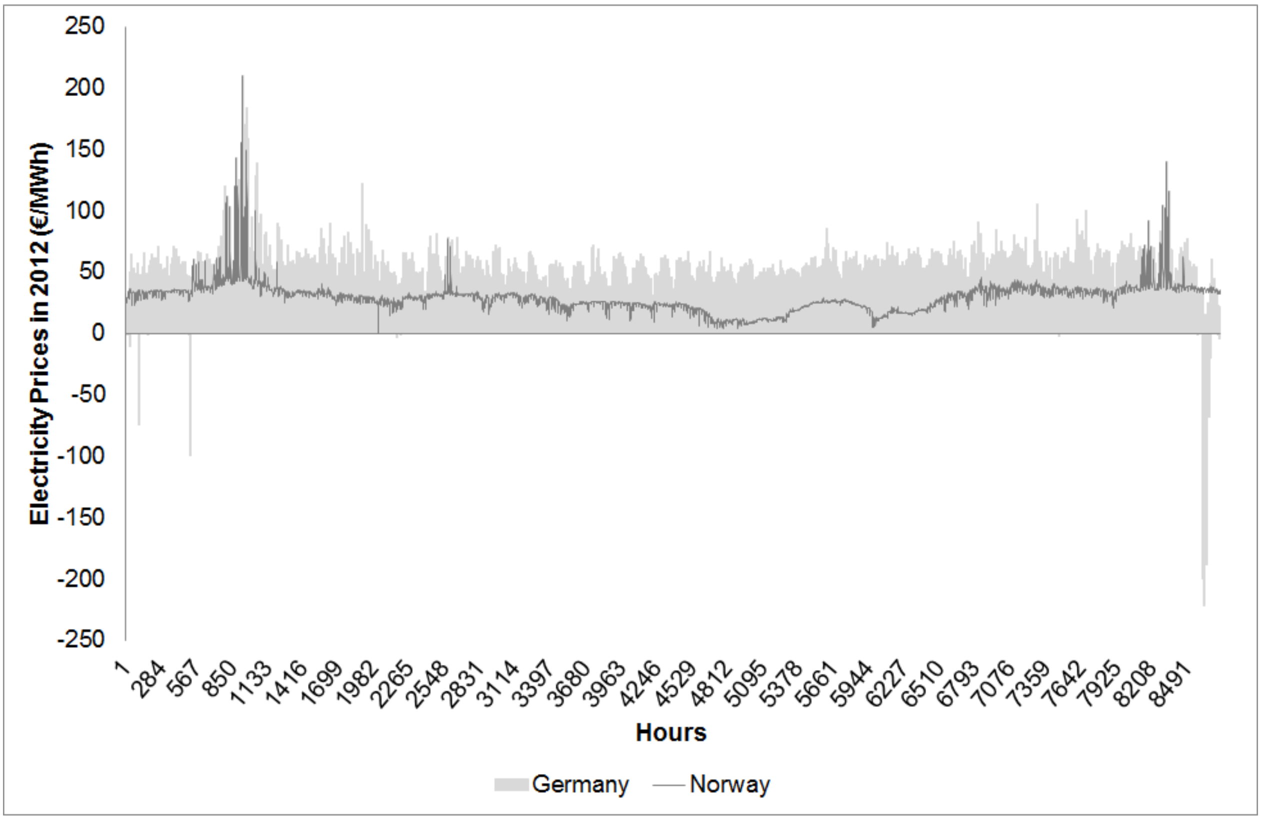
[6] Due to the fact that this study only considers historical data from 2012, it is likely that the outcome of this analysis will underestimate the additional financial benefits associated with an interconnection between the German offshore wind farm and Norway as future market interactions are not taken into account.

[7] The modelling exercise simply assumes that the cable investment would not change price levels in Germany and Norway. Different parameters such as prices for fossil fuels, the prices for EUAs and the evolution of the power plant fleet in both countries are variables that warrant further consideration in future research.

Figure 3 Comparison of electricity prices in 2012 between Germany and Norway



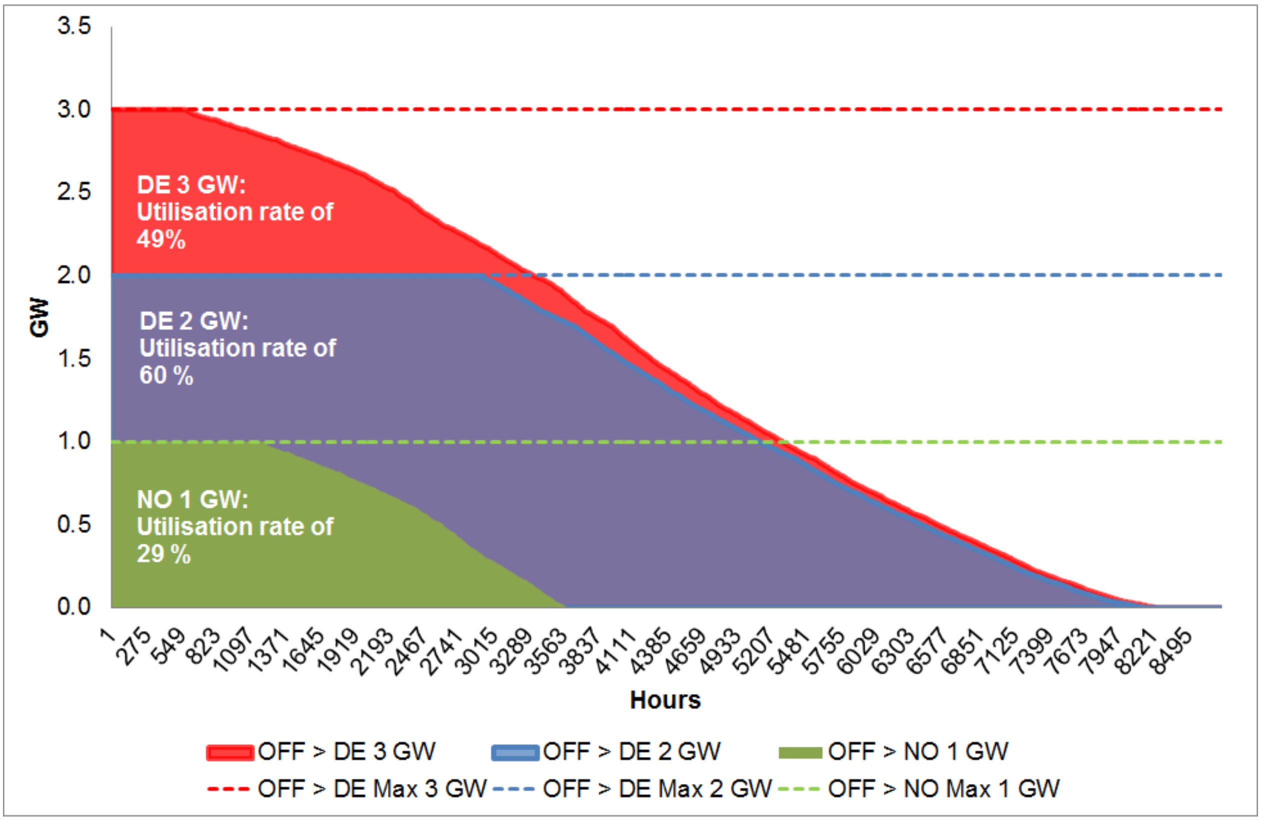
Source: EEX, Nordpoolspot

4. Modelled load flows

A comparison of the utilisation rates associated with the different configurations of the connection cables in both the reference and alternative scenario was undertaken in this study by completing two runs of the modelling exercise (i.e. with and without the ability to trade electricity on the 1 GW interconnection to Norway during hours when it was not fully used by the offshore wind farm).

The first model run assumed that no trading of electricity took place between Germany and Norway when the capacity of the 1 GW interconnection to Norway was not fully used. The utilisation rate of the 1 GW interconnection to Norway (i.e. green area in Figure 4) in this model run was relatively low (i.e. 29 %) compared to the 2 GW connection to Germany (i.e. blue area in Figure 4). This was due to the frequently higher electricity prices in Germany in 2012 (Figure 3), which resulted in the majority of the electricity generated from the 3 GW offshore wind farm being sold to Germany in order to obtain higher revenues. Interestingly, even without the inclusion of trade, the utilisation rate was higher for Germany under the alternative scenario (i.e. 60 %) with less capacity than under the reference scenario (i.e. 49 %).

Figure 4 Utilisation rates of the electricity from a 3 GW German offshore wind farm to both Germany and Norway (without the trading of electricity)

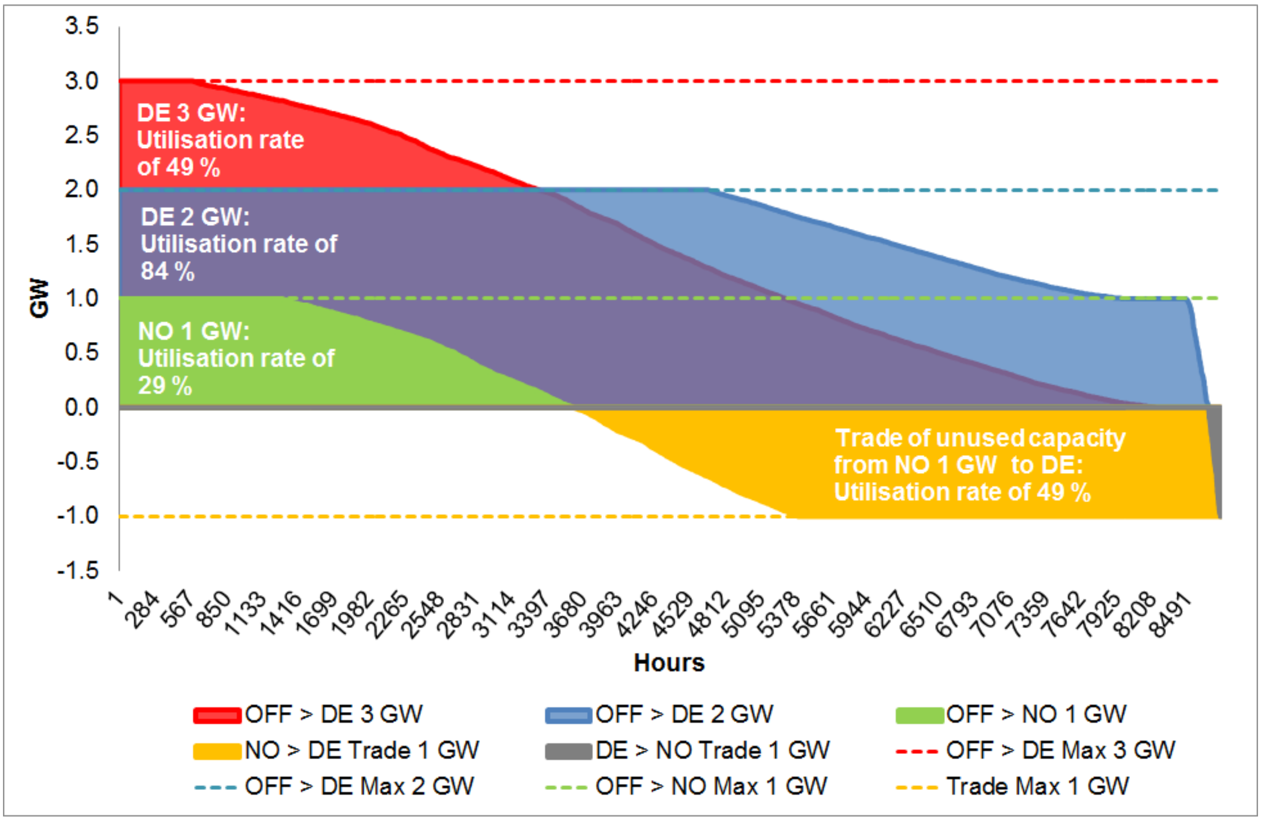


Source: Own calculation

The second model run assumed that trade would take place between Germany and Norway when the capacity of the 1 GW interconnection to Norway was not fully used. The most striking difference with the previous model run was the additional usage of the 1 GW interconnector from the German offshore wind farm to Norway, which enabled Norway in this model run to also export electricity to Germany. Indeed, the modelling showed that 49 % of the capacity of the 1 GW interconnector was used for this trade flow (i.e. orange area in Figure 5). With the inclusion of this additional electricity trade, the utilisation rate of the 1 GW interconnection to Norway increased to 78 %. The trading of electricity with Norway also increased the utilisation rate of the 2 GW connection to Germany (i.e. 84 %) as it operated at a full load for longer than the higher capacity 3 GW connections in the reference scenario (red area in Figure 5). This demonstrates that the contrasting electricity price profiles of Germany and Norway could be complementary and result in a more efficient use of the electricity generated from the offshore wind farm.

The modelling shows that trade from Germany to Norway would be very limited (grey area in Figure 5), however this may change over time as the deployment of renewables in Germany continues to increase and electricity prices converge between the two regions.

Figure 5 Utilisation rates of the electricity from a 3 GW German offshore wind farm to both Germany and Norway (with the trading of electricity)



Source: Own calculation

In summary the electricity brought to the German mainland delivered more full load hours in the modelling exercise. This reduces both the need for the expansion of grids within Germany and the need for storage. In the next section, the additional revenues associated with the increased operating hours will be estimated to build a financial case for the establishment of an interconnection between German offshore wind resources and Norway.

5. Economic assessment

In a second step, it was necessary to calculate the potential additional revenue from a 3 GW German offshore wind farm based upon the alternative scenario (i.e. 2 GW national connections to the mainland & 1 GW interconnection with Norway) compared to the reference scenario (i.e. 3 GW national connections to the mainland).

For the reference scenario this was simply calculated by multiplying the electricity generated by a historical hourly electricity price for the year 2012. However, the alternative scenario required a simple modelling approach to determine the direction of flow of electricity to either Germany or Norway, which was dependent upon capacity and the difference in hourly electricity prices. The electricity flows were then multiplied by the corresponding hourly electricity prices in each country for 2012 to ascertain the potential revenue.

The results in Table 1 show that revenues from selling all electricity to the German electricity market leads to revenues of 532 million €. This is 15 million € higher compared to the alternative scenario were electricity is sold to Germany and Norway (revenues of 517 million €). However, when the ability to trade electricity between both countries is taken into account (i.e. congestion rents[8]) this leads to additional revenues of 80 million € per year. Overall revenues are 65 million € higher per year in the alternative scenario.

Table 1 Revenues achieved under the reference scenario and the alternative scenario

	Revenue Mio.	Power TWh	Specific Revenue €/MWh
Reference scenario (3 GW connection to Germany)			
Germany	532	13	41
Alternative scenario (1 GW connection to Norway, 2 GW to Germany)			
Norway	77	3	31
Germany	440	10	42
Total	517	13	40
Congestion Rent	80	4	18

Source: Own calculation

In order to determine the financial viability of the alternative scenario, the additional revenues of were also compared to the additional investment costs estimated in Section 2. The results in Table 2 show that the additional revenues associated with the alternative scenario offset the additional costs (i.e. 42 million additional annual capital cost) of extending the connection to Norway based upon our transparently documented assumptions. In addition a further benefit would be that the need for network extensions in Germany would be reduced considerably if such an interconnection with Norway was established.

Table 2 Comparison of the profitability of the reference scenario and the alternative scenario

	Reference	Alternative	Change
	Mio.		
Revenue	532	517	-15
Additional cost of interconnection to Norway	0	-42	-42
Congestion Rent	0	80	80
Profit*	532	555	23

Note*: Both scenarios exclude the costs for hvdc-cables that would be installed in the reference scenario, because they are the same and it is intended to only show the change in profit that can be achieved in the alternative scenario.

Source: Own calculation

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[8] Congestion rents were calculated in the following way: First the minimum capacity that was unused for both Germany and Norway was determined at a particular point in time. Minimum capacity multiplied by the price differential in electricity prices between Germany and Norway equals to the congestion rent. When calculating additional revenues any negative electricity prices (due to over-supply of electricity) were not considered.

6. Conclusion

We have quantified the additional revenues, albeit under simplified assumptions, for the installation of an interconnection between a German offshore wind farm and Norway. For the time period examined, additional revenues were created under the alternative scenario when compared to a reference scenario where all of the 3 GW transmission lines were connected to Germany only. The modelling exercise suggests that the additional revenue would justify the additional capital costs associated with extending the transmission line from a German offshore wind farm to Norway. Given that this analysis only considers historical data from 2012, it is likely that the additional financial benefits of an interconnection between a German offshore wind farm and Norway may be even greater when future market interactions are also considered within the modelling exercise. Indeed, future research should also address the merit-order effect of renewables in Germany and the effect of interconnectors on price convergence in both Germany and Norway. Given the outcome of this paper, it is strongly recommended that connecting German offshore wind resources to neighbouring countries should be carefully considered in the on-going network development planning process.

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