Wind valleys of opportunity

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PERFACE/ACKNOWLEDGEMENTS

This document reports activities and results of Task 2.3 of the Intelligent Energy Europe supported project RES 4 Less. This work has been conducted on the base of data provided by the modelling tool RESolve-E. The development and improvement of the tool is the result of the work carried out by ECN staff, specifically Francesco Dalla Longa and Joost van Stralen, jointly with Lachlan Cameron and Rodrigo Rivera Tinoco.

This input has been provided by ECN and later, fruitfully discussed with Francesco Dalla Longa, Karina Veum, Tjaša Bole-Rentel and Paul van der Oosterkamp, as well as with colleagues at DTU Sascha Schröder.

The preliminary results were also shared and enriched by comments from other members of the RES 4 Less Team during an internal meeting of the project.

EXECUTIVE SUMMARY

The objectives of this report are (i) to assess the results regarding wind energy presented in Work Package 2 Task 2.2 within the RES 4 Less Project and complement them with insights from additional sources, and (ii) to identify a suitable case-study for cooperation based on wind energy to be further analyzed in Work Package 3.
The report focuses on the main findings for on-shore and off-shore wind with regard to the applicability for cooperation mechanisms that can reduce the compliance costs of countries for their 2020 RES targets.

Due to the fact that onshore wind is generally cheaper than offshore wind, it is expected that onshore wind resources will be mainly used nationally. Therefore the case-study will focus on offshore wind.

One of the criteria for identifying the case study is that the North Sea Region includes some countries with high compliance costs and some with relatively low cost surpluses. It has been found that Denmark and Germany are the largest potential host countries for off-shore wind Valleys of Opportunity (VoO) while the UK and the Netherlands are the largest user countries.

The actual deployment of offshore wind capacity in German waters is far behind schedule: current estimates indicate that achieving the national targets will already be challenging. This is mainly due to long authorization procedures and major delays of grid connection. Therefore Germany cannot be considered as a realistic host country for offshore wind Valleys of Opportunity.

In the Danish North Sea, suitable sites that could host (surplus) offshore wind developments have been identified in the Horns Rev area. Moreover grid-related barriers appear less severe in the case of Denmark, in particular due to the upcoming *Cobra* connection between Denmark and the Netherlands.

With this in mind this report concludes by suggesting to concentrate the wind case-study on the Netherlands as the user country with Denmark as the host country.

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1 INTRODUCTION

This report ”Wind Valleys of Opportunity” evaluates the specific results of work package 2.2 “Methodology to Identify Possible Valleys Of Opportunity for Cooperation Among EU Countries” with regard to wind energy within the RES 4 Less Project. This report builds on the modelling as stated in the report for work package 2 Task 2.2 including more detailed inputs and outputs than reported there.

The objective for this document is to report on the main findings for on-shore and off-shore wind with regard to the applicability for cooperation mechanisms that can reduce the compliance costs of countries for their 2020 RES targets. The modelling results are assessed and complemented with insights from other sources. As a result, a possible case-study for wind is being proposed.

For wind energy, the focus is on the identification of regional resources that might be exploited jointly.
This identification is carried out as the first step by listing some of the major wind potentials identified with the RESolve-E model (**chapter 2**) based entirely on the model outcome. The regional opportunity is then addressed in **chapter 3** by comparing countries pairwise and examining in more detail the offshore wind surplus characteristics. In **chapter 4** other external constraints limiting this availability are treated and comparisons are made to actual development plans in Denmark and Germany. Those are constraints due to other uses and grid integration problems. This is done based on other studies reporting on physical constraints alternative land use restrictions and national planning constraints. The report finally identifies an area of wind opportunities as an input to the case-studies in the following work packages (**chapter 5**).

2 WIND ENERGY SURPLUS

This chapter builds on the results of the model analysis reported in D2.2 (Dalla Longa F, Bole-Rentel T, 2011). Some numbers used in this chapter 2 are already reported in tables in the D2.2 report, but additional data for wind has been produced for the onshore and offshore wind technologies. Wind energy is the dominant option reported for the renewable surplus technologies that are available above the NREAP targets in 2020. Wind onshore and off-shore accounts for 69% of the total surplus in 2020.

2.1 Onshore wind

Onshore wind surpluses are smaller than the off-shore potentials and they will be exploited first due to the relatively low cost nature of this option. Much of the onshore wind potential will already be exploited in the national plans, NREAPs. However compared to other technologies on-shore wind surplus is still very important with 24% of total renewable surplus.
The total eligible surplus for on-shore wind in 2020 is found to be 65.3 TWh in the Deliverable 2.2 report. Onshore wind is a low cost potential, but also associated with a lot of barriers in terms of public acceptance and local resistance in many countries. Therefore this resource will tend to be exploited were is serves national target compliance and not other countries target compliance.

2.1.1 Comparison of on-shore wind surpluses

France is dominating the eligible surpluses for on-shore wind with Norway second.

Table 2.1 On-shore wind eligible surpluses for 2015-2020 sorted by size (TWh)

Country	2015	2020
France	24.5	24.0
(Norway	9.4	17.5)
Sweden	4.3	6.5
Poland	0	4.1

The onshore wind surpluses are within the cheaper RES options in general. The construction time is short and not as dependent on logistics as the offshore wind which is probably the reason for identical potential for France in 2015 and 2020. However, this relatively cheap option is often associated with local resistance and approval procedures that may delay the installation. With this public opinion dilemma in mind these onshore wind options will most likely be restricted to fulfilling the national RES targets in 2020 and the expected increase in the years hereafter.

2.2 Offshore wind

The total eligible surplus for off-shore wind in 2020 is found to be 121.8 TWh according to the RESolve-E model calculations in task 2.2. This is double the size of the on-shore surplus and nearly 45% of the total eligible surplus.

The costs of the off-shore wind is much higher than the onshore wind which means that in the pairwise comparison the on-shore potentials enters first followed by the off-shore. The cost difference for the off-shore potentials in the countries can also make the list of countries that appears in pairwise analyses different from the one based on the global analyses.

2.2.1 Comparison of off-shore wind surpluses

France also dominates the eligible surpluses for off-shore wind. Denmark has the second largest surplus. Sweden, Germany and Ireland are also included with potentials that could make them host countries if their cost levels for this resource are competitive.

Table 2.2 Off-shore wind eligible surpluses for 2015-2020 sorted by size (TWh)

Country	2015	2020
France	3.2	39.5
Denmark	14.9	30.9
Sweden	6.2	17.2
Germany	0	15.7
Ireland	4.6	8.1

The French surplus in offshore wind is an obvious candidate for cooperation mechanisms, if the onshore surplus is not considered or already exploited by some other user countries. Here the cost profile of the French off-shore wind has not been further explored also because it is not fully in line with NREAP plans for France.

Denmark also has a large surplus in 2020, whereas the surplus in Germany and Sweden is somewhat smaller. Finally Ireland has a surplus that is relatively large compared to the country size. The larger the surplus compared to country size the more likely it is that cost competitive offshore wind will be available for cooperation. If the surplus is small the country might withhold it for later use under new RES targets or just because of uncertainties regarding other RES expansion until 2020. Because of the uncertainties regarding the UK user categorisation and the off-shore cost profiles for UK this will not be further exploited here. There are however some ongoing activities from UK and Ireland to engage in cooperation projects in the Irish Sea.

3 POTENTIAL HOSTS AND USERS OF VALLEYS OF OPPORTUNITY FOR WIND ENERGY

The host countries are those with low cost surplus resources that might be expanded and counted towards the 2020 targets of the user countries. Host and user countries have incentives to engage in cooperation on target compliance for mutual benefit created by cost efficient renewable expansion. This chapter use
For the onshore wind France has a considerable resource and the other countries with lots of wind resource also have some. The on-shore resources are more limited than the off-shore and they are at much lower costs. This means that they will first be exploited nationally and as on-shore are facing more planning/acceptance constraint domestically they take time to implement. On-shore wind will be exploited even without cooperation. Therefore excess resources that might be exploited by cooperating on RES expansion will most likely have to be found in the medium cost interval with a very large resource - namely off-shore wind energy.

3.1 Offshore wind

Off-shore wind is reported as an option in most of the pairwise comparisons and in the global analysis. The resource is however concentrated in a few countries, which would most likely act as hosts for offshore wind projects. At the same time, potential user countries are also dominated by some large users. This representation is distinguished from above as the hosts are competing in the supply and the users are competing for exploiting the resources in host countries. It is not possible to sum the rows of host countries and users do not demand the sum of columns. All the numbers in this table are dependent on the relative costs between the host and the user country for each combination.

Table 3.1 Main pairwise off-shore VoO's in 2020 sorted by size of host (TWh) (source Table A.3 in Dalla Longa F, Bole-Rentel T, 2011)

Host\user	UK	Netherlands	Poland	Greece	Belgium
Denmark	30.8	19.7	13.0	11.2	6.0
Germany	15.7	13.6	9.2	9.2	3.5
Ireland	0	7.0	6.7	8.1	4.4

According to the findings reported in the table Denmark is the largest potential host country for off-shore wind VoO's. The results are consistent with regard to the pairwise size of opportunities as Denmark is the largest host for all the 5 user countries in the table. The demand from the UK is however large enough to correspond to the entire Danish supply.
UK is found to be the largest user country which is found for the two largest host countries but not for Ireland. This should be interpreted with care since some UK data are a bit uncertain especially regarding costs. The surplus of Ireland compared to UK might also show up in table 3.1 with slight modification of modelling details. In the global analyses this surplus of Irelands (7 TWh) shows up.

With regard to costs Denmark exhibit a quite large variation as illustrated in Figure 1. To realise the large gains from cooperation countries should have different marginal RES costs. This is not the case for off-shore wind which for most countries have costs ranging from 10-20 €ct/kWh (see Figure 3) depending on wind conditions, sea-depths and distance from shore. In contrast to other countries Denmark have considerable off-shore potentials in the lower/middle part of this interval and these could provide a basis for cooperation gains with the user countries included in Table 3.1.

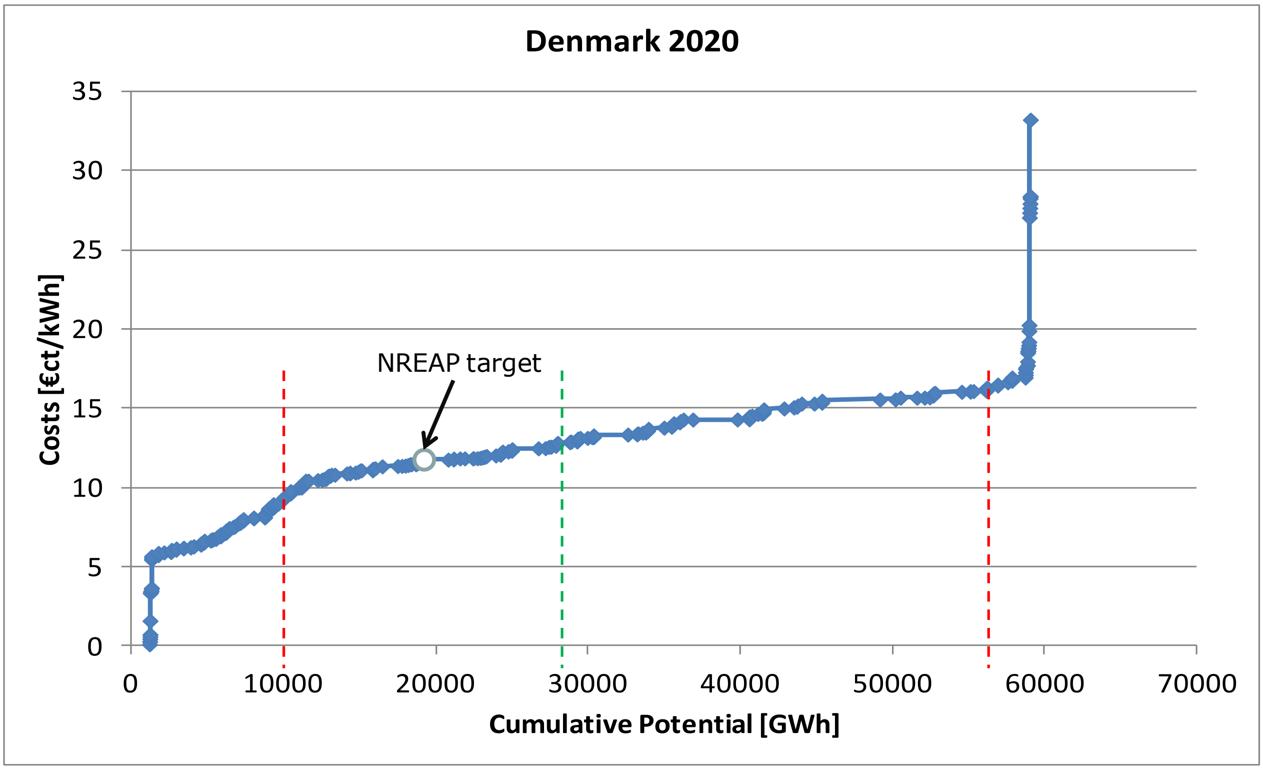

Figure 1 Cost Supply curve for renewable technologies in Denmark in 2020. Onshore and Offshore wind technologies appear between the red bars. (Dalla Longa F, Bole-Rentel T, 2011)

Looking at Denmark it is evident that the wind potential dominates the total opportunities for renewable (80%). Wind constitutes 95% of all resources between the two red bars. In costs this correspond to the interval from approx 10 €ct/kWh to 20 €ct/kWh. The cost variation for Denmark is similar to that of Netherlands in Figure 2 and also Netherlands has some resources from 10 €ct/kWh to 20 €ct/kWh. The surplus for Denmark is found above the cost level 11.75 €ct/kWh.

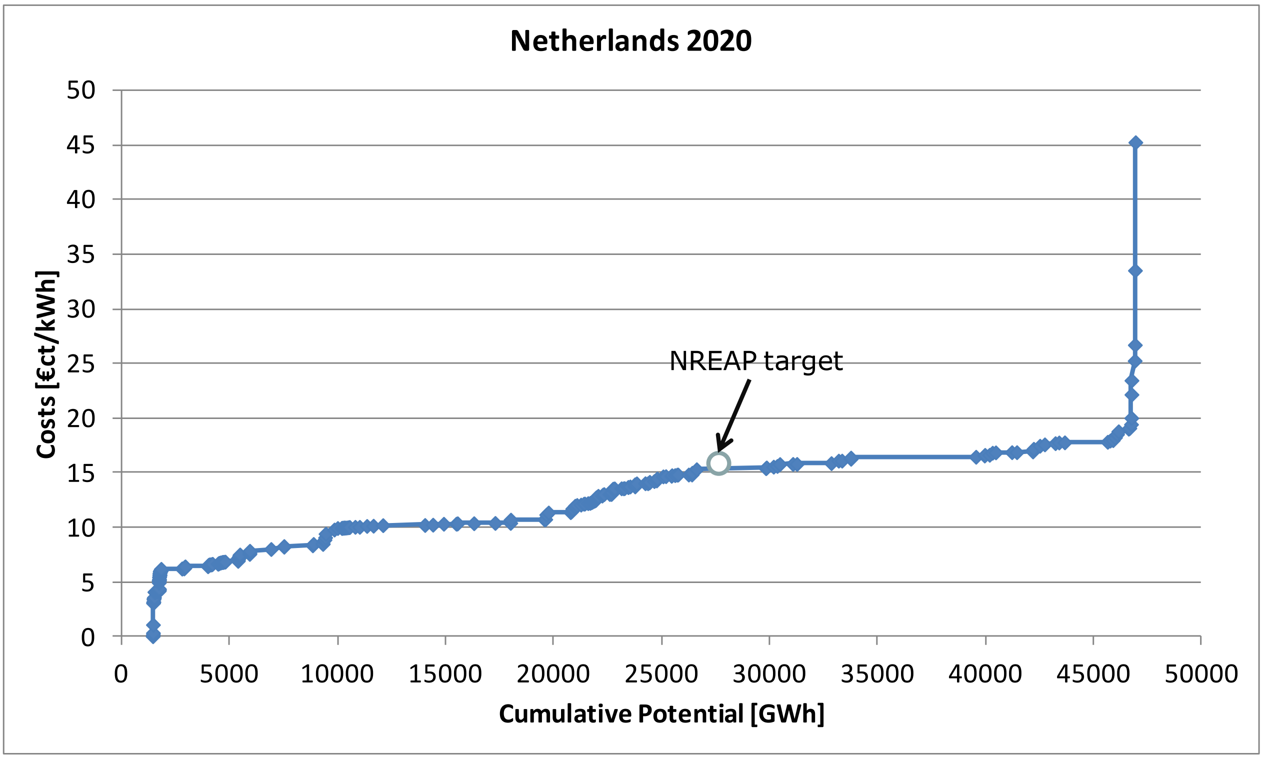

Figure 2 Cost curve for all renewable technologies in the Netherlands (Dalla Longa F, Bole-Rentel T, 2011)

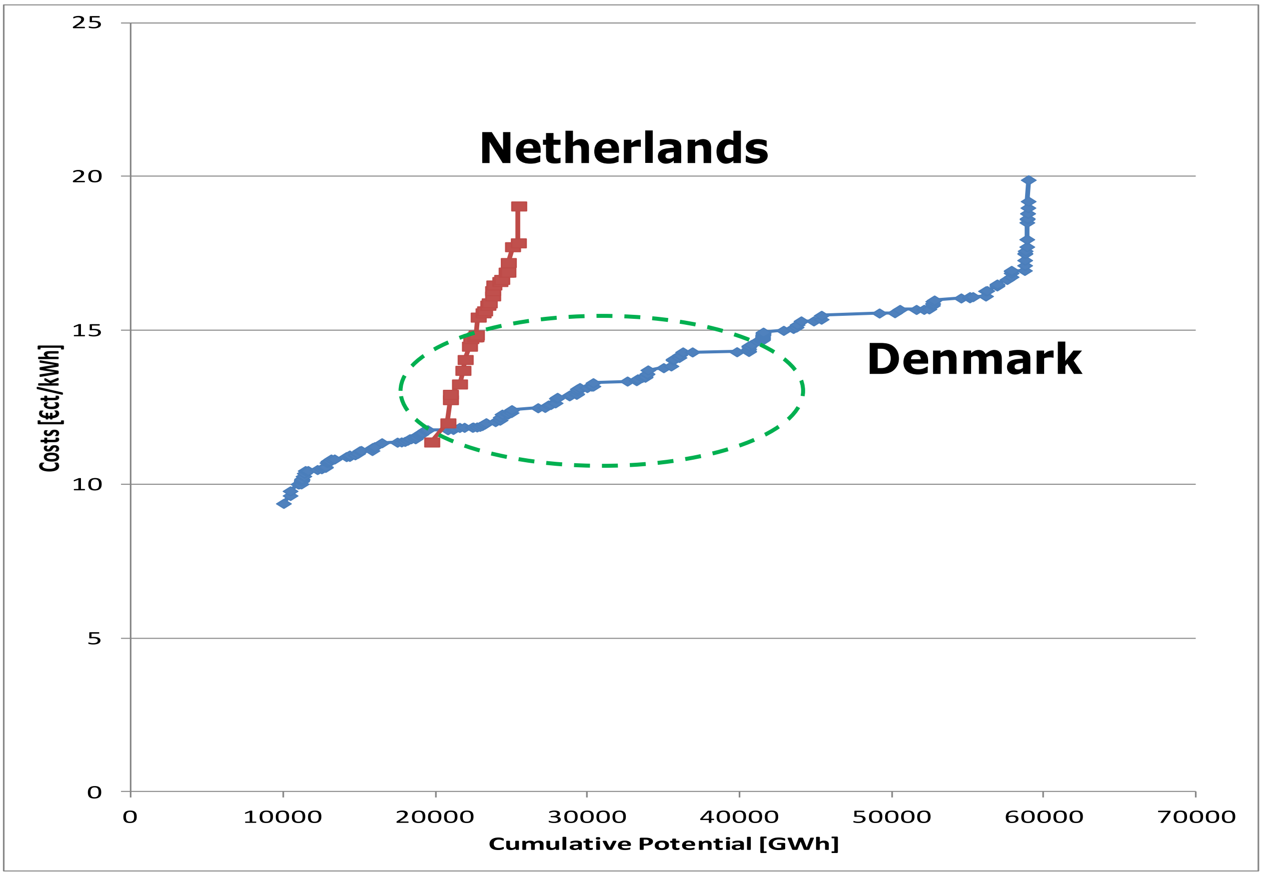

Figure 3 Comparison of marginal cost and potential for offshore wind generation in DK and NL in 2020

Figure 3 illustrates the power generation costs for potential wind expansion in DK and the Netherlands. The two cost curves are similar with respect to the cost interval but differs with respect to the potential of wind. For DK and the Netherlands the cost variation is overlapping but the wind potential in the Netherlands is very small compared to DK. For all cost levels DK has much more potential wind resources. Cooperation on RES compliance between DK and the Netherlands will thus not be driven by cost differentials in general but a general shortage of suitable low cost off-shore wind locations in the Netherlands. The cost interval that is attractive for cooperation mechanisms between the two countries is marked by the dotted circle. These wind costs are above the costs corresponding to the Danish target in 2020% and similar to the equilibrium cost range identified in Deliverable D2.2 of the RES 4Less Work Package 2 report (fig 4.7).

The large bilateral cooperation opportunities are also reflected in the equilibrium prices reported in D2.2 table 4.2 that include more technologies than wind but are dominated by the offshore wind resources which constitute 90% of the DK surplus in 2020. Here Denmark records the highest price in trade with UK (16.9 €ct/kWh) and a bit lower in trade with the Netherlands (15.3 €ct/kWh) because less is traded in this case (NL has a smaller deficit). There are other cheaper options for the UK (14.4€ct/kWh) and the Netherlands (13.8 €ct/kWh) with France that has the cheaper surplus in on-shore wind. However these differences in equilibrium price are so small that no conclusion can be drawn from that.

3.2 Offshore wind in a regional context

The pairwise comparison of countries identifies very interesting potential VoOs in the region around the North Sea. Countries like Denmark and Germany are obvious host candidates, while possible user countries are UK, the Netherlands and Belgium. The total off-shore surplus for this constellation is 46.6 TWh, which corresponds to almost 40% of the EU wide off-shore wind surplus from . Based on the aggregate indicators from table A.2 in (Dalla Longa F, Bole-Rentel T, 2011) it covers 2 of the four largest user countries and 2 of the 4 largest host countries.

An alternative is to include Norway in this constellation but Norway has exceptionally low costs resulting in very low equilibrium prices and is primarily based on on-shore wind. Therefore this is a separate analyses, which does not involve the complex off-shore wind issues. As a candidate for cost saving cooperation Norway should be considered separately as a general host country.

4 ASSESSMENT OF RESTRICTING FACTORS FOR THE POTENTIAL VALLEYS OF OPPORTUNITY

The previous chapter indicated which bilateral cooperation combinations might be promising for the development of wind resources in Europe. The country combinations were characterised by the amount of energy that could be developed and at what cost. This is what we referred to as "potential VoO for wind energy". These VoOs are entirely chosen based on cost-effectiveness of reaching Member States RE targets.

Cost-effectiveness is of course but one of the many considerations countries take into account when deciding on the development of additional RE potential for export (in the case of host countries) or buying or co-developing part of RE in another country (in the case of user countries). This section addresses in a qualitative manner some of the main constraints that narrow down all the potentially interesting economic opportunities for cooperation to those that are "readily exploitable," or in other words, distinguish a "potential VoO" from a "real VoO".

The constraints we focus on are the physical use constraints of the sea areas (potential sites), the cost characteristics and the network constraints. Most of these will be assessed from the point of view of the host country. However, the cost constraints and the network constraints are just as relevant for user countries, which should consider their assessment as part of their due diligence on the cooperation option they are considering. In this analysis Denmark as well as Germany are assessed as possible host countries.

4.1 Physical restricting factors – alternative uses – environmental protection

The identified potential valleys of opportunity do not take all physical and planning constraints into account. For offshore wind expansion these constraints can considerably reduce the most attractive low cost close to shore wind potentials. This is because these sea areas are used extensively for competing uses, namely shipping lanes, sand extraction and also contains the most abundant wildlife resources. We therefore address these limiting constraints for the potential host countries Denmark and Germany.

The Windspeed project has addressed the offshore wind potentials in the North Sea (Veum et al., 2011). Focus has been on the cost profile for different locations and technologies in the North Sea area and the limitations that other economic use and regulation pose on these areas. The potentials include in some of the scenarios deep water locations that are beyond the scope of the RES 4 LESS 2020 focus. The most restricted scenario without prioritisation and cooperation (Little will Little wind) estimates a total potential for the North Sea of 38 GW capacity by 2030. The restricting factors identified and described in this project (Munoz and Jacquemin, 2009, Veum et. al. 2011) are also relevant for the RES4LES potentials.

- Sand extraction
- Fisheries
- Oil and gas extraction
- Military areas
- Shipping
- Nature conservation (reserves)
- Marine wildlife preservation
- Cables and pipelines

The off-shore wind potential identified for the North Sea have to be verified against these constraints for the specific areas that have the cost characteristics to qualify for cooperation. The lower cost offshore potentials are at shallow waters and these must be assumed to be the most exposed to competing use and nature reserve restrictions. For the slightly higher cost potentials at deeper water the most restricting factor must be assumed to be shipping lanes. Nature reserves, sand extraction and military purpose are less pronounced in deeper waters. Below some of these restrictions are discussed in relation to the German and Danish offshore potential identified in Deliverable 2.2 (Dalla Longa F, Bole-Rentel T, 2011).

4.2 Germany

In this chapter, the models results for offshore wind in Germany are being compared with the deployment in reality. This makes it possible to appraise, if the total eligible surplus calculated by the model is a realistic option. Additionally this chapter looks at the general restrictions to offshore wind deployment as well as restrictions due to grid issues.

4.2.1 Assessment of the models outcome

The total offshore wind production in Germany as calculated by the RESolve-E model stated in the report for Workpackage 2 Task 2.2 within the RES 4 Less Project is 93.1 TWh by 2020. Assuming 3,250 full load hours (Bundesrepublik Deutschland, 2009), some 28.6 GW of offshore wind turbines must be installed to reach this production.
Today, some 469.5 MW of offshore capacity are deployed in the German North Sea. Authorized wind park deployments in the first stage of expansion add up to 12 GW of installed capacity. Looking at the final stage of expansion, readily deployed and authorized wind park capacity adds up to around 20.5 GW.[1]
The Offshore Grid Project developed scenarios in which they expect some 10 GW of installations of offshore wind capacity until 2020 in Germany (Decker; Kreutzkamp, 2011). This amount corresponds with the figures of authorized wind park developments in the first stage of expansion mentioned in the section above.
Also the German NREAP Report states that 10 GW of offshore wind capacity should be feasible by 2020. It has to be taken into account, that this amount is highly dependent on delays in installation and commissioning as well as reinforcement of the grid on the coast. (Bundesrepublik Deutschland, 2009)
The German DENA Grid Study II assumes 12 GW of installed offshore wind capacity in the North Sea by 2020 (DENA, 2010).
Figure 4 shows that a large difference exists between the results for offshore wind capacity from the model and the actual development and also the national target of 10 GW.

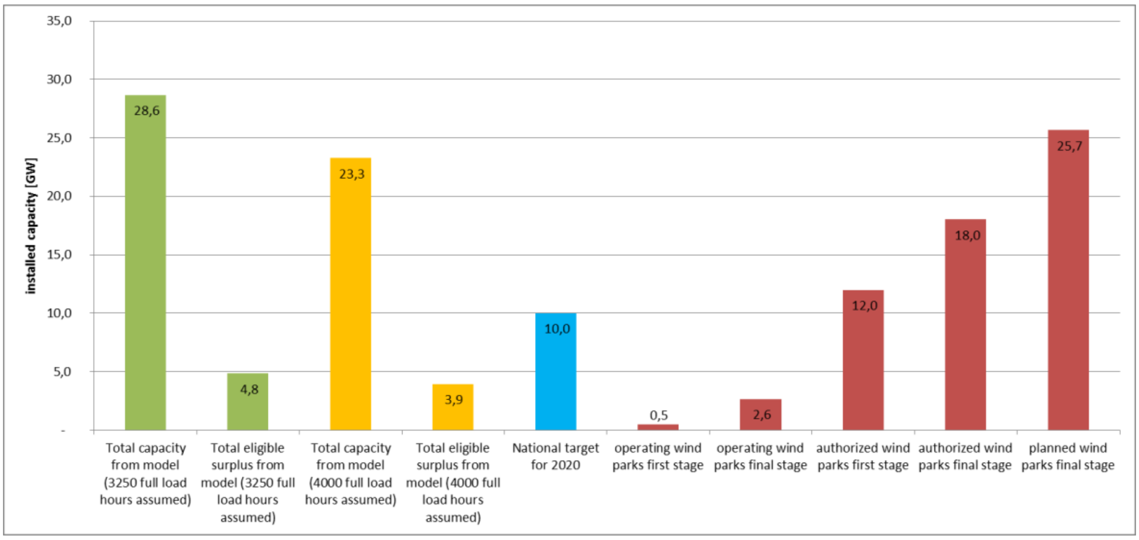

Figure 4: Comparison of the models results with the reported offshore development

[1] http://www.offshore-wind.de/page/index.php?id=4761 12.01.2012

In addition, due to the following problems major players in Germany do not believe that even the target of 10 GW of offshore wind capacity will be reached by 2020. More likely seem to be 6.5 to 7 GW. The main problems, which possibly result in missing the target, are:

- Financing
- Grid connection
- Transport of electricity (Uken, 2012)

The problem of **financing** the offshore wind parks seem to have eased out as more and more private investors take on the risks involved in offshore wind projects. Also the Federal Government has improved the support for deployment of offshore wind parks.(Uken, 2012) [2]

Regarding the problem of **transporting the electricity** a study conducted by ECOFYS for the Bundesverband Windenergie e.V. gives an impression of the amount of wind energy curtailed due to grid problems. The study states that 72 to 150 GWh of production have been lost in 2010 mainly in Northern and Eastern Germany. This accounts for 0,2 to 0,4 % of the total wind energy produced in this respective year. Nevertheless, most important for the issues discussed here is that curtailment grew between 2009 and 2010 from 36 to 69%. (Bömer, 2011)

This shows that not only grid connection is a major factor for possible delays, but also transportation of energy.

4.2.2 Restricting spatial factors

To get an impression on the development of deployment costs for offshore wind parks in German waters the average distance to shore and water depth have been taken into account. The distance to shore of the average offshore wind park in operation is about 34 kilometers. If the average distance is weighted with the installed capacity in the final stage of expansion the average distance to shore is 71 kilometers.

Looking at the authorized wind parks the average weighted distance to shore is 67 kilometers.

The same analysis has been carried out for the water depth. The average weighted water depth is 36 meters for the wind parks in operation while the average for the authorized wind parks is 30 meters. These numbers show a substantial increase in distance to shore as well as a moderate decrease of average depth for future wind park deployment. This might give be an indication of increasing costs for future wind parks offshore.

The following Figure 5 shows some of the restricting factors in the German North Sea region. The map shows priority areas for offshore wind as red boxes. Further authorized wind parks are shown as grey boarded boxes. Some main conclusions can be drawn from the map:

1. Possibly due to the important harbor of Hamburg and also some fishing industries, major parts of the exclusive economic zone are being reserved for shipping.
2. Major parts of the exclusive economic zone are very far away (>150km) from shore.
3. Some large areas – especially those close to the Schleswig-Holstein – are occupied by NATURA 2000 areas.

This leads to the conclusion that Germany has limited areas available for offshore wind deployment relatively close to shore. Most of the authorized and operating wind parks (red and grey boxes) are occupying the closed areas to shore already. Therefore following projects have to move further away from shore into deeper waters. Deployment costs will rise accordingly.

[2] http://www.foerderdatenbank.de/Foerder-DB/Navigation/Foerderrecherche/suche.html?get=4aa561e46fff16fb87d819d09c769842;views;document&doc=11416 18.01.2012

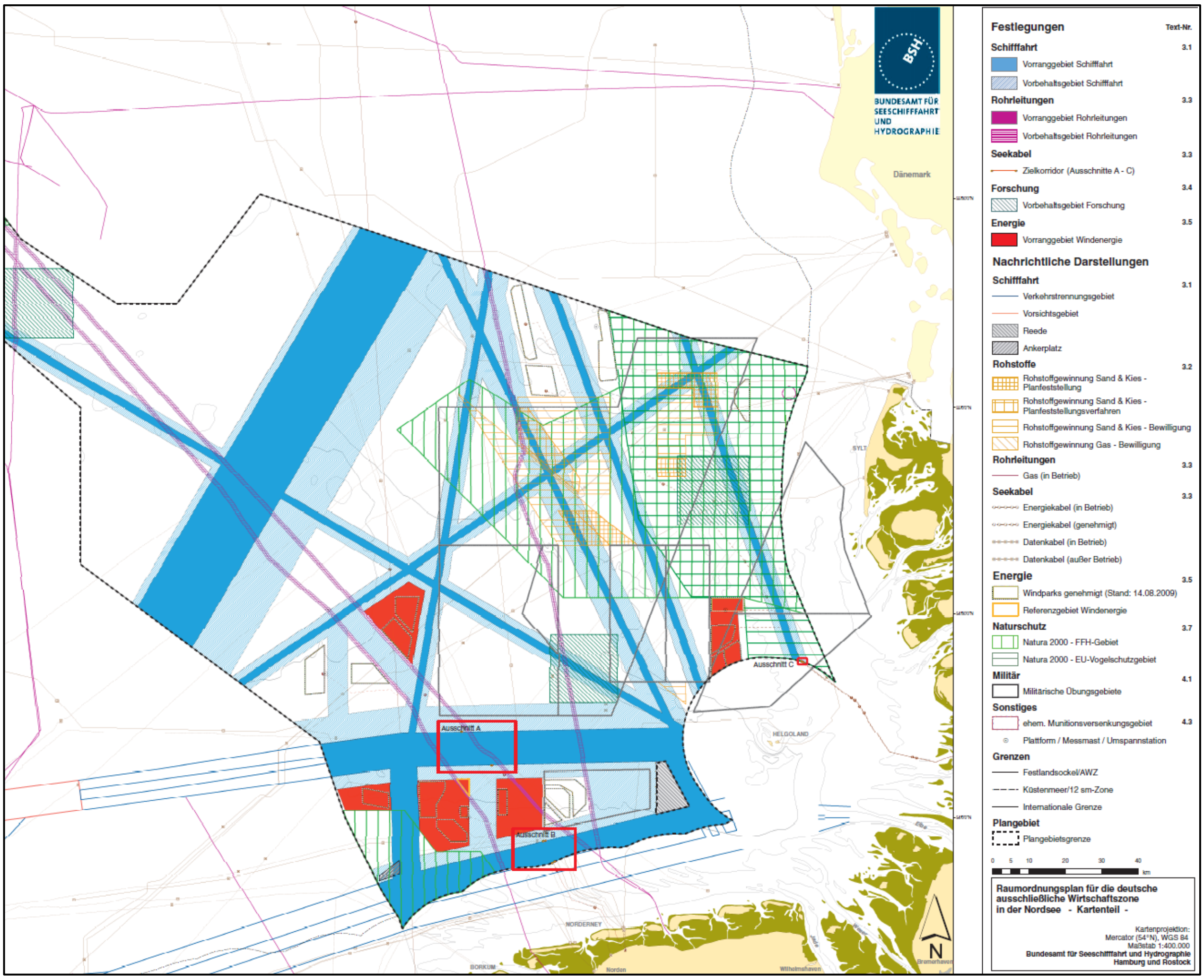

Figure 5: Restricting factors for the use of North Sea for offshore wind (Bundesamt für Seeschifffahrt und Hydrographie[3])

4.2.3 German network limiting factors in 2020

By the end of 2011there were four offshore wind parks operating in German waters in the North Sea. In the final stage of expansion about 2,645 MW of those operating wind parks will be connected to shore in Emden. Looking at the total capacity of all authorized and operating wind parks in their final stage of expansion, some 14 GW will be connected to the area of Norden/Emden. This accounts for 68 % of the offshore wind capacity by that time.[4]

The significance of the region of Norden/Emden can also be seen in Figure 6.

[3] http://www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/index.jsp 23.02.2012

[4] http://www.offshore-wind.de/page/index.php?id=4761 12.01.2012

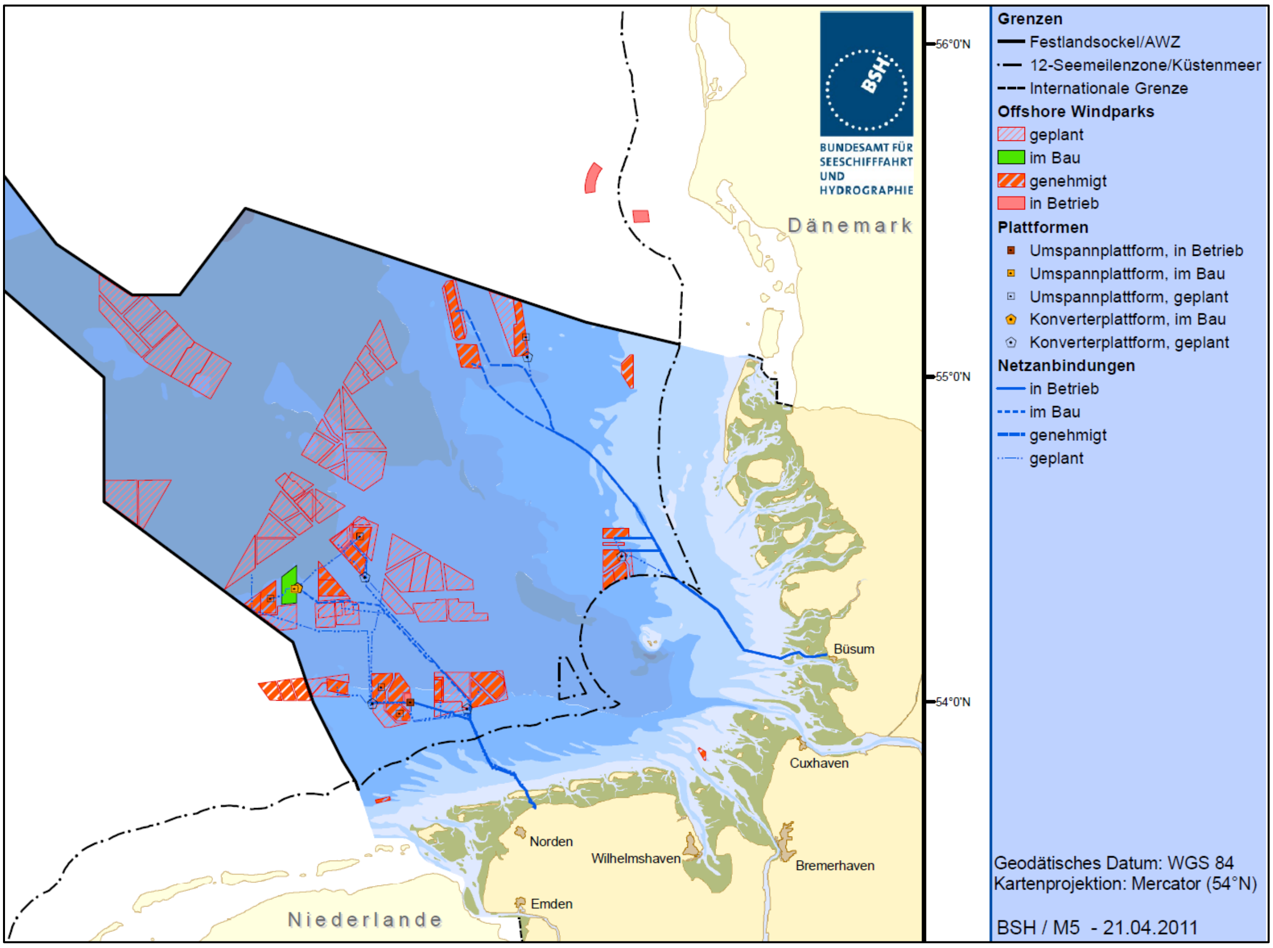

Figure 6: Offshore wind parks (authorized and operating) in the German North Sea (Bundesamt für Seeschifffahrt und Hydrographie[5])

Due to this concentration of offshore energy reaching the shores in this region, some grid reinforcements have already been stated in the Ten Year Network Development Plan (TYNDP) which has been conducted by Entso-E, the European Network of Transmission System Operators for Electricity. They mainly concern the connection in between Emden and the Ruhr District.

The RES 4 Less Workpackage 2 Task 2.2 report shows that Germany could sell surplus offshore energy to the Netherlands. As the Netherlands are bordering the region of Norden/Emden possible grid issues limiting the physical transfer of electricity seem to be irrelevant at first sight. There is an existing 380kV grid from the south of Emden to the Netherlands. Assuming that all the surplus energy being sold to the Netherlands also has to be transported to the Netherlands most of this energy will be the offshore wind energy reaching the shore in the Emden Region. Further connections from this region to the Netherlands are not mentioned in the TYNDP of entso-e. Therefore it is questionable whether this connection is sufficient in case of physical transfer of the surplus energy to the Netherlands. This assumption also corresponds with statement made by the grid operator TenneT.

Tennet states on its website that there is a major shortage of interconnector capacity between Germany and the Netherlands which already leads to congestion problems[6].

4.2.4 Conclusion for Germany as a host-country for offshore wind energy

In conclusion, the previous sections have shown that:

[5] http://www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/index.jsp from 23.02.2012

[6] http://www.tennettso.de/site/en/Transparency/publications/congestion-management/overview from 27.01.2012

1. the total installed capacity calculated by the model dramatically exceeds the realistic installed capacity,
2. therefore it is doubted that surplus will be available for the use of cooperation mechanisms and
3. grid infrastructure issues (connection and transport of energy to load centers) are the crucial factors why the actual deployment is behind schedule.

This being the situation, a case study with Germany as a host-country for offshore wind energy does not seem realistic.

4.3 Denmark

The offshore surplus for Denmark identified in RES 4 Less WP2 task 2.2 will only be available in 2020 if adequate action is taken for cooperation and planning years ahead. The actual investment in the wind parks do also have to be gradual as it is not possible to implement the physical investment/construction of the wind farms only during 2019. This is illustrated in the two different scenarios reported in the task 2.2 report (Dalla Longa F, Bole-Rentel T, 2011). Here it is shown that the Danish wind surplus is only available in 2020 if cooperation has already been initiated earlier.
In the Danish NREAP estimate of offshore wind only 1340MW are identified as contributing to the total RES target of 30% in 2020. The main contribution towards Danish 2020 targets is seen from solid biomass based CHP. Therefore Denmark has a considerable surplus based on offshore wind as identified in (Dalla Longa F, Bole-Rentel T, 2011) and also included in the site planning of future wind parks by Danish authorities. There are not yet any agreements or funding for off-shore wind extensions included in the surplus. The surplus is assumed to be only in areas where large scale wind parks will open. Compared to the geographical North Sea area the offshore target in the NREAP of 1340MW is very little and no additional North Sea wind parks have to be build to meet this target. The other North Sea countries have considerable higher targets compared to their area with Germany 10GW and the Netherlands 5GW. It is therefore more likely to find lower cost options in offshore locations in Denmark than in the two other countries.

The Danish identified surplus is found both in the North Sea and in other areas. In the following a division is made to estimate the share for the North Sea and the corresponding cost profile. The Danish specific wind parks planning (DEA 2007, 2011) identified 14 sites for 200MW projects in the North Sea corresponding to 61% and 9 in other areas. The distribution of additional potentials above these 4600MW must be characterised with a higher share in the North Sea, because other areas are more affected by especially nature reserve and wildlife protection. Of the total identified surplus for Denmark (31TWh) the share of the North Sea is thus estimated to contain 70% corresponding to 22TWh or approximately 5300MW which is twice the size of the already planned parks in this area namely 2800MW.

4.3.1 Characterization of the Danish North Sea surplus wind potential

According to DEA (2011) the planned areas for large scale offshore windparks cover 4200MW beyond 2012/13 corresponding to approximately 17 TWh. Of this the 2800MW are North Sea locations at max around 25m depth. The identified surplus potential in this project includes capacities at depth levels 30-50m not included in the location specific Danish planning. The sea areas identified for future wind parks also include deeper locations without planned parks yet. This is where some part of the surplus potential is to be found.

The 2800MW at specific sites in the North Sea would constitute nearly 40% of the identified surplus from the model. The additional 60% might be accommodated in the same areas as the planned windparks but at deeper levels and further from shore with corresponding costs. This is also seen from the cost curve in Figure 3.

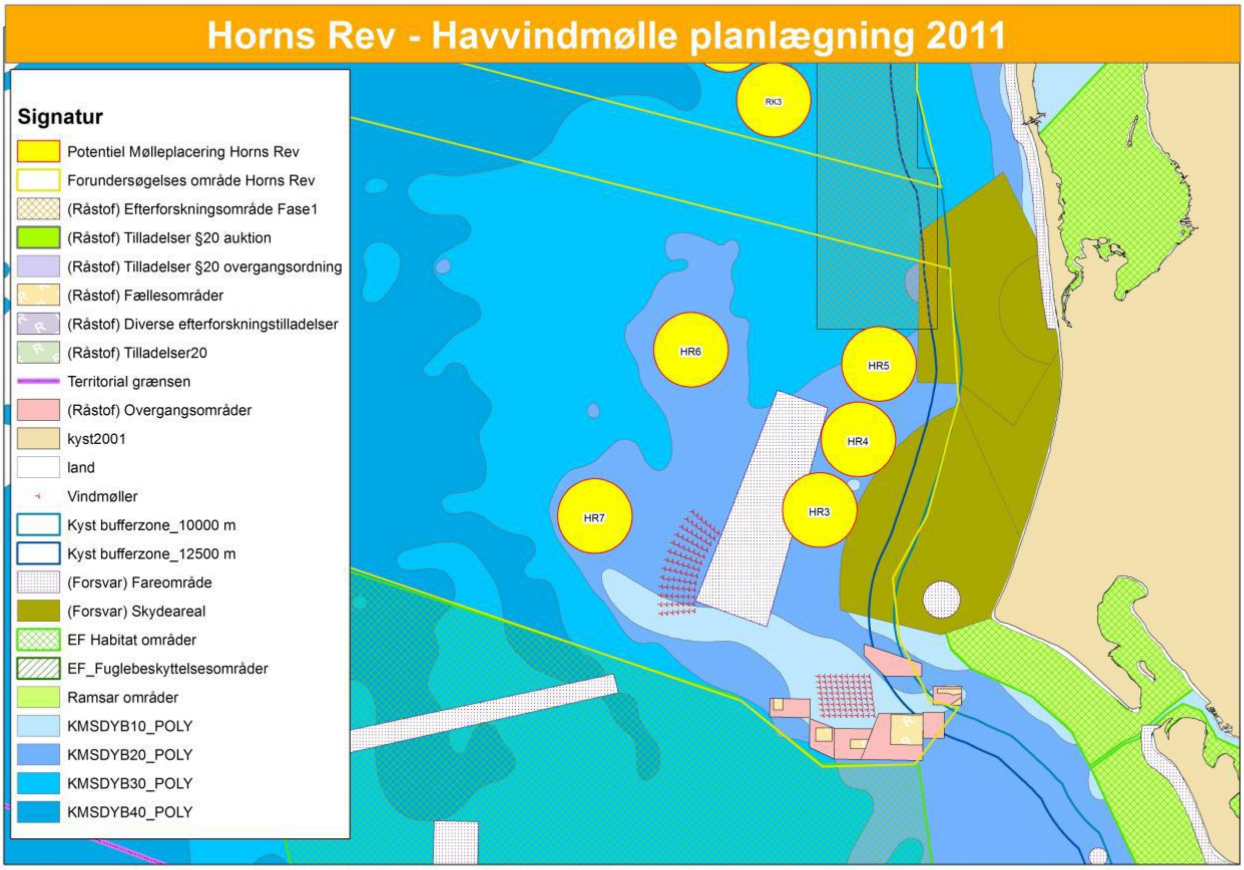

Figure 7: Wind parks in the Horns Rev area (reproduced from DEA 2011)

The planning in Denmark has focused on the least cost off-shore areas taking into account all the alternative use and regulatory restrictions. The example from the Horns Rev in Fig. 7 illustrates that the potential closest to shore HR3-HR5 represents the cost characteristics that will not be available for cooperation as they are below the cost level of the Danish target for RES in 2020. The deeper and further ashore locations similar to HR6 and HR7 around depths of 20m are limited and the potential should mostly be found in areas of depth around 25m on average. In the figure the northerly located wind park RK3 is at depth of approximately 25m and thus represents a typical location for potential cooperation resources. The distance from shore will be in the interval from 20-50 km, such as for example RK3 at 20 km.

It is noteworthy that Germany might have similar areas just south of the German- Danish border at similar depths to the Horns Rev and Ringkøbing area, but part of this area might be occupied by approved offshore projects not yet in development.

The Horns Rev area illustrates three of the important restricting factors for off shore potentials.

1. Natura 2000 areas
2. Shipping routes
3. Raw materials extraction (sand, gravel)

A large area from Horns Rev and south to the border is a Natura 2000 reserve. This restricting factor is of importance in relation to possible cooperation projects. However the main effect of this constraint is an increase in the network connection costs in terms of longer distance for the direct connection to a cable to the Netherlands (Cobra) as compared to building wind parks in the Natura 2000 reserve. Other cost characteristics are similar to those found further north in the planned offshore Horns Rev area and even further north. If connections for wind parks are made to the shore instead of to an interconnection cable there is only minor network cost implications.

At the same time shipping routes out of Esbjerg necessitate a corridor just south of Horns Rev overlapping the Natura 2000 area restriction. Further ashore, west of the Natura 2000 area there are also some areas with depth 25-35m, but this is a limited area and might conflict with shipping. This potential is also further from shore and is mostly relevant if connection can be made directly to the interconnection cable.
For the relevant Horns Rev offshore area the depths of 25-30m means that the south going route along Jutland is outside the area for this potential. If extensions to deeper water in the Horns Rev area where considered there might be a conflict with this shipping route.

For natural resource extractions there are widespread activities in the Horn Rev area especially at lower dephts. The constraints in the assigned area for offshore wind are however limited and at depths of 25m or more the competition with this activity is little.

With regard to additional restrictions due to limitations from concern for birdlife the depth of 25m and more means that the offshore locations considered for cooperation are outside the major feeding grounds and thus it is not restricting the potential.

To conclude the competing activities do not seem to further reduce the available locations at depths of 25-30 m in the Horns Rev area. To address a cost efficient potential above 1500-2000 MW and avoid shipping routes, the areas north of Horns Rev such as the Ringkøbing offshore area should be exploited. This may increase the costs slightly in terms of longer distance to service port, but this is not as substantial as increasing the water depth. If the surplus potential identified in D2.2 for cooperation between DK and the Netherlands is examined (19.7 TWh, 4500 MW) this means locations further north at the same depths might have to be included (they have same cost characteristics). An alternative is to increase the density of the wind parks with resulting efficiency losses (wake effects). In the Windspeed Roadmap report the used distance is approximately 12 km between parks. Reducing this distance when shallower depths are scarce should be considered. The losses would have to be compared to the possible cost consequence of locating further north or at deeper locations. Without detailed modelling of the actual conditions it is not possible to address if the total potential in cost range 12-15 €ct in the Horns Rev and Ringkøbing area is as high as 4600 MW. A conservative guess based on planned sites and some extension in the north-south direction for nearby sites to marginally deeper locations is that these areas can accommodate up to 3000 MW in this cost range.

4.3.2 Danish network limiting factors in 2020

For Denmark the planned transmission network extensions up to 2025 are sufficient to cope with the expected offshore wind plans for up to 4200MW if they are implemented. This is not the case for additional offshore wind capacity. Therefore restrictions may apply that reduce the realistic surplus if no additional transmission capacity is involved in the cooperation project. This points to prioritising cooperation projects that are located where additional transmission and interconnection is the cheapest or technically feasible. The Cobra connection from Jutland to the Netherlands (700 MW) might be relevant also for direct connections of offshore parks. The EU support grant has been partly motivated by this. The Cobra Cable is scheduled for 2016 and will thus be available for projects before 2020 if the final decision is made in 2012.

The expansion of capacity to Germany from Jutland of a total 2000 MW south in 2012 and 2500 MW south in 2025 will also make integration of a more wind possible. The importance of this is however closely connected to developments in Germany. The Skagerak 4 connection is scheduled for 2014 with an additional capacity to Norway of 700 MW.

If the planned projects are delayed or cancelled the additional potential for offshore wind will imply higher costs in terms of lower power prices (value) and more curtailment. Large additional capacity will not be feasible at all.

5 INDICATIONS FOR INTERESTING CASE STUDIES

The goal of this report was to narrow down the results calculated by the RESolve-E model stated in the report for work package 2 Task 2.2 within the RES 4 Less Project, in order to find suitable case-studies for cooperation based on wind energy.

The first task was to analyze whether surpluses of onshore or offshore wind would be more suitable being used by cooperation mechanisms. Due to the fact that onshore wind is the cheaper option, it won't be used for cooperation mechanisms. Instead it is assumed that those resources will be used nationally.

It has been found that Denmark and Germany are the largest potential host countries for off-shore wind VoO's while the UK and the Netherlands are the largest user countries. A valley of opportunity between Ireland and the UK does not appear in the modelling results. This is for two reasons; firstly Ireland's predicted surplus is too small to cover the whole predicted deficit of UK, hence the model does not predict a VoO between the two and secondly the considerable net user position of the UK with regard to wind energy and in particular off-shore wind can be questioned.

One of the criteria for identifying the case study is that the North Sea Region includes some countries with high compliance costs and some with relatively low cost surpluses. There is not a large difference between the two user countries UK and Netherlands with regard to the equilibrium price they trade in the pairwise comparison. This and in addition the planned cobra cable as well as the signalized interest for using cooperation mechanisms of both countries justifies to address the Netherland as the user country within the case study.

The actual deployment of offshore wind RES in German waters is far behind schedule. Even not complying with the national targets is possible. This is mainly due to long authorization procedures and major delays of grid connection. Therefore Germany cannot be considered as a host country for offshore wind.

With this in mind it is arguable to concentrate case studies on the Netherlands as the user country with Denmark host country.

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