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Koivisto, Matti Juhani; Traber, Thure

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Thure Traber, DTU Management Engineering

Matti Koivisto, DTU Wind Energy

DTU Wind Energy Report E-0146

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Ea Energy Analyses

DTU Management Engineering
Department of Management Engineering

DTU Wind Energy
Department of Wind Energy

Authors: Thure Traber[1], Matti Koivisto[2]

Title: NSON-DK energy system scenario

Department: [1]DTU Management Engineering

[2]DTU Wind Energy

Summary (max 2000 characters):

This report introduces the set of basic data to define scenarios with realistic yet ambitious targets for offshore wind power development in the North Sea to be used in the NSON-DK project. The assumptions are in line with those of IEA for a two degree temperature increase scenario and correspond with a strong recovering of coal and crude oil prices, and a pronounced increase of CO2 prices from 2020. For the countries around the North Sea that are considered, the evolution of electricity demand is projected to be strongly impacted by aggressive energy efficiency policies that lead in total to stagnating consumption despite substantial electric vehicle up-take. To the contrary, Denmark is assumed to substantially increase its consumption, i.e. by 14% from 2020 to 2050. However, the Danish electricity system is looking forward to a decommissioning of the remaining coal fired power plants towards the mid of the century and replacing these capacities essentially with natural gas power plants. In Belgium, and Germany nuclear power plants are expected to be phased-out by 2035, with Sweden following this policy by 2050. Moreover, the economic outlook for nuclear in the other countries is also weak mainly due to pronounced competition from fluctuating renewable energies. In regard to wind energy, for Denmark it is suggested that onshore installations are not increased significantly after 2030. By contrast, a major increase in offshore wind energy is assumed. Corresponding with these offshore and onshore wind power developments, the proposed NSON-DK scenario projects at least 8 TWh higher expected annual wind generation for Denmark. Given the pronounced increases of offshore wind farms, the installations are expected to form significant clusters from 2030 onwards with particularly strong developments in the British Hornsea and on the Dogger Bank.

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Technical University of Denmark
Department of Wind Energy
Frederiksborgvej 399
Building 118
4000 Roskilde
Denmark
Telephone 21 36 27 66

posq@dtu.dk
www.vindenergi.dtu.dk

Preface

The work presented in this report is deliverable D2.1.Ed1 of the North Sea Offshore Network – Denmark (NSON-DK) project. The report is prepared in collaboration between DTU Management Engineering and DTU Wind Energy.The NSON-DK project is funded by contract nr. 2016-1-12438 under the ForskEL program administrated by the Danish Transmission System Operator Energinet.dk. It is carried out as collaboration between DTU Wind Energy (lead), DTU Management Engineering and Ea Energy Analyses.

Lyngby and Risø, Denmark, May 2017

Thure Traber and Matti Koivisto

Content

Summary

The research conducted within NSON-DK aims to explain how the future massive offshore wind power and the associated offshore grid development will affect the Danish power system on short term, medium term and long term. This report introduces the set of basic data to define scenarios with realistic yet ambitious targets for offshore wind power development in the North Sea. This includes a special focus on the development of the Danish power system.

Our assumptions are in line with those of IEA for a two degree temperature increase scenario (2DS) within its Energy technology perspectives 2016. They are corresponding with a strong recovering of coal and crude oil prices post 2015, and a pronounced increase of CO2 prices from 2020. By contrast, natural gas prices do not substantially recover. Following 2030, fossil fuel prices stagnate while emission prices increase beyond 80 and towards 136 €/ton by 2050. The development of electricity demand is projected to be strongly impacted by the assumption of aggressive energy efficiency policies that lead in total to stagnating consumption despite substantial electric vehicle up-take. The study Nordic Energy Technologies 2016 provides the basis for further scenario development for NSON-DK and projects a stagnant demand development for the complete set of countries until 2050. To the contrary, Denmark is assumed to substantially increase its consumption, i.e. by 14% from 2020 to 2050. However, the auspices until 2050 have to be regarded as highly unclear as is suggested by a comparison of electricity consumption in Denmark across different studies.

On the basis of these assumptions, the Danish electricity system is looking forward to a decommissioning of the remaining coal fired power plants towards the mid of the century and replacing these capacities essentially with natural gas power plants. In Belgium, and Germany nuclear power plants are expected to be phased-out by 2035 in accordance with both the German nuclear phase-out decision and the Belgium plans. Sweden follows with the phase-out until 2050. Moreover, the economic outlook for nuclear in the other countries is also weak mainly due to pronounced competition from fluctuating renewable energies. In regard to wind energy, for Denmark it is suggested that onshore installations are not increased significantly after 2030. By contrast, a major increase in offshore wind energy is assumed. Corresponding with these offshore and onshore wind power developments, the proposed NSON-DK scenario projects at least 8 TWh higher expected annual wind generation compared to the Nordic Energy Technology Perspectives by 2050. For the remaining countries of the EU that are neighbouring the North Sea, we propose to rely in regard to offshore wind generation on the central scenario from WindEurope, and adjust onshore wind downwards. As a result, the energy contribution of both wind technologies is the same as in the Nordic Energy Technology Perspectives through 2050. Given the pronounced increases of offshore wind farms, the installations are expected to form significant clusters from 2030 onwards with particularly strong developments in the British Hornsea and on the Dogger Bank.

In regard to photovoltaic electricity, we suggest a fleet of generators that develops similar to the EU reference scenario and capacity sums up to about 105 GW in the countries adjacent to the North Sea by 2035. Notably, we assume that the installed solar capacity remains on the same level post 2035, whereas the EU reference scenario foresees an increase to more than 150 GW by 2050. Finally, substantial transmission enforcements in addition to the anticipated

development from the ENTSO-E are expected after 2030. Most notably, large capacity additions are anticipated between Germany and France, and between Belgium and Great Britain. Besides, Norway is set to develop as a major hub for connection of the Nordic system with continental Europe and the British Isles.

1. Introduction

The work presented in this report is deliverable D2.1.Ed1 of the North Sea Offshore Network (NSON-DK) project. The objective of the NSON-DK project is to study how the future massive offshore wind power and the associated offshore grid development will affect the Danish power system on short term, medium term and long term in the transition towards a future sustainable energy system.

The purpose of this deliverable D2.1.Ed1 is to provide a common set of basic data for the energy system scenarios used for the studies in the NSON-DK project. Considering the specific objective of the NSON-DK project, this set of basic data intends to define scenarios with realistic yet ambitious targets for offshore wind power development in the North Sea. Also, there is special focus on the scenarios for development of the Danish power system.

In D2.1.Ed1, the energy system scenario is based on previous works on scenario development. D2.1.Ed1 will be followed D2.1.Ed2, where the energy system scenario will be optimized specifically for the NSON-DK project. However, the first edition of D2.1 provides a preliminary scenario that can be already used as a starting point in the other NSON-DK work packages. Overall, D2.1 will be followed by D2.2 providing more details on the offshore wind locations and offshore grid as well as time series for wind power and PV generation and forecasts.

In 2016, at DTU and Ea Energy Analyses the model Balmorel was used to explore different scenarios for carbon neutrality in the Nordic countries. These provide the basis for the development of the underlying onshore power system for the assessment of impacts triggered by the establishment of different offshore grid structures in the North Sea region. Two scenarios developed within the NETP2016 [1] research program are of particular interest for the studies commenced with NSON-DK: the Baseline scenario, and the flexibility scenario. The flexibility scenario (Flex scenario) assumes flexibility on the demand side, which is motivated by the development of demand side response, storage and sectoral interlinkage. By contrast, the Baseline scenario assumes a rigid electricity demand that does essentially not respond to market signals. However, both scenarios are compatible with the development of a carbon neutral energy system in the Nordic countries and the achievement of emissions consistent with limiting global warming to two degrees above pre-industrial levels as they are based on IEA`s ETP 2DS scenario, i.e. a scenario aiming at only two degrees (2D) temperature increase compared to pre-industrial levels. In this report we focus on the more optimistic development laid out in the Flex scenario as agreed among the NSON-DK project partners.

This report is structured as follows. We first describe the basic assumptions that are in line with IEAs ETP 2016 [2]. Second, we feature the development of electricity demand through 2050 in the countries under consideration, i.e. the Nordic countries, Central-Western Europe (Belgium, France, Germany, the Netherlands and Luxemburg) the British Island, and the Baltic States as illustrated in Figure 1.

Figure 1: The countries investigated in the NSON-DK project. Although the focus is on the North Sea area, surrounding countries are considered, e.g., for analysing interconnection power flows.

Third, we feature the generation park assumed for the project including a special section on fluctuating renewable energies and a dedicated section on adjustments that align the outlook for Denmark with major policy goals. Fourth, we present the development of the international transmission capacities including the assumptions based on governmental plans and additional grid expansion calculated with the model. Finally, we give an outlook on the most likely locations of offshore wind farms in the North Sea region in the foreseeable future.

2. Basic assumptions aligned with IEAs ETP 2016

The alignment of the scenarios conducted with Balmorel with IEAs is basically achieved by the harmonisation of assumptions regarding fossil fuel prices, emission prices, and the capacities for the supply of renewable energy based electricity (RES-E) in the base year 2014.

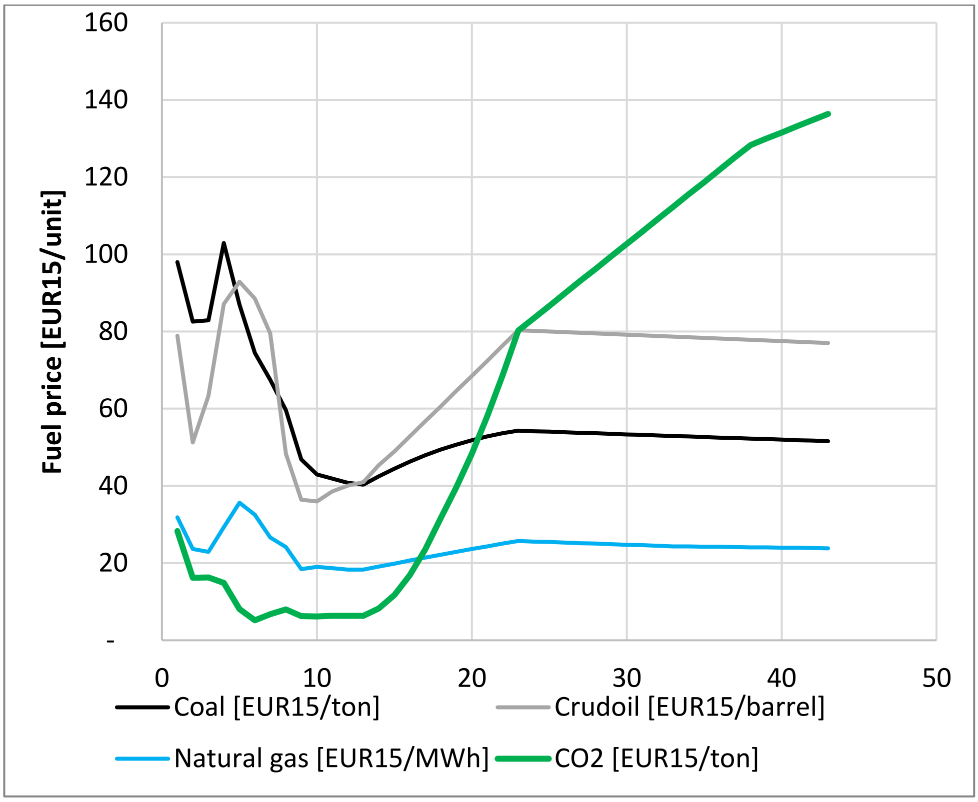
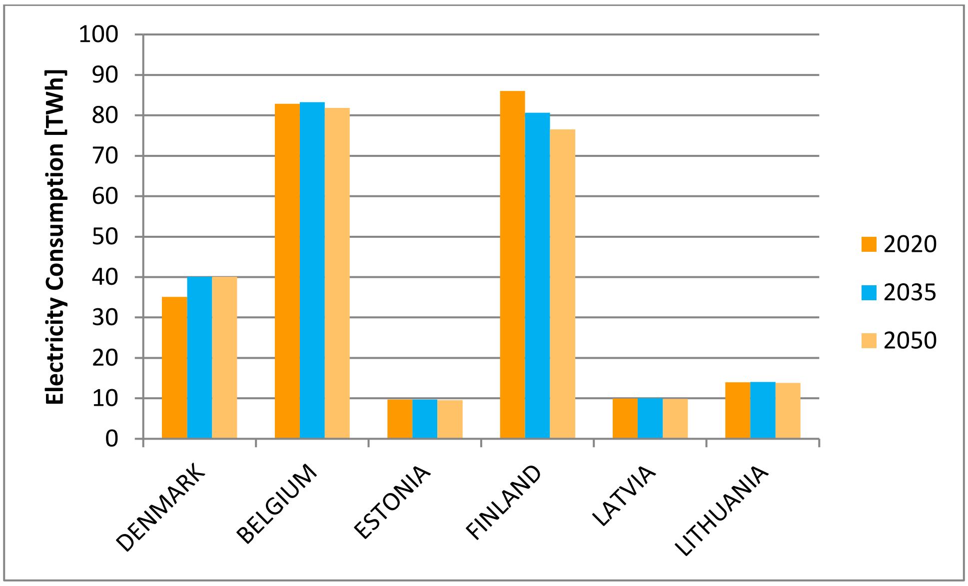


Figure 2: Fuel price developments NETP 2016

It is apparent from Figure 2 that assumptions from IEA in a 2DS are corresponding with a strong recovering of coal and crude oil prices after 2015, and a pronounced increase of CO2 prices after 2020. By contrast, the natural gas prices do not substantially recover. Following 2030, fossil fuel prices stagnate while emission prices increase beyond 80 and towards 136 €/ton by 2050.

3. Demand development

The development of electricity demand is strongly impacted by the assumption of aggressive energy efficiency policies that lead in total to stagnating consumption despite substantial electric vehicle up-take. Hence, efficiency increases in the classical electricity consumption sectors and improvements in the provision of heat from electricity due to the application of heat pumps in combination with improved insolation more than compensates for the transition towards a larger share of electricity within final consumption. As the figures below show, this general picture does not hold for all countries that are investigated.



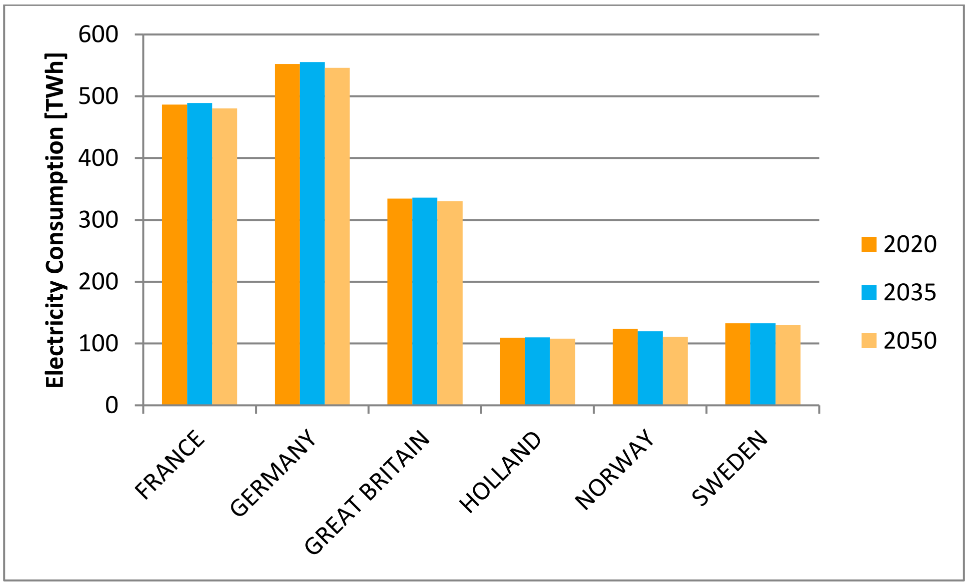


Figure 3: Electricity demand development through 2050 in the NETP 2016-Flex scenario.

Towards 2035, a significant electricity consumption increase is expected in Denmark due to a particularly pronounced increase in electricity for household heating appliances and the increased use of electricity for electric vehicles. However, in the decade towards the mid of the century electricity consumption stagnates or decreases in all countries.

The NETP 2016 projects a stagnant demand development in total until 2050. By contrast, Denmark is assumed to increase its consumption by 14% from 2020 to 2050. With the exception of Denmark, the NETP 2016 projection can be regarded as conservative in the sense that scenarios computed by other institutions frequently project some electricity demand increases while reaching climate goals, e.g. the EU reference scenario [1] finds a 19% increase of electricity consumption from 2020 to 2050 in the EU countries neighbouring the North Sea. However, the political targets often foresee an only stagnant consumption that is compatible with NETP 2016. Moreover, there is no reason why the basic rationale of demand development should have changed since the conduction of NETP 2016.

4. Power plants

4.1 Dispatchable/Conventional

Developments of the dispatchable part of the power plant systems in the Nordic and neighbouring countries are laid out in Figure 4 and Figure 5 below. On the basis of increasing emission prices, the Danish electricity system is experiencing a decommissioning of the remaining coal fired power plants towards the mid of the century and replacing these capacities essentially with natural gas plants. Remarkably, the Danish power system is also reducing reliance on biomass fired power plants which can be explained by a sharply increasing price for biomass given a global climate policy.

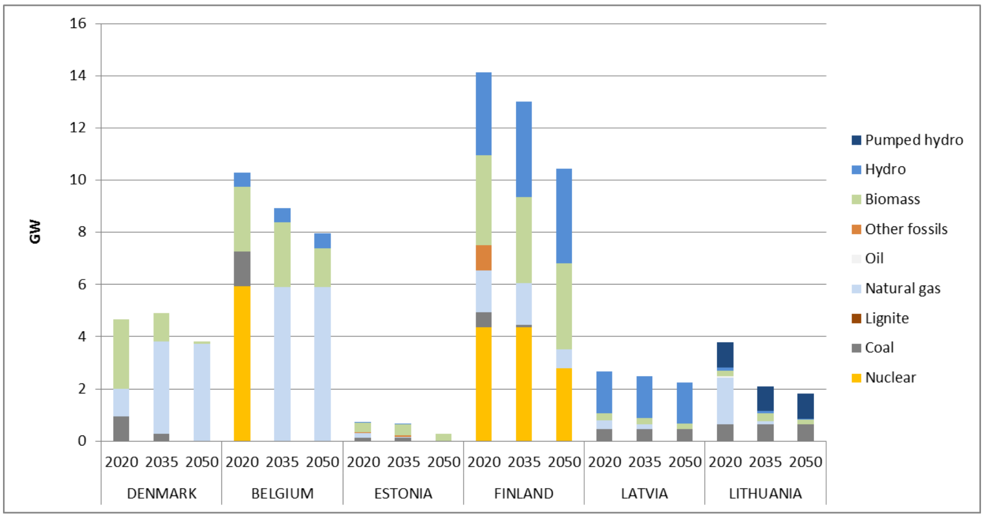


Figure 4: Dispatchable power plant capacities in Denmark and smaller neighbouring electricity systems through 2050.

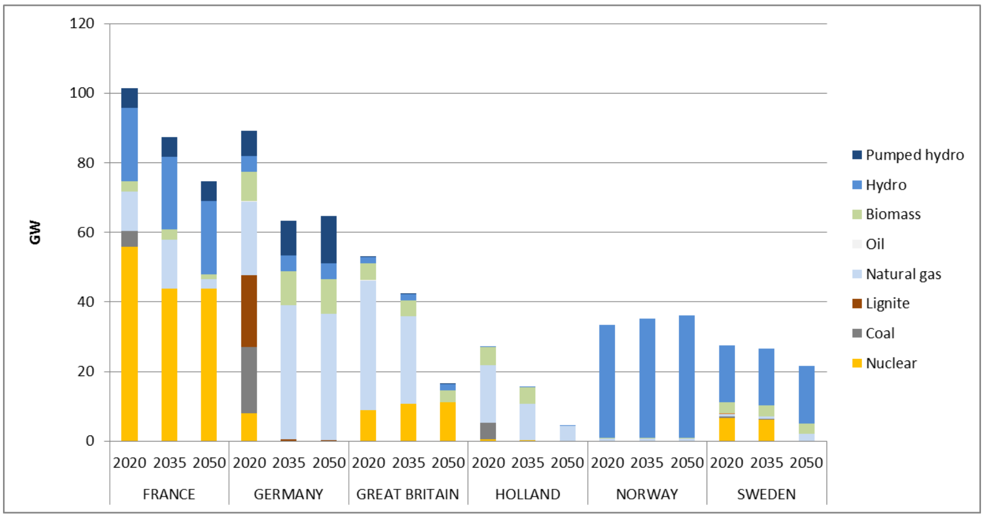


Figure 5: Dispatchable power plant capacities in larger neighbouring electricity systems through 2050.

In Belgium, and Germany nuclear power plants are expected to be phased-out by 2035 in accordance with both the German nuclear phase-out decision and the Belgium plans that reflect the assumptions from the CNS scenario of NETP 2016. Sweden follows with the phase-out until 2050. Moreover, the economic outlook for nuclear in the other countries is also weak mainly due to pronounced competition from fluctuating renewable energies. However, similar to projections of the British Department for Energy and Climate Change (DECC), there is some increase of nuclear capacities assumed for Britain. Regarding hydro power, the perspective in the NETP Flex scenario that we propose is also modest. Clearly, existing units are set to be maintained due to their favourable economics. Due to the exploitation of suitable sites in the past, even in the carbon neutral scenario there is no substantial roll-out of simple hydro or hydro pump storage plants. Exceptions are Germany, Norway and Finland. Germany shows some development of pump storage facilities, while Norway and Finland are projected to develop several Gigawatt of hydro power without storage possibilities.

4.2 Variable renewable energies of the power system

Dealing with the impact of the North Sea offshore development on the Danish power system, NSON-DK will have special focus on offshore wind power, but it will also include the impact of onshore wind power and photovoltaic electricity generation.

Comparing to the WindEurope Central scenario (formerly European Wind Energy Agency, EWEA) for 2020 and 2030 [3], the NETP Flex scenario includes less offshore wind power. However, the EWEA Central and NETP Flex scenarios are relatively similar when considering the overall wind power installations (onshore plus offshore), as can be seen in Figure 6.

In regard to offshore wind capacities, we decided to use the EWEA Central scenario for the NSON-DK project for 2020 and 2030 (the EWEA scenarios are not available for further years). However, the expected annual energy generated from wind in NETP Flex was respected (using the capacity factor assumptions shown in Appendix A). This lead to lower onshore wind installations in the NSON-DK scenario than in NETP Flex, as can be seen in Figure 6.

Moreover, EWEA scenario data is not available for 2040 and 2050. We assume that the share of offshore versus onshore wind remains the same from 2030 onwards (considering expected annual energy generation). The resulting installed capacities can be seen in Figure 6; the sum of installed onshore and offshore capacity is lower in NSON-DK than in NETP Flex for 2030-2050 because the expected annual generation is kept the same (capacity factor assumptions shown in Appendix A).

The development of wind installations explained in the previous paragraphs is applied for all analysed countries, except Denmark and Norway. As the focus of the NSON-DK project is on Denmark, it was considered separately. For Denmark, both onshore and offshore wind installations are taken from the EWEA report for 2020 and 2030 [3]. DTU Wind Energy's database includes more than 6 GW of offshore wind farm plans for Denmark (of which some are very early plans or development areas); it was considered feasible that 6 GW of these will be developed by 2050, with 4.5 GW completed by 2040 (country-wise wind installations are reported in Appendix A).

With such a high volume of offshore wind installations in Denmark, it was considered that onshore installations are not increased significantly after 2030. With these offshore and onshore installations, and assuming capacity factors shown in Appendix A, the NSON-DK scenario gives 8 TWh higher expected annual wind generation than the NETP Flex scenario in 2050. The differences in the installed capacities in NETP Flex and NSON-DK can be seen in Appendix A for all scenario years. The significance of the additional 8 TWhs of wind generation is discussed in the next section.

For Norway, the offshore wind installations are taken from TWENTIES [4] (the baseline 2030 was assumed to occur in 2030, and the high 2030 in 2050 for the NSON-DK scenario). As with the other countries, the expected annual energy generated from wind in NETP Flex was respected (the offshore and onshore installations for Norway can be seen in Appendix A for all scenario years).

It needs to be noted, that while the target was to get the same expected yearly energy generation from wind in both the NSON-DK and NETP Flex scenarios, this does not hold exactly for each scenario year for each country. Some manual adjustments were made to keep the phase of offshore installations from one scenario year to another feasible (for example, it was assumed that the installed capacities do not decrease over time).

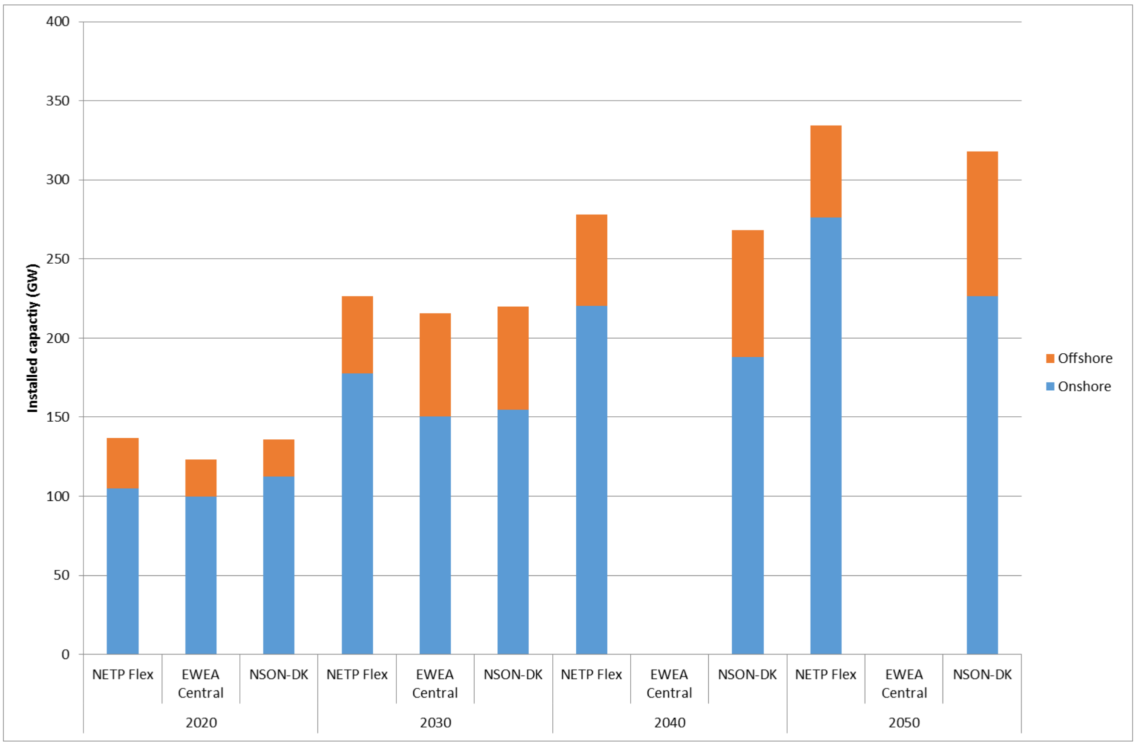


Figure 6: Installed wind generation capacities of the Nordic and Baltic EU-countries, Benelux, France, Germany, the United Kingdom and Ireland; Scenarios: NETP Flex [1], EWEA Central [3] and the proposed scenario for the NSON-DK project.

Regarding the development of photovoltaic electricity, the NETP Flex scenario is also suggested for the modelling in NSON-DK. Compared with the roll-out that is expected in the EU reference scenario [5], NETP Flex only foresees a modest development. This is due to the assumption of a phasing- out of support policies and almost complete reliance on market forces for the investments post 2030. By contrast, the EU reference scenario is based on the prolongation of the current policy setting. Through 2035 though, the fleet of solar power generators develops similar to the EU reference scenario and capacity sums up to about 105 GW in the countries under consideration, which is only 5 percent below the respective value documented in [5]. Notably, in the NETP Flex [1] the installed solar capacity remains on the same level towards 2050, whereas [5] foresees an increase to more than 150 GW by 2050. The comparatively modest solar expansion which is envisaged in NETP Flex by 2050 [1] leaves room for a more pronounced development of wind energy.

5. Adjustments for the Danish energy system

In order to ensure a scenario most relevant for Danish policy making, we suggest analysing a Danish power system that achieves major policy targets. Basically, Denmark aims at an energy system that is independent from fossil fuel imports by 2050 [6]. By contrast, the scenario simulated in NETP 2016 do not replicate country specific policy targets in addition to climate policy goals. Consequently, NETP Flex foresees some 15 TWh of natural gas electricity generation, thereof 8.7 TWh generated in units that are equipped with carbon capture and storage. While the outlook for this technology is considered as particularly questionable, we suggest assuming no CCS power generation in Denmark. Thus, the additional generation from wind installation assumed for the NSON-DK project compared to the NETP-Flex scenario would energetically be more than compensated by the reduction of inflexible generation with CCS power plants. This would facilitate a completely self-sufficient electricity generation of Denmark in 2050 since about 7 TWh are expected to be exported net of imports, which more than balances the expected remaining generation from natural gas as calculated in the NETP 2016 framework. However, the auspices until 2050 have to be regarded as highly unclear as is suggested by a comparison of electricity consumption in Denmark according to NETP 2016 with the scenario called “vindspor” considered by Energinet [6]. While both scenarios are roughly in line until 2035, towards 2050 Energinet foresees a sharp increase of about 50%, leading to a consumption of about 60 TWh. This contrasts with NETP 2016 which foresees a stagnation of electricity consumption until 2050, which seems reasonable to achieve complete carbon neutrality as chosen for the NSON-DK framework.

6. Transmission system

The transmission system development assumed for the NETP 2016 scenarios until 2030 is based on the Ten Year Network Development Plan (TYNDP 2014 [7]), and is laid out in Figure 7 for the countries adjacent to the North Sea. In addition, the figure shows the capacity investments in the featured NETP Flex scenario that take place between 2030 and 2050 based on model calculations. According to the calculations in NETP Flex, the most substantial network enforcements in addition to the anticipated development by 2030 [7], are expected between Germany and France (+8.1 GW), and between Belgium and Great Britain (+6.9 GW). Besides, Norway is set to develop as a major hub for connection of the Nordic system with continental Europe and the British Isles. On top of the interconnections scheduled within the TYNDP, 7.8 GW of additional transmission capacity between Norway and these countries is expected by 2050. For Denmark, there are also significant additions between DK_W and NO_SW (+2.2 GW; Skagerrak) and between DK_E and SE_S (+1.3 GW; Øresund).

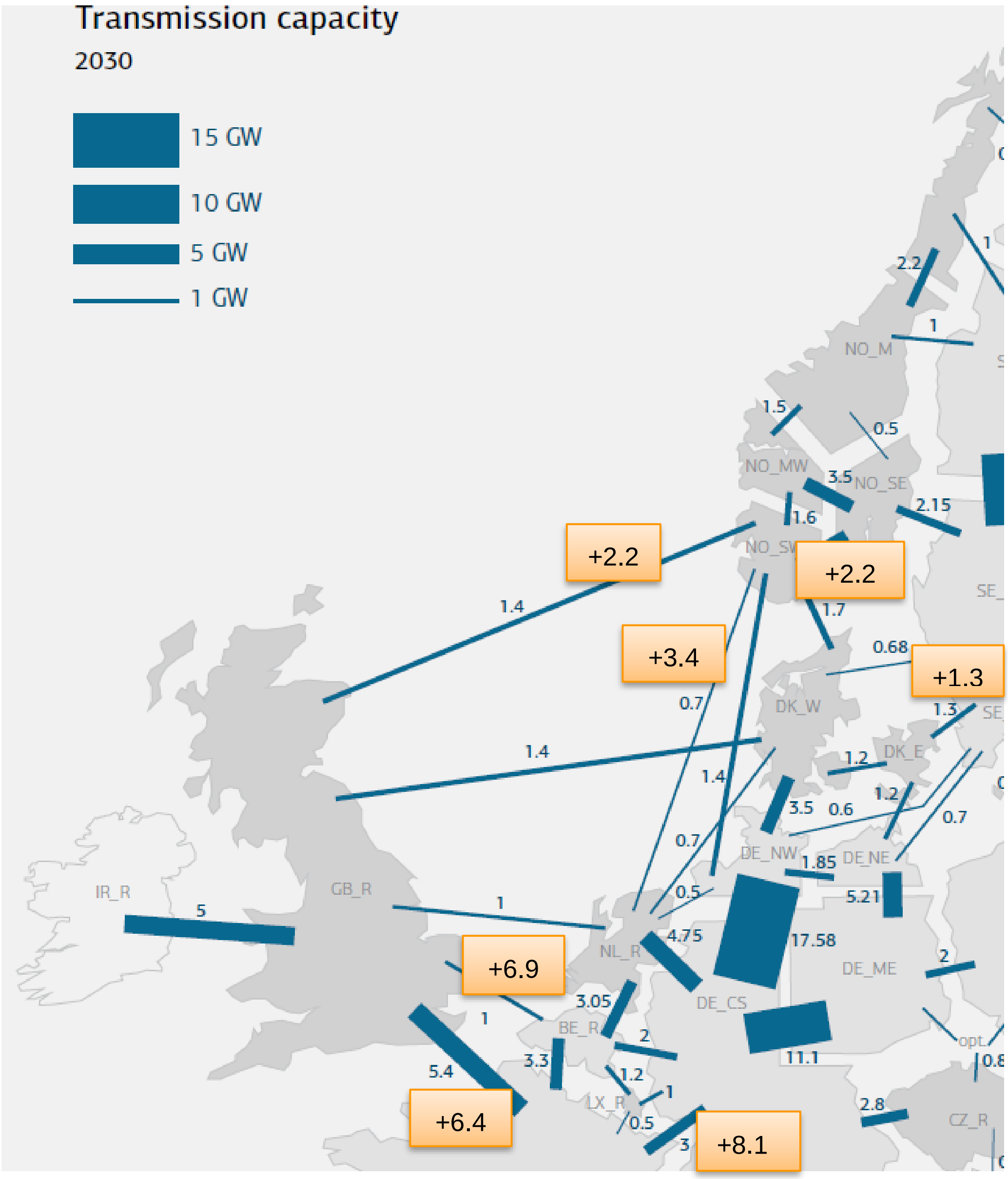


Figure 7: Transmission capacity according to TYNDP 2014 [7] by 2030 (dark blue) and calculated capacity additions [1] (GW; orange fields) by 2050. The additions are also reported in the matrix in Table 1.

Except from transmission capacity investments around the North Sea, there are only comparatively little investments indicated in the other regions under investigation. However, the connection between Finland and Estonia is strengthened by additional investments of 1.4 GW, as can be seen from Table 1, which summarizes the transmission capacity investments between 2030 and 2050. Finally, some 1.3 GW is expected to be established between Norway and Finland on top of what is scheduled until 2030.

	Be	DK	EE	Fin	Fr	De	GB	Nl	Nor	SE
Be		-	-	-	-	-	6.9	-	-	-
DK	-		-	-	-	-	-	-	2.2	1.3
EE	-	-		1.4	-	-	-	-	-	-
Fin	-	-	1.4		-	-	-	-	1.3	-
Fr	-	-	-	-		8.1	6.4	-	-	-
De	-	-	-	-	8.1		-	-	-	-
GB	6.9	-	-	-	6.4	-		-	2.2	-
Nl	-	-	-	-	-	-	-		3.4	-
Nor	-	2.2	-	1.3	-	-	2.2	3.4		-
SE	-	1.3	-	-	-	-	-	-	-	

Table 1: Transmission capacity additions between all model regions from 2030 to 2050 (GW).

7. Locations of offshore wind farms until 2030

Figure 8 shows the geographical distribution of the offshore wind farms for the NSON-DK scenario in the North Sea based on DTU Wind Energy's database for 2020 and 2030. The installations start to form significant clusters in 2030; two important clusters are formed by the UK wind farms in Dogger Bank and Hornsea, which have been considered as offshore grid hub locations in previous studies, such as [4], [8]. Offshore hubs, and a multi-terminal grid based on these hubs, will be considered in detail in the next stage of the NSON-DK project, going all the way to the scenario year 2050.

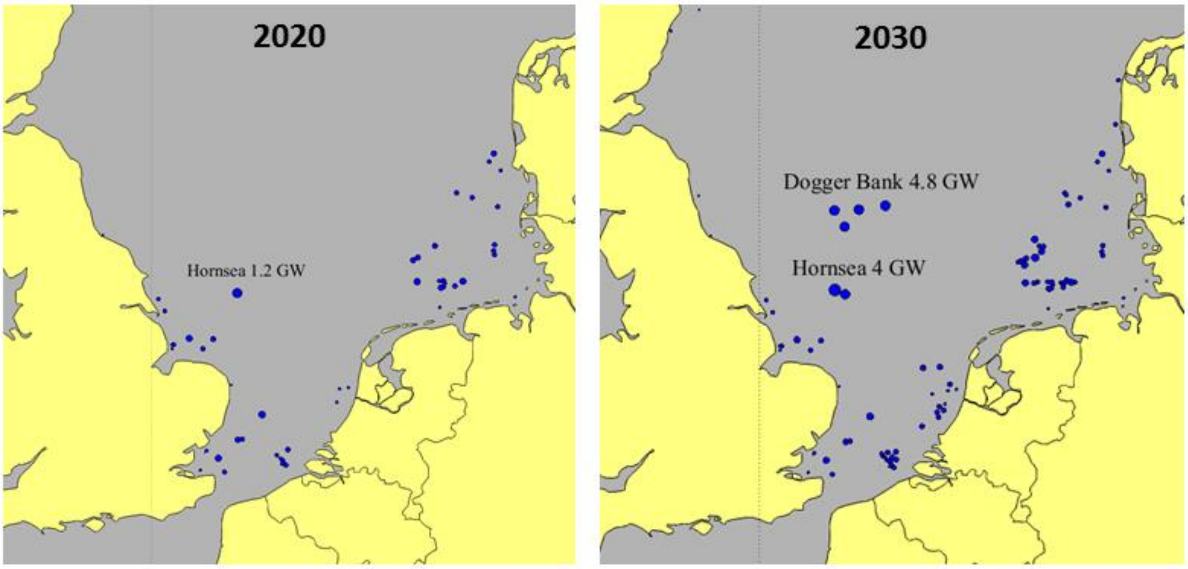


Figure 8: The geographical distribution of the offshore wind installations in the North Sea in 2020 (left) and 2030 (right) of the NSON-DK scenario; dot sizes refer to the installed capacities.

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[8] EC 2014, Study of the benefits of a meshed offshore grid in Northern Seas region: http://ec.europa.eu/energy/en/content/benefits-meshed-offshore-grid-northern-seas-region (accessed on January 6th, 2017)

Appendix A: Installed wind generation capacities and capacity factors by country

NSON-DK installed capacities (MW)																										
	Offshore wind												Onshore wind													
Year	**DK**	**SE**	**FI**	**EE**	**LV**	**LT**	**UK+IE**	**DE**	**NL**	**BE**	**FR**	**NO**	**DK**	**SE**	**FI**	**EE**	**LV**	**LT**	**UK+IE**	**DE**	**NL**	**BE**	**LU**	**FR**	**NO**
2020	2800	212	900	250	0	0	9525	6500	5000	1500	1500	415	3700	5214	1600	400	793	500	13643	49887	5000	3076	57	26549	3031
2030	3530	1000	1206	250	0	0	23800	17500	6500	3000	9000	3215	4600	13939	1600	400	3870	1925	14957	59750	5458	3076	57	41741	3031
2040	4500	1600	1206	250	0	0	31108	18514	7114	3883	13425	4378	4738	22160	1600	400	3330	1925	20650	60595	6085	3956	57	62996	4629
2050	6000	2092	1206	250	0	0	34103	18514	7677	4754	17695	5540	4875	28592	4303	400	3361	6810	25250	60595	6836	4912	57	85130	5777

Capacity factors used in the calculations (2050 targets are from the NETP 2016 report)																									
	Offshore wind												Onshore wind												
Year	**DK**	**SE**	**FI**	**EE**	**LV**	**LT**	**UK+IE**	**DE**	**NL**	**BE**	**FR**	**NO**	**DK**	**SE**	**FI**	**EE**	**LV**	**LT**	**UK+IE**	**DE**	**NL**	**BE**	**LU**	**FR**	**NO**
2020	0.454	0.339	0.337	0.332	0.327	0.409	0.416	0.410	0.413	0.432	0.405	0.360	0.309	0.288	0.246	0.259	0.264	0.249	0.238	0.196	0.265	0.286	0.286	0.242	0.297
2030	0.471	0.368	0.365	0.375	0.372	0.423	0.442	0.443	0.426	0.439	0.421	0.394	0.323	0.288	0.246	0.259	0.264	0.249	0.280	0.216	0.285	0.293	0.293	0.270	0.307
2040	0.488	0.398	0.392	0.419	0.417	0.437	0.467	0.476	0.439	0.446	0.436	0.427	0.337	0.288	0.246	0.259	0.264	0.249	0.321	0.235	0.306	0.300	0.300	0.299	0.318
2050	0.505	0.427	0.420	0.462	0.462	0.451	0.493	0.509	0.453	0.453	0.451	0.460	0.351	0.288	0.246	0.259	0.264	0.249	0.363	0.255	0.326	0.307	0.307	0.328	0.328

NETP Flex installed capacities (MW)																									
	Offshore wind												Onshore wind												
Year	**DK**	**SE**	**FI**	**EE**	**LV**	**LT**	**UK+IE**	**DE**	**NL**	**BE**	**FR**	**NO**	**DK**	**SE**	**FI**	**EE**	**LV**	**LT**	**UK+IE**	**DE**	**NL**	**BE**	**LU**	**FR**	**NO**
2020	2016	215	900	250	180	0	8240	6690	5178	2000	6000	0	4069	5210	1600	400	570	500	15890	49490	6000	2320	57	19000	3535
2030	2016	215	1206	250	180	0	17051	14515	5178	2000	6000	0	5209	14943	1600	400	3616	1925	25622	65877	7433	4536	57	46409	7023
2040	2016	215	1206	250	180	0	22315	18514	5178	2000	6000	0	6344	24072	1600	400	3046	1425	33444	60595	8866	6752	57	73818	10512
2050	2016	215	1206	250	180	0	22315	18514	5178	2000	6000	0	8000	31377	4303	400	3046	6810	41265	60595	10299	8968	57	101227	13548

The United Kingdom and Ireland numbers are combined because of a different way of presenting the installed capacities in NETP [1] and EWEA [3] for these countries. The capacity factor target for 2050 assumes that all wind farms are repowered using the full load hour assumptions for new installations given in the NETP report.

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DTU Wind Energy is a department of the Technical University of Denmark with a unique integration of research, education, innovation and public/private sector consulting in the field of wind energy. Our activities develop new opportunities and technology for the global and Danish exploitation of wind energy. Research focuses on key technical-scientific fields, which are central for the development, innovation and use of wind energy and provides the basis for advanced education at the education.

We have more than 240 staff members of which approximately 60 are PhD students. Research is conducted within nine research programmes organized into three main topics: Wind energy systems, Wind turbine technology and Basics for wind energy.

Technical University of Denmark
Department of Wind Energy
Frederiksborgvej 399
Building 118
4000 Roskilde
Denmark
Telephone 46 77 50 85

info@vindenergi.dtu.dk
www.vindenergi.dtu.dk