Bremer Energie Institut

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Bericht

Inventory and Analysis of Impacts of Power Plants in the Wadden Sea Region

Final report

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1 Background and overall objectives of the research

The Wadden Sea Forum (WSF)[1] is an independent platform of stakeholder organisations in the international Wadden Sea Region (WSR). The central goal of the WSF is to contribute to sustainable development in the Wadden Sea Region. The WSF working group "Energy/Industry/Infrastructure" is dealing with the development and its impacts in this field. The main focus is planning and development of energy supplying facilities, with a particular interest on offshore wind energy, and its ecological and economic consequences. An inventory and analysis of all existing plants and their development was commissioned by the Bremer Energie Institut.

The overall objectives of the study are:

I. Creation of an inventory, and subsequent analysis, of all existing power plants and of those plants which are substantiated in an official planning process in the Wadden Sea Region and the southern North Sea Exclusive Economic Zones (EEZs) of Denmark, Germany and The Netherlands.

II. Evaluation and assessment of the potential impacts and economic consequences of the energy plants and related facilities.

III. An assessment of the proportion of installed renewable energy within the Wadden Sea Region in the view of the development of a sustainable electricity supply.

[1] All abbreviations are listed in the glossary at the end of this report.

2 Inventory and analysis of power plants in the Wadden Sea Region

As defined in the terms of reference the focus of the study will be on three types of power plants:

- Conventional power plants in the Wadden Sea Region,
- Offshore wind farms in the Wadden Sea Region and the southern North Sea EEZs of Denmark, Germany and The Netherlands,
- Onshore wind farms in the Wadden Sea Region.

The inventory will differentiate between existing power plants, those under construction, and those which are in an official planning process. With respect to the strong development process in the field of offshore wind farms, projects which are not yet in an official planning process but were announced with details about the planned capacity will be also listed.

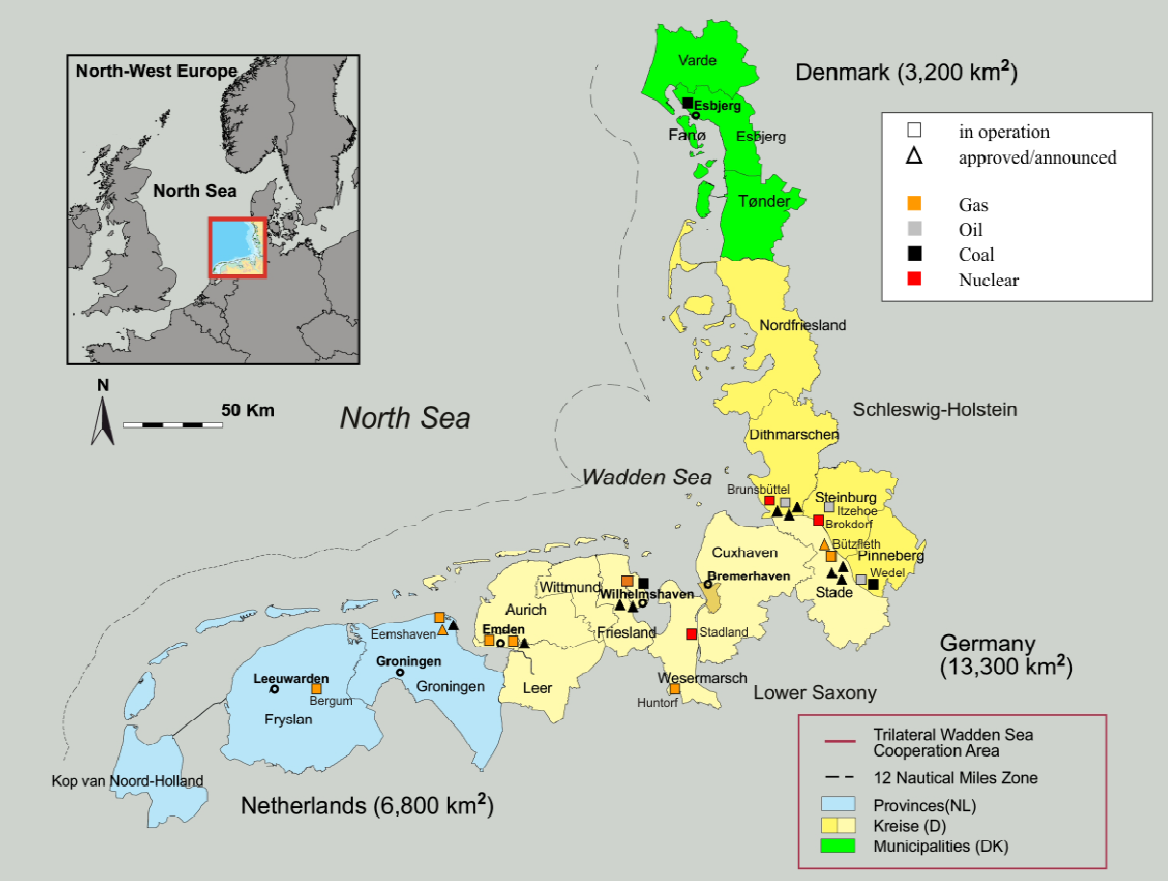
2.1 Conventional power plants

The inventory of conventional power plants located in the WSR was based on publicly accessible data sources. All power plants with a capacity higher than 30 MW were included. Last update of the inventory took place at the end of May 2009. It has to be mentioned, that the listed data of the operating and planned conventional power plants represent a "snap-shot" of the given situation at the studied time. Changes in the plans of companies might be announced on daily basis. This is true with respect to the constructions in progress of the new power plants, as well as with respect to the announced investment plans, and with respect to the published or assumed data about the close down of power plants.

2.1.1 Summary for the Wadden Sea Region

Actually, 16 conventional power plants with a total capacity of 9,500 MW are located in the Wadden Sea Region, most of them in Germany (13), only 2 plants in the Netherlands, and one Danish power station (see Table 1 and Figure 1).

Figure 1: Conventional power plants in the Wadden Sea Region – Plants in operation and approved / announced plants



Source: [Wadden Sea Forum 2009]

Table 1: Conventional power plants in the Wadden Sea Region – Plants in operation and planned projects

Country and energy source	Number	Capacity (MW)
In Operation		
Denmark		
Coal	1	378
Germany		
Nuclear	3	3,656
Coal	2	1,048
Gas	5	895
Oil	3	453
Total Germany	*13*	*6,052*
The Netherlands		
Gas	2	3,081
Total in operation	**16**	**9,511**
Planned Projects		
Denmark	no planned projects	
Germany		
Coal		
Approved	1	800
Announced	8	8,100
Gas - Announced	1	30
Total Germany	*10*	*8,930*
The Netherlands		
Coal - Announced	1	1,600
Gas - Announced	1	1,200
Total the Netherlands	*2*	*2,800*
Total planned projects	**12**	**11,730**

Altogether 12 new conventional power plants with a capacity of 11,700 MW are announced but only one of them is already approved. More than 80 % of them are projected in the German part of the Wadden Sea Region possessing a capacity of nearly 9,000 MW. Two plants are announced in the Netherlands part with a total capacity of 2,800 MW.

With respect to the energy sources of existing power plants in the Wadden Sea Region, nuclear and gas powers are the dominating ones with a total share of 80%. Coal and oil are of a minor importance with shares of 15% (coal) and 5% (oil) (see Table 2). But the figures are different when the involved countries are distinguished. In Germany, all energy

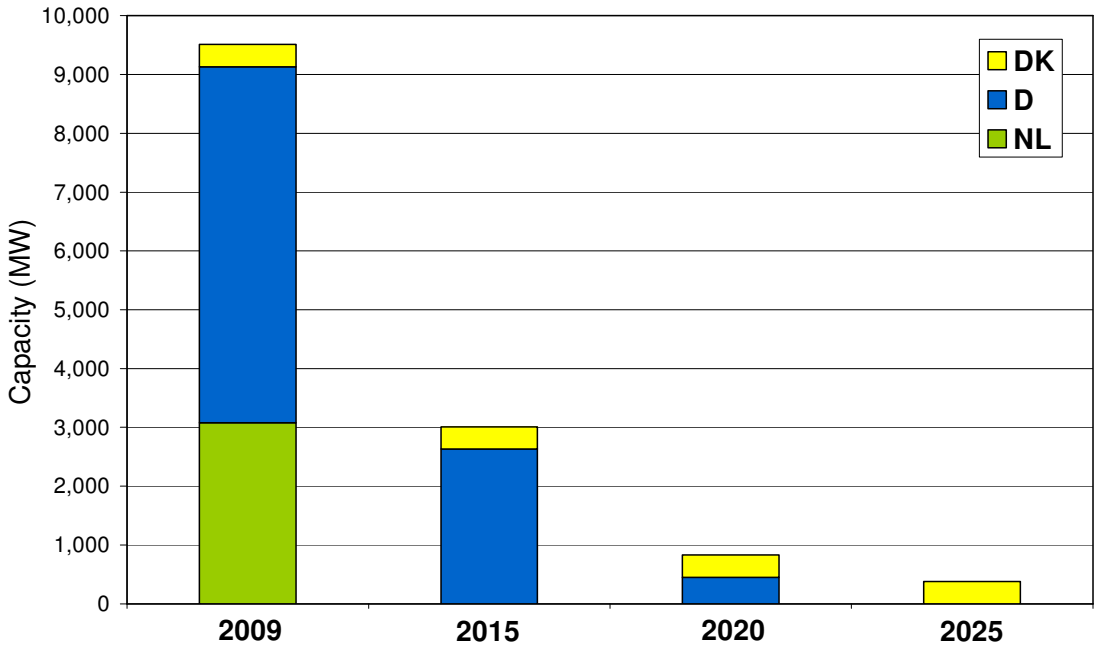
sources can be found; nuclear with the highest contribution of 60% of the total power installed in the German part of the Wadden Sea Region, followed by coal (17%) and gas (15%). Only one coal fired power plant is located in the Danish part of the Wadden Sea region, and in the Netherlands there exist two gas-fired plants with a total capacity of more than 3,000 MW.

Table 2: Conventional power plants in operation - Share of energy source

	Total		Denmark (DK)		Germany (D)		Netherlands (NL)	
Energy source	**(MW)**	**(%)**	**(MW)**	**(%)**	**(MW)**	**(%)**	**(MW)**	**(%)**
Nuclear	3,656	38%	-	-	3,656	60%	-	-
Coal	1,426	15%	378	100%	1,048	17%	-	-
Gas	3,976	42%	-	-	895	15%	3,081	100%
Oil	453	5%	-	-	453	8%	-	-
Total	**9,511**	**100%**	**378**	**100%**	**6,052**	**100%**	**3,081**	**100%**

Many of these plants will reach the end of operation period within the next years [IHK 2008]. This fact is illustrated in Figure 2. This forecast is based upon an individual assessment of the technical life expectation of every power plant with an average life time of about 40 years for coal fired power plants and of 30 to 40 years for gas fired power plants.

Figure 2: Conventional power plants in operation – Development of installed capacity until 2025



Until 2020, only 10% of today's installed capacity will be left. In Germany, this is mainly due to the phaseout of the nuclear power plants, a consequence of the agreement between the German government and the energy industry in 2002 [Nuclear Phaseout 2002]. But also numerous fossil powered plants will reach the end of their life time in Germany as well as in the Netherlands.

For the planned conventional power plants, Table 3 shows the shares of energy sources. Only coal and gas fired plants are planned for the future. Coal fired plants are found to clearly dominate with 90% in the Wadden Sea Region, 97% in the German part and 57% in the part located in the Netherlands.

Table 3: Conventional power plants in planning - Share of energy source

	Total		Denmark (DK)		Germany (D)		Netherlands (NL)	
Energy source	**(MW)**	**(%)**	**(MW)**	**(%)**	**(MW)**	**(%)**	**(MW)**	**(%)**
Nuclear	-	-	-	-	-	-	-	-
Coal	10,500	90%	-	-	8,900	99.7%	1,600	57%
Gas	1,230	10%	-	-	30	0.3%	1,200	43%
Oil	-	-	-	-	-	-	-	-
Total	**11,730**	**100%**	**-**	**-**	**8,930**	**100%**	**2,800**	**100%**

Figure 3 shows the expected development of the new installed capacity within the next years. Following the recent planning data, the total capacity of 11,730 MW should be in operation in 2015. In the Netherlands, the two plants being projected should be installed within the next four years. Doubts, if this ambitious aim can be reached, are legitimate.

Figure 3: Conventional power plants in operation – Development of expected capacity until 2015

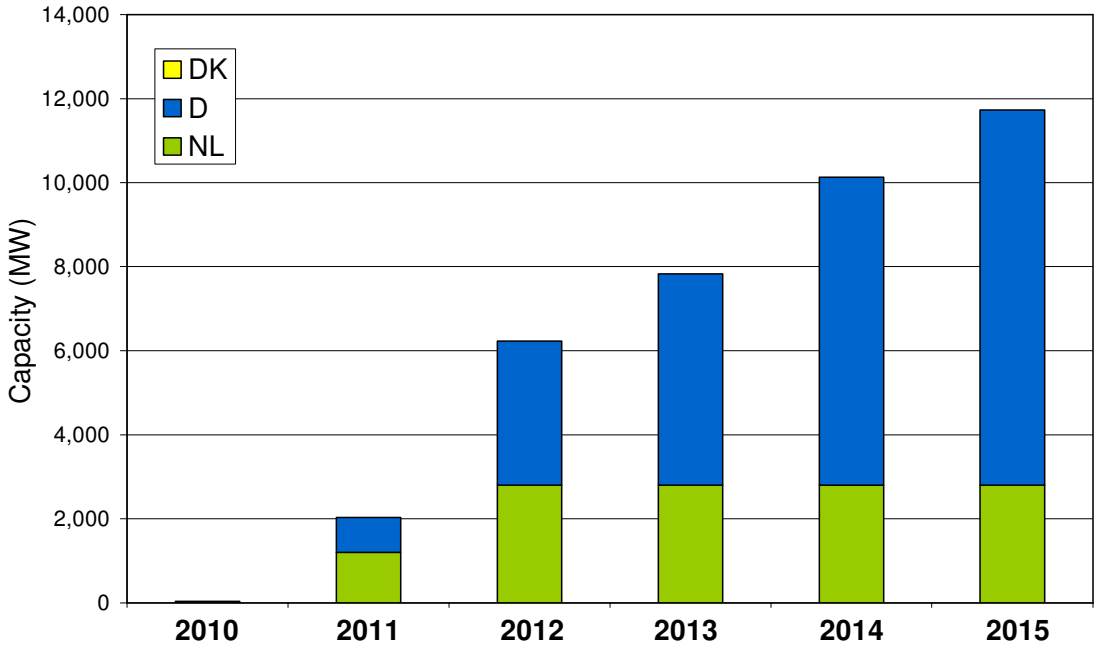
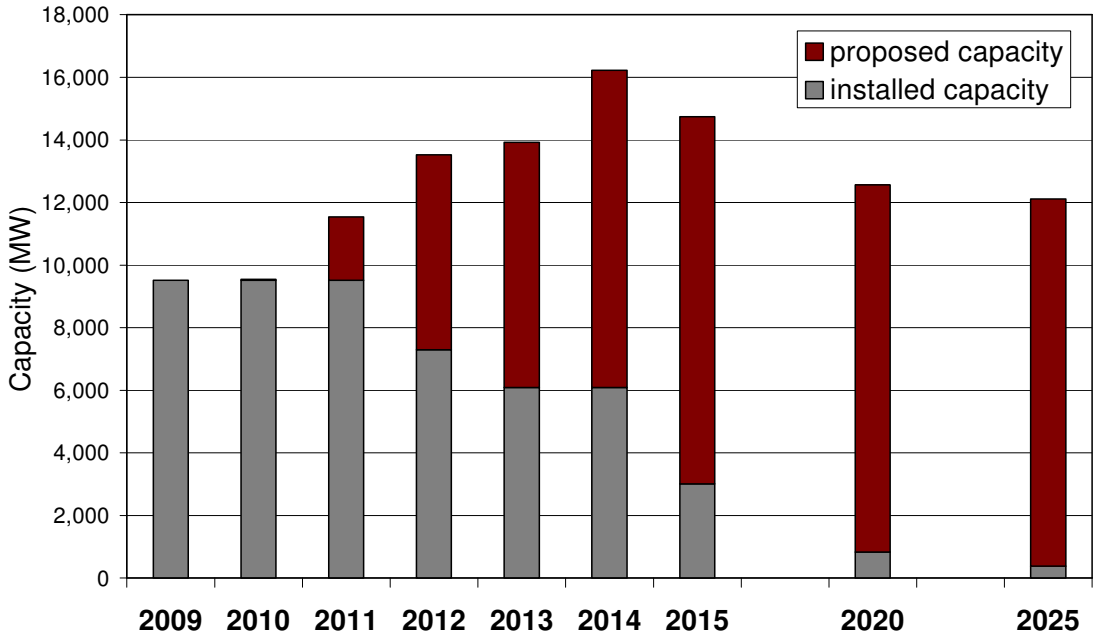


Figure 4 shows the total changes of the installed capacity in the Wadden Sea Region until 2025. The grey columns present the actually installed capacity, including the estimated shut-downs, while proposed new capacities are marked in red. After 2010, one can see a steady rise of conventional power plants until the year 2014. Particularly in 2012 the greatest yearly expansion of capacity (4,200 MW) is intended. After 2014, the installed capacity is anticipated to decrease again but, in 2025, the use of conventional power will probably be still greater than nowadays.

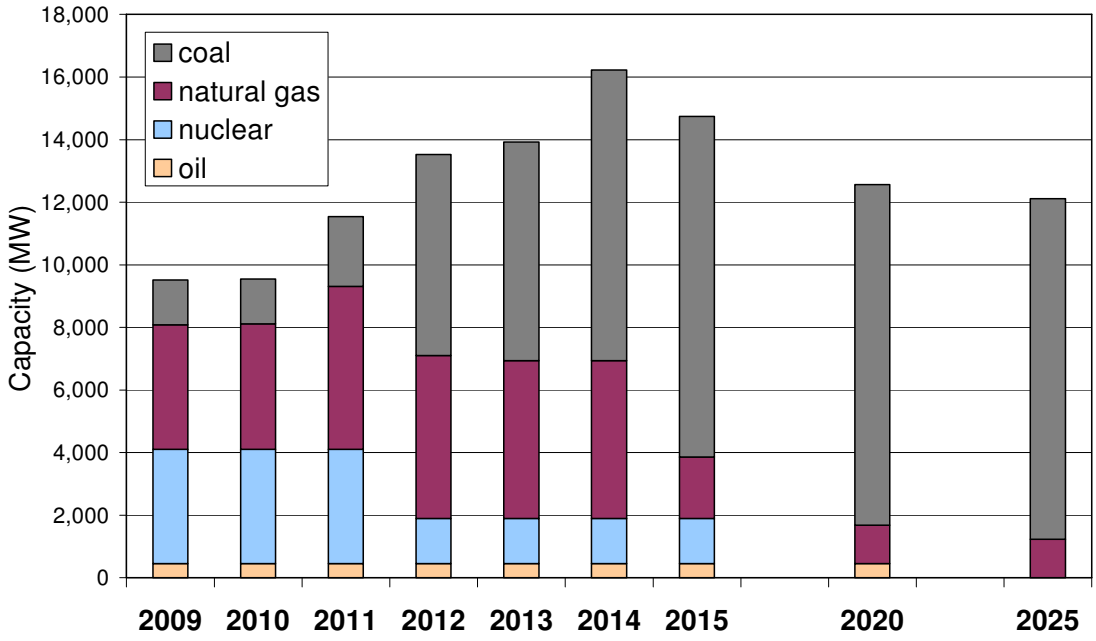
Figure 4: Conventional power plants - Development of capacity in the Wadden Sea Region until 2025



The next figure (Figure 5) shows the expected development of applied technologies, alternatively the development of the energy mix. In 2009 the nuclear and gas-powered plants possess the major capacity with nearly 8,000 MW. The contribution of coal-powered plants does not even achieve 2,000 MW in 2009, but it will change completely in the following years. Already in 2012, coal will be the most used fossil fuel in the Wadden Sea Region.

In 2012 the capacity of coal-powered plants reaches more than 8,000 MW or 60% of total capacity and increases up to more than 11,000 MW or 90% until 2025. The contribution of gas-powered plants will be nearly constant until 2014, but will then be reduced due to considerable shut-downs in the Netherlands. The final shut-down of nuclear power plants in the Wadden Sea Region is intended for the year 2019.

Figure 5: Conventional power plants - Shares of energy source until 2025



The following tables show the detailed information about all the specific power plants in the Wadden Sea Region.

2.1.2 Denmark

Table 4: Operating conventional power plants in Denmark

Name (company)	Capacity (MW)	Location	Fuels	Status/Start-up
Power Station (Dong Energy) [Esbjerg]	378	Esbjerg	coal	in operation/1992

2.1.3 Germany

Table 5: Operating conventional power plants in Germany

Name (company)	Capacity (MW)	Location	Fuels	Estimated de-commissioning date
Kernkraftwerk Brokdorf (E.ON/Vattenfall) [UBA 2008]	1,440	Brokdorf	nuclear power	2019
Kernkraftwerk Brunsbüttel (KKW Brunsbüttel GmbH) [UBA 2008]	806	Brunsbüttel	nuclear power	2009
Gasturbinenkraftwerk Brunsbüttel (Vattenfall Europe AG) [UBA 2008]	256	Brunsbüttel	light fuel oil	2025
Emden Gasturbine (Statkraft Markets GmbH) [Statkraft]	50	Emden	natural gas	(in operation since 1972)
Emden 4 (Statkraft Markets GmbH) [Statkraft]	400	Emden	natural gas	(in operation since 1972)
Kraftwerk Huntorf (E.ON Kraftwerke GmbH) [UBA 2008]	290	Huntorf (Elsfleth)	natural gas	2018
Gaskraftwerk Itzehoe (E.ON Kraftwerke GmbH) [E.ON]	87	Itzehoe	oil	(in operation since 1987)
Dow Kraftwerk (Dow Chemical GmbH) [UBA 2008]	105	Stade Bützfleth	natural gas	2013
Kernkraftwerk Unterweser (E.ON Kernkraft GmbH) [UBA 2008]	1,410	Stadland	nuclear power	2012
Heizkraftwerk Wedel (Vattenfall Europe AG) [UBA 2008]	260	Wedel	coal	2013
Gasturbinenkraftwerk Wedel (Vattenfall Europe AG) [UBA 2008, Vattenfall]	102	Wedel	light fuel oil	2025
Kraftwerk Wilhelmshaven (E.ON Kraftwerke GmbH) [UBA 2008]	788	Wilhelmshaven	coal	2013
Kraftwerk Wilhelmshaven (E.ON Kraftwerke GmbH)	50	Wilhelmshaven	natural gas	(in operation since 1976)

Listed in alphabetical order of location.

Table 6: Approved conventional power plants in Germany

Name (company)	Capacity (MW)	Location	Fuels	Status/Start-up
Kohlekraftwerk (GDF Suez Energie (Electrabel)) [Electrabel 2008]	800	Wilhelmshaven	coal	Pre construction phase/2012

Table 7: Announced conventional power plants in Germany

Name (company)	Capacity (MW)	Location	Fuels	Status/Start-up
Kohlekraftwerk (GDF Suez Energie (Electrabel)) [BDEW 2008, Tageblatt 2009]	800	Brunsbüttel	coal	licensing procedure/2012
Kohlekraftwerk Südweststrom/Iberdrola [BDEW 2008, Umweltstiftung 2009, Tageblatt 2009]	1,800	Brunsbüttel	coal	Iberdrola get off the co-financing partnership, no application/2012
Kohlekraftwerk Getec Energie AG [BDEW 2008, Tageblatt 2009]	800	Brunsbüttel	coal	no application/ 2013
Kraftwerk Emden (Dong Energy) [Umweltstiftung 2009, Ostfriesenzeitung 2009]	1,600	Emden	coal	no application/ 2015
Kohlekraftwerk (E.ON Kraftwerke GmbH) [BDEW 2008, Tageblatt 2009]	800	Stade	coal	no application/ 2011
Kohlekraftwerk EnBW/Dow Chemical GmbH [BDEW 2008, Tageblatt 2009]	1,000	Stade	coal	no application/ 2014
Kohlekraftwerk (GDF Suez Energie (Electrabel)) [BDEW 2008, Umweltstiftung 2009, Tageblatt 2009]	800	Stade	coal	licensing procedure is suspended/2012
Gaskraftwerk (Aluminium Oxid Stade) [BDEW 2008]	30	Stade-Bützfleth	natural gas	2010
Kraftwerk 50plus (E.ON Kraftwerke GmbH) [BDEW 2008, 50plus]	500	Wilhelmshaven	coal	application is intended in 2009/ 2015

Listed in alphabetical order of location.

2.1.4 The Netherlands

Table 8: Operating conventional power plants in the Netherlands

Name (company)	Capacity (MW)	Location	Fuels	Status/Start-up
Centrale Bergum (Electrabel Nederland) [Electrabel B]	664	Bergum	natural gas	In operation/ 1974/75
Eemscentrale (Electrabel Nederland) [Electrabel E]	2,417	Eemshaven	natural gas	In opera-tion/1977

Table 9: Announced conventional power plants in the Netherlands

Name (company)	Capacity (MW)	Location	Fuels	Status/Start-up
Kraftwerk Eemshaven (RWE Power AG) [RWE 2009]	1,600	Eemshaven	coal	planning permis-sion under review/ 2012/2013
Nuon Magnum (Nuon) [Nuon 2009b]	1,200	Eemshaven	Multifuel IGCC (gas, coal, etc.)	licensing proce-dure/2011

2.2 Offshore wind farms

The inventory distinguishes between two area types and three states of planning, i.e. realisation. The different area types are:

- WSR: The Wadden Sea Region itself, which we assumed to be equivalent with the 12 nautical miles zone.
- Economic Exclusive Zone (EEZ) in front of the WSR: The part of the national EEZ which is located in front of the WSR, looking from the coast in direction of the North Sea

This differentiation is made for the initial inventory only. Afterwards we use WSR in a broad sense containing the EEZs of the three countries.

The various states of planning or realisation are:

- In operation: The offshore wind farm (OWF) is producing electricity.
- Approved: The OWF is approved by the appropriate authority and it may be under construction.
- Planned: The OWF is at least publicly announced by a project developer. It may be in the approval process of the appropriate authority, but has not yet passed the process.

As the legal situation in the three countries is described in the Quality Status Report Update 2009, Chapter 3.8.3 Wind Energy, there will be no further description in this study.

2.2.1 Summary for the Wadden Sea Region

Only 114 offshore wind turbines exist in the WSR. 80 of them are located in Denmark near Esbjerg (OWF Horns Rev), 32 in the Dutch Ijsselmeer and 2 on the German coast. As the regulations for the approval of OWF in the Wadden Sea are very demanding, there is only one additional OWF approved within the WSR. It is the German OWF Nordergründe with 18 turbines with a capacity of 5 MW each (see Table 13). In the category “planned” but not yet approved, we find another OWF in the German WSR called Borkum Riffgat with a planned capacity of 220 MW delivered by 44 turbines (see Table 14) and three in the Dutch Ijsselmeer with an overall estimated capacity of 445 MW (see Table 17). Building this five OWF will enlarge the production capacity of the OWF in the WSR from about 190 MW to about 950 MW[2] (see Table 10). Although this will be a growth by factor of 5, the production capacity of all the OWF in the WSR will be small compared to the expected capacity outside the WSR in the EEZs adjacent to the WSR of the three countries.

The majority of all approved projects are located in the German EEZ, where we have 17 projects with a capacity of about 5,800 MW. In the EEZs in front of the Dutch and the Danish WSR we find one approved OWF with an estimated capacity of together 574 MW. All together, these about 6,600 MW[3] of existing and approved capacities in the EEZs in front of the WSR are about 24 times larger than the existing and approved capacities of OWF

[2] 943.5 MW offshore wind farm capacities in the WSR = 188.5 MW offshore wind farms in operation + 90 MW approved offshore wind farms + 665 MW announced offshore wind farms

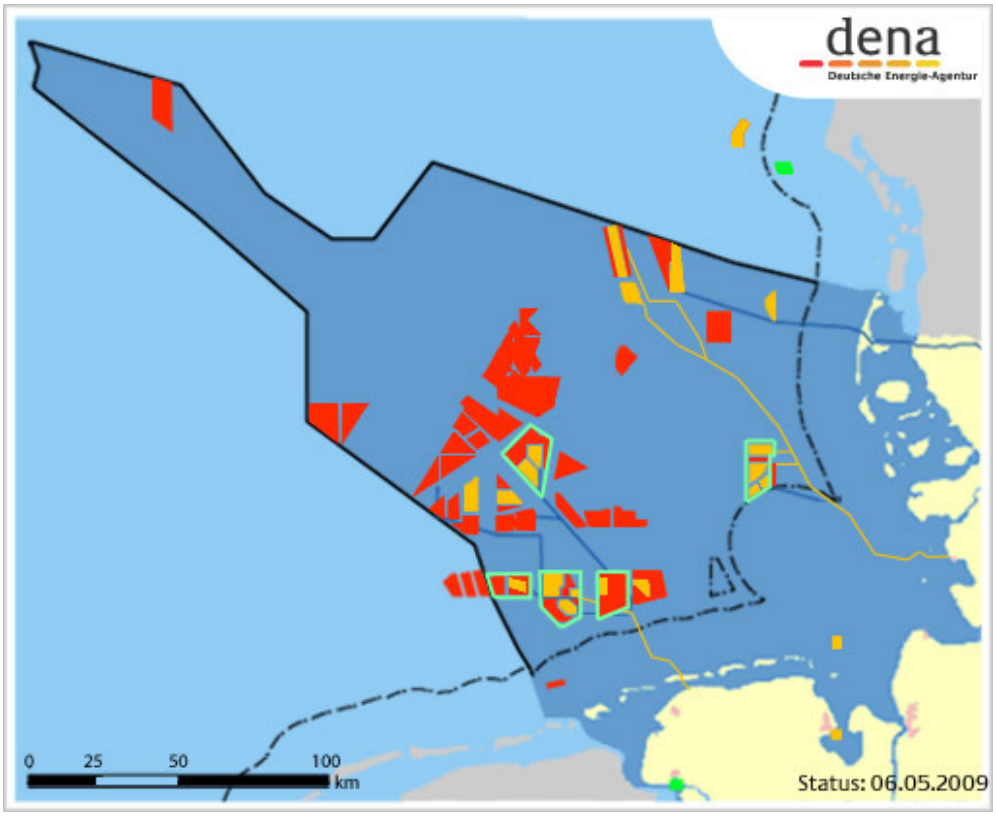
[3] 6,613 MW offshore wind farm capacities in the EEZs adjacent to the WSR = 228 MW offshore wind farms in operation + 6,385 MW approved offshore wind farms

within the WSR with about 280 MW (compare Figure 8 with Figure 9). An overview of offshore wind farms in the Danish, the German and the Dutch North Sea is given in Figure 6 and Figure 7.

Table 10: Offshore wind farms in the Wadden Sea Region and in the EEZ

Country and area	Capacity (MW)	Estimated yearly production (GWh)
In Operation		
Denmark		
WSR	160	600
EEZ in front of the WSR	no offshore wind farms	
Germany		
WSR	9.5	40
EEZ in front of the WSR	no offshore wind farms	
The Netherlands		
WSR	19	75
EEZ in front of the WSR	228	900
Total The Netherlands	*247*	*975*
Total in Operation	**416.5**	**1,615**
Planned Projects		
Denmark		
WSR	no offshore wind farms	
EEZ in front of the WSR		
Approved	224	800
Total Denmark	*224*	*800*
Germany		
WSR		
Approved	90	300
Announced	220	800
EEZ in front of the WSR		
Approved	5,811	20,700
Announced	31,412	112,100
Total Germany	*37,533*	*133,900*
The Netherlands		
WSR-Announced	445	1,600
EEZ in front of the WSR		
Approved	350	1,200
Announced	3,140	11,200
Total The Netherlands	*3,935*	*14,000*
Total Planned Projects	**41,692**	**148,700**

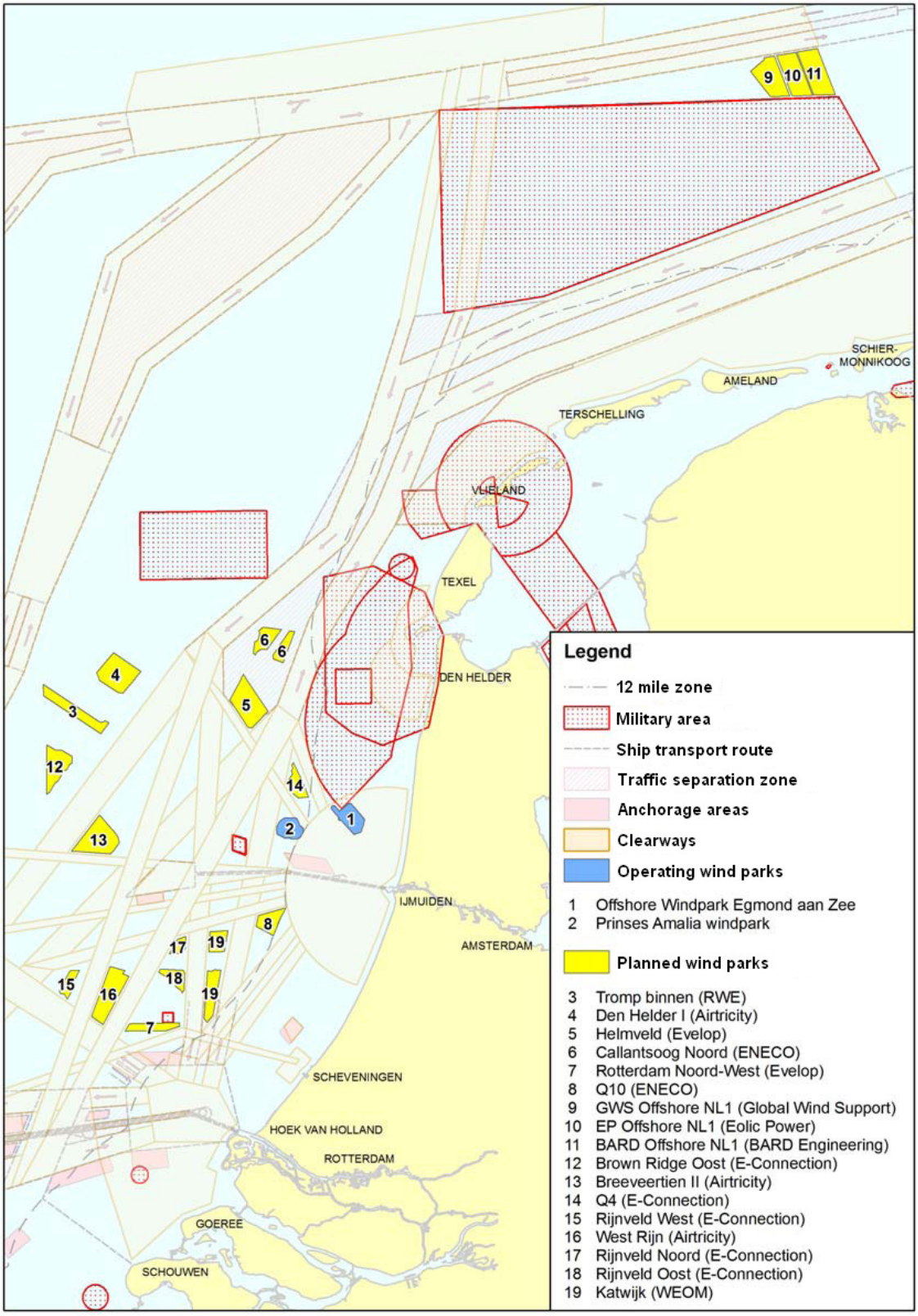
Figure 6: Offshore wind farms in the Danish and German North Sea



Legend	
Wind farms:	Borders:
Online	Continental Shelf / EEZ
Approved	12 nm zone
Under consideration	National borders
	Deep water roads
	High Voltage Cable (approved)
	High Voltage Cable (pending)
	High Voltage Cable (in use)
	Priority Use Wind Energy (Draft)
The maps are based on the BSH Bundesamt für Seeschifffahrt und Hydrographie maps showing the offshore wind farm pilot projects in the North Sea (189 KB) and the Baltic Sea (253 KB)	

Source: [Dena 2009]

Figure 7: Offshore wind farms in the Dutch North Sea



Source: [Nordzeeloket 2009]

Figure 8: Offshore wind farms directly in the WSR

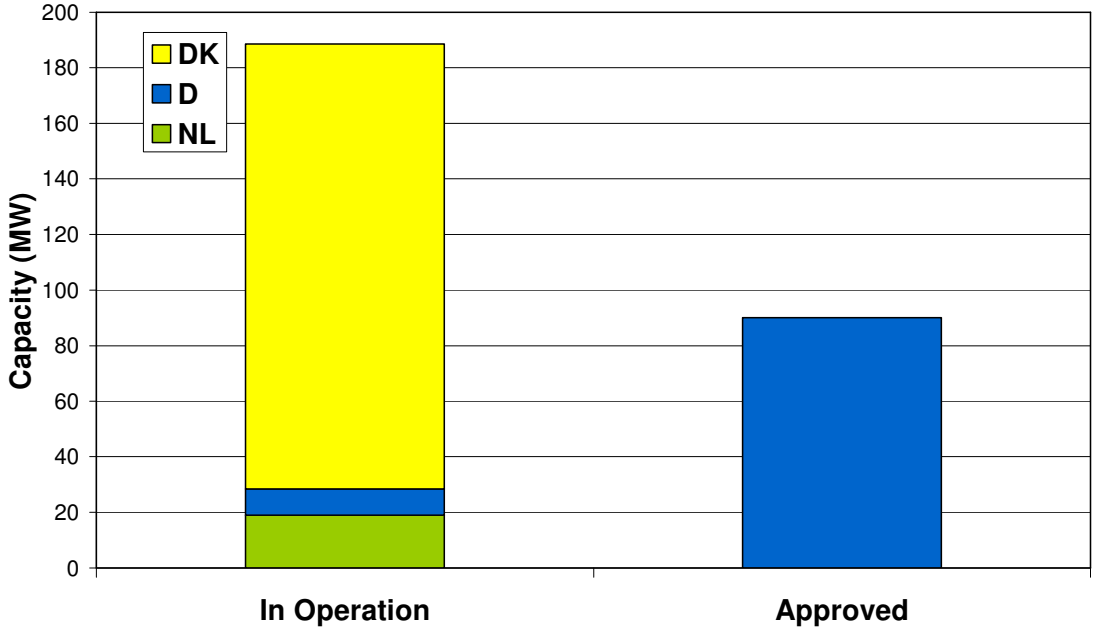
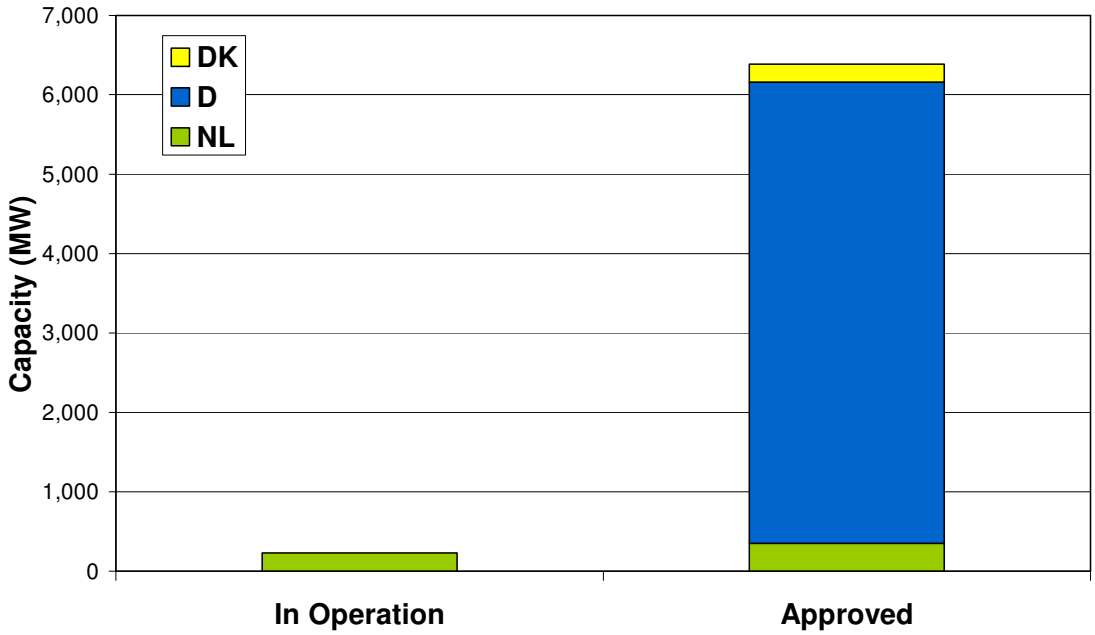


Figure 9: Offshore wind farms in the EEZ adjacent to the WSR

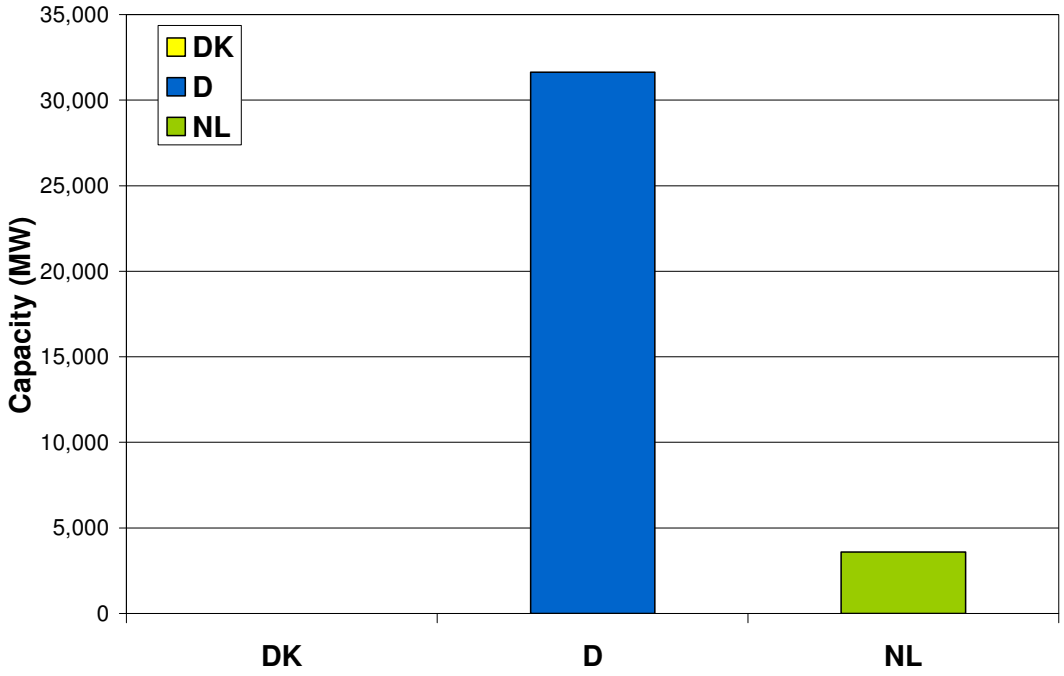


The majority of all planned projects are still not approved with a total of about 35,200 MW[4] or 84 % of the total planned capacity of about 41,700 MW[5] (see Figure 10). It has to be

[4] 35,217 MW announced offshore wind farm capacities = 665 MW announced capacities in the WSR + 34,552 MW announced capacities in the EEZs adjacent to the WSR

taken into consideration that the data quality of these planned projects is much lower than the data quality of the approved projects.

Figure 10: Announced offshore wind farms in the WSR and in the EEZ adjacent to the WSR



There are a great number of announced projects, which partly compete for the same building areas, for the same building resources and in addition in The Netherlands for the same subsidies. Therefore, it is evident that not all of these projects will be realised. But there will be other projects planned and realised in the near future. Having an actual production and installation capacity of less than 1,000 MW per year [DEWI 2008], it will take more than one decade to install all the planned OWF. During this time, the technical development will continue and the wind turbines will become even larger. The capacity of 7 or even 10 MW will be realised within the next years. What will happen to the planned OWF? Will the developers and investors change to these more powerful machines or will they stick to their old plans? Nobody knows – therefore, the estimates of the capacity and the power production have to be used and interpreted with a great care.

Concerning the estimated yearly production of electricity (see last column of Table 10), there exists another forecast uncertainty. We have calculated the electricity production of the offshore wind turbines with an average of 3,570 yearly hours of full production as it is done by [Nitsch 2008, p. 75] in a new study for the German Government. Compared with about 2,000 yearly hours of full production onshore this seems to be realistic even though other experts, like [WAB 2008a], expect much higher production numbers with more than 5,000 yearly hours of full production. But, in reality, there exists no experience with the power production at offshore locations 40 or more km from the coast. So these numbers are a cautious estimation and the future has to prove them.

[5] 41,692 MW total planned offshore wind farm capacities = 35,217 MW announced offshore wind farms + 6,475 MW approved offshore wind farms (= 90 MW in the WSR + 6,385 MW in the WSR adjacent to the WSR)

2.2.2 Denmark

Directly within the Danish WSR exists one offshore wind farm “Horns Rev”. Adjacent to the Danish WSR, another offshore wind farm is approved and under construction (Horns Rev II). For details see Table 11. In the Danish North Sea, another wind farm is to be found called Rønland. As its position is near to Limfjord in the north of Jutland (about 140 km north of Esbjerg), we decided that it has no relation to the Danish WSR.

Table 11: Offshore wind farms in or near the Danish part of the Wadden Sea

Name (company)	Capacity (MW)	Location	Characteris-tics	Status
Horns Rev (Vattenfall and Dong Energy) [Offshore Center]	160	14 – 20 km off Skallingen; within 12 Nautical Miles Zone	80 turbines	In operation since 2002
Horns Rev II (Dong Energy) [Offshore Center]	224	30 – 40 km off Esbjerg	94 turbines	Approved

2.2.3 Germany

In March 2009, there were only two wind turbines in operation in the German North Sea. For details see Table 12. The positions of these pilot turbines are not really offshore but “near shore” and within the German WSR.

Table 12: Operating offshore wind farms in the German North Sea

Name (company)	Capacity (MW)	Location	Characteris-tics	Status
Emden (Enova GmbH) [Offshore Center]	4.5	In the river Ems	1 turbine	In operation since October 2004
Hooksiel (Bard Engineering GmbH) [Offshore Center]	5	Near Wilhelmshaven	1 turbine	In operation since October 2008

In February 2002, in Germany, the political aim was set to build offshore wind turbines with an installed capacity of around 20,000-25,000 MW by the year 2030. According to this, there are many projects planned, especially for the German North Sea. Two of them have their site within the 12 nautical miles zone and within the German Wadden Sea Region: Nordergründe, which is approved since November 2007, and Borkum Riffgat, which is still in the process for approval. Most of the German project developers plan to construct much more than 80 turbines in their wind farms but the national authority for the approval of offshore projects, the Federal Maritime and Hydrographic Agency (BSH), has the rule to allow not more than 80 turbines in the actual pilot phase. Therefore, those projects with more than 80 turbines in the long run are virtually split up into one approved project

with 80 turbines (or less) and one “announced” project with the rest of the turbines. The details for the approved wind farms are listed in Table 13 and the details for the announced wind farms are listed in Table 14.

Table 13: Approved offshore wind farms in the German North Sea

Name (company)	Capacity (MW)	Location	Characteristics	Status
Borkum West (Prokon Nord) [BSH 2009]	60	43 km north of Borkum	12 turbines in pilot phase (planned 208)	Approved November 2001
Borkum Riffgrund-West (Energiekontor) [Energiekontor]	280	50 km north-west of Borkum	80 turbines in pilot phase (planned 458)	Approved February 2004
Borkum Riffgrund (PNE2 Riff I GmbH) [BSH 2009]	231	34 km north of Borkum	77 turbines in pilot phase (planned 180)	Approved February 2004
Amrumbank West (Amrumbank West GmbH) [BSH 2009]	400	36 km south-west of Amrum	80 turbines	Approved June 2004
Nordsee Ost (Winkra GmbH) [BSH 2009]	400	30 km north-west of Helgoland	80 turbines in pilot phase (planned 250)	Approved June 2004
Butendieck (Butendieck GmbH) [BSH 2009]	240	37 km west of Sylt	80 turbines	Approved December 2002
Sandbank 24 (Sandbank 24 GmbH) [BSH 2009]	480	90 km west of Sylt	96 turbines in pilot phase (planned 980)	Approved August 2004
North Sea Windpower (Enova GmbH) [BSH 2009]	240	39 km north of Juist	48 turbines in pilot phase (planned 286)	Approved February 2005
DanTysk (Gesellschaft für Energie und Oekologie mbH [BSH 2009]	400	70 km west of Sylt	80 turbines in pilot phase (planned 300)	Approved August 2005
Nördlicher Grund (Nördlicher Grund GmbH) [BSH 2009]	400	84 km west of Sylt	80 turbines in pilot phase (planned 402)	Approved December 2005
Global Tech I (Nordsee Windpower GmbH & Co.KG [BSH 2009]	400	93 km north of Juist	80 turbines in pilot phase (planned 320)	Approved May 2006
Hochsee Windpark Nordsee (EOS Offshore AG) [BSH 2009]	400	90 km north of Borkum	80 turbines (planned 508)	Approved July 2006
Gode Wind	400	38 km north of	80 turbines	Approved

Name (company)	Capacity (MW)	Location	Characteris-tics	Status
(Plambeck Neue Energien AG) [BSH 2009]		Juist	(planned 220)	August 2006
BARD Offshore 1 (BARD Engineering GmbH) [BSH 2009]	400	89 km north-west of Borkum	80 turbines	Approved April 2007
Meerwind Ost & Meerwind Süd (Meerwind Südost GmbH & Co Rand KG und Meerwind Süd-ost GmbH & Co Föhn KG [BSH 2009]	280	24 km north of Helgoland	80 turbines with 3,5 MW (2 windfarms with 40 turbines each) (planned 186)	Approved May 2007
Offshore-Windpark Nor-dergründe (Energiekontor AG) [Energiekontor]	90	12 sm Zone; 15 km north-east from Wil-helmshaven	18 turbines	Approved November 2007/ Octo-ber 2008
Hochsee Windpark Hedreiht (EOS Offshore AG) [BSH 2009]	400	85 km north of Borkum	80 turbines (planned 119)	Approved December 2007
Borkum West II (Prokon Nord Energiesysteme GmbH) [BSH 2009]	400	45 km north of Borkum	80 turbines	Approved June 2008

Listed in the order of approval.

There is no general and easy way to estimate the time of realisation of an approved project. For example, the time needed for the process of financing can demand more, or less, time depending on the owner structure. In addition, it is very much decisive which project developers have reserved the scarce resources of turbine production, offshore cables, and offshore construction of the foundations, towers, and turbines for example [DEWI 2008]. Therefore, we will make no projection of the development of the number and capacity of wind farms in the German North Sea over time in this study.

Table 14: Announced offshore wind farms in the German North Sea

Name (company)	Estimated Capacity (MW)	Distance to the coast (km)	Characteristics
Aiolos (EOS Offshore Aiolos GmbH) [WPD 2009]	400	Ca. 89	80 turbines
Albatros (LCO Nature GmbH) [Dena 2008]	400	Ca. 75	80 turbines
Aquamarin	400	83	80 turbines

Name (company)	Estimated Capacity (MW)	Distance to the coast (km)	Characteristics
(Bard Emden Eney GmbH & Co. KG) [Dena 2008]			
AreaC I (Aircity Germany Developments GmbH) [Dena 2008]	400	66	80 turbines
AreaC II (Aircity Germany Developments GmbH) [Dena 2008]	400	66	80 turbines
AreaC III (Aircity Germany Developments GmbH) [Dena 2008]	400	66	80 turbines
Offshore Windpark "Austerngrund" (Global Wind Support GmbH) [Dena 2008]	400	87	80 turbines
Bernstein (Bard Building Management GmbH) [Dena 2008]	400	108	80 turbines
BightPower I (Aircity Germany Developments GmbH) [Dena 2008]	400	74	80 turbines
BightPower II (Aircity Germany Developments GmbH) [Dena 2008]	400	74	80 turbines
Borkum Riffgat (Offshore Windpark RIFFGAT GmbH & Co. KG) [Enova 2008]	220	12 sm Zone	44 turbines
Borkum Riffgrund II (PNE2 Riff GmbH) [Plambeck 2009]	385	Ca. 35	77 turbines (second stage of Borkum Riffgrund)
Borkum Riffgrund II, (PNE2 Riff GmbH) [Plambeck 2009]	130	Ca. 35	26 turbines out of 180 planned
Borkum Riffgrund West II (Energiekontor AG) [Dena 2008]	400	52	80 turbines (second stage of Borkum Riffgrund West)
Borkum Riffgrund West (Energiekontor AG) [Dena 2008]	1,490	52	298 turbines
Borkum West (Prokon Nord) [Dena 2008]	580		116 turbines
Citrin	400	111	80 turbines

Name (company)	Estimated Capacity (MW)	Distance to the coast (km)	Characteristics
(Bard Service GmbH) [Dena 2008]			
Offshore-Windpark "Deutsche Bucht" (Eolic Power GmbH) [Dena 2008]	250	87	50 turbines
Dan Tysk (Gesellschaft für Energie und Oekologie mbH) [Dena 2008]	1,100	70 km west of Sylt	220 turbines out of 300 planned
Diamant (Bard Schiffsbetrieb GmbH & Co. Nathalie KG) [Dena 2008]	400	111	80 turbines
Innogy Nordsee I (RWE Innogy) [Enova 2008]	400	40	80 turbines (150 to 180 turbines planned in total)
Gaia I – V (Northern Energy GAIA I - V GmbH) [Dena 2008]	2,000	110 to 135	400 turbines in 5 OWF with 80 turbines each
Globaltech II (Norther Energy GlobalTech II GmbH) [Dena 2008]	380	70	76 turbines out of 320 planned
Globaltech III (Norther Energy GlobalTech III GmbH) [Dena 2008]	105	70	21 turbines out of 320 planned
Globaltech (Nordsee Windpower GmbH & Co. KG) [Dena 2008]	715		143 turbines out of 320 planned
Gode Wind II (Plambeck Neue Energien AG) [Plambeck 2009]	400	Ca. 45	80 turbines out of 220 planned
Gode Wind (Plambeck Neue Energie AG) [Plambeck 2009]	300		60 turbines out of 220 planned
H2-20 (Gesellschaft für Energie und Ökologie mbH (GEO mbH)) [Dena 2008]	400	200	80 turbines (800 planned in total)
He Dreiht (EOS Offshore AG, WPD) [Dena 2008]	195	Ca 85	39 turbines out of 119 planned
Hochsee Testfeld Helgoland (Plambeck Neue Energien) [Plambeck 2009]	75	Ca 35	19 turbines
Hochsee Windpark Nordsee	2,140		428 turbines out of

Name (company)	Estimated Capacity (MW)	Distance to the coast (km)	Characteristics
(EOS Offshore AG) [Dena 2008]			508 planned
Horizont (Mainstream Renewable Power Ltd (UK)) [Dena 2008]	400	125	80 turbines
Horizont Ost (Mainstream Renewable Power Ltd (UK)) [Dena 2008]	400	121	80 turbines
Horizont West (Mainstream Renewable Power Ltd (UK)) [Dena 2008]	330	131	66 turbines
Kaikas (EOS Offshore Kaikas GmbH) [WPD 2009]	400	Ca. 89	80 turbines (110 turbines planned in total)
Kaskasi (Essent GmbH) [Dena 2008]	200	35	40 turbines
Meerwind (Meerwind Südost GmbH & Co Rand KG und Meerwind Südost GmbH & Co Föhn KG [Dena 2008]	530		106 turbines out of 186 planned
MEG Offshore I (Prokon Nord Energiesysteme GmbH) [Dena 2008]	400	45	80 turbines
Nördlicher Grund (Nördlicher Grund GmbH) [Dena 2008]	1,610	84 km west of Sylt	322 turbines out of 402 planned
Nordpassage (Vattenfall Europe New Energy GmbH) [Dena 2008]	400	75	80 turbines
Nordsee Ost Winkra GmbH [Dena 2008]	850		170 turbines out of 250 planned
Notos (Eos Offshore Notos i. Gr.) [WPD 2009]	165	Ca. 89	33 turbines
Offshore North Sea Windpower Delta Nord-see II (ENOVA Offshore Projektentwicklung GmbH & Co. KG) [Enova 2008]	32	40	6 turbines (s)
North Sea Windpower (ENOVA Offshore Projektentwicklung GmbH & Co. KG) [Enova 2008]	1,160	40	232 turbines out of 286 planned
OWP West	400	40	80 turbines

Name (company)	Estimated Capacity (MW)	Distance to the coast (km)	Characteristics
(LCO Nature GmbH) [Dena 2008]			
Sanbank 24 ext. (Sandbank Power GmbH & Co. KG) [Sandbank 2009]	200	90	40 turbines
Sanbank 24 (Sandbank Power GmbH & Co. KG) [Sandbank 2009]	4,220		844 turbines out of 980 planned
Sea Storm (Nordsee Windpower GmbH & Co. KG) [Dena 2008]	400	110	80 turbines
Sea Strom II (Northern Energy SeaStrom II GmbH. i.Grdg.) [Dena 2008]	190	110	38 turbines
Sea Wind I (Nordsee Windpower GmbH & Co. KG) [Dena 2008]	400	90	80 turbines
Sea Wind II (Nordsee Windpower GmbH & Co. KG) [Dena 2008]	300	90	60 turbines
Sea Wind III (Northern Energy SeaWin III GmbH i. Grdg.) [Dena 2008]	400	110	80 turbines
Skua (OPG Projekt GmbH) [Dena 2008]	400	85	80 turbines
Uthland (Geo mbH) [Dena 2008]	400	49	80 turbines from 80 planned in total
Veja Mate (Cuxhaven Steel Construction GmbH) [Dena 2008]	400	Ca. 85	80 turbines
VentoTec Nord I (Arcadis Consult GmbH) [Dena 2008]	150	132	50 turbines with 3 MW (200 planned)
VentoTec Nord II (Arcadis Consult GmbH) [Dena 2008]	150	104	50 turbines with 3 MW (200 planned)
Weiße Bank (Energiekontor GmbH) [Dena 2008]	280	83	80 turbines with 3.5 MW (170 planned)

Listed in alphabetic order of the wind farms.

2.2.4 The Netherlands

The further development of wind farm projects plays a decisive role for the Dutch energy policy objectives. The Dutch government intends to realize 6,000 MW of offshore wind energy in operation by 2020 in the Dutch part of the Continental Shelf of the North Sea. In the middle of 2008, the cabinet outlined the proposed script for the development and realisation of offshore wind energy. According to the government targets, the Netherlands is committed (permits and subsidies) to possess wind farms worth minimally 450 MW in addition to the two existing offshore wind farms, Egmond aan Zee (108 MW) and Prinses Amalia (120 MW), in 2012 (see Table 15 operating offshore wind farms).

Since February 2005, eleven initiators submitted plans for several offshore wind farm projects. For 17 wind farms (each 300 - 500 MW), applications for building licenses in the North Sea have already been submitted. Two building permissions have been approved so far.

Below, one will find the details for the operating, approved, and planned offshore wind farm projects “in or near the Dutch part of the Wadden Sea”. These are located in the area between Ijmuiden in the west, the German border, and the island Schmiermonnikoog in the north.

Table 15: Operating offshore wind farms in the Dutch part of the Wadden Sea

Name (company)	Capacity (MW)	Location	Characteristics	Status
Lely (Nuon) [WSH 2009, Nuon 2009a]	2	Near-shore wind park: Distance to shore 800 meters from the quay in the Ijsselmeer close to Medemblik	4 turbines	In operation since 1994
Irene Vorrink (Dronten) (Nuon) [WSH 2009, Nuon 2009a]	17	Near-shore wind park: Distance to shore - 30 meters from the dyke in the Flevopolder	28 turbines	In operation since 1996
Offshore Windpark Egmond aan Zee (OWEZ) (NoordzeeWind: Cooperation between NUON and Shell) [WSH 2009, Noordzeewind]	108	10 to 18 km from the coast at Egmond aan Zee	36 turbines	In operation since Nov. 2006
Q7-WP / Prinses Amalia (Eneco and Econcern) [WSH 2009, PrinsesAmalia]	120	23 km from IJmuiden	60 turbines	In operation since May 2008

Table 16: Approved offshore wind farms in the Dutch part of the Wadden Sea

Name (company)	Capacity (MW)	Location	Characteris-tics	Status
Breeveertien II, North Sea (Airtricity, Scottish and Southern Energy (SSE)) [WSH 2009, Breeveertien]	350 (min. 234 / max. 415)	60 km off the coast to the west of IJmuiden	104 turbines	Approved in October 2007*

* This already licensed North Sea project is required to compete furthermore in a tender procedure (max. capacity 950 MW) which will be settled before April 2010.

Table 17: Announced offshore wind farms in the Dutch part of the Wadden Sea

Name (company)	Capacity (MW)	Location	Characteris-tics	Status
Location Ijsselmeer				
Noordermeerdijk, Ijsselmeer (Developer/owner not available) [WSH 2009, Ministerie]	100 - 160	Distance to shore 400 m.	26 - 30 turbi-nes	
Westermeerdijk, IJsselmeer (Westermeerwind) [WSH 2009, Ministerie]	180-250	Distance to shore 500 - 1.200 m.	30 - 45 turbi-nes	
Wieringermeerdijk IJsselmeer (NUON / WCI) [WSH 2009, Ministerie]	Approx. 100	Distance to shore 800 m.	30 - 40 turbi-nes	
Location north of the is-lands Ameland and Schmiermonnikoog in the Dutch EEZ				
Bard Offshore NL1 (Bard Engineering GmbH) [WSH 2009, Ministerie, Bard]	Max. 390	Distance to shore: approx. 56 km in the northwest of the is-lands Schiermon-nikoog and Rot-tumerplaat	78 turbines	Application complete
EP Offshore NL1 (Eolic Power GmbH) [WSH 2009, Ministerie, Eo-lic Power]	Max. 390	Distance to shore: approx. 56 km in the northwest of the is-lands Schiermon-nikoog and Rot-tumerplaat	78 turbines	Application complete
GWS Offshore NL1 (Global Wind Support	Max. 400	Distance to shore: approx. 56 km in the	80 turbines	Application complete

Name (company)	Capacity (MW)	Location	Characteris-tics	Status
GmbH) [WSH 2009, Ministerie, Global Wind Support]		northwest of the islands Schiermonnikoog and Rottumerplaat		
Location northwest of Ijmuiden in the Dutch EEZ				
Brown Ridge Oost (E-Connection) [WSH 2009, Ministerie, E-Connection]	Max. 282	Distance to shore: approx. 74 km in line with Ijmuiden	94 turbines	Application complete
Callantsoog-Noord (ENECO Milieu B.V.) [WSH 2009, Ministerie, ENECO]	Approx. 303 (nominal)	Distance to shore: 30 km in line with Den Helder	101 turbines	Application complete
Den Helder I (Airtricity) [WSH 2009, Ministerie, [Airtricity]]	Approx. 468	Distance to shore: 63 - 72 km in line with Den Helder	78 turbines	Application complete
Helmveld (Evelop Netherlands B.V.) [WSH 2009, Ministerie, Evelop]	Approx. 493	Distance to shore: 34 km in line with Petten	137 turbines	Application complete
Q4-WP (E-Connection) [WSH 2009, Ministerie, E-Connection]	120	Distance to shore: at least 23 km from Egmond aan Zee	40 turbines	Application complete
Tromp Binnen (RWE Offshore Wind Nederland B.V.) [WSH 2009, Ministerie, RWE Wind]	295	Distance to shore: approx. 75 km from Ijmuiden	59 turbines	Application complete

2.3 Onshore wind farms

2.3.1 Summary for the Wadden Sea Region

In addition to the inventory for offshore wind farms mentioned in chapter 2.2, the following table shows information about the present onshore wind energy production and potential wind energy capacities in the Wadden Sea Region in 2020. While the inventory for conventional power plants and offshore wind parks is based on the analysis of primary data and enumerates single projects, the following register for onshore wind parks includes data on the level of rural districts and provinces and is predicated on the secondary data. This is due to the fact that primary data were not consistently available.

The table includes data published by the Danish Energy Agency, the German Deutsches Windenergie Institut (DEWI) and the Dutch Wind Service Holland (WSH). Detailed information on the level of rural districts, local authorities, and provinces as well as references are given in the following chapters.

Table 18: Present onshore wind farms and potential wind energy capacities in the Wadden Sea Region in 2020

Country	Capacity (MW)	Estimated yearly production (GWh)
In Operation		
Denmark	277	567
Germany	3,634	8,177
The Netherlands	695	1,812
Total in operation	**4,606**	**8,746**
Potential wind energy capacities 2020		
Denmark	340	700
Germany	4,450	10,000
The Netherlands	1,350	3,600
Total potential wind energy capacities 2020	**6,140**	**14,300**

Actually, more than 4,800 wind energy turbines with a total capacity of about 4,600 MW are located in the Wadden Sea Region. The estimated yearly production adds up to almost 8,750 GWh. Over three-fourths of the present onshore wind energy capacities are installed in the German Wadden Sea Region (79%), whereas 15 % are located in the Dutch part of the Wadden Sea Region, and only 6 % in the Danish part (see Table 18).

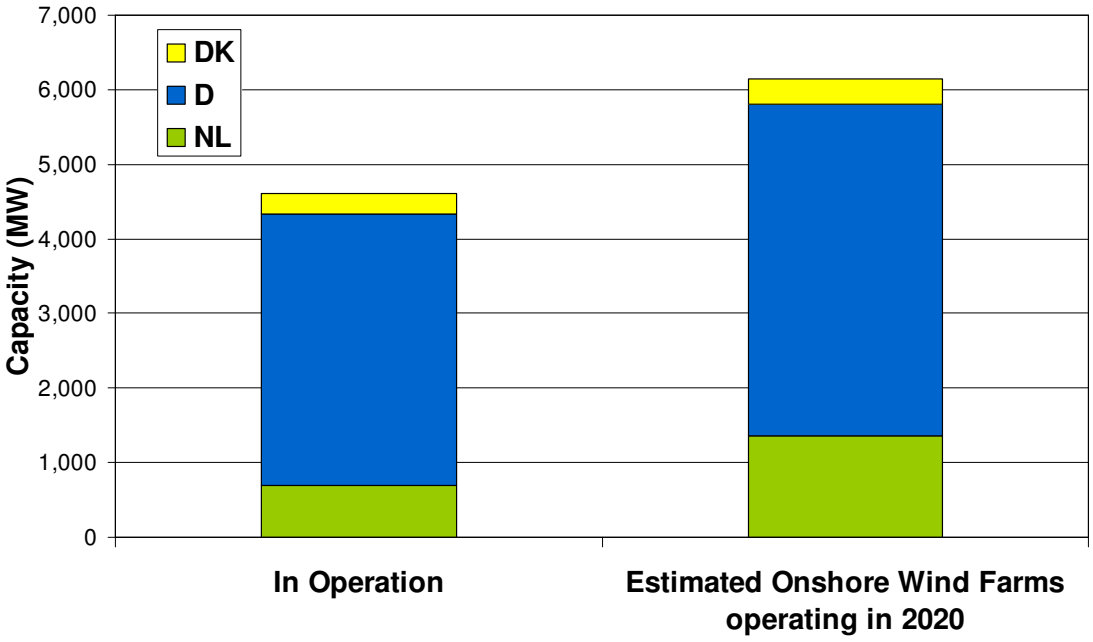
The expansion of onshore wind farms in the Wadden Sea Region is estimated until 2020. This forecasting horizon was chosen since, in reference to [DEWI 2006], the remaining potentials for onshore wind farms in Lower Saxony will be exhausted until 2015 by using currently known technologies. A similar situation can be presumed for the remaining part

of the Wadden Sea Region. In addition to that, reliable long-term predictions for the nationwide development of energy capacities are made on the political level until 2020, too.

The estimation of potential wind energy capacities in 2020 is based on the present capacities listed above. Apart from the detailed information on existing wind turbines and currently planned installations given by the Dutch Wind Service Holland [WSH 2009], the study also considers repowering potentials[6] and remaining potentials (depending on the areas designated for wind use) estimated by [DEWI 2006]. It is assumed, that all existing potentials will be used in 2020. The yearly production in 2020 was calculated according to the present full load hours known for the provinces and rural districts in Denmark, Germany and the Netherlands.

Corresponding to our estimation, the onshore wind energy capacities in the Wadden Sea Region will enlarge from about 4,600 MW to about 6,150 MW in 2020. This will be a growth by more than 30 %. More than 70 % of the onshore wind energy capacities in 2020 will be installed in the German Wadden Sea Region (72%) whereas about 22 % will be located in the Dutch part of the Wadden Sea Region and about 6 % in the Danish part (see Figure 11). The estimated yearly production in 2020 is assumed to be about 14,300 GWh.

Figure 11: Onshore wind farms in the Wadden Sea Region



[6] By installing larger wind turbines land use can be optimised assuming that repowering will result in a higher power density per site. Further information about repowering of onshore wind farms is available at Wind Energy Agency Bremerhaven/Bremen (WAB). The WAB is currently undertaking the project “Dialogverfahren Repowering von Windenergieanlagen”.

2.3.2 Denmark

The following table includes detailed data about operating onshore wind farms in the Danish part of the WSR on the level of local authorities as published by the Danish Energy Agency. At present, more than 450 wind energy turbines with a total capacity of about 280 MW are located in the Danish part of the WSR. The estimated yearly production adds up to almost 570 GWh.

Table 19: Operating onshore wind farms in the Danish part of the Wadden Sea Region

Local authority	Capacity (MW)	Estimated yearly production (GWh)	Number of turbines
Esbjerg	57	118	75
Fanø	2	6	3
Tønder	156	326	256
Varde	61	117	117
Total Denmark [Danish Energy Agency 2009]	**277**	**567**	**451**

As described in the previous chapter, the potential wind energy capacities in the Danish part of the Wadden Sea Region in 2020 are calculated according to the estimates given by [DEWI 2006] for the further extension of onshore wind energy in Lower Saxony. According to our calculations, the estimated onshore capacity in 2020 will be about 340 MW assuming that all existing potentials will be used in 2020. The yearly production is based on the present full load hours and is assumed to be about 700 GWh.

Table 20: Potential wind energy capacities in the Danish part of the Wadden Sea Region 2020

Reference	Capacity (MW)	Estimated yearly production (GWh)
Own calculations on the basis of [Danish Energy Agency 2009] and [DEWI 2006]	340	700

2.3.3 Germany

Table 21 shows data about operating onshore wind farms in the German part of the WSR on the level of rural districts as published by the German Deutsches Windenergie Institut (DEWI). Actually, about 3,650 wind energy turbines are located in the German part of the WSR with a total capacity of about 3,640 MW. The yearly production is estimated to be about 8,200 GWh.

Similarly to Denmark, potential wind energy capacities in the German part of the Wadden Sea Region in 2020 are calculated according to the estimates given by [DEWI 2006] for

the further extension of onshore wind energy in Lower Saxony. According to our calculations, the estimated onshore capacity in 2020 will be about 4,450 MW assuming that all existing potentials will be used in 2020 (see Table 22). The yearly production is estimated to add up to 10,000 GWh. It is calculated on the basis of the average present full load hours as given by [ISET 2005].

Table 21: Operating onshore wind farms in the German part of the Wadden Sea Region

Rural district	Capacity (MW)	Estimated yearly production (GWh)	Number of turbines
Aurich	533	1,198	518
Bremerhaven (municipality)	39	88	16
Cuxhaven	430	967	472
Dithmarschen	564	1269	852
Emden (municipality)	139	312	84
Friesland	122	275	164
Leer	163	367	139
Nordfriesland	723	1,626	578
Pinneberg	14	31	11
Stade	277	622	212
Steinburg	253	569	195
Wesermarsch	135	304	128
Wilhelmshaven (municipality)	43	97	25
Wittmund	201	452	247
Total Germany [DEWI 2009]	**3,634**	**8,177**	**3,641**

Table 22: Potential wind energy capacities in the German part of the Wadden Sea Region 2020

Reference	Capacity (MW)	Estimated yearly production (GWh)
Own calculations on the basis of [DEWI 2009], [DEWI 2006] and [ISET 2005]	4,450	10,000

2.3.4 The Netherlands

Table 23 includes data about the operating onshore wind farms in the Dutch part of the WSR on the level of provinces as published by the Dutch Wind Service Holland (WSH). One can see that about 770 wind energy turbines with a total capacity of about 700 MW are located in the Dutch part of the WSR. The estimated yearly production adds up to more than 1,800 GWh.

Table 23: Operating onshore wind farms in the Dutch part of the Wadden Sea Region

Province	Capacity (MW)	Estimated yearly production (GWh)	Number of turbines
Friesland	154	379	329
Groningen	356	1,011	198
Kop van Noord Holland	185	422	243
Total The Netherlands [WSH 2009] and own calculations on the basis of [WSH 2009]	**695**	**1,812**	**770**

The potential wind energy capacities in the Dutch part of the Wadden Sea Region in 2020 are calculated on the basis of data given by the Dutch Wind Service Holland [WSH 2009]. According to our estimations, the onshore capacity in 2020 will be about 1,350 MW assuming that all existing onshore potentials will be used in 2020. The estimated yearly production is based on the present full load hours known for the provinces and is assumed to be about 3,600 GWh.

Table 24: Potential wind energy capacities in the Dutch part of the Wadden Sea Region 2020

Reference	Capacity (MW)	Estimated yearly production (GWh)
Own calculations on the basis of [WSH 2009]	1,350	3,600

2.4 Summary on inventory and analysis of power plants in the Wadden Sea Region

The inventory of the existing power production facilities and the planned facilities in the WSR shows us six main results:

- Today, the WSR is an important location for electricity production in fossil and nuclear power plants. On the first sight, the WSR shows to be an export region for electricity with a great relevance for the energy supply of the three WS states, i.e. Denmark, Germany and The Netherlands. This point will be deepened during the next steps of our research.
- Offshore wind energy does not, actually, play an important role in the electricity supply of the WSR but there exist far reaching plans of expanding this kind of electricity production in the German and in the Dutch EEZ adjacent to the WSR. In Denmark only, one additional OWF is planned near Esbjerg.
- The potential for onshore wind energy production in the Wadden Sea Region is already used to a large extent. However, there remains still some potential for further extension. Altogether, the production capacity of onshore wind farms in 2020 and beyond will be small compared to the expected offshore wind energy capacities in the WSR and in the EEZs adjacent to the WSR.
- The energy industry has quite a number of plans for the new fossil power plants, especially for the coal fired ones, to be built in the German and in the Dutch WSR. These power plants will more than offset the electricity production of those power plants which will be shut down in the next 10 years. This will strengthen the position of the WSR as an export region for electricity.
- The prediction of the development of OWF in the North Sea in front of the WSR is very difficult. There are a great number of announced projects which partly compete for the same building areas, for the same building resources, and, in addition in the Netherlands, for the same subsidies. Above all, there is little experience with installations of big OWF in the North Sea locations far away from the coast. Therefore, nobody really knows how many wind turbines can be installed within the next decade. But, in the long term, one can expect that more electricity will be produced by OWF adjacent to the WSR than by fossil power plants located in the WSR.
- Concerning the further development of onshore wind farms in the WSR, one can conclude that the remaining potential in the areas designated for the wind use will be completely used in 2020 assuming that the currently known technologies will have been applied. According to an analysis of primary data made by [DEWI 2006], the remaining potential for onshore wind energy in Lower Saxony will already be exhausted in 2015. Due to the continuous development of new turbine generations and the growing obsolescence of operating wind turbines, installed capacities in designated wind areas will be replaced by modern and more efficient turbines (repowering). All in all, the estimation of installed onshore wind energy capacities in the WSR in the following decades is much more reliable and predictable than the adequate estimation of offshore wind energy capacities.

To summarize: The WSR will hold its status as export region for electricity. The development of offshore wind energy will strengthen this status. Whether wind energy production could be sufficient to make the WSR independent from fossil electricity production will be answered in the next part of our study.

3 Sustainable electricity supply in the Wadden Sea Region

3.1 Feasible power plant capacities in the Wadden Sea Region until 2020

In order to calculate the renewable electricity production in the WSR one has to know the installed power plant capacities until 2020. It seems to be evident that not all of the announced offshore wind parks and conventional power plants, which are included in the inventory, can be realised:

- Offshore wind parks: e.g. due to the lacking experience with the set up of big OWF, competition for the same building areas, and the further development of wind turbines.
- Conventional power plants: e.g. due to the observation of growing public pressure against the construction of new power plants of a certain capacity and the effort of energy companies to ensure new locations for power plants by announcing more projects than they will realise.

For these reasons, we made an amendatory assessment of the feasible power plant capacities in the WSR until 2020.

Feasible potential of conventional power plants:

The evaluation of conventional power plants in the Danish part of the Wadden Sea Region is comparatively straightforward. In the field of conventional power plants, the present capacity equals to the feasible capacity in 2020 since there are no announcements of the new conventional power plants available. With regard to the development of conventional power plants in Germany and the Netherlands, we estimate that the number of announced projects will exceed the number of projects to be realised. Due to the observation of growing public pressure against the construction of new power plants of a certain capacity, we can assume that, at locations with two power plants already installed, energy companies will not be able to construct a third one. Therefore, only two conventional power plants were considered at the same location for the calculation of the feasible potential.

As a result, the feasible potential of conventional power plants in the WSR is expected to reach 10,960 MW (Inventory: 12,560 MW) until 2020.

Feasible potential of offshore wind farms:

As the development of offshore wind farm capacities until 2020 is difficult to predict, the calculation of its feasible potential was based on current political and scientific assessments. Power plants directly in the WSR, as well as in the EEZ adjacent to the WSR, were included in the calculation.

Concerning the expansion of offshore wind energy, the Danish government and administration is not willing to fix new development objectives beyond 2012 [Neue Energie 2008]. Therefore, we assumed that the approved 224 MW offshore wind energy capacities will be realised until 2020. The German ministry of environment anticipates 10,000 MW of offshore wind energy capacities in the German WSR to be installed until 2020 [IWR 2009]. As described in chapter 2.2.4, the Dutch government has set a target for the development of 6,000 MW of wind power in the Dutch part of the North Sea by

2020. In spring, [We@sea 2009] published two scenarios for the development of Dutch offshore wind farms until 2020. According to the slow-going scenario, [We@sea 2009] came to the conclusion that, by the end of 2020, offshore wind energy capacities of about 3,700 MW could be installed. We refer to this estimate of wind energy capacities realisation potential in the Dutch part of the WSR, as we consider it to be more realistic than the fast-going scenario. Since a reliable announcement of areas designated for the offshore wind use in the Netherlands is currently not available, we assumed that 50 % of the estimated 3,700 MW in 2020 will be built in the Dutch part of the WSR. To realise this offshore wind energy capacity of 1,850 MW until 2020, additional 1,600 MW have to be constructed in the following years.

As a result, the feasible potential of offshore wind farms in the WSR is estimated to add up to about 12,000 MW (Inventory: 42,100 MW) until 2020.

Feasible potential of onshore wind farms:

Compared to the development of offshore wind energy capacities, the deployment of onshore wind energy capacities in the WSR in the following decades can be predicted comparatively reliably. Therefore, we supposed that the estimated onshore wind energy potential in the Danish, German, and Dutch part of the Wadden Sea Region, of about 6,100 MW according to the inventory, will be realised until 2020. It considers planned projects, as well as remaining potentials, and repowering potentials.

Figure 12 displays the feasible power plant capacities in the WSR per country until 2020. The power plant capacities given by the inventory, and the calculated feasible potential, are shown in Table 25.

Figure 12: Feasible power plant capacities in the WSR per country until 2020 (MW)

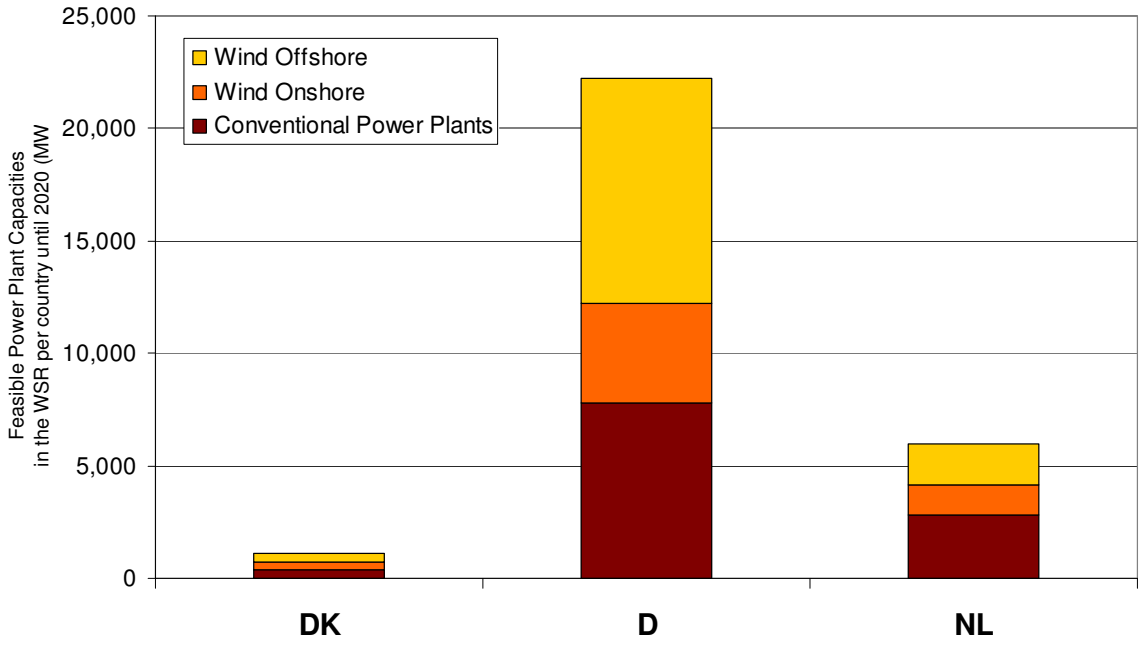


Table 25: Power plant capacities in the Wadden Sea Region: Present capacity, estimated stock in 2020 and feasible potential until 2020

Country	Conventional Power Plants	Onshore Wind Farms	Offshore Wind Farms	Overall result
Existing capacity according to inventory				
Denmark				
Capacity (MW)	380	280	160	820
Proportion	46%	34%	20%	100%
Germany				
Capacity (MW)	6,050	3,630	10	9,690
Proportion	62%	37%	0%	100%
The Netherlands				
Capacity (MW)	3,080	700	250	4,030
Proportion	76%	17%	6%	100%
Total WSR	**9,510**	**4,610**	**420**	**14,540**
	65%	**32%**	**3%**	**100%**
Stock of power plants and wind farms in 2020 according to inventory (Summation of present stock plus planned, approved or announced projects)				
Denmark				
Capacity (MW)	380	340	380	1,100
Proportion	35%	31%	35%	100%
Germany				
Capacity (MW)	9,380	4,450	37,540	51,370
Proportion	18%	9%	73%	100%
The Netherlands*				
Capacity (MW)	2,800	1,350	4,180	8,330
Proportion	34%	16%	50%	100%
Total WSR	**12,560**	**6,140**	**42,100**	**60,800**
	21%	**10%**	**69%**	**100%**
Feasible potential until 2020 (Summation of present stock plus feasible power plant development)				
Denmark				
Capacity (MW)	380	340	380	1,100
Proportion	35%	31%	35%	100%
Germany				
Capacity (MW)	7,780	4,450	10,000	22,230
Proportion	35%	20%	45%	100%
The Netherlands				
Capacity (MW)	2,800	1,350	1,850	6,000
Proportion	47%	23%	31%	100%
Total WSR	**10,960**	**6,140**	**12,230**	**29,330**
	37%	**21%**	**42%**	**100%**

3.2 Electricity production in the Wadden Sea Region

The feasible power plant capacities in the Wadden Sea Region were taken as a basis for the estimation of the yearly electricity production in the WSR in 2020. Present yearly electricity production in the Wadden Sea Region was calculated with recourse to the data given in the inventory. The results are shown in Table 26.

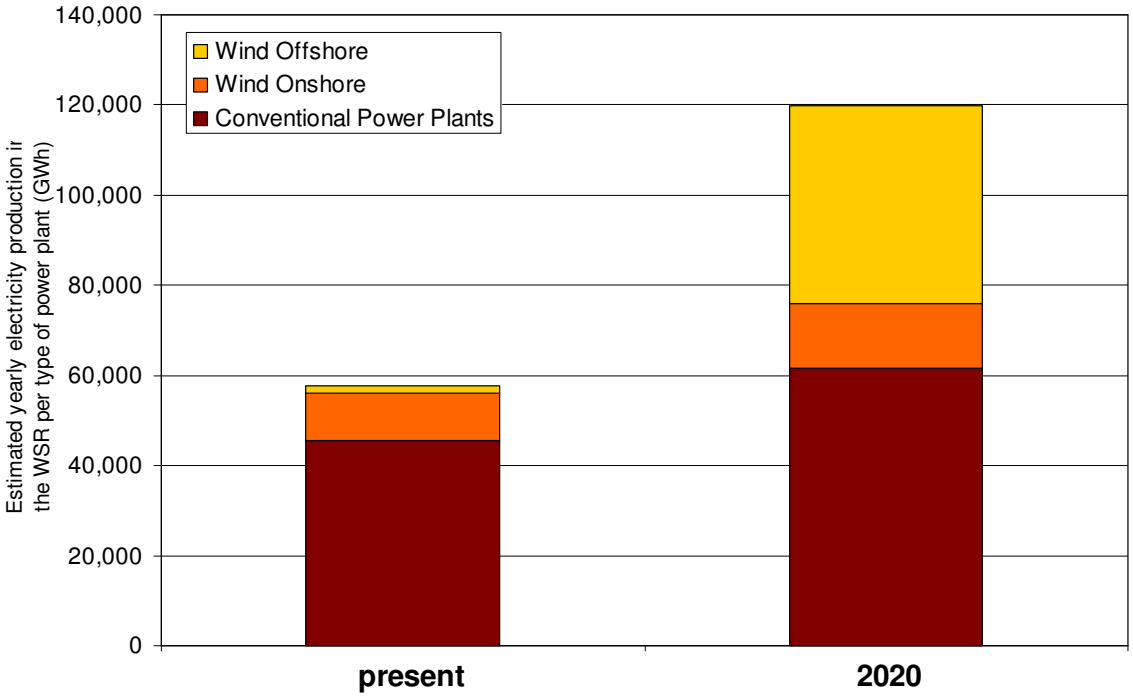
As one can see, the present electricity production in the WSR is still dominated by conventional power plants (80 %). But, until 2020, the share of electricity produced by conventional power plants will decrease to about 50 %. Vice versa, the present share of electricity produced by wind energy is already about 20 %. Until 2020 it will increase to almost 50%. Until 2020, the estimated yearly electricity production in the Wadden Sea Region will increase from present about 57,600 GWh to about 120,000 GWh. Over the same time period, the electricity production from onshore and offshore wind energy will rise from about 12,200 GWh to about 58,000 GWh in 2020. This will be a growth by more than a factor of 4.5.

Table 26: Estimated yearly electricity production in the Wadden Sea Region: present and 2020

	Denmark	Germany	The Netherlands	Overall result	
Estimated present yearly electricity production in the Wadden Sea Region (GWh)					
Conventional Power Plants	2,200	31,750	11,500	45,450	79%
Wind Onshore	570	8,180	1,810	10,560	18%
Wind Offshore	600	40	980	1,620	3%
Total WSR	**3,370**	**39,970**	**14,290**	**57,630**	**100%**
	6%	**69%**	**25%**	**100%**	
Estimated yearly electricity production in the Wadden Sea Region 2020 (GWh)					
Conventional Power Plants	2,300	45,100	14,300	61,700	52%
Wind Onshore	700	10,000	3,600	14,300	12%
Wind Offshore	1,400	35,700	6,610	43,710	37%
Total WSR	**4,400**	**90,800**	**24,510**	**119,710**	**100%**
	4%	**76%**	**20%**	**100%**	

As shown in Figure 13, the growing amount of renewable electricity production in the WSR from present until 2020 results mainly from the planned development of offshore wind farm capacities directly in the WSR and in the EEZs adjacent to the WSR. Considering the current political and scientific prognoses, we expect a yearly electricity production from offshore wind energy in 2020 to be about 44,000 GWh. More than 80 % of the electricity produced by offshore wind farms in the WSR in 2020 is expected to descend from the German part of the Wadden Sea Region.

Figure 13: Estimated yearly electricity production in the WSR by type of power plant: Present and 2020 (GWh)



3.3 Consumption of electricity in the Wadden Sea states and within the Wadden Sea Region

As proven in the previous chapter, the Wadden Sea Region will continue to be an important location for fossil and renewable electricity production in the following decades. But, in order to assess the Wadden Sea Region as an export region for electricity, one also has to analyse the consumption of electricity in the WSR itself and in the three Wadden Sea States, i.e. in Denmark, Germany and the Netherlands. The overall results of our estimation are shown in Table 27.

Table 27: Yearly consumption of electricity in the Wadden Sea states and within the Wadden Sea Region: Present and 2020

	Denmark	Germany	The Netherlands	Overall result
Present yearly consumption of electricity (GWh)				
In the Wadden Sea States (DK + D + NL)[1]	33,720	530,430	92,300	**656,450**
In the WSR[2]	1,400	20,700	9,500	**31,600**
Estimated yearly consumption of electricity 2020 (GWh)				
In the Wadden Sea States (DK, D, NL)[3]	30,600	480,700	83,600	**594,900**
In the WSR[3]	1,300	18,800	8,600	**28,700**

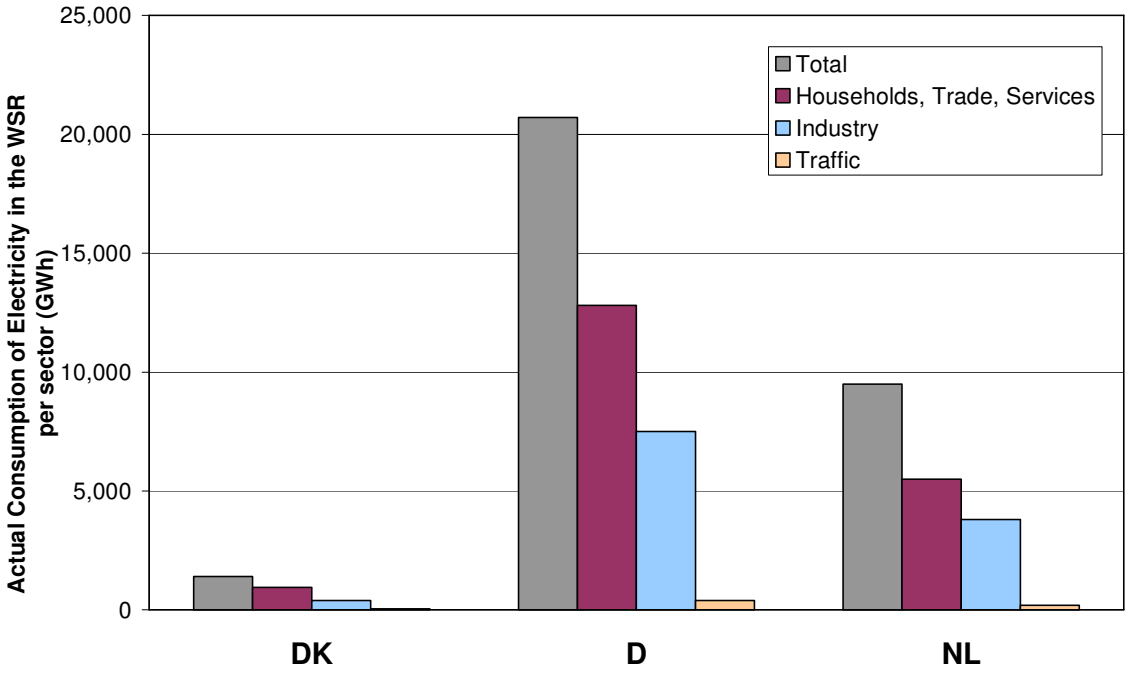
[1] in reference to [Eurostat 2009] and [CBS 2009a]

[2] Own calculations on the basis of the present yearly consumption of electricity in the Wadden Sea States and in reference to [CBS 2009b], [Ministerium für Wissenschaft, Wirtschaft und Verkehr des Landes Schleswig-Holstein 2009], [Pestel Institut 2008], [SABL 2009a], [STATDEN 2009a], [STATDEN 2009b], [Statistisches Landesamt Bremen 2009]

[3] Own calculations on the basis of the estimated present yearly consumption of electricity and in reference to [Prognos/EWI 2007]

The present yearly consumption of electricity was calculated on the basis of national and regional statistical data. While the three Wadden See States actually consume about 656,000 GWh of electricity per year, the present yearly consumption of electricity in the WSR is estimated to be about 32,000 GWh. A general view of the present consumption of electricity within the Wadden Sea Region per sector is given in the Figure 14 (for references see Table 27). In all parts of the Wadden Sea Region, the sector households, trade, and services has the biggest share on the electricity consumption.

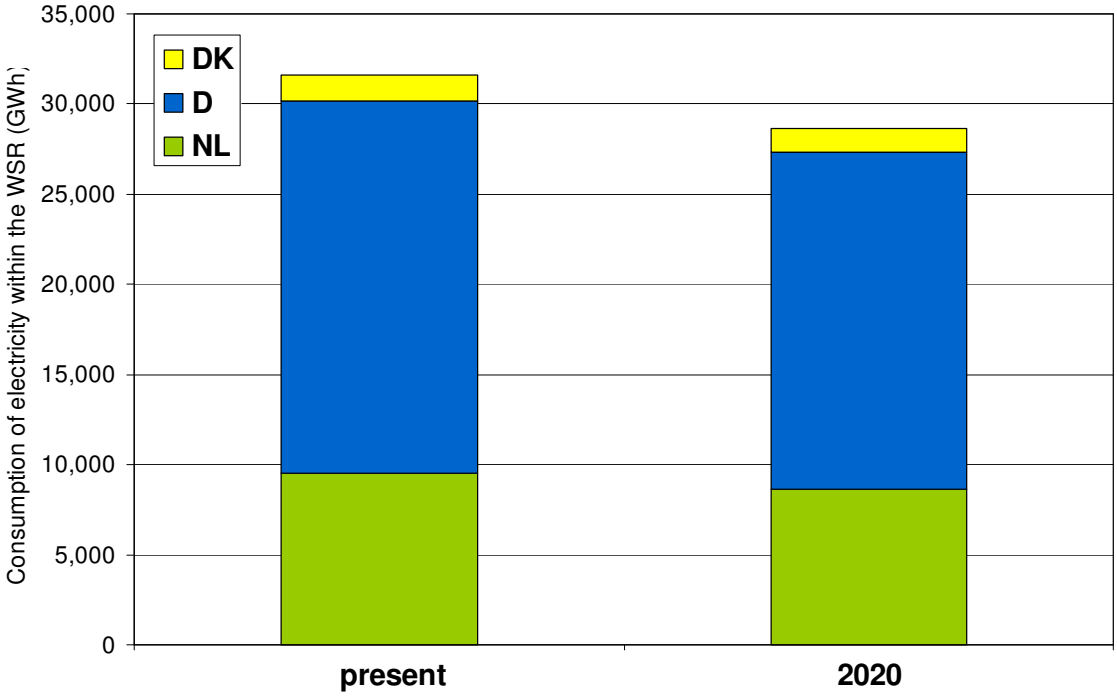
Figure 14: Estimated present consumption of electricity within the WSR per sector (GWh)



The prospective consumption of electricity in the WSR was estimated on the basis of long term trends as estimated by [prognos/EWI 2007]. [prognos/EWI 2007] published energy scenarios for Germany until 2020 and assumed decreasing energy consumption, as is aimed for by the national legislative bodies, particularly with regard to the households' sector. As a result, we estimate the yearly consumption of electricity in 2020 to be about 595,000 GWh in the three Wadden Sea States and about 29,000 GWh within the WSR.

The expected development of the yearly consumption of electricity within the WSR until 2020 is shown in Figure 15.

Figure 15: Estimated consumption of electricity within the WSR until 2020 (GWh)



3.4 The Wadden Sea Region: Exporting region of sustainable electricity?

To assess the Wadden Sea Region as an export region for electricity, we made an estimation of:

- the yearly production of electricity in the WSR at present and in 2020,
- the yearly consumption of electricity in the WSR at present and in 2020,
- the yearly consumption of electricity in the three Wadden Sea States, i.e. in Denmark, Germany and the Netherlands, at present and in 2020.

Finally, the electricity production within the Wadden Sea Region was compared with

1. the yearly consumption of electricity in the WSR and
2. the yearly consumption of electricity in the three Wadden Sea States.

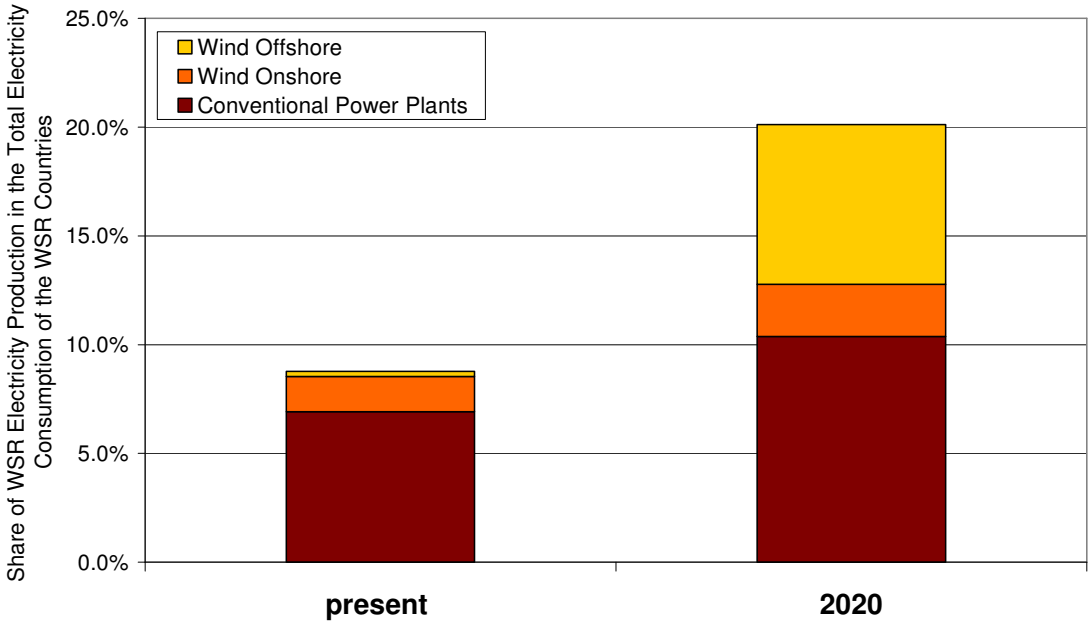
The results of the comparison are given in Table 28. At present, the electricity production in the WSR amounts to almost 57,600 GWh and exceeds the electricity consumption in the WSR by about 26,000 GWh. Until 2020, the WSR will strengthen its status as an export region for electricity. In 2020, the electricity production in the WSR will add up to almost 120,000 GWh whereas the electricity consumption in the WSR will decrease to 29,000 GWh.

Table 28: Electricity production within the WSR in comparison with electricity consumption within the WSR and within the three Wadden Sea States

	Electricity production in the WSR (GWh)	Electricity consumption in the WSR (GWh)	Electricity production in the WSR in % of electricity consumption in the WSR	Electricity consumption in the three Wadden Sea States (GWh)	Electricity production in the WSR in % of electricity consumption in the three Wadden Sea States
Present					
Conv. Power Plants	45,450		143.8%		6.9%
Wind Onshore	10,560		33.4%		1.6%
Wind Offshore	1,620		5.1%		0.2%
Total WSR	**57,630**	**31,600**	**182%**	**656,450**	**9%**
2020					
Conv. Power Plants	61,700		215.0%		10.4%
Wind Onshore	14,300		49.8%		2.4%
Wind Offshore	43,710		152.3%		7.3%
Total WSR	**119,710**	**28,700**	**417%**	**594,900**	**20%**

The results of the second comparison are shown in Figure 16. At present, the electricity production in the WSR is sufficient to cover 9 % of the electricity consumption in the three Wadden Sea States. Until 2020, the share of WSR electricity production in the total electricity consumption of the WSR countries is estimated to rise up to 20 %.

Figure 16: Share of WSR electricity production in the total electricity consumption of the WSR countries: Present and 2020

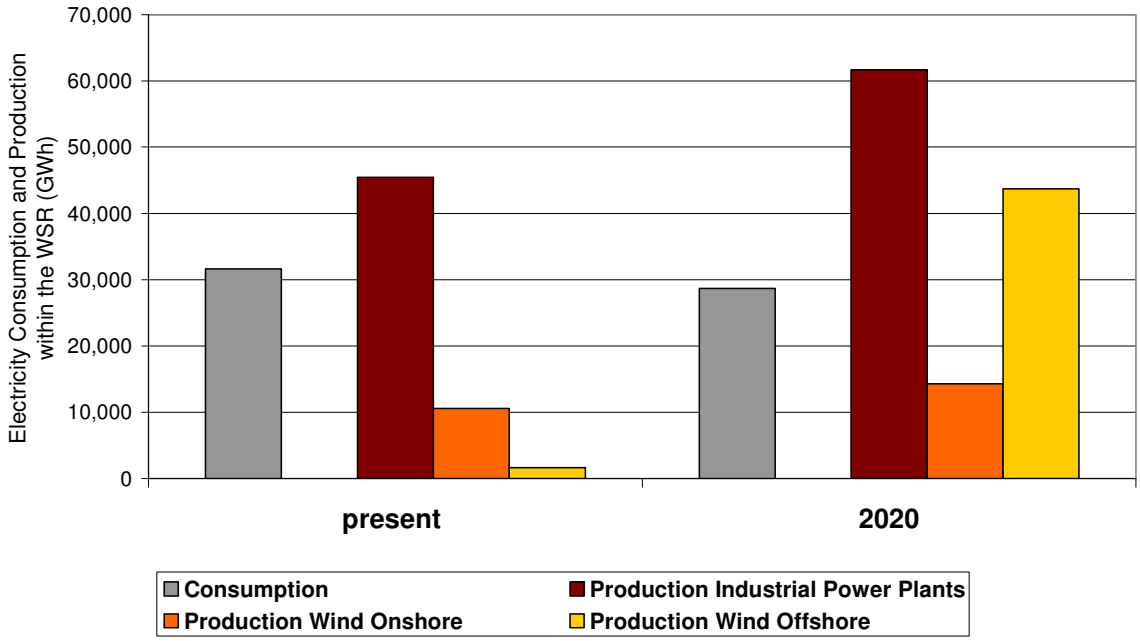


The other question was whether the Wadden Sea Region can be an export region of sustainable electricity. Therefore, we concentrated on electricity production from on- and offshore wind farms. As shown in Figure 17, whereas the electricity production generated by onshore wind farms is expected to rise slightly, the electricity production generated by offshore wind farms in the WSR will increase from about 1,600 GWh at present to almost 44,000 GWh in 2020. This is about 1,5 times the electricity consumption in the WSR in 2020 (29,000 GWh).

The results show that, until 2020, the electricity production generated by onshore and offshore wind farms in the WSR will be more than adequate to provide renewable electricity supply to the Wadden Sea Region and it will be sufficient to cover almost 10 % of the electricity consumption in the three Wadden Sea States in 2020. Referring exclusively to the amount of electricity, the WSR will be independent from fossil electricity production.

However, because of the fluctuations in wind production, and therefore in the electricity production with wind turbines, the electricity supply system needs a backup with fossil power plants or – maybe in the future – with great storage facilities for electricity.

Figure 17: Electricity production per type of power plant and electricity consumption within the WSR: Present and 2020 (GWh)



3.5 Electric power generation and CO_2 emissions until 2020

The annual CO_2 emissions of the WSR conventional power plants have been calculated in order to evaluate the WSR power production sustainability. The calculation of the expected power production, and the resulting CO_2 emissions, was based on the results of the feasibility analysis for the planned power plant capacities in the WSR until 2020 (see chapter 3.1)

Figure 18: Conventional power plants - Electric power generation until 2020

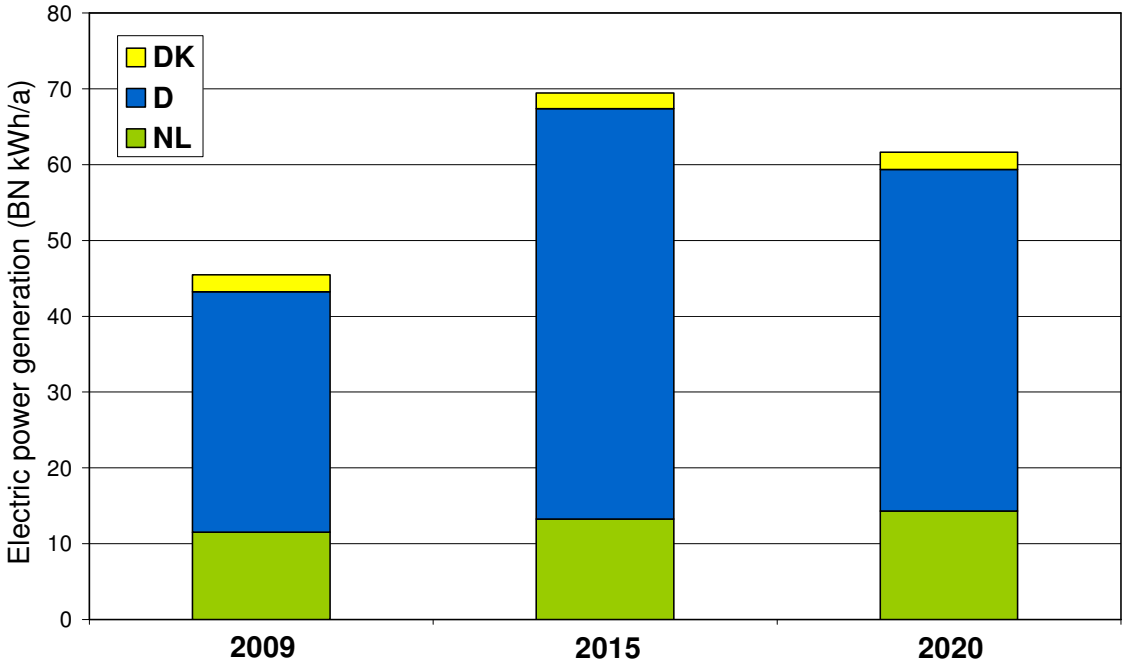


Figure 18 shows the actual (2009) and the expected power generation in the years 2015 and 2020. The three colours represent the three WSR states. The power generation of the German nuclear power plants was calculated as the total amount of the power left until the power plants' phase out [BfS 2008] divided by the odd times of the given power plants. For the other conventional power plants, the annual power production has been calculated as the number of the full load hours [Energiereport IV 2005] multiplied by the installed capacities, differentiated by primary energy used.

The power generation in the WSR is expected to increase by 53% until 2015 due to the significant growth of power plant capacities. For example, Germany by itself is expected to expand its capacity by 70% until 2015. After 2015, the annual power generation is expected to partially decline due to the phase out of old facilities, but it will nevertheless stay above the current production levels by 35%.

Figure 19: Conventional power plants - CO_2 emissions until 2020

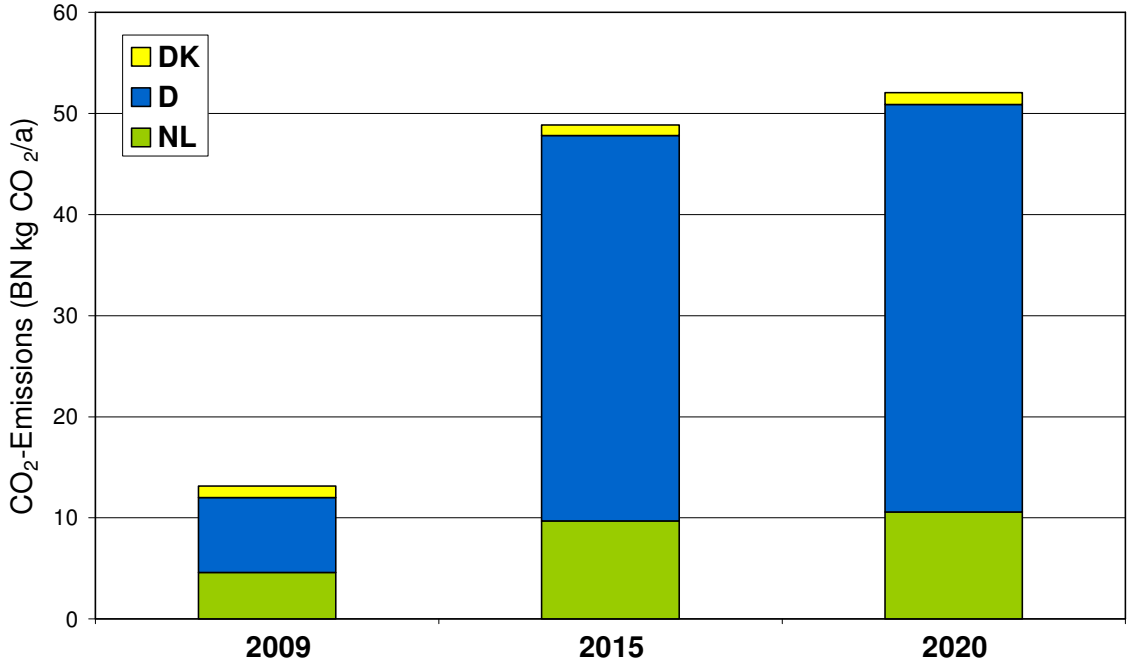


Figure 19 shows the annual CO_2 emissions of the conventional power plants in the WSR for the years 2009, 2015, and 2020. They were calculated on the basis of the annual electric power generation using a specific CO_2 coefficient depending on fossil fuels applied (see appendix, chapter “Specific CO_2 emissions of electric power plants”).

The CO_2 emissions within the WSR are found to triple from more than 13 billion (BN = 10^9) kg CO_2 /a in 2009 to nearly 49 BN kg CO_2 /a in 2015. This strong increase in the WSR CO_2 emissions until 2015 is associated, especially, with the following aspects:

- Increase in the fossil fuel power plant capacities in the WSR by more than 50 % (see chapter Inventory, Figure 4).
- Replacement of the low-carbon gas and nuclear power plants with mostly by coal power plants. The share of the coal power plants is expected to increase to 70 % in 2015 and to 85 % in 2020 (9,300 MW).
- High carbon intensity of the coal power plants in comparison to the other fossil fuel power plants. Per kWh generated, a coal power plant emits twice the amount of CO_2 as a comparable gas and steam power plant (see appendix, chapter “Specific CO_2 emissions of electric power plants”).

3.6 Summary on sustainable electricity supply in the Wadden Sea Region

The results of the previous chapter already showed that the WSR is an important location for electricity production in fossil and nuclear power plants. The results of this chapter prove that the Wadden Sea Region will strengthen this status and will become an export region not only for electricity production in fossil and nuclear power plants but also for renewable electricity production in the near future:

- **At present:** The electricity production in the WSR amounts to about 57,600 GWh. It exceeds the electricity consumption in the WSR (31,600 GWh) and covers about 9 % of the electricity consumption in the three Wadden Sea States (656,500 GWh).
- **Estimation 2020:** The electricity production in the WSR is expected to add up to about 120,000 GWh whereas the electricity consumption in the WSR is estimated to decrease to 29,000 GWh. The share of WSR electricity production in the total electricity consumption of the WSR countries (594,900 GWh) will probably rise up to 20 %.
- **Fossil Electricity Production:** There will be a number of new fossil power plants, especially coal fired, to be built in the German and in the Dutch WSR which will more than offset the electricity production of those power plants which will be shut down in the next ten years. On one hand, this will strengthen the position of the WSR as an export region for electricity. On the other hand, the CO_2 emissions within the WSR are expected to triple until 2015. As the overall CO_2 emissions in the European energy sector are restricted by the EU ETS (Emission Trading Scheme), this development will be connected to the closedown of old coal fired power plants in other parts of Germany or Europe.
- **Renewable Electricity Supply:** The electricity production generated by onshore and offshore wind farms in the WSR is estimated to increase from about 12,200 GWh to almost 60,000 GWh in 2020. It will then be adequate to provide renewable energy supply to the Wadden Sea Region and it will be sufficient to cover nearly 10 % of the electricity consumption in the three Wadden Sea States.

Referring exclusively to the amount of electricity, the WSR will become more and more independent from fossil electricity production in the following years. As already stated in chapter 2, we assume that, in 2020, almost as much electricity will be produced by onshore and offshore wind farms in the WSR (58,010 GWh) as by fossil power plants located in the WSR (61,700 GWh). Particularly the further deployment of offshore wind energy capacities will play an important role in the electricity supply of the WSR until 2020 and beyond, since there exist far reaching plans for its further development in the German and in the Dutch EEZ adjacent to the WSR:

- The Netherlands aims to have 20,000 MW offshore wind energy capacities installed in the entire Dutch EEZ. According to the slow-going scenario (see chapter 3.1), [We@sea 2009] come to the conclusion that the planned development could be realised until the year 2043.
- The German ministry of the environment anticipates 25,000 MW of offshore wind energy capacities to be installed in the German WSR until 2030 [IWR 2009].

Especially with respect to the German situation, an important barrier for the development of offshore wind energy has to be mentioned: the expansion of the high-voltage grid for the long distance transport of electricity from the coast to the regional centres of population and industry in the middle and in the south of Germany. This is an absolute inevitable precondition for the further expansion of the offshore electricity production. If the transport of the electricity is not assured, than the projected development with all its positive effects will be delayed or even stopped. Therefore, the transport system operators and the government have to work hard on this topic in order to overcome all the problems connected with the planning and building of new, or the expansion of existing, transport lines. The resistance of concerned people and communities should not be underestimated. Further details of this aspect are discussed in chapter 5.1.1 Infrastructure.

The expected expansion of power plants - especially of offshore wind farms - in the Wadden Sea Region from present until 2020 will likely ensure economic chances to the Wadden Sea Region in the forthcoming years. In the following chapters, we will have a further look at these economic chances starting with an observation of the employment effects in the WSR.

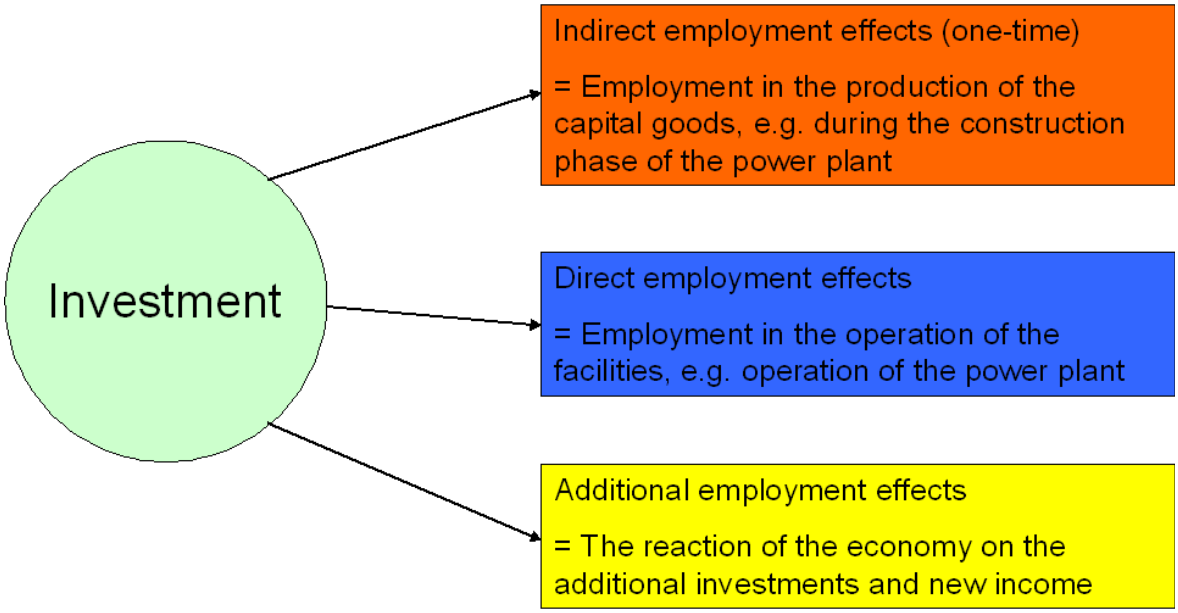
4 Employment effects

As mentioned in the previous chapter, the expected expansion of power plants - especially of offshore wind farms - in the Wadden Sea Region from present until 2020 will likely ensure economic chances to the Wadden Sea Region in the forthcoming years. The operation of existing power plants, and the construction of new ones, will preserve, for instance, existing jobs and provide new jobs in several industrial sectors such as strategical planning, plant construction, electrical engineering, and maintenance or service activities in the Wadden Sea Region. In this chapter, we will have a further look at the employment effects due to investments into conventional power plants and wind farms in the WSR.

4.1 Theory: The different types of employment effects

Investments into the energy sector, similar to the investments in other sectors, result in three different employment effects which are shown in Figure 20. Posing differing theoretical and practical demands, as dependant on the research goals, each of these effects might be studied[7].

Figure 20: Three employment effects of an investment



Employment effects from the investment emerge through:

[7] For more detailed description of the difficulties connected to the employment effects estimation see Pfaffenberger et. al., 1996, Hamburg. New practice oriented application which includes a detailed theoretical background can be found in Pfaffenberger et. al., 2003, Bremen: “Ermittlung der Arbeitsplätze und Beschäftigungswirkungen im Bereich Erneuerbarer Energien“

- (1) Production of the capital goods, i.e. production of the machines and other materials which are installed at the power plant location. Here, one talks about an indirect employment effect which is limited to the construction period.
- Direct employment effects (2), on the other hand, are present over the whole consumption period of the capital good, i.e. over the technically and economically defined useful life of e.g. a power plant or of a wind turbine. In their case, the new job positions are created directly in the operation of a facility as well as in the facility's supply and service industries. These industries are responsible for the production of the spare parts and other materials, alternatively for the supply of a qualified staff, necessary for the regular service and maintenance of the facility.
- The additional effects (3), presented in the Figure 20, can be described as the reaction of the national economy on the additional investment and income and are of minor importance.

Because of limited financial resources, this study had to concentrate on the evaluation of direct and indirect employment effects of the currently operating facilities and of the future investments into the power production facilities within the Wadden Sea Region (WSR). The employment effects are presented in the form of employment volume, i.e. full-time equivalent employment (FTE). One FTE equals to one person working full-time over the period of one year.[8]

4.2 Working assumptions used for the calculation of the direct and indirect employment effects

The following working assumptions have been met in order to allow for the estimation of the employment effects resulting from the investment into the conventional power plants and wind energy turbines in the Wadden Sea Region (for further information see appendix):

- There are three types of power plants recognised within the study, namely the conventional power plants, the onshore wind turbines, and the offshore wind turbines.
- In order to calculate the employment effects, one has to know the installed power plant capacities until 2020. As basis for this calculation, the feasible potential derived in chapter 3 was chosen (see chapter "Sustainable Electricity Supply in the WSR").
- The direct employment effects of the present and future power plants are presented for the years 2009 and 2020. The trends and developments over the studied period are described only within the text.
- The indirect employment effects were comprehended as averaged employment volume for the time period when the power plants should be constructed, but maximally until 2020.

[8] Generally, employment figures are expressed as full-time equivalent employment (FTE) [U.S. Census Bureau 2009]. Within this study, FTE is a computed statistic representing the number of full-time employees that could be employed due to investments into conventional power plants and wind farms in the WSR.

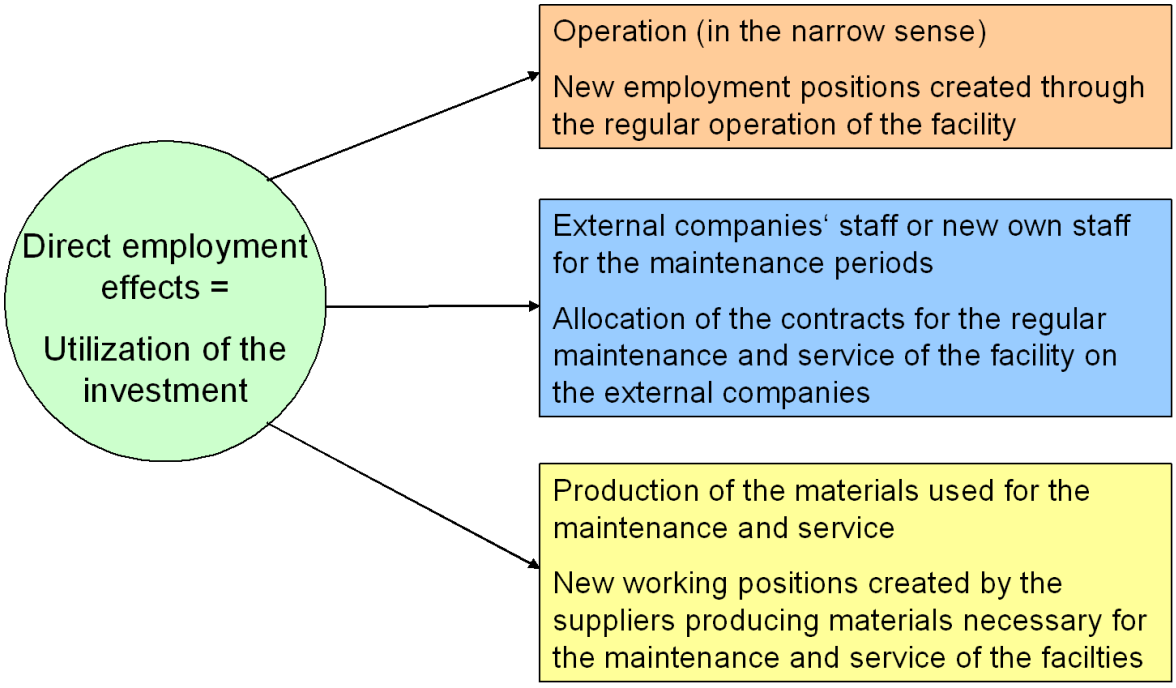
- The specific effects of an investment on the job positions within each power plant type are assumed to be the same for the three studied countries within the WSR (Denmark, Germany, the Netherlands).
- The spatial distribution of the indirect employment effects is not attempted within this study as the production of the investment goods, e.g. generators or wind turbines, might be often located outside of the WSR.

4.3 Direct employment effects

Direct employment effects are the job positions created through the operation of the capital good which was purchased by the investment. Thereby, one needs to differentiate between three types of direct employment effects (see Figure 21), namely between the:

- job positions necessary for the operation of a capital good,
- the qualified staff supplied by the external companies specializing on the service and maintenance of the capital good, and
- the job positions created in the production of the materials necessary for the service and maintenance of the facility.

Figure 21: Components of direct employment effects



Within this study, each of these effects has been calculated for the three types of the power plants identified above within the given time period. The effects on the economy of the WSR, as well as on the economies of the three WSR countries, were estimated. Table 29 below summarizes the results of the calculation. More detailed data on the calculations can be found in the appendix of the study (see chapter “Additional calculations of the direct employment effects”).

Table 29: Direct employment effects caused by the operation of onshore and offshore wind farms, and of conventional power plants in the WSR countries in 2009 and 2020

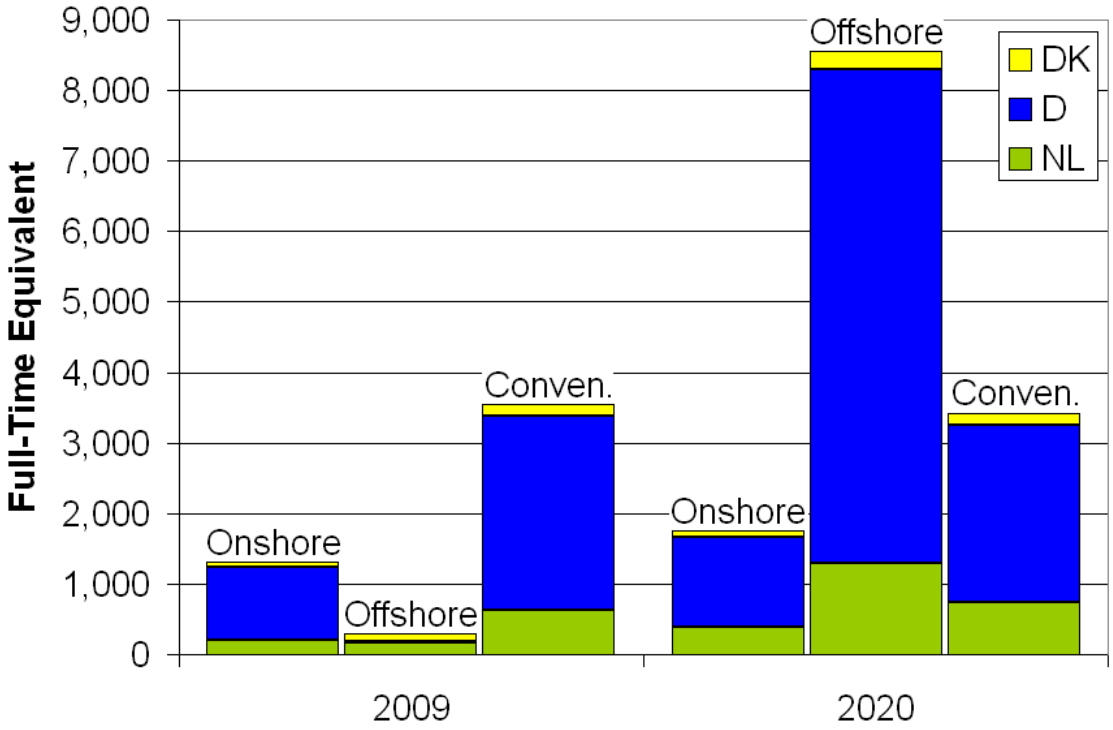
(FTE)		Countrywide Employment Effects		Regional Employment Effects	
		2009	2020	2009	2020
Denmark	Total	**360**	**540**	**240**	**370**
	Onshore	80	100	60	70
	Offshore	110	270	80	200
	Conv. Power Plants	170	170	100	100
Germany	Total	**3,800**	**10,770**	**2,475**	**7,440**
	Onshore	1,040	1,270	760	940
	Offshore	10	7,000	5	5,250
	Conv. Power Plants	2,750	2,500	1,710	1,250
Netherlands	Total	**1,010**	**2,440**	**580**	**1,610**
	Onshore	200	390	150	280
	Offshore	180	1,300	130	970
	Conv. Power Plants	630	750	300	360
Total	Total	**5,160**	**13,740**	**3,300**	**9,430**
	Onshore	1,320	1,760	970	1,290
	Offshore	290	8,560	220	6,420
	Conv. Power Plants	3,550	3,420	2,110	1,720

Source: Own calculations; for further information see appendix, chapter “Working assumptions and data underlying the calculation of direct employment effects”

As can be seen in Table 29, the employment volume resulting from the operation of the conventional power plants, onshore, and offshore wind parks within the WSR increases within the three Wadden Sea states from about 5,200 FTE in 2009 to about 13,700 FTE in 2020. At the same time, one might observe an increase in the regional employment effects within the WSR from slightly above 3,300 FTE in 2009 to about 9,400 FTE in 2020.

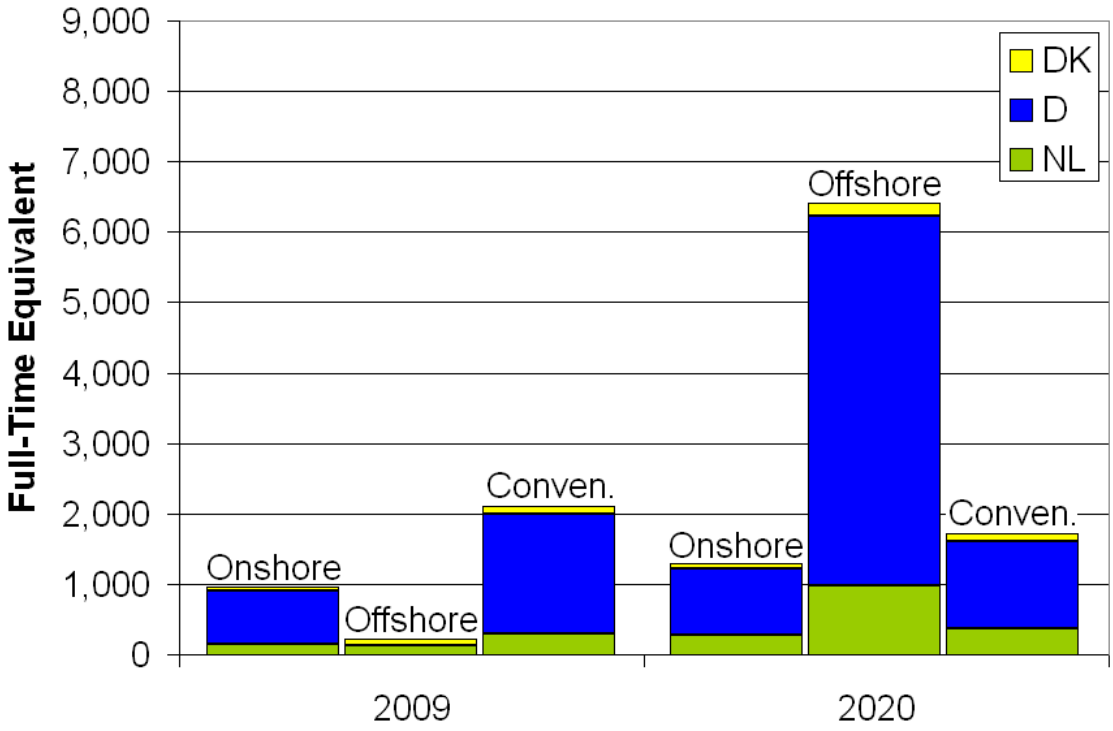
Based on these results, it can be stated that, at present, about two thirds of the employment volume, which sources from the operation of the WSR power plants, stays within the WSR. This trend is expected to remain unchanged also in the future (see Figure 22 and Figure 23 below).

Figure 22: Countrywide direct employment effects of the onshore and offshore wind parks, and of the conventional power plants in the WSR 2009 and 2020



With respect to the other observed trend of strong increase in the employment volume from 2009 until 2020, we find that it results mainly from the increasing number of the operating offshore wind turbines (see Figure 22 and Figure 23). If one puts the employment volume caused by the WSR power plants in 2009 in relation to about 266,000 job positions in the WSR manufacturing industry (see appendix, chapter “Labour Force in the Wadden Sea Region”), in 2009, the WSR power plants share equals to 1.25 %. Until 2020, this share is expected to rise up to almost 4 %.

Figure 23: Regional direct employment effects of the onshore and offshore wind parks, and of the conventional power plants in the WSR 2009 and 2020



4.4 Indirect employment effects

Having evaluated the direct employment effects of the operating power plant facilities in the WSR 2009 and 2020, we assessed the indirect employment effects caused by the construction of new conventional power plants (2009-2015) and by the development of onshore and offshore wind farms within the Wadden Sea Region until 2020.

Indirect employment effects from the construction of new conventional power plants in the WSR until 2020

Investments in the construction of new conventional power plants are expected to be present within the WSR from 2009 to 2015. Their total effect is predicted to be equal to about 122,700 FTE which, assuming equal distribution over the seven years, can be imagined as about 17,500 full-time job positions over the 7 years period. 77 % share of this employment effect stems from the power plant construction within Germany with the additional 23 % coming from the new constructions in the Netherlands.

It is not possible to estimate the share of the regional employment effects which is supposed to stay within the region. This stems from the fact that the tenders for the new conventional power plant constructions are announced internationally. Nevertheless, considering that most of the necessary works have to be done by the experts, the local employment effects are expected to be relatively low.

Indirect employment effects from the further development of onshore wind farms in the WSR until 2020

New constructions of onshore wind parks are expected to be present over the whole studied period, i.e. from 2009 to 2020. This equals to the employment effect of 28,000 FTE which, assuming equal distribution over the twelve years, represents 2,300 secure job positions. From these, around 90 positions are associated with the new constructions in Denmark, 1,250 with the new constructions in Germany, and the last 1,000 job positions with the constructions in the Netherlands.

Regional employment effects are rather difficult to estimate due to the international character of the market for wind turbines. Nevertheless, the local employment effects for the locations within the WSR are expected to be rather low. The locations of wind energy industry as e.g. Emden, Husum, or Bremerhaven are expected to benefit from the onshore wind constructions. However, at present, it is not possible to estimate the regional effect of these benefits.

Indirect employment effects from the development of offshore wind farms in the WSR until 2020

New constructions of offshore wind farms are also expected to be present over the whole period from 2009 to 2020. The capacities for the production and installation of the offshore wind plants have to increase significantly, from the current 100 MW per year to possibly up to 1,500 MW/a in 2015 (estimate) in order to satisfy the demand. Hence, the employment effect of these developments is estimated to be 425,000 FTE over the studied period. This equals to an increase from present about 2,000 job positions to about 50,000 job positions in 2015 and later.

Many of the offshore wind park (OWF) components have to be produced directly on the coast or on the waterways due to their high weight. This then implies big opportunities for the port towns in the WSR. At present, precise estimation is not possible but several 10,000s of working positions are expected. Considering the big offshore plans of the Wadden See states and the high employment effects through the operation, maintenance, and the necessity to dismantle, respectively to replace, the OWF in 20 to 30 years connected with these plans, the authors of this study estimate the newly created working positions to exist for several upcoming decades.

Indirect employment effects: Overall result

The overall results of the indirect employment effects evaluation from the construction of new conventional power plants (2009-2015) and the development of onshore and offshore wind farms within the Wadden Sea Region until 2020 are given in Table 30.

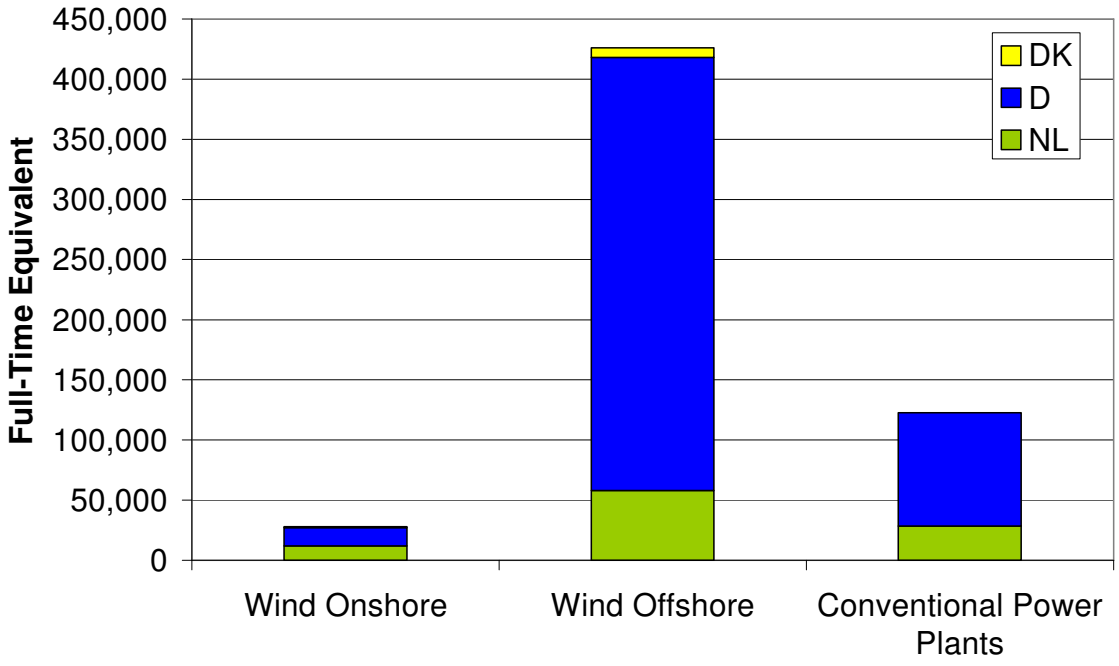
Table 30: Indirect employment effects due to the construction of new conventional power plants (2009-2015) and the development of onshore and offshore wind farms within the Wadden Sea Region until 2020

(FTE)	Wind Onshore	Wind Offshore	Conventional Power Plants
Denmark	1,000	8,000	-
Germany	15,000	360,000	94,360
Netherlands	12,000	58,000	28,380
Total	**28,000**	**426,000**	**122,740**

Source: Own calculations; for more information see appendix, chapter "Working Assumptions and data underlying the calculation of indirect employment effects"

One can see that employment effects sourcing from the new constructions of conventional power plants (2009-2015) and onshore wind farms are rather limited and within the WSR noticeable only to a very low degree. In contrast, the constructions of offshore wind farms are expected to account for several 10,000s of lasting working positions as shown in Figure 24.

Figure 24: Indirect employment effects due to the construction of new conventional power plants (2009-2015) and the development of onshore and offshore wind farms within the Wadden Sea Region until 2020



The long term character of these employment effects comes from the facts that:

- The Wadden Sea states have rather big offshore plans.
- The operation and the maintenance of the OWF mean rather high employment effects.
- There is a necessity to dismantle or to replace the OWF in 20 to 30 years at latest.

This implies big opportunities for the WSR port towns which have been already taken by a few towns as e.g. Eemshaven, Esbjerg, Emden, Bremerhaven, Cuxhaven or Wilhelmshaven. For example, if one would assume that 50 % of the new working positions created by the OWF construction industry could become located in the WSR, the regional employment effect would equal to 25,000 working positions. These would then account for a significant share from the currently present around 370,000 working positions in the sectors of manufacturing and construction industries.

4.5 Summary on employment effects

In this chapter, the employment effects of the present and future (2020) power plants in the Wadden Sea region were studied. The study focused on the direct and indirect employment effects of three types of power plants, namely the conventional power plants, the onshore wind parks, and the offshore wind parks. Referring to the future conventional power plants and offshore power plants, the plans announced were evaluated on their feasibility prior to the employment effects calculations (see chapter 3.1).

With respect to these results, the employment volume sourcing from the operation of the conventional power plants, onshore, and offshore wind parks within the WSR is estimated to increase within the three Wadden Sea states from about 5,200 FTE in 2009 to about 13,700 FTE in 2020. As a result, the direct employment effects of the present WSR power plants were found to account for about 1.25 % of the total WSR manufacturing industry. Until 2020, this share is expected to rise up to almost 4 %. In other words, strong increase in the employment volume is expected mostly due to the increasing number of the operating offshore wind turbines. From these newly created working positions, around two thirds are expected to stay within the WSR.

With respect to the indirect employment effects of the WSR power plants, the employment effects stemming from the new constructions of the conventional power plants and onshore wind farms are rather limited and expected to be very low within the WSR. In contrast, the new constructions of the offshore wind parks are expected to create several 10,000s of new and lasting working positions for the next few decades. This implies new big opportunities particularly for the WSR port towns.

As stated in chapter 3.6, it has to be underlined that these positive employment effects of the expansion of offshore wind energy in Germany strongly depend on the assumption that the necessary expansion of the high-voltage grid will be realised in time (see chapter 5.1.1 Infrastructure).

5 Potential impacts and further economic consequences due to the development of power plants in the Wadden Sea Region

Beneath the outcomes in form of employment effects from the operation of existing power plants and from the construction of new ones, there are further economic and environmental chances and risks for the Wadden Sea Region to be expected. In this chapter, we will have a short look at these additional economic effects - especially on energy relevant sectors such as infrastructure, harbours, shipping, fisheries and tourism - as well as at environmental effects and conflict potentials stemming from the construction and operation of conventional power plants and wind farms within the Wadden Sea Region.

5.1 Additional economic effects on energy relevant sectors

Economic effects on the WSR emerge throughout the whole value added chain of the conventional power plants and wind parks:

- Planning and construction of the conventional or of the wind power plants,
- Operation and maintenance of the power plants,
- Decommissioning and removal of the power plants.

In addition to the employment effects sourcing from the supplies necessary for the construction and operation of the power plants, there are additional financial effects emerging from the activities of the operators and suppliers. These take the form of:

- Business taxes,
- Rents and returns on capital.

Apart from the settlement of the operating companies and of the suppliers within the WSR, increasing worldwide export of the wind energy technologies and facilities from the WSR is also expected to lead to further positive effects on the WSR economy. Already at present, exports account for a significant portion of incomes within the wind energy industry and hence play an important role in the economies of the respective countries. For example, exports of the German wind industry worth 6.0 billions EUR accounted for roughly half of the industry's total income in 2007 [BWE 2008]. In Denmark, the wind industry exports with 5.7 billion EUR accounted for the 7.2 % of the total countries exports [DWIA 2009].

Nevertheless, the various economic effects mentioned in the study have unevenly distributed impact on the various industry sectors. Below, brief overview of the industries, which were found to have a strong relation to the development of the regional power sector, will be offered. These are infrastructure, harbours, shipping, and tourism. More detailed analysis of the economic effects taking place within these sectors is beyond the scope of this study and hence is not covered here.

5.1.1 Infrastructure

The increasing importance of the offshore wind energy is expected to result in growing transport of supplies necessary for it. The transport of the extremely big and heavy con-

struction parts of the multi-mega-watt turbines is inland possible only to a limited degree. The new dimensions of turbine housing, foundations, tower segments, and rotor blades make the transport of these parts to the coastal embark points, using the regular infrastructure, barely manageable. Therefore, independent of the high capacity inland infrastructure, the distribution of the wind turbine production locations is expected to change. These are expected to move from inland to coastal locations which will allow for the access of the sea ships. Inland water routes and inland harbours are also expected to increase in importance as a transport option for the big turbine parts. Therefore, an expansion of the existing harbour infrastructures (see following chapters) and ensuring a sufficient supply of special transport infrastructure, as e.g. trucks, cranes, ships, helicopters, storage capacities, and embark points, appears to be necessary [Dena 2006b].

Keeping in mind the economic effects emerging from the offshore wind industry, the settlement of the parks operating companies and their suppliers in the WSR appears to have special infrastructural importance. The magnitude of these effects is found to depend on the opportunities for the newly settled companies to export their products worldwide. These opportunities, in turn, seem to depend on the number of the company settlements present in the region. Here, it has to be mentioned that many of the known companies in the field of offshore wind, such as Enercon, Vestas, Siemens, Repower, or Multibrid, have already some of their facilities located in the WSR (see the web-sites of the respective companies).

Apart from the above mentioned, the degree and the speed with which the economic effects of the onshore and offshore wind parks are generated is found to depend on the grid infrastructure development, both inland and on the sea, as well. Grid access and sufficient capacity for the feed in and the transmission of generated power, especially in the case of offshore wind farms, has to be granted. Additional cable routes, which transport power from the new offshore wind farms in the coastal regions to the centres of population and industry, might become necessary and, hence, they deserve a particular attention. Within this field, there are still many administrative barriers present which make the new project construction times disproportionally long. As a result, market uncertainty is created. The future growth of the wind energy sector, and the consequent creation of many new job positions, is expected to depend strongly on the governmental efforts to remove grid access barriers that currently hinder the wind energy projects. In this respect, questions concerning compatibility of additional cable routes on sea with the existing European grid infrastructure and questions regarding the secure integration of renewable electricity generated by offshore wind farms into the electricity system have to be solved. First attempts towards solving the administrative problems might be already indentified in the new “cable construction regulation” introduced at the beginning of May 2009 [Niedersächsische Staatskanzlei 2009]. However, the degree to which this regulation will prove to be successful, and hence the degree to which it will allow for the realisation of economic effects, could be assessed only over the time.

Nevertheless, the WSR infrastructure will be influenced not only by development of offshore wind farms but also by construction of new conventional power plants. In 2009, nuclear and gas-powered plants actually represent one of the major capacities in the WSR together accounting for more than 7,500 MW whereas the contribution of the coal-powered plants does not achieve even 1,500 MW. However, this is expected to change completely in the following years. Already in 2012, coal will become the most used fossil fuel in the Wadden Sea Region. Until 2020, the capacity of coal-powered plants increases up to 85 % (9,300 MW). With regard to the conventional power plant construction, the development of the WSR infrastructure in the upcoming years, and the development of the accompanying economic effects, is expected to be primarily defined by the increasing re-

source supplies necessary for the coal fired plants. But what does the transport of coal for the planned power plants mean to the infrastructure sector? Let's take the plans of Dong for a coal fired power plant at Emden, as they are reported in [Ostfriesenzeitung 2009]. This Power plant with 1,600 MW would burn about 3.6 mil. t of hard coal per year if it runs about 7,500 hours of full load. Ocean-going vessels can transport 120,000 t of coal. That means 30 ships full of coal have to unload their cargo per year or about one ship every 12 days. For a harbour like Emden this is not a really remarkable number. If we convey these numbers to the overall newly planned capacity of about 10,000 MW coal fired power plants in the WSR, the coal transport will sum up to about 200 ships with 120,000 t coal per year or about four ships per week. This would not mean a perceptible growth of shipping traffic in the Wadden Sea.

5.1.2 Harbours

As mentioned before, offshore wind energy is an important business field within the portfolio of the WSR harbours. Many of the offshore wind farm components have to be produced directly on the coast or on the waterways due to their high weight. Therefore, harbours represent an important link between transport and working processes on land and on sea within the value added chain of offshore wind. They are expected to become future centres of production, assembling, logistics, and distribution of turbine components, replacement parts, and services necessary for the offshore wind [Dena 2006b].

Considering the big offshore plans of the Wadden See states and the high employment effects through the operation, maintenance, and the necessity to dismantle, respectively to replace, the OWF in 20 to 30 years, this development then implies big opportunities for the port towns in the WSR. In reference to [Dena 2006a], one can expect a significant expansion of the offshore harbour infrastructure in the following years, such as:

- Opening up of industrial areas,
- Offers of new industrial areas for production locations within the harbours, resp. near the harbours,
- Attraction and settlement of turbine producers and their suppliers,
- Expansion of the infrastructure necessary for the maintenance and servicing staff.

Beyond that, the new constructions of the planned offshore wind farms are expected to create several 10,000s of new and lasting working positions for the next few decades (see chapter employment effects).

In the following, one can find an example of the economic effects on the offshore harbour Cuxhaven in reference to [verkehrsrundschau 2009] and [blogspan 2009]:

- Opened in March 2009, within its ca. 50 ha area, the harbour infrastructure includes three new mooring facilities, road and railroad track facilities.
- From 2006, almost 200 mil. EUR has been invested into the offshore base Cuxhaven infrastructure by private and public hands. Further investments are announced.
- Settlement of industry specific infrastructure and production locations:

  - AMBAU GmbH produces offshore towers for various producers of serial production wind turbines.
  - Cuxhaven Steel Construction GmbH (CSC) produces fundaments for offshore wind turbines of BARD Engineering GmbH.
- Creation of new working positions:
  - CSC and AMBAU employ together more than 300 employees. Until the end of 2011, both of the companies are planning to create ca. 1,000 new job positions in Cuxhaven.
  - The construction company Züblin plans to begin its production of offshore concrete fundaments in Cuxhaven from 2011. It is expected to create 500 new working positions.

The expected opportunities for the port towns in the WSR already lead to an increasing competition among the domestic and the foreign harbours within and outside of the WSR for the „funds“, each being a location used for development, assembling, and shipping of the offshore wind components. As the harbour competition presumably will be decided on the basis of capacities, technical competence, and past experience, one can expect specialization of harbours on the different steps of the value added chain, e.g. shipping of components or servicing contracts, in order to gain a competitive advantage within the offshore market, as well [Dena 2006a].

As a further economic effect, the development of offshore harbours on sea have to be mentioned. Future locations of offshore wind parks are expected to be increasingly present at great distance from the coast due to the limited potential for the new constructions within the coastal areas. Considering the extend of the future transport, assembling, and maintenance activities necessary for the wind parks, the demand for a “support base on the open see” might emerge in case of big and distant from the coast offshore areas. Furthermore, using the, in the future developed, offshore working harbours could lead to cost reductions in construction and operation of offshore wind farms [We@sea 2009].

5.1.3 Shipping

The sector of sea transport will be significantly influenced by the new constructions of offshore wind farms as a strong competition for space is expected to emerge between the two sectors. This stems from the fact that the new wind farm constructions imply decline in the shipping routes and their subsequent relocation [Giertz 2008].

Apart from that, the new offshore wind park constructions also contain a great interference potential with the safety on sea. On the one hand, this stems from the increased number of crossings between the construction transport and the shipping routes during the park construction periods. On the other hand, once the wind park is constructed, there is still an increased risk of ship-turbine or ship-ship collisions due to higher traffic concentration on the remaining routes.

In order to reduce these risks, various measures have been suggested as, e.g. with reference to [Kremser]:

- Risk analysis included in the approval procedure of the offshore wind park,
- Improved security measures on the ships (e.g. double hull),

- More intensive monitoring of the given sea region (radar, Automatic Identification Systems (AIS), Intervention),
- With respect to the wind farms, introduction of e.g. wind farm entries into nautical maps, use of buoying and other signalization, use of damage minimizing fundaments.

Additionally, emergency plans are also worked on. This includes, with reference to [Krieg 2008], e.g.:

- Definition of emergency measures,
- Permanent availability of emergency capacities and emergency management in the form of hauling, emergency apparatus, qualified personnel, etc.,
- Creation of safety and security concepts by the wind farm operators.

As safety in shipping and ship's safety play an outstanding role for the Wadden Sea Region, Denmark, Germany, and the Netherlands “have implemented special IMO- and EC-legislation and have established several trilateral and national measures to enhance shipping safety and the protection of the marine environment. However, during the investigation for this study it was realised that measures and instruments could be improved to a certain extent on a national as well as on a trilateral level and that even the implementation of IMO- and EC-legislation fails in particular respects. [GAUSS mbH 2004]”

Independent of competition for space and potential wind farm interferences with safety on sea, construction and operation of ships specialised on the construction and operation of offshore wind farms might appear to be economically beneficial for the WSR. These ships are necessary for transport of wind farm construction parts to the desired location, their installation on sea, as well as for servicing of the park. In addition, these specialised ships are also used for installation of sea cables. As already mentioned in the chapter “Employment Effects”, it is not possible to estimate the share of the regional employment effects and further economic effects which is supposed to stay within the region. This stems from the fact that, similar to the conventional power plant constructions, the tenders for the new constructions of these ships are announced internationally. Nevertheless, the growing demand for specialised ships could be an economic chance for several shipyards in the WSR.

In order to learn about the impact of coal transport, which is connected with the planned conventional power plant constructions, on the sea transport sector, please refer to chapter 5.1.1 Infrastructure.

5.1.4 Fisheries

The sector of fisheries is also primarily defined by “land use” competition between offshore wind farms and fishing vessels. Within this sector, the new constructions of wind farms imply, with reference to [Weser Kurier 2009a], for instance:

- Permanent loss of significant fishing areas,
- Ban of fishing procedures using active catching methods in the given sea regions,
- Significant catch losses during the construction phase of the offshore wind parks.

This competition has already given rise to the first lawsuits between fisheries and offshore wind park investors. Fishermen feared the catch losses of up to 50 % due to the exclusion zones of the wind farm constructions nearby the islands Wangerooge (Nordergründe) and Borkum (Riffgat). Therefore, they started a lawsuit against the trade supervisory centre in Oldenburg which had approved the wind parks. The agency and the wind farm operators considered the fishermen's complaints as illegitimate. They argued that the future output and gain is uncertain [Radio Bremen 2009]. The court ruling took place at the beginning of June 2009 with the result that the administrative court in Oldenburg dismissed the lawsuite against the named offshore wind farms [Weser Kurier 2009b]. Nevertheless, the possibly negative effect of similar conflicts on operating and planned WSR offshore wind farm approval procedures remains to be seen.

However, and looking away from the conflict potential of land use competition, the new constructions of offshore wind farms might have also positive environmental impacts as well as positive economic impacts, as e.g.:

- The decline in the fishing activities will ensure „grow up" and „fallback" areas for fish. This should lower the degree of overfishing present in the North Sea [Kafemann/Ehrich 2007].
- The use of wind park areas as areas for aquacultures (mussels, oysters, and macro-algea) appears to be possible and especially relevant for the WSR [Forschungsverbund Zukunft Küste].

5.1.5 Tourism

At present, tourism represents one of the most important economic sectors within the overall, rather structurally weak, Wadden Sea Region. Within the WSR coastal areas and on the WSR islands, it is expected to represent a major source of income. Broadly speaking, tourism is overall found to react to the environmental interferences to a much higher degree than the other economic sectors. Apart from the potential conflicts stemming from construction of new conventional power plants, conflicts might emerge with respect to the landscape changes connected to the development of wind energy farms on land and at sea. Fear of wind turbines being visible over long distances, which implies negative effects on tourism and hence on regional economy, are often pronounced [BMU 2006].

This source of conflict has already given rise to lawsuits between communities and wind farm investors. Nevertheless, the administrative court in Oldenburg has dropped the charges of the island community of Wangerooge and of the city Borkum against the 12 nautical miles zone planned wind farms "Borkum Riffgat" and "Nordergründe" at the beginning of December 2008. The communities charged the farm operators for harming their rights through the construction and operation of the farms. They argued that the new wind farm constructions will disguise the island's clear view of the sea. Negative effects on the landscape view, and consequently on the tourism, were suggested [WAB 2008b].

With respect to onshore wind parks, particular attention should be paid to a lack of acceptance, especially, for repowering projects sourcing from the supposed environmental impacts as e.g. contamination of the natural scenery, optical and acoustic emissions, or implications on the avifauna. Therefore, the prerequisite for the realisation of repowering potentials in the WSR is the abolition of existing administrative restrictions concerning e.g. limit on turbine height or on minimum distances between the turbines.

At the same time, the success of the WSR in attracting tourists within the international competition will primarily depend on the development and application of strategies which will make a consequent use of the WSR landscape resources for marketing purposes. From this point of view, and keeping in mind the risk of charges by lawsuits against the power plant projects, the development of innovative concepts using onshore and offshore wind farms also for purposes of tourism, and hence increasing the regional economic potential, might be expected. Onshore turbines are used for tourist purposes in the form of “tower hiking” already at present. Tours to offshore wind park constructions, as a form of “offshore-sightseeing” are also imaginable. Additionally, sea harbours which were already mentioned in chapter 5.1.2 Harbours, could be also used as holiday and sailor harbours.

5.2 Environmental effects

In addition to the economic effects, the impact of conventional power plants and of wind power plant construction and operation on the ambient environment needs also to be evaluated. Apart from the people, the environmental effects are especially relevant for the birds, fish, marine mammals (e.g. porpoises), and benthos (crabs, starfish, etc.).

In the following, one can find negative environmental effects stemming from the conventional power plants:

- Production of the CO_2 emissions and of other pollutants (NO_x, SO_2) stemming from the facility operation,
- New infrastructure constructions as well as increased traffic volume connected to the construction and operation of the facility,
- Extraction and transport of the raw materials necessary for the operation of the facility.

Examples of negative environmental effects stemming from the onshore and offshore wind power plants are given below:

- Noise pollution (airborne, aquatic, and terrestrial),
- Interference with the current flows, sediment dynamics, temperature profile, and sediment profiles,
- Creation of electric and magnetic fields,
- Sealed sediment surfaces,
- Overlap between offshore wind areas and suggested protected marine areas,
- Collision hazard (offshore: ship collisions, onshore: moving parts).

Otherwise, one can also find examples of positive environmental effects:

- Avoided CO_2 emissions through the power production from renewable energies,
- Protection and stabilization of the overfished fish stocks due to fishing bans,
- Introduction of new solid bodies in the form of wind turbine foundations. These bodies are used as settlement basis by various algae, mussels, and barnacles.

Several studies focusing on the environmental impacts of the conventional and wind power plants have been conducted thus far. Nevertheless, the present situation is still characterized by the significant uncertainty with respect to the long term environmental effects (positive or negative) of these facilities [Aktionskonferenz Nordsee e.V.]. One of the most contested areas appears to be the size of the irreparable damages caused by the construction of the offshore wind parks. At present, significant data collection efforts are included within the approval process of these facilities in order to avoid the negative environmental impacts. Additionally, extensive ecological monitoring of flora and fauna is planned throughout the construction and operation phases of the parks. With respect to the political circles, a unifying national plan on environmentally acceptable connection cable distribution is aimed for.

Nevertheless, and considering the significant uncertainty with respect to the extent and irreversibility of the environmental impacts of the WSR power plants, there is a significant conflict potential identified, especially with respect to the environmental organizations, regarding the construction and operation of the power plants within the WSR.

5.3 Possible sources of conflict

As already mentioned in the previous chapters, the planned construction of new power plants will strengthen the position of the WSR as an important region for electricity production. Particularly the development of offshore wind energy capacities will play an import role in the prospective electricity supply of the WSR. However, the construction and operation of conventional power plants and of wind farms within the WSR might also give rise to numerous conflicts; for example:

- With political circles and administrations at the local, the regional, and the national level.
- Due to the negative environmental impacts during the construction and operation phase of the power plants, the conflict might arise with environmental associations.
- Due to the competition of the offshore wind parks with the shipping and fishery industries for the land use, the conflict might arise with shipping and fishery associations.
- Due to the change in countryside view through the wind parks, or due to the emissions of the coal power plants, the conflict might arise with tourist associations, the hotel and restaurant industry, administrative districts, and communities.
- Due to the constructions of the new conventional power plants, the conflict might arise with residents and environmental associations.
- With other interests present in the industry, agriculture, coast protection, army, etc.

Considering these possible sources of conflict, several interferences might emerge with respect to the construction and operation of conventional power plants and wind farms in the WSR, such as:

- Delays in the approval procedure of the new power plant projects,
- Restrictions on the construction projects of the planned power plants,
- Delays in the grid construction and in the grid connection of the new power plants,
- Profitability losses caused by e.g. height or areal limits on the repowering of onshore wind power plants
- …

Therefore, future growth of the electricity sector in the WSR, and the consequent creation of numerous new job positions, will strongly depend on the ability of the WSR to avoid, resp. solve, these conflicts. As already analysed by [COWI 2004], sustainable development strategies, based on a genuine stakeholder approach, are needed in order to balance and integrate economic, social, and environmental concerns of the three Wadden Sea countries, i.e. of Denmark, Germany, and the Netherlands.

6 Summary on the overall result of the study

The Wadden Sea Forum (WSF) commissioned an inventory and analysis of all existing power plants and developments to the Bremer Energie Institut. The overall objectives of the study were:

I. Creation of an inventory, and subsequent analysis, of all existing power plants and of those plants which are substantiated in an official planning process in the Wadden Sea Region.

II. An assessment of the proportion of installed renewable energy within the Wadden Sea Region in the view of the development of a sustainable electricity supply.

III. Evaluation and assessment of the potential impacts and economic consequences of the energy plants and related facilities.

According to the terms of reference, the focus of the study was on conventional power plants and onshore wind farms in the WSR as well as on offshore wind farms in the Wadden Sea Region and the southern North Sea EEZs of Denmark, Germany and the Netherlands.

Inventory and analysis of existing and planned power plants in the WSR

The WSR is an important location for electricity production. Due to the planned construction of new conventional power plants and the development of onshore and offshore wind farms in the following years, it will strengthen this status until 2020.

Actually, 16 conventional power plants with a total capacity of about 9,500 MW are located in the Wadden Sea Region, most of them in Germany (13). Many of these plants will reach the end of their operation within the next years. The energy industry has quite a number of plans for new fossil powered plant constructions, especially for coal fired ones, in the German and in the Dutch WSR. These will more than offset the electricity production of those power plants which will be shut down in the next ten years. In 2020, total capacity of about 11,000 MW in the form of conventional power plants is expected.

Offshore wind energy does not actually play an import role in the electricity supply of the WSR. Building the five planned OWF (one approved OWF / four announced OWF) will enlarge the production capacity of the OWF in the WSR (narrow definition: within the 12 nautical miles zone) from about 190 MW to about 950 MW[9]. Nevertheless the production capacity of all the OWF in the WSR will be small compared to the existing and approved capacities of about 6,600 MW[10] outside the WSR, in the EEZs adjacent to the WSR of the three countries.

The majority of all planned offshore wind projects with about 35,200 MW[11], or 84 % of the total planned capacity of about 41,700 MW[12], are still not approved. Similar to the an-

[9] 943.5 MW offshore wind farm capacities in the WSR = 188.5 MW offshore wind farms in operation + 90 MW approved offshore wind farms + 665 MW announced offshore wind farms

[10] 6,613 MW offshore wind farm capacities in the EEZs adjacent to the WSR = 228 MW offshore wind farms in operation + 6,385 MW approved offshore wind farms

[11] 35,217 MW announced offshore wind farm capacities = 665 MW announced offshore wind farms in the WSR + 34,552 MW announced offshore wind farms in the EEZs adjacent to the WSR

nounced constructions of new conventional power plants in the WSR, it is evident that not all of the announced offshore wind farm projects will be realised e.g. due to the lacking experience in the setting up of big OWFs, competition for the same building areas, and the further development of wind turbines. Therefore, the calculated amendatory assessment for the feasible capacities of offshore wind parks in the WSR until 2020 came to the result that the capacity of about 12,230 MW could be realised until 2020, whereof 10,000 MW shall be installed in the German WSR (wide definition: including the EEZ).

The potential for onshore wind energy production in the Wadden Sea Region is already used to a large extent. Actually, more than 4,800 wind energy turbines with a total capacity of about 4,600 MW are located in the Wadden Sea Region. Although there remains still some potential for the further extension of onshore wind energy production in the WSR, the estimated production capacities of onshore wind farms in 2020 and beyond will be small compared to the expected development of offshore wind energy capacities mentioned above. Corresponding to our estimation, the onshore wind energy capacities in the Wadden Sea Region will enlarge from about 4,600 MW to about 6,150 MW in 2020.

The Wadden Sea Region as an exporting region of sustainable electricity

To assess the Wadden Sea Region as an export region of electricity, the electricity production within the Wadden Sea Region was compared with the yearly consumption of electricity in the WSR and the yearly consumption of electricity in the three Wadden Sea States (Denmark, Germany and the Netherlands) for present and for 2020. The results show, that the WSR is already an export region of electricity sourcing from fossil and nuclear power plants. At present, the electricity production in the WSR amounts to about 57,600 GWh. It exceeds the electricity consumption in the WSR (31,600 GWh) and covers about 9 % of the electricity consumption in the three Wadden Sea States (656,500 GWh). Until 2020, the electricity production in the WSR is expected to grow to almost 120,000 GWh whereas the electricity consumption in the WSR is estimated to decrease to 29,000 GWh. The share of WSR electricity production in the total electricity consumption of the WSR contries (594,900 GWh) will probably rise up to 20 %.

Although the present electricity production in the WSR is still dominated by conventional power plants (80 %), the WSR will become an export region not only for fossil and nuclear but also for renewable electricity until 2020. The renewable electricity production generated by onshore and offshore wind farms in the WSR is estimated to increase from about 12,200 GWh at present to about 58,000 GWh in 2020. Until 2020, the share of electricity generated by onshore and offshore wind farms in the WSR will increase from about 20 % at present to almost 50 % in 2020. It will then be adequate to provide renewable energy supply to the Wadden Sea Region and it will be sufficient to cover nearly 10 % of the electricity consumption in the three Wadden Sea States. Referring exclusively to the amount of electricity, the WSR will become independent from fossil electricity production in the following years. However, because of the fluctuation of wind production, and therefore of the electricity production with wind turbines, the electricity supply system needs a backup with fossil power plants or – maybe in the future – with great storage facilities for electricity.

Especially with respect to the German situation, an important barrier for the development of offshore wind energy has to be mentioned: the expansion of the high-voltage grid for

[12] 41,692 MW total planned offshore wind farm capacities = 35,217 MW announced offshore wind farms + 6,475 MW approved offshore wind farms (= 90 MW in the WSR + 6,385 MW in the WSR adjacent to the WSR)

the long distance transport of electricity from the coast to the regional centres of population and industry in the middle and in the south of Germany. Solving this problem is an absolutely inevitable precondition for the further expansion of the offshore electricity production. If the transport of the electricity is not assured, than the projected development with all its positive effects will be delayed or even stopped. Therefore, the transport system operators and the government have to work hard on this topic in order to overcome all the problems connected with the planning and building of new or the expansion of existing transport lines.

Economic consequences of the energy plants and related facilities

The expected expansion of power plants - especially of offshore wind farms - in the Wadden Sea Region until 2020 will ensure economic chances for the Wadden Sea Region in the forthcoming years. In this respect, the direct and indirect employment effects stemming from the operation of and investments into conventional power plants and wind farms in the WSR are of particular importance.

With respect to the results, the direct employment volume sourcing from the operation of the conventional power plants, onshore and offshore wind parks within the WSR is estimated to increase within the three Wadden Sea states from about 5,200 full-time-equivalents (FTE) in 2009 to about 13,700 FTE in 2020. As a result, the direct employment effects of the present WSR power plants were found to account for about 1.25 % of the total WSR manufacturing industry. Until 2020, this share is expected to rise up to almost 4 %. The strong increase in the employment volume is mostly caused by the increasing number of the operating offshore wind turbines. From these newly created working positions, around two thirds are expected to stay within the WSR.

The indirect employment effects stemming from the new constructions of the conventional power plants (2009-2015) and the development of onshore wind farms until 2020 are rather limited and are noticeable within the WSR to only very low degree. In contrast, the development of offshore wind farms until 2020 is expected to create several 10,000s of new and lasting working positions for the next few decades.[13] This implies new big opportunities, in particular, for the seaports in the WSR. As there is a great competition among the cities for the settlement of companies, every town or region has to work hard to realise the chances for new employment.

It has to be underlined that these positive employment effects of the expansion of offshore wind energy in Germany strongly depend on the assumption that the necessary expansion of the high-voltage grid will be realised in time.

Apart from the outcomes in form of employment effects, the operation of existing power plants and the constructions of new ones include further economic and environmental chances and risks for the Wadden Sea Region which could not be discussed in depth in the study. Therefore, the broadly scattered results, which are listed in the study, shall not be reported in this summary.

[13] At present, precise estimation is not possible.

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8 Appendix

8.1 Specific CO_2 emissions of electric power plants

The annual CO_2 emissions of the conventional power plants in the WSR given in chapter 3.5 were calculated by using specific CO_2 coefficients as depend on the fossil fuels applied. These are shown in the following table.

Table A 1 Specific CO_2 emissions of electric power plants (incl. prior processes and material used for the facility production)

Power source:	CO_2 emissions [g/kWh_{el}]
Nuclear power plant	31
Power plant (coal)	897
Combined heat and power plant (coal)	508
Combined heat and power plant (natural gas)	398
Gas turbine (natural gas)	602
Gas turbine (light fuel oil)	707

Source: [Öko-Institut 2007], [Gemis 2008]

8.2 Working assumptions and data underlying the calculation of direct employment effects

Following working assumptions have been met in order to estimate the direct employment effects of investments into the WSR electricity generating facilities:

Operation	Usual number of job positions was used for the given types of facilities
Service and maintenance	Usual service and maintenance cost estimates were used for the given investment categories
Cost division on the personnel and on the material	50% personnel costs
	50% material costs

The detailed inputs used for the employment effect analysis in the fields of „Operation“, „Personnel: Service and Maintenance”, and “Personnel: Production of Service and Maintenance Material” can be found in the tables below. They are based on the own calculations and experience with comparable projects, e.g. with reference to [BEI 2007].

Table A 2 Inputs used for the direct employment effects calculation: Employed in the facility operation

Facility type	Workforce necessary for the operation (in FTE = Full-time employment)	System dimensions
Nuclear Power Station	300	per Station 1,400 MW
Coal Power Station	70	per Station 600 – 1,100 MW
Gas Power Station	35	per Station 400 – 1,100 MW
Oil Power Station	35	per Station 400 – 1,100 MW
Wind Offshore	1	per 20 MW of installed power
Wind Onshore	1	per 10 Mil. Euro of Investment

Table A 3 Inputs for service and maintenance cost estimates

Technology	Costs of service and maintenance (% of Inv. Costs)	Labor Costs (% of Inv. Costs)	Costs for Material (% of Inv. Costs)
Nuclear	1,50%	0,75%	0,75%
Coal	1,50%	0,75%	0,75%
Gas	2,00%	1,00%	1,00%
Oil	2,00%	1,00%	1,00%
Wind Offshore	2,00%	1,50%	0,50%
Wind Onshore	1,00%	0,50%	0,50%

Additional assumptions with respect to the direct employment effects of the conventional power plants

With respect to the conventional power plants, 50% of the personnel necessary for the service and maintenance were assumed to origin from the WSR companies. 50% was expected to come from outside of the region.

In addition, production of the materials necessary for the service and maintenance of the plants was seen as having mostly national character. Therefore, jobs emerging from this production were expected to be settled within the region only at the rate of 5%.

The long term employment effects of the three, in 2020 non-operating, German nuclear power plants, which stem from the decommissioning of these plants, were not taken into consideration.

Additional assumptions with respect to the direct employment effects of the wind power plants

As with the conventional power plants, we assume that all operational working places are located in the WSR. With respect to the working places for service and maintenance, we assume higher regional effects than for conventional power plants because the wind industry is more concentrated near the shore. This argument is especially strong with respect to the offshore technology where many new companies are located in harbour towns. Additionally, there is a big part of logistic work within the service and maintenance of offshore wind farms because all materials and the service craftsman have to be transported to the offshore turbines. The assumed regional fractions of the employment effects are documented in Table A 4.

Table A 4 Assumptions for the regional fraction of the employment effects

Technology	Operation	Service and Maintenance	Production of Material for Maintenance
Conventional Power Plants	100 %	50 %	5 %
Wind Offshore	100 %	80 %	50 %
Wind Onshore	100 %	67 %	40 %

8.3 Additional calculations of the direct employment effects

Table A 5 Countrywide direct employment effects due to the operation of onshore and offshore wind farms and conventional power plants in the WSR 2009 by effect and country

(FTE)		Operation	Maintenance		Total
			Work costs	Material Costs	
Denmark	**Total**	**109**	**168**	**87**	**364**
	Wind Onshore	31	31	18	80
	Wind Offshore	8	80	24	112
	Conv. Power Plants	70	57	45	172
Germany	**Total**	**1,590**	**1,377**	**825**	**3,792**
	Wind Onshore	399	399	240	1,038
	Wind Offshore	1	5	2	7
	Conv. Power Plants	1,190	973	584	2,747
Netherlands	**Total**	**225**	**510**	**269**	**1,003**
	Wind Onshore	77	77	46	200
	Wind Offshore	13	125	38	175
	Conv. Power Plants	135	308	185	628
Total	**Total**	**1,923**	**2,055**	**1,181**	**5,159**
	Wind Onshore	507	507	304	1,318
	Wind Offshore	21	210	63	294
	Conv. Power Plants	1,395	1,338	814	3,547

Table A 6 Countrywide direct employment effects due to the operation of onshore and offshore wind farms and conventional power plants in the WSR 2020 by effect and country

(FTE)		Operation	Maintenance		Total
			Work costs	Material Costs	
Denmark	**Total**	**126**	**284**	**124**	**535**
	Wind Onshore	37	37	22	97
	Wind Offshore	19	190	57	266
	Conv. Power Plants	70	57	45	172
Germany	**Total**	**1,625**	**6,656**	**2,494**	**10,774**
	Wind Onshore	490	490	294	1,273
	Wind Offshore	500	5,000	1,500	7,000
	Conv. Power Plants	635	1,166	700	2,501
Netherlands	**Total**	**411**	**1,434**	**583**	**2,427**
	Wind Onshore	149	149	89	386
	Wind Offshore	93	925	278	1,295
	Conv. Power Plants	170	360	216	746
Total	**Total**	**2,162**	**8,373**	**3,201**	**13,736**
	Wind Onshore	675	675	405	1,756
	Wind Offshore	612	6,115	1,835	8,561
	Conv. Power Plants	875	1,583	961	3,419

Table A 7 Regional direct employment effects due to the operation of onshore and offshore wind farms and conventional power plants in the WSR 2009 by effect and country

(FTE)		Operation	Maintenance		Total
			Work costs	Material Costs	
Denmark	**Total**	**109**	**113**	**22**	**244**
	Wind Onshore	31	21	7	59
	Wind Offshore	8	64	12	84
	Conv. Power Plants	70	29	2	101
Germany	**Total**	**1,590**	**758**	**126**	**2,474**
	Wind Onshore	399	268	96	763
	Wind Offshore	1	4	1	5
	Conv. Power Plants	1,190	487	29	1,706
Netherlands	**Total**	**225**	**306**	**46**	**577**
	Wind Onshore	77	52	18	147
	Wind Offshore	13	100	19	131
	Conv. Power Plants	135	154	9	298
Total	**Total**	**1,923**	**1,177**	**194**	**3,294**
	Wind Onshore	507	340	122	969
	Wind Offshore	21	168	32	221
	Conv. Power Plants	1,395	669	41	2,105

Table A 8 Regional direct employment effects due to the operation of onshore and offshore wind farms and conventional power plants in the WSR 2020 by effect and country

(FTE)		Operation	Maintenance		Total
			Work costs	Material Costs	
Denmark	**Total**	**126**	**206**	**40**	**372**
	Onshore	37	25	9	71
	Offshore	19	152	29	200
	Power Plants	70	29	2	101
Germany	**Total**	**1,625**	**4,911**	**902**	**7,438**
	Onshore	490	328	117	935
	Offshore	500	4,000	750	5,250
	Power Plants	635	583	35	1,253
Netherlands	**Total**	**411**	**1,019**	**185**	**1,616**
	Onshore	149	99	36	284
	Offshore	93	740	139	971
	Power Plants	170	180	11	361
Total	**Total**	**2,162**	**6,136**	**1,127**	**9,425**
	Onshore	675	453	162	1,290
	Offshore	612	4,892	917	6,421
	Power Plants	875	792	48	1,715

8.4 Working assumptions and data underlying the calculation of indirect employment effects

Following working assumptions have been met in order to estimate the direct employment effects of investments into the WSR conventional power plants:

- In line with the current investment plans, investments into the conventional power plants are expected to be undertaken in the period from 2009 to 2015
- The employment effects of the new investments into the conventional power plants within the WSR are distributed equally on the years from 2009 to 2015
- No differentiation between the single countries is undertaken as the new power plant constructions are usually undertaken by the international companies
- The indirect employment effect was estimated to equal to 129 full-time equivalent jobs per 10 mil. € of investment.
- Investment costs were calculated in reference to [Pfaffenberger et. al. 2004]

With respect to investment in wind energy, we expect specific higher employment effects equal to 144 full-time equivalent jobs per 10 mil. € of investment because there is a higher portion of work intensive input from the construction industry. The investment volume is calculated with 1.1 mil. € per MW onshore wind energy and 2.5 mil € per MW offshore wind energy. This numbers are estimated to be the long run average of the investment costs.

All figures are based on own calculations and experience with comparable projects.

8.5 Labour force in the Wadden Sea Region

If one wants to know the importance of the employment effects of the energy sector, it is necessary to compare the numbers with the labour force in the WSR, especially with the labour force in the production sector and in the construction sector. Therefore, we collected these numbers from various statistics and show them in the following table.

Table A 9 Labour force in the Wadden Sea Region 2006

Country / Sector	Germany		Denmark		Netherlands*		WSR	
	Employed		Employed		Employed		Employed	
	(1000)	(%)	(1000)	(%)	(1000)	(%)	(1000)	(%)
Agriculture, Forestry, and Fishery	36,5	4%	6,1	6%	41,0	6,2%	83,6	5%
Production of Manufactures	125,4	15%	21,8	21%	119,0	18,1%	266,2	17%
Production in Construction	50,7	6%	7,6	7%	43,0	6,6%	101,3	6%
Trade, restaurants and hotels, transport	236,8	29%	24,7	23%	146,7	22,3%	408,2	26%
Finance, real estates, and business activities	95,6	12%	9,6	9%	87,3	13,3%	192,5	12%
Public and private services	268,9	33%	35,6	34%	219,4	33,4%	523,9	33%
Total	**813,9**	**100%**	**105,4**	**100%**	**656,4**	**100,0%**	**1.575,7**	**100%**

* Estimated values

Source: [CBS 2009b], [Prognos 2004], [SABL 2009b], [STATDEN 2009c]

9 Glossary

12 nm zone	12 nautical miles zone
/a	per annum
BN kg	billions of kilograms
BSH	Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrografie, Hamburg)
Ca.	circa
CO_2	carbon dioxide
Conv.	Conventional
D	Germany
DEWI	Deutsches Windenergie Institut
DK	Denmark
EC	European Community
EEZ	exclusive economic zone
e.g.	for example
EUR	Euro
EWI	Energiewirtschaftliches Institut an der Universität Köln
FTE	full-time equivalent
GWh	gigawatt hour; equals to 1,000,000 kilowatt hours
ha	hectare; equals to 10,000 square meters
IMO	International Maritime Organization
Inv. Costs	Investment costs
kW	kilowatt
mil	Million
MW	megawatt
MWh	megawatt hour; equals to 1,000 kilowatt hours
NL	Netherlands
OWF	offshore wind farm
t	ton, equals to 1,000 kg
WAB	Wind Energy Agency Bremerhaven/Bremen
WSF	Wadden Sea Forum
WSH	Wind Service Holland
WSR	Wadden Sea Region