

Selected wind farms

Selection of sites for the EPD of electricity from
Vattenfall's wind power

Confidentiality class: None (C1)

1. Selected Sites

Vattenfall's Environmental Product Declaration (EPD) for wind power is based on environmental data for a number of reference sites, selected to be representative for the whole wind power portfolio. Vattenfall manages approximately 50 wind farms in five countries with a total annual generation of close to 9 TWh. More than half of this is generated in offshore farms. See **Table 1** below.

Instead of assessing each of Vattenfall's wind farms, a representative selection has been made based on size, capacity factor, technology, manufacturer etc. Since wind condition is the single most important parameter for the environmental performance of a wind turbine, all Vattenfall's wind farms have been grouped with respect to wind conditions, expressed as the capacity factor¹, and wind farms have been selected in each group to make up a simplified portfolio where the production in each group mirrors the actual production in Vattenfall's total wind portfolio.

Table 1 Vattenfall's total installed wind power and wind power production in 2020 (Vattenfall's share of capacity and generation, pro-rata ownership as per 2020-12-31)

Country	Installed capacity 2020 [MW]		Net average generation [GWh/year]		Total net average generation [GWh/year]
	Offshore	Onshore	Offshore	Onshore	
Denmark	502	233	1 869	629	2 498
Sweden	110	148	327	382	709
UK	613	391	1 845	1 079	2 924
Germany	294	12	1 307	20	1 327
Netherlands	0	501	0	1 420	1 420
Sum	1 518	1 285	5 348	3 530	8 878

This EPD for wind power covers 15 of Vattenfall's wind farms in Denmark, Sweden, the UK, Germany and the Netherlands. Compared to the previous version of the EPD, this updated version consists of three additional windfarms to mirror changes in the portfolio due to new constructions, farms decommissioned and divested. These added farms are located in the Netherlands (Princess Ariane), Denmark (Hons Rev 3) and northern Sweden (Blakliden/Fäbodberget).

The sites in this selection together generate 73% of Vattenfall's wind power production during an average year (74% of the offshore production and 70% of the onshore production)).

Beside the production the selection has also been made to achieve a representative geographical spread where all countries where Vattenfall has wind power production are covered, and in different environments including geographical regions and surrounding biotopes.

¹ The capacity factor is determined as follows: (recorded electricity generation, during the year) / (installed capacity x 8 760 h).

1.1 Description of selected farms

The selected farms are described in Table 2 below.

Table 2 Description of the studied wind farms and their respective contribution to the Vattenfall wind power portfolio in terms of average generation (five-year average). Vattenfall's share of the generation in brackets. Installed power is total capacity of the farm (not only Vattenfall's share).

Group	Farm	Installed power [MW]	Average net generation per farm (Vattenfall's share) [GWh]	Country	Portion of Vattenfall's wind power generation
0	Horns Rev 1*	158	481 (289)	Denmark	3%
	Horns Rev 3	407	1580	Denmark	17,8%
	Lillgrund	407	327	Denmark	18%
	Thanet	110	888	Sweden	4%
	Kentish Flats	300	239	UK	10%
	DanTysk*	90	1281 (653)	UK	3%
1	Klim**	70	220	Denmark	2%
	Pen y Cymoedd	228	649	UK	7%
	BlaFa	353	1100***	Sweden	4%
	Princess Ariane	184	672***	Netherlands	8%
2	Stor-Rotliden	78	200	Sweden	2%
	Edinbane	41	106	UK	1%
	Lyngsmose	5	12	Denmark	0,1%
	Bajlum	15	42 (37)	Denmark	0,4%
3	Princess Alexia	122	256	Netherlands	3%

* Vattenfall owns 60% of the wind farm Horns Rev 1 and 51% of DanTysk. Both total generation and Vattenfall's share is shown under average generation per farm, with Vattenfall's generation in brackets

** Vattenfall owns 21 out of the 22 turbines at Klim. Number in table represents Vattenfall's turbines only

*** Since BlaFa and Princess Ariane are new the estimated production has been used

OFFSHORE

Horns Rev 1

Horns rev 1 is an offshore wind farm located on the western coast of Jutland in Denmark. The farm consists of 79 turbines from Vestas with a total electricity capacity of 158 MW. Vattenfall's ownership share of the farm is 60%.

Horns Rev 3

Horns Rev 3 is located in the North Sea, 25-40 km off the Danish Jutland coast. The farm consists of 49 turbines (MHIVestas) with a total installed capacity of 406,7 MW. The first foundation was placed in the seabed in October 2017 and the first turbines began delivering electricity to consumers in December 2018. The official inauguration of Horns Rev 3 took place in August 2019.

Lillgrund

Lillgrund is the largest offshore wind farm in Sweden. The wind farm is in the Öresund between southern Sweden and Denmark. When Lillgrund Wind Farm was commissioned in December 2007 it was the third largest wind farm in the world. The 48 turbines have a capacity of 2.3 MW each. The wind turbine supplier for the wind farm is Siemens.

Thanet

The Thanet wind farm is located on the outer Thames estuary approximately 12 km off Foreness Point, the most eastern part of Kent. The farm consists of 100 Vestas V90 3 MW wind turbines with a total installed capacity of 300 MW. The annual electricity generation amounts to about 877 GWh. The wind farm was built in 2010.

Kentish Flats

Kentish Flats is located on the southern side of the outer Thames estuary and consists of 30 turbines at 3.0 MW each, manufactured by Vestas Wind Systems A/S. The annual electricity generation amounts to about 256 GWh. The wind farm was built in 2005. This study includes only the original Kentish Flats, Kentish Flats Extension (KFE) including 15 extra turbines, has not been included.

DanTysk

The DanTysk offshore wind farm, 70 km west of the island of Sylt and right next the border with Denmark, is one of the first large marine wind farms built in the German North Sea. The wind farm comprises 80 wind turbines of 3.6 MW from Siemens and has a total installed capacity of 288 MW. The wind farm was installed in 2014 and Vattenfall owns 51%.

ONSHORE

Klim

Klim Fjordeholme wind farm was originally commissioned in 1996. Vattenfall decommissioned the existing 35 wind turbines on Klim Fjordholme in the early summer of 2014 and replaced them with larger, much more efficient wind turbines, which were up and running in 2015. The farm now consists of 22 Siemens 3.2 MW turbines (of which Vattenfall owns 21), with a total installed capacity of 70.4 MW. Klim is the largest onshore wind farm in Denmark.

Pen y Cymoedd

The wind farm Pen y Cymoedd consists of 76 Siemens SWT-3.0-113 turbines, located on land in South Wales. Pen y Cymoedd was installed in 2017, with a total capacity of 228 MW. Vattenfall owns 100% of the wind farm.

Blakliden Fäbodberget (BlaFa)

Blakliden Fäbodberget is Vattenfall's largest onshore wind farm with its 84 turbines. 50 turbines are constructed in Balkliden (Åsele municipality) and 34 in Fäbodberget (north of Fredrika, Åsele and Lycksele municipalities). The farm will be commissioned in 2022. The turbines are of the type Vestas 4.2 MW and total installed power, 353 MW and annual generation about 1,1 TWh. The farm is co-owned by Vattenfall, Vestas and AIP Management (Vattenfall owns 30% of the farm).

Princess Ariane (Wieringermeer)

The farm was by the inauguration in 2020 the largest Dutch onshore farm. The farm is a part of a repowering programme and was officially renamed Princess Ariane during the opening ceremony (former name Wieringermeer). The first part of Princess Ariane wind farm consists of 50 turbines of the type Nordex N117 / 3,6 MW with a total installed capacity of 184 MW. Princess Ariane Extension brings additionally 32 turbines and 118 MW to the area but was sold in 2021.

Stor-Rotliden

The wind farm Stor-Rotliden is located in northern Sweden. The farm consists of 40 Vestas turbines and has an installed capacity of 78 MW. The wind farm was commissioned in 2010.

Edinbane

The Edinbane wind farm on the Isle of Skye in western Scotland consists of 18 Enercon 2.3 MW turbines. The total capacity is 41.4 MW and the annual average electricity generation is about 103 GWh. The farm was built in 2010.

Lyngsmose

Lyngsmose has two turbines of 2.3 MW each, manufactured by Siemens. The wind farm is located in the inland of Jutland and generates about 13 GWh annually. The wind farm was built in 2008.

Bajlum

Bajlum is an onshore wind farm located on Jutland in Denmark. The farm consists of 5 wind turbines from Siemens with a total capacity of 15 MW. Co-owners own 12.5% of the farm. The wind farm was commissioned 2013.

Princess Alexia

The wind farm Princess Alexia is located in the central parts of Netherlands, about 30 km east of Amsterdam. It consists of 36 Senvion 3.4M104 turbines and has a total installed capacity of 122 MW. Princess Alexia is the second largest onshore windfarm in the Netherlands and Vattenfall owns 100%.

1.2 Representativeness – capacity factor and production

Wind condition is the single most important parameter for the environmental performance of a wind turbine. All Vattenfall's wind farms have been grouped with respect to wind conditions expressed as the capacity factor² and several wind farms from each group have been selected to be representative of their group, see table below.

Table 3 Definition of the groups for allocation of environmental impact

Groups	Capacity factor
Group 0: Offshore	>0.25
Group 1: Onshore	>0.32
Group 2: Onshore	0.25-0.32
Group 3: Onshore	<0.25

When divided into these groups, the overall contribution of each farm looks like follows. Altogether the studied wind farms generate about 73% of Vattenfall's total electricity from wind power (74% of the offshore production and 70% of the onshore production) in Denmark, Sweden, the UK, Germany and the Netherlands.

Table 4 Overview of Vattenfall's total generation in respective group and allocated share to each farm in the groups

Group	Studied farms	Average capacity factor	The group's portion of Vattenfall's wind power generation 2020 (average)	The plant's portion of the sample group
G0	Horns Rev 1	35%	60,2%	7,3%
	Horns Rev 3	44%		39,7%
	Lillgrund	34%		8,2%
	Thanet	34%		22,3%
	Kentish Flats	30%		6,0%
	Dan Tysk	51%		16,4%
G1	Klim	38%	22,4%	11,7%
	Pen Y Cymoedd	32%		34,7%
	BlaFa	36%		17,6%
	Wieringermeer	42%		35,9%
G2	Stor-rotliden	29%	11,4%	56,4%
	Edinbane	29%		29,9%
	Lyngsmose	30%		3,4%
	Bajlum	32%		10,3%
G3	Princess Alexia	24%	5,9%	100,0%

Table 5 Vattenfall's share of generation in each group

	Vattenfall's wind power generation [GWh, net]	Share of total generation	Generation from selected farms [GWh]	Share of generation in the selection	Studied farms share of group's generation [%]
G0	5 348	60%	3 976	62%	74%
G1	1 989	22%	1 870	29%	94%
G2	1 014	11%	355	6%	35%
G3	527	6%	256	4%	49%
Total	8 878	100%	6 458	100%	73%

As can be seen in the table above, G0 (offshore) and G1 (onshore) are slightly over-represented while G2 and G3 are somewhat under-represented.

² The capacity factor is determined as follows: (recorded electricity generation, during the year) / (installed capacity x 8 760 h).

During 2021, which was the year when this update took place, the wind power portfolio has gone through large changes. For example, both BlaFa and Princess Ariane will be taken into operation, as well as the 605 MW offshore farm Kriegers Flak. This leads to the portion of production in each group in the end of 2021 will have changed in favor for the offshore wind power generation: when including changes that are planned in 2021 offshore generation makes up approximately 70% of Vattenfall's wind power production. The table below shows the estimated generation in each group, based on average generation up to 2020 but with the wind farms represented in the portfolio by the end of 2021.

Table 6 Vattenfall's share of generation in each group after 2021, estimation based on 2020 production data and planned inaugurations and divestments during 2021.

	Vattenfall's wind power generation [GWh, net]	Share of total generation
G0	7 996	70%
G1	2 291	20%
G2	788	7%
G3	379	3%
Total	11 453	100%

1.3 Share of production covered in each country

Even though the wind farm selection cannot be considered to be representative for each country by itself, only for the portfolio as a whole, the ambition when selecting the farms is that the representation should be as good as possible even when looking to the individual countries. Especially the production in the Nordic countries, and the UK production, has been given special concern.

The generation numbers are based on the average during a five-year period and the portfolio represents the situation by the end of 2020.

Table 7 Vattenfall's average generation in the respective European countries and coverage of selected sites (Vattenfall's share)

Country		Net average generation [GWh/year]	Share of country total	Number of studied farms	Net average generation in selected farms [GWh/year]	Share of country total
Denmark	Offshore	1869	75%	2	1869	87%
	Onshore	629	25%	3	269	13%
Sweden	Offshore	327	46%	1	327	38%
	Onshore	382	54%	2	530	62%
UK	Offshore	1845	63%	2	1127	60%
	Onshore	1079	37%	2	755	40%
Germany	Offshore	1307	99%	1	653	100%
	Onshore	20	1%	0	0	0%
Netherlands	Offshore	0	0%	0	0	0%
	Onshore	1420	100%	2	928	100%
Sum	Offshore	5348	60%	6	3976	62%
	Onshore	3530	40%	9	2482	38%

In Denmark Vattenfall owns and operates 271 turbines (by end of 2020, Vattenfall's share 238 turbines). The total installed capacity of Vattenfall's Danish wind power amounts to 802 MW, of which Vattenfall's share is 735 MW, and the average annual electricity generation is about 2500 GWh (Vattenfall's share). The major part, three quarters, of the wind power generation comes from offshore. The electricity generation from the selected sites in Denmark is equal to 2138 GWh, which makes up 85% of the total generation in Denmark. In the selection, 87% of the electricity generation is in group G0 (offshore), 10% in G1 and 3% in G2. Group G3 corresponds to 6% of the actual production in Denmark.

In Sweden Vattenfall by the end of 2020 owned and operated 139 turbines (114 according to ownership shares. The total installed capacity was 328 MW (258 MW Vattenfall's share) and the average annual electricity generation is about 891 GWh (Vattenfall's share 709 GWh). The majority of the generation 2016-2020 came from group 0 and group 2; 46% each. However, after inauguration of Blakliden/Fäbodberget G1 is expected to make up almost half of the generation in Sweden. The electricity generation from the selected sites in Sweden is equal to 858 GWh, which makes up 63% of the total generation in Sweden. 38% of this electricity generation is in group G0, 38% in group G1 and 23% in group G2.

In the United Kingdom Vattenfall owned and operated 336 (321 Vattenfall's share) turbines by the end of 2020. The total installed capacity of Vattenfall's UK wind power amounts to 1077 MW, of which Vattenfall's ownership covers 1004 MW, and the average annual electricity generation is about 2900 GWh (Vattenfall's share), of which the major part comes from wind farms in groups 0 and 1. The electricity generation from the selected sites in UK is equal to 1882 GWh which makes 64% of the total generation in UK. In the selection, group G0 makes 60% of the generation and 34% from group G1, the remaining 6% from group 2.

In Germany Vattenfall by the end of 2020 owned and operated 170 turbines, almost exclusively offshore turbines (Vattenfall's share corresponds to 84 of these). The total installed capacity of Vattenfall's German wind power amounts to 648 MW, with an annual average generation of almost 2700 GWh. Vattenfall's share of the installed capacity is 306 MW and the average annual electricity generation is about 1300 GWh. 99% of this generation is from offshore wind farms. The electricity generation from the selected sites in Germany is equal to 653 GWh, which is 49% of the total generation in Germany.

In the Netherlands Vattenfall owns and operates 236 turbines (corresponding to 212 in Vattenfall's share). The total installed capacity of Vattenfall's Dutch wind power amounts to about 575 MW, of which Vattenfall owns 501 MW, and the average annual electricity generation is about 1400 GWh (Vattenfall's share). About 64% of the generation in the Netherlands is within group G1, 11% in G2 and 25% in G3. The generation from the two selected sites in Netherlands (one in G1 and one in G3) equals to 928 GWh which corresponds to 65% of the total generation in Netherlands.

1.4 Representativity in the Nordic sites

The table below shows the relative generation in each group in the Nordic countries, together with the generation in the selected Nordic farms. The studied wind farms cover 100% of Vattenfall's offshore generation in the Nordic countries. Here as well G0 and G1 wind farms have a higher portion of the generation than G2 and G3 among the selected sites, compared to the actual generation. It might look odd that the generation in G1 in the selected farms is higher than the average generation, but this is simply a consequence of Blakliden/Fäbodberget not being inaugurated during 2020 and hence not included in the average generation, while the estimated production is included in the numbers for generation in selected farms.

Table 8 Production in each of the capacity groups, Vattenfall's Nordic wind farms

	Vattenfall's Nordic wind power generation [GWh, net]	Share of total Nordic generation	Generation from selected farms [GWh]	Share of generation in the selection
G0	2 196	68%	2 196	73%
G1	421	13%	550	18%
G2	449	14%	249	8%
G3	141	4%	0	0%
Total	3 207	100%	2 995	100%

1.5 Representativeness of farms in the UK

In UK, the studied wind farms cover 64% of Vattenfall's generation, 61% of the offshore generation and 70% of the onshore generation. The selection has a little higher share in G1 than what the total generation indicates and instead a little bit lower in G2 but a relatively fair representation between off- and onshore.

Table 9 Production in each of the capacity groups in the UK

	Vattenfall's UK wind power generation [GWh, net]	Share of total	Generation from selected farms [GWh]	Share of generation in the selection
G0	1 845	63%	1 127	60%
G1	663	23%	649	34%
G2	409	14%	106	6%
G3	7	0%	0	0%
Total	2 924	100%	1 882	100%

1.6 Representativeness land use and impact on biodiversity

The studied farms are located from Stor-Rotliden in the north of Sweden to Gotland in the east, Edinbane in Scotland, UK, in the west, all over Jutland in Denmark and in the south coastal areas of the North Sea. Of the 15 studied farms three are in Sweden (one offshore and two onshore), five in Denmark (two offshore and three onshore), one in Germany (offshore), two in the Netherlands (onshore) and four in the United Kingdom, two of those are offshore and two onshore. In Table 10 the location of each of the studied farms is presented.

Table 10 Location of the selected wind farms

Farm	Location	Biotope
Horns Rev 1*	North Sea West of Jutland	Offshore – Denmark
Horns Rev 3	North Sea West of Jutland	Offshore – Denmark
Lillgrund	South Sweden Öresund	Offshore – Sweden
Thanet	Outer Thames Estuary, east of London	Not included in the Biodiversity Survey
Kentish Flats	Outer Thames estuary, east of London	Offshore – UK
DanTysk*	North Sea West of Jutland	Offshore - Germany
Klim*	Northern Jutland	Not included in the Biodiversity Survey
Pen y Cymoedd	South Wales	Onshore – forest and seminatural landscape, large site
BlaFa	Northern Sweden, Lappland	Onshore – forest and seminatural landscape, large site
Princess Ariane	Wieringermeer, Northern Netherlands	Onshore – agriculture landscape – large site
Stor-Rotliden	Northern Sweden, Åsele	Onshore – forest and seminatural landscape, large site
Edinbane	Isle of Skye in western Scotland	Onshore – forest and seminatural landscape, large site
Lyngsmose	Central Jutland	<i>Not included in the Biodiversity Survey</i>
Bajlum	Northwest Jutland	Onshore – agricultural landscape – small site
Princess Alexia	Central Netherlands	Onshore – agriculture landscape – large site

* Vattenfall owns 60% of Horns Rev 1, 51% of DanTysk and 21 of 22 turbines at Klim.

The selection of wind farms is ecologically representative since the wind farms are geographically spread over the countries and regions where Vattenfall has its wind power generation. In Sweden, all regions where Vattenfall has most of its wind power generation are covered. Vattenfall's Swedish offshore wind farm is located in Öresund. Vattenfall's onshore wind power in Denmark is mainly located in Jutland where the ecosystem is fairly homogenous, and by the time of this study Horns Rev 1 and Horns Rev 3 were Vattenfall's only offshore wind farms in Denmark. DanTysk is the first wind farm in Germany that is included for the EPD study. DanTysk, together with Sandbank that is of almost the same size, together make up over 90% of the generation in Germany and are located close to each other in the German North Sea. In the UK, Edinbane and Pen y Cymoedd are selected to represent the southern and northern parts and different landscapes (stepped moorland and forest). Princess Alexia and Princess Ariane are both representative due to the size and location in agricultural landscape which is typically for the country.

Figure 1 below shows where the studied wind farms are located.

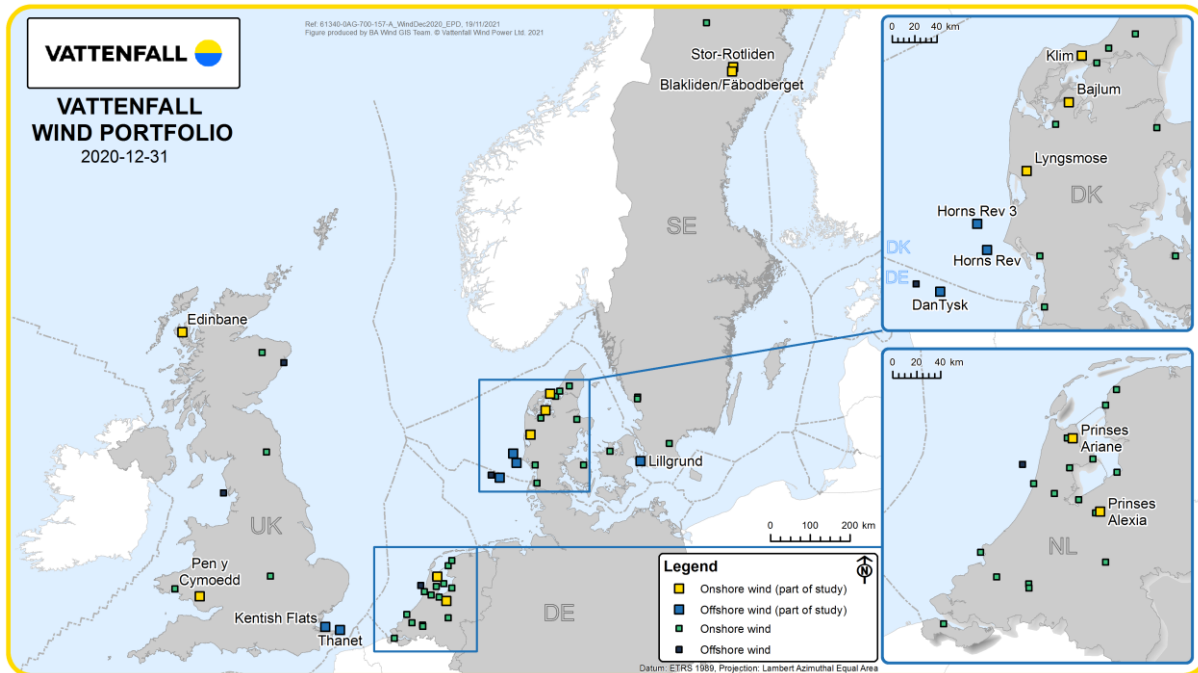


Figure 1 The locations of Vattenfall's studied wind farms. Some dots indicate several farms. The farms presented in this EPD® are marked with yellow (onshore) and blue (offshore) boxes. The figure shows the situation by the end of 2020.

1.7 Representativeness – size and technology

The 15 studied farms comprise both on- or offshore technology. The turbine capacities vary between 1.8 MW and 8.3 MW. The smallest wind farm in terms of number of turbines consist of 2 turbines and the largest consists of 100 turbines. The turbine capacities at Vattenfall's wind farms vary between 0.6 MW and 8,8 MW.

Vattenfall's oldest turbine in operation was constructed in 1995. Of the selected wind farms the oldest turbine was constructed in 2002 and the most recent under constructed in 2021. See Table 11 below.

Table 11 Technology in the selected wind farms

Farm	No of turbines	Manufacturer	Power per turbine [MW]	Construction year
Horns Rev 1*	79	Vestas	2	2002
Horns Rev 3	49	Vestas	8,3	2018
Lillgrund	48	Siemens	2,3	2006
Thanet	100	Vestas	3	2010
Kentish Flats	30	Vestas	3	2005
DanTysk*	80	Siemens	3,6	2014
Klim*	22	Siemens	3,2	2015
Pen y Cymoedd	76	Siemens	3,0	2017
BlaFa	84	Vestas	4,2	2021
Princess Ariane	50	Nordex	3,6	2019
Stor-Rotliden	40	Vestas	1,8-2	2010
Edinbane	18	Enercon	2,3	2010
Lyngsmose	2	Siemens	2,3	2008
Bajlum	5	Siemens	3	2013
Princess Alexia	36	Senvion	3,4	2013

* Vattenfall owns 60% of Horns Rev 1, 51% of DanTysk and 21 of 22 turbines at Klim.

Supplier coverage

The selected farms in the study include the majority of Vattenfall's wind turbine suppliers. The suppliers included in the studied farms, including their subsidiaries, have in total delivered about 97% of all Vattenfall's wind power turbines. Six of the studied wind farms are using turbines from Siemens while Vestas has delivered turbines to six of the studied wind farms and Enercon, Nordex and Senvion have delivered to one of the studied wind farms each. In Table 11 above the supplier of the wind turbines for each wind farm is presented.