

# Selected wind farms

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

2019-01-31

Confidentiality class: None (C1)

## 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 60 wind farms and assessing all of them would not be possible. Therefore, a representative selection is made based on size, capacity factor, technology, manufacturer, geographic location, surrounding biotopes etc.

During the update of the EPD in 2018, starting from one EPD for the Nordic wind power and one for the wind power in the UK, these two were merged together to become one and completed with wind farms in Germany and the Netherlands to become representative for Vattenfall's whole wind power portfolio. In addition, one new farm in the UK and one in Denmark were inventoried to reflect changes in the portfolio.

Table 1 Vattenfall's total wind power portfolio for 2017 (Vattenfall's share of capacity and generation, pro-rata ownership as per 2017-12-31)

Country	Installed capacity 2017 [MW]		Net average generation [GWh/year]		Total net average generation [GWh/year]
	Offshore	Onshore	Offshore	Onshore	
Denmark	95	243	368	684	1 052
Sweden	120	183	364	487	851
UK	516	391	1 549	1 145	2 694
Germany	309	12	1 294	19	1 313
Netherlands	54	254	170	483	653
<b>Sum</b>	<b>1 095</b>	<b>1 083</b>	<b>3 745</b>	<b>2 819</b>	<b>6 564</b>

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 factor<sup>1</sup>, and several wind farms from each group have been selected to be representative of their group.

Altogether, the studied wind farms generate close to 62% of Vattenfall's total electricity from wind power (66% of the offshore production and 56% of the onshore production) in Denmark, Sweden, the UK, Germany and the Netherlands during an average year. All groups of wind conditions are covered and the geographical spreading is good; all countries where Vattenfall has generation are covered and all different types of vegetation.

### 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	614 (368)**	Denmark	5,6%
	Lillgrund	110	333	Sweden	5,1%
	Thanet	300	877	UK	13,4%
	Kentish Flats	90	256	UK	3,9%
	DanTysk*	288	1 239 (632)**	Germany	9,6%
1	Bajlum	15	45	Denmark	0,7%
	Sigvards 3	1,5	4	Sweden	0,1%

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

	Klim**	70,4	226	Denmark	3,4%
	Pen y Cymoedd	228	743	UK	11,3%
	Lyngsmose	5	13	Denmark	0,2%
2	Stor-Rotliden	78	202	Sweden	3,1%
	Edinbane	41	103	UK	1,6%
3	Prinses Alexia	122	265	Netherlands	4,0%

\* 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.

## 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%.

### 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

### 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.

### Sigvards 3

Sigvards 3 is not a wind farm but a single turbine and one of the turbines in the wind farm Näsudden located the Swedish island Gotland. Sigvards 3 is a wind turbine from Vestas with a capacity of 1.5 MW. Sigvards 3 was commissioned 2001.

### 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.

### 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.

### 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.

### Prinses Alexia

The wind farm Prinses 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. Prinses Alexia is the second largest onshore windfarm in the Netherlands and Vattenfall owns 100%.

## 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 factor<sup>2</sup> 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

Table 4 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 [%]
<b>G0</b>	3 745	57%	2 467	61%	66%
<b>G1</b>	1 333	20%	1 031	25%	77%
<b>G2</b>	761	12%	305	7%	40%
<b>G3</b>	725	11%	265	7%	36%
<b>Total</b>	<b>6 553</b>	<b>100%</b>	<b>4 056</b>	<b>100%</b>	<b>62%</b>

Altogether the studied wind farms generate about 62% of Vattenfall's total electricity from wind power (66% of the offshore production and 57% of the onshore production) in Denmark, Sweden, the UK, Germany and the Netherlands.

## 3. Portion of production covered in each country

Below is a description on what groups are covered in each country specifically. It is important to note here that the wind farm selection cannot be considered to be representative for each country by itself, but for the portfolio as a whole. The generation numbers are based on the average during a five-year period and the portfolio represents the situation by the end of 2017.

Table 5 Vattenfall's average generation in the respective European countries and coverage of selected sites (Vattenfall's share)

Country	Net average generation [GWh/year]		Number of studied farms (Net average generation [GWh/year])	
	Offshore	Onshore	Offshore	Onshore
Denmark	368	684	1 (368)	3 (284)
Sweden	364	487	1 (333)	2 (206)
UK	1 549	1 145	2 (1133)	2 (846)
Germany	1 294	19	1 (632)	0
Netherlands	170	483	0	1 (265)
<b>Sum</b>	<b>3 745</b>	<b>2 807</b>	<b>5</b>	<b>8</b>

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

**In Denmark** Vattenfall owns and operates 225 turbines (by end of 2017). The total installed capacity of Vattenfall's Danish wind power amounts to 401 MW, of which Vattenfall's share is 338 MW, and the average annual electricity generation is about 1052 GWh (Vattenfall's share). The major part of the wind power generation comes from groups 0 and 1. The electricity generation from the selected sites in Denmark is equal to 652 GWh, which makes up 62% of the total generation in Denmark. In the selection, 57% of the electricity generation is in group 0 and the remaining 43% from group 1 thereby neither group 2 nor 3 are represented in the studied farms in Denmark. Group 2 and 3 correspond to 12% and 11% respectively of the average production in Denmark.

**In Sweden** Vattenfall, by the end of 2017, owned and operated 168 turbines. The total installed capacity was 371 MW (303 MW Vattenfall's share) and the average annual electricity generation is about 1030 GWh (Vattenfall's share 851 GWh). The majority of the generation comes from group 0 and group 2; 43% and 38% respectively. The electricity generation from the selected sites in Sweden is equal to 539 GWh, which makes up 63% of the total generation in Sweden. 62% of this electricity generation is in group 0, 1% in group 1 and 37% in group 2. Group 3 is not represented by the studied farms in Sweden (group 3 makes only 2% of the average generation in Sweden).

**In the United Kingdom** Vattenfall owned and operated 325 turbines by the end of 2017. The total installed capacity of Vattenfall's UK wind power amounts to 981 MW, of which Vattenfall's ownership covers 907 MW, and the average annual electricity generation is about 2 700 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 1 979 GWh which stands for 73% of the total generation in UK. In the selection, group 0 makes 57% of the generation and 38% from group 1, the remaining 5% from group 2. There is no studied farm in United Kingdom belonging to group 3. Group 3 stands for 5% of the average production in the United Kingdom.

**In Germany** Vattenfall by the end of 2017 owned and operated 170 turbines, the major part of these at sea. The total installed capacity of Vattenfall's German wind power amounts to 648 MW, with an annual average generation of almost 2 700 GWh. Vattenfall's share of the installed capacity is 321 MW and the average annual electricity generation is about 1 300 GWh. 99% of this generation is from offshore wind farms. The electricity generation from the selected sites in Germany is equal to 632 GWh, which is 48% of the total generation in Germany.

**In the Netherlands** Vattenfall owns and operates 210 turbines. The total installed capacity of Vattenfall's Dutch wind power amounts to about 389 MW, of which Vattenfall owns 308 MW, and the average annual electricity generation is about 653 GWh. Most part, 65%, of the average generation in the Netherlands is within group 3, and for that reason 100 % of the electricity generation of the studied wind farms is derived from group 3. The electricity generation from the selected sites in Netherlands is equal to 265 GWh, which corresponds to 41% of the total generation in Netherlands.

Table 6 Coverage of selected wind farms for groups in each country

Country	Group	Average production	Share of total in group and country	Average production selected farms	Selected farms share of total in group and country
Sweden	G 0	364	43%	333	62%
	G 1	121	14%	4	1%
	G 2	321	38%	202	37%
	G 3	45	5%	0	0%
Denmark	G 0	368	35%	368	57%
	G 1	430	41%	284	43%
	G 2	130	12%	0	0%
	G 3	113	11%	0	0%
UK	G 0	1 549	58%	1133	57%
	G 1	757	28%	743	38%
	G 2	265	10%	103	5%
	G 3	123	5%	0	0%
Netherlands	G 0	170	26%	0	0%
	G 1	14	2%	0	0%
	G 2	45	7%	0	0%
	G 3	424	65%	265	100%
Germany	G 0	1 294	99%	632	100%
	G 1	0	0%	0	0%
	G 2	0	0%	0	0%
	G 3	19	1%	0	0%

## 4. Representativeness Biotope

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 13 studied farms three are in Sweden (one offshore and two onshore), four in Denmark (one offshore and three onshore), one in Germany (offshore), one in the Netherlands (onshore) and four in the United Kingdom, two of those are offshore and two onshore. In Table 7 the location of each of the studied farms is presented.

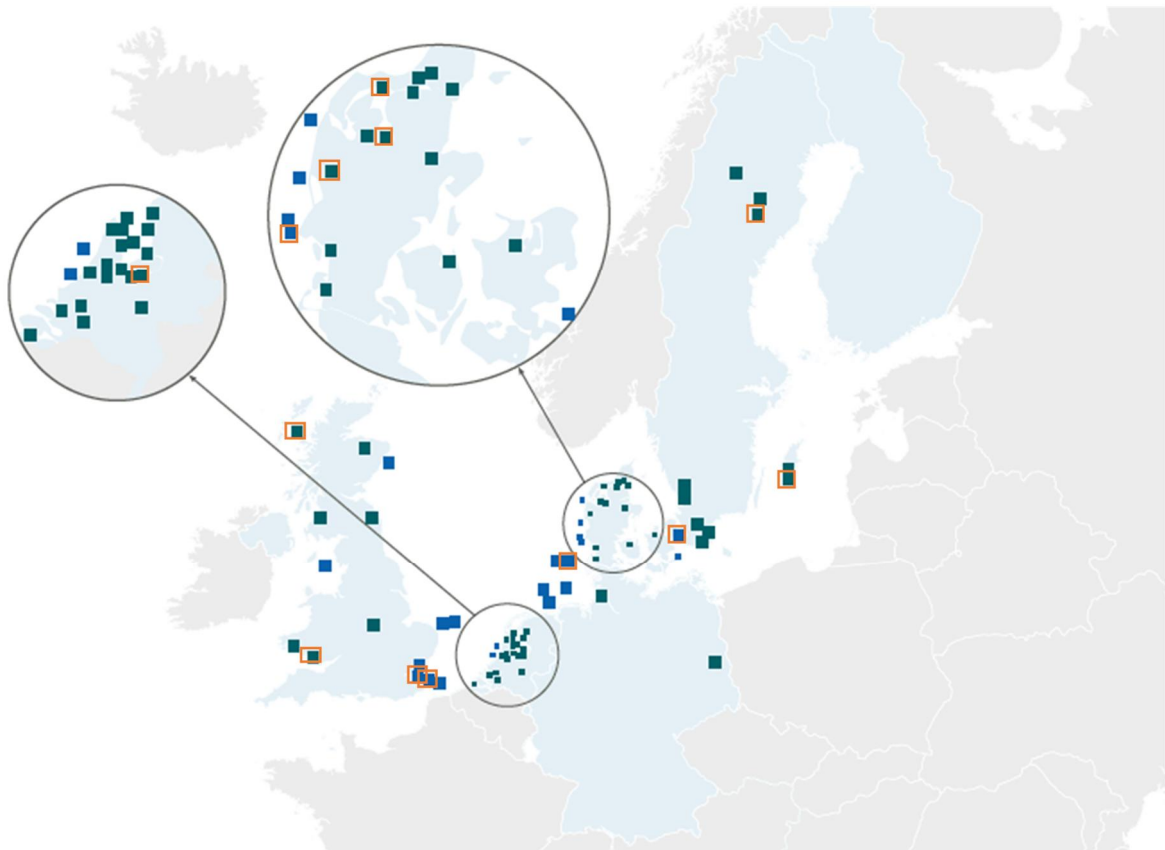
Table 7 Location of the selected wind farms

Farm	Location	Biotope
Horns Rev 1*	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
Bajlum	Northwest Jutland	Onshore – agricultural landscape – small site
Sigvards 3	Näsudden Gotland	Onshore – agricultural landscape – small site
Klim*	Northern Jutland	Not included in the Biodiversity Survey
Pen y Cymoedd	South Wales	Onshore – forest and seminatural landscape, large site
Lyngsmose	Central Jutland	Not included in the Biodiversity Survey
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
Prinses Alexia	Central Netherlands	Onshore – agriculture landscape – large site

\* Vattenfall owns 60% of Horns Rev 1, 51% of DanTysk and 95% of 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 farms were by the end of 2017 located in Kalmarsund (decommissioned in 2018) and 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 was Vattenfall's only offshore wind farm in Denmark, even though several developments have been initiated since. 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). Prinses Alexia is the first site in Netherlands to be selected for the EPD study. It is 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 an orange box. The figure shows the situation in 2018.

## 4. Representativeness – size and technology

The 13 studied farms comprise both on- or offshore technology. The turbine capacities vary between 1.5 MW and 3.6 MW. The smallest wind farm in terms of number of turbines consist of 1 turbine and the largest consists of 100 turbines. The turbine capacities at Vattenfall's wind farms vary between 0.6 MW and 5MW. The studied farm's capacities vary between 1.5 MW and 3.6 MW. The most modern farms in Vattenfall's portfolio have turbines of much larger capacities, but the turbines with a capacity of more than 3.6 MW together generated 290 GWh in 2017 which was about 4.5% of Vattenfall's total wind electricity production. The next EPD update in 2021 would need to take larger turbines into account when selecting the scope since most ongoing projects consist of larger turbines.

Vattenfall's oldest turbine in operation was constructed in 1995. Of the selected wind farms the oldest turbine was constructed in 2001 and the most recent was constructed in 2017. See Table 8 below. Farms inaugurated and under construction during 2018 will be considered for future updates of the EPD.

Table 8 *Technology in the selected wind farms*

Farm	No of turbines	Manufacturer	Power per turbine [MW]	Construction year
Horns Rev 1*	79	Vestas	2	2002
Lillgrund	48	Siemens	2,3	2006
Thanet	100	Vestas	3	2010
Kentish Flats	30	Vestas	3	2005
DanTysk*	80	Siemens	3,6	2014
Bajlum	5	Siemens	3	2013
Sigvards 3	1	Vestas	1,5	2001
Klim*	22	Siemens	3,2	2015
Pen y Cymoedd	76	Siemens	3,0	2017
Lyngsmose	2	Siemens	2,3	2008
Stor-Rotliden	40	Vestas	1,8-2	2010
Edinbane	18	Enercon	2,3	2010

Prinses Alexia	36	Senvion	3,4	2013
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\* 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 90% of the different wind turbine suppliers for Vattenfall. The suppliers included in the studied farms, including their subsidiaries, have in total delivered about 96% of all Vattenfall's wind power turbines. Six of the studied wind farms are using turbines from Siemens, see Table 8. Vestas has delivered turbines to five of the studied wind farms and Enercon and Senvion have delivered to one of the studied wind farms each. In Table 8 above the supplier of the wind turbines for each wind farm is presented.