

Wind & Solar

Opportunities for system integration
with batteries and hydrogen production



Join our journey

Below 2°C – this ambitious target for limiting global warming was set by the international community in December 2015 within the framework of the Paris Agreement. It immediately became clear that this would not be achieved without great effort on the part of the energy industry. Renewable energy, however, is though the key to global carbon reduction. This is particularly true for the EU, whose institutions agreed in June 2018 binding to a 32% renewables target by 2030, covering the three sectors of electricity, heat and transport.

And Vattenfall? Today, 35% of Vattenfall's generation capacity already comes from renewable sources. We are one of the leading actors in the European energy transition and want to continue on this path. Our message is therefore clear: we at Vattenfall want to enable our customers to live without fossil fuels within one generation. Expanding and integrating new renewable generation capacity is a core part of that mission. Every year, we invest more than a billion euros in these technologies.

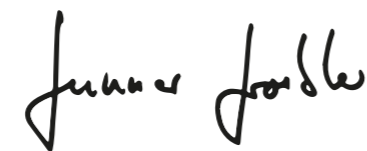
We are proud that renewable energy is our strongest growth area

With approximately 3,000 megawatts of installed capacity, we are among the leading developers and operators of wind and solar farms in Europe. We not only want to systematically expand our wind farm portfolio and open up new markets, but also to continue to grow in the solar sector, installing solar panels for our customers, or in addition to our own assets, including existing hydro plants and wind farms.

But other than an expansion of renewable generation capacity, what else is needed to meet our ambitious targets? We are focused on the following key actions:

- Strengthening the market and the competitiveness of renewable energy through cost-efficiencies, new market-based instruments and innovation for new, increasingly digital, business models
- Consistent focus on the digitalisation of our entire value chain
- Increased decarbonisation through electrification of the transport and heating sectors, for example power-to-gas and power-to-heat
- Use of hydrogen and batteries to support the widespread integration of renewable electricity in other industrial sectors
- Seek new partnerships and cooperations, for example with cities and municipalities, large industrial companies and start-ups

With knowledge and experience, courage and passion, we are shaping the fossil-free energy world of tomorrow. Join us as a partner on our journey!



Gunnar Groebler

Member of the Group Executive Board Vattenfall AB
Head of Business Area Wind

Innovative projects on land and at sea

Trying new things, making the tried and tested even better – we are realising innovative onshore and offshore projects in northern and north-western Europe.

1 PPA for one of Sweden's largest wind farms

In our home market of Sweden, we are currently working to construct the country's largest onshore wind farm, Blakliden/Fäbodberget. The project has a capacity of 353 megawatts. Around 60% of the expected annual electricity production of 1.1 terawatt hours is already firmly contracted: Norsk Hydro will buy this quantity of energy over 20 years. This was agreed between Vattenfall and the aluminium producer within the framework of an electricity supply contract, called a Power Purchase Agreement (PPA). Another project partner is the Danish turbine manufacturer Vestas, which supplies the wind turbines and also holds a 70% stake in the project together with the Danish pension fund PKA. Vattenfall holds the other 30% and is responsible for construction and operation.



2 Premiere off the Scottish coast

In Aberdeen, off the Scottish coast, we are taking the European Offshore Wind Deployment Centre (EOWDC) wind farm to new heights. Vattenfall has installed V164-8.8 turbines from turbine manufacturer MHI Vestas at two locations on the eleven wind power stations. These are currently the largest offshore wind turbines used commercially worldwide. All wind turbines are installed on what are known as suction bucket foundations. This makes Aberdeen Bay the first offshore wind farm to be built entirely on suction buckets. Transmission to the UK's Power Grid is at the 66 kilovolt (kV) level, which is a first for offshore wind projects in Scotland and can carry twice as much electricity as conventional lines. This achievement will contribute to further cost reductions.

3 First non-subsidised offshore wind farm

With the Hollandse Kust 1&2 offshore wind farm, we are not only making a contribution to the sustainability of the Dutch energy system, but have also set new standards in terms of cost efficiency. We successfully bid to develop the first wind farm worldwide with no guaranteed feed-in tariff.

For us, this confirms that continuous efforts to reduce costs along our entire value chain are working successfully. The further development of the project is now underway: over a total area of 325 square kilometres and about 22 kilometres off the Dutch North Sea coast, with an installed capacity of between 700 and 750 megawatts, the offshore wind farm will be built within the next five years.

Our wind farms, solar farms, battery storage systems and planned projects

Vattenfall's five largest offshore wind farms

1. (D) Norfolk Boreas, 1.8 GW
2. (D) Norfolk Vanguard, 1.8 GW
3. (D) Hollandse Kust Zuid 1&2, 700 MW
4. (D) Danish Kriegers Flak, 605 MW
5. (C) Horns Rev 3, 400 MW

Vattenfall's five largest onshore wind farms

1. (C) Blakliden/Fäbodberget, 353 MW
2. (C/D) Wieringermeer, 300 MW
3. Pen y Cymoedd, 228 MW
4. (D) South Kyle, 200 MW
5. Princess Alexia, 122 MW

United Kingdom

- 1 Edinbane, 41.4 MW
- 2 Ormonde, 150 MW (51%)
- 3 Parc Cynog, 5 MW
- 4 Swinford, 22 MW
- 5 Kentish Flats, 90 MW
- 6 Thanet, 300 MW
- 7 Clashindarroch, 36.9 MW
- 8 Pen y Cymoedd, 228 MW
- 9 Kentish Flats Extension, 49.5 MW
- 10 Ray, 54 MW
- 11 Aberdeen, 92 MW
- 12 (D) Norfolk Vanguard, 1.8 GW
- 13 (D) Norfolk Boreas, 1.8 GW
- 14 (D) Thanet Extension, 272 MW
- 15 (D) South Kyle, 200 MW

Denmark

- 1 Ryå, 7.5 MW
- 2 Nørre Økse Sø, 18 MW
- 3 Klim, 67.2 MW (98%)
- 4 Nordjyllandsværket, 6 MW
- 5 Nørrekær Enge 1, 29.9 MW
- 6 Hollandsbjerg, 16.5 MW
- 7 Lyngmose, 4.6 MW
- 8 Hagesholm, 23 MW
- 9 Horns Rev 1, 160 MW (60%)
- 10 Tjæreborg Enge, 16.8 MW
- 11 Dræby Fed, 9.2 MW
- 12 Rejsby Hede, 23.4 MW
- 13 Bajlum, 15 MW
- 14 (C) Ejning, 6.9 MW
- 15 (C) Horns Rev 3, 400 MW
- 16 (C) Danish Nearshore (Vesterhav Nord, Vesterhav Syd), 344 MW
- 17 (D) Danish Kriegers Flak, 605 MW

The Netherlands

- 1 De Bjirmen, 6 MW
- 2 Hiddum Houw, 3.5 MW
- 3 Oom Kees, 6 MW (12%)
- 4 Enkhuizen, 2.4 MW
- 5 Oudendijk, 4.8 MW
- 6 Egmond aan Zee, 108 MW (50%)
- 7 Irene Vorrink, 16.8 MW
- 8 Reyndersweg, 9 MW (50%)
- 9 Windpoort I, 13.2 MW (40%)
- 10 Jaap Rodenburg, 16.5 MW
- 11 Eemmeerdijk, 18 MW
- 12 Princes Alexia, 122 MW
- 13 Princes Alexia, 3 MW
- 14 Echteld, 8 MW
- 15 Mariapolder, 4.8 MW
- 16 Hoofdplaatpolder, 10 MW (70%)
- 17 (C/D) Wieringermeer, 300 MW (50%)
- 18 (D) Wieringermeer, 28 MW (50%)
- 19 (D) Haringvliet, 38 MW
- 20 (D) Haringvliet, 3 MW
- 21 (D) Haringvliet, 21 MW
- 22 (D) Hollandse Kust Zuid 1&2, 700 MW
- 23 (D) Oudendijk, 5 MW
- 24 (C) Slufterdam, 29 MW
- 25 (D) Nieuwe Hemweg, 19 MW
- 26 (D) Moerdijk, 21 MW
- 27 (C) PV@Heat, 10 MW at three locations

Germany

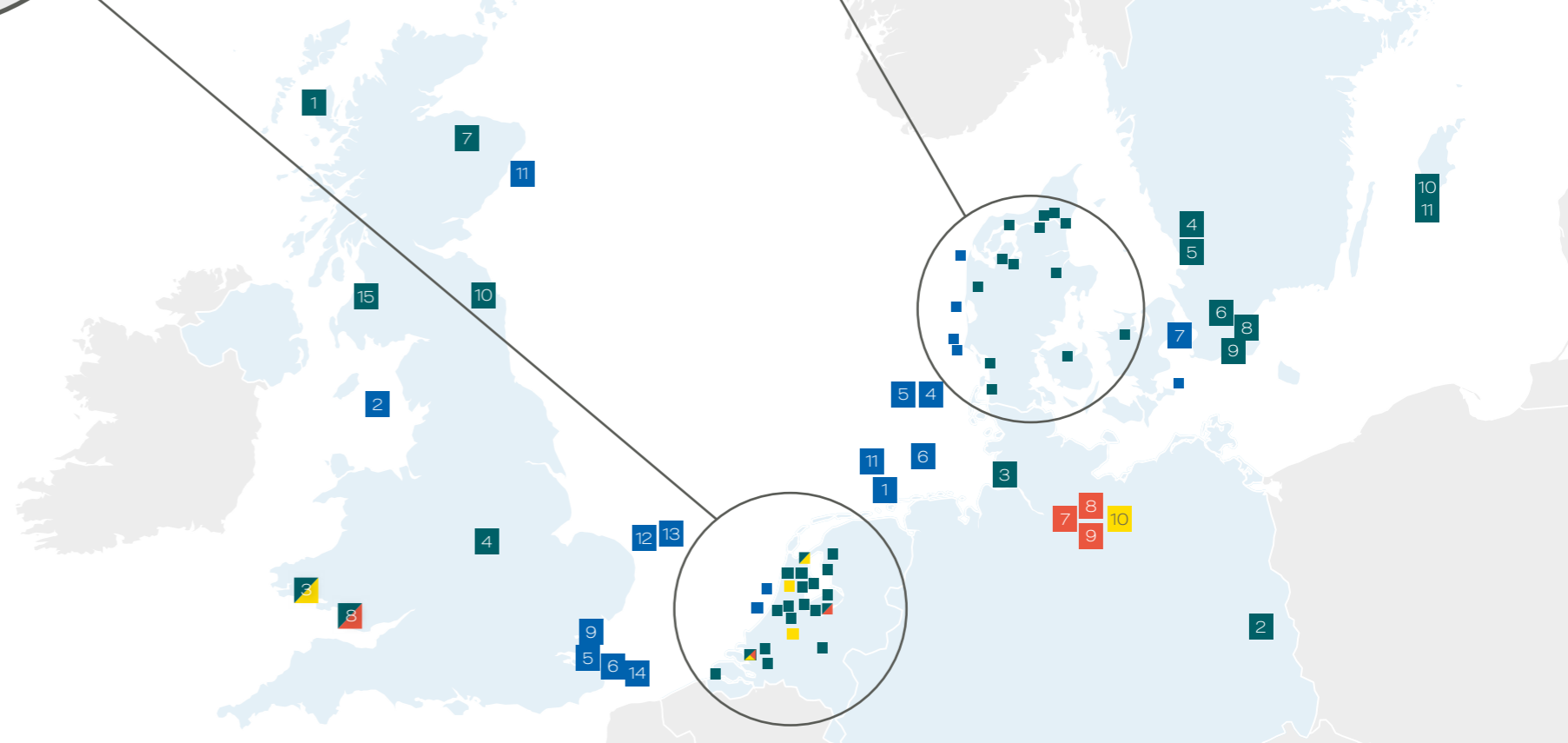
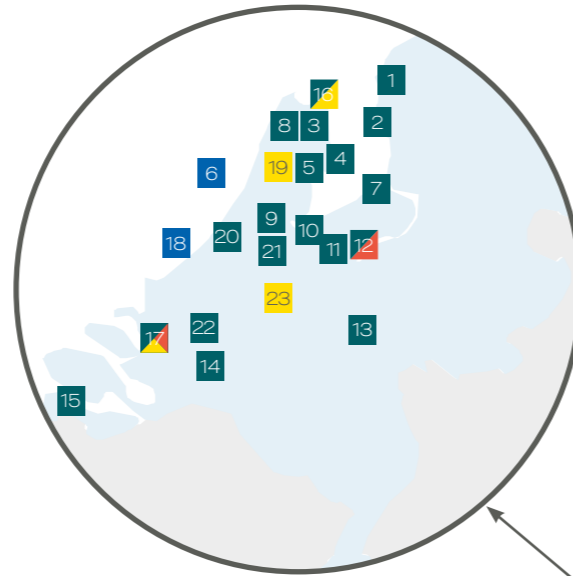
- 1 alpha ventus, 60 MW (26.25%)
- 2 Jänschwalde, 12 MW
- 3 Westküste, 7.4 MW (20%)
- 4 DanTysk, 288 MW (51%)
- 5 Sandbank, 288 MW (51%)
- 6 (D) Global Tech II
- 7 Curslack, 1 MW
- 8 Peakshaving, 1 MW
- 9 Hafenbatterie, 1 MW
- 10 (D) Kogel West, 10 MW
- 11 (D) Atlantis

Sweden

- 1 Juktan, 29 MW (50%)
- 2 (C) Blakliden/Fäbodberget, 353 MW
- 3 Stor-Rotliden, 78 MW
- 4 Hjuleberg, 36 MW (50%)
- 5 Högabjär-Kårsås, 38.4 MW
- 6 Höge Våg, 38 MW (50%)
- 7 Lillgrund, 110 MW
- 8 Östra Herrestad, 16.2 MW
- 9 Hedeskoga, 5.9 MW
- 10 Kulle, 1.2 MW
- 11 Näsudden, 10.24 MW

- Onshore
- Offshore
- Battery
- Solar

% = Vattenfall's share
(D) = Development
(C) = Construction



Vattenfall's wind farms in numbers

(as of July 2018)

Under operational control of Vattenfall¹:

Offshore wind farms: 1,603 megawatts
Onshore wind farms: 1,156 megawatts
Produced capacity: 7,6 TWh/anno²

¹including shares of partners

²This production equates to the electricity consumption of around 2.5 million households (with an average consumption of 3,000 kWh/a).



Vattenfall operates more than 50 wind farms in five European countries



Strong growth in ground-mounted and roof-top solar installations at customer sites



Batteries stabilise the grid, support sector coupling and optimise the trade

A stable investment framework for the expansion of renewables in Europe

Climate goals and the integration of renewables in energy markets can only succeed through adaptation of the regulatory framework, a challenge throughout Europe.



To ensure the necessary investment stability for project developers in the current era of energy market change, alternative instruments to stabilise revenues should be considered when devising renewables policy. For example, the Contract for Difference (CfD) mechanism has proven itself in various European countries. This contract is a two-way tariff, so if the market price is below the negotiated base price during the electricity supply phase, the operator receives the difference as a subsidy. Conversely, if the market price is above the base price, the producer pays back the difference to the state. In this way, risks and chances are shared and renewable electricity can expand cost-efficiently.

Power Purchase Agreements - a strong market instrument

Long-term direct supply contracts for electricity from renewable sources (Power Purchase Agreements/PPAs) can also help electricity producers to stabilise their income and thus reduce the investment risk for new projects. PPAs also enable companies in energy-intensive industries to reduce the carbon intensity of their production processes and protect themselves against rising energy costs.

Chances of Contract for Difference (CfD)

In recent years, there has been an enormous increase in renewable energy generation capacity in Europe, accompanied by falling costs for the various technologies. This expansion is politically driven by European and national energy and climate targets for 2020 and 2030; expansion at this rate would not have been possible without appropriate state support systems.

We are convinced that both market integration and the competitiveness of renewable technologies will continue to progress rapidly and that the need for subsidy will continue to decrease. However, important prerequisites for this to happen include the successful implementation of European regulations on the internal electricity market, the strengthening of the emissions trading system and large-scale grid expansion.



Vattenfall is focusing on PPAs

We conclude PPAs for both third-party plants and our own plants. In the Netherlands, for example, we have signed a contract with Microsoft for the direct supply of green electricity from the Wieringermeer onshore wind farm. Aluminium producer Norsk Hydro has secured around 60% of the total electricity production from our Blakliden/Fäbodberget wind cluster in northern Sweden. Read more about this on page 3.

Intelligent co-located technology

In our Renewable Hybrid Power Plants we get the most out of the combined potential of solar, wind and battery technology. In the field of sector coupling, we will establish hydrogen as part of the solution for decarbonisation.

Synergies of wind and sun

Wind and solar energy complement one another well. Solar works best in the summer, when wind energy output tends to be lower, and wind generation is most effective in winter, when solar energy is very low. As a result, hybrid parks support grid stability and, in addition, are able to optimise the sale of electricity. In 2016, Vattenfall built a solar power plant with over 18,000 panels at Parc Cynog wind farm in Wales. In the Netherlands, we are building a solar park at the Haringvliet wind farm, which in time will be combined with a 12 MW battery storage system.

Growth in solar energy

The cost of constructing photovoltaic systems has dropped sharply. In 2017 more than 100 GW of solar capacity was installed worldwide and the share of solar energy in electricity production is steadily increasing. Vattenfall is currently developing and building several solar projects: ground-mounted - some are co-located with wind farms - in cooperation with our customers and in addition to our own assets like hydro plants. Vattenfall's investment program is expected to be up to 100 million euros for solar in 2018/19.

Batteries support sector coupling

Vattenfall has already launched numerous battery projects and has more in development. In 2018, at our Pen y Cymoedd onshore wind farm in Wales, we commissioned our largest battery storage system to date with a capacity of 22 MW. The lithium-ion batteries not only help to stabilise the transmission network, but also provide valuable insights into the coupling of wind and battery storage technology. In Hamburg-Curslack, we also installed a battery next to a wind farm in 2018.

Hydrogen: important element for the future energy system

The HYBRIT project in Sweden is a ground-breaking project to create the world's first fossil-free steel on an industrial scale. Together with our partners SSAB, LKAB and the Swedish energy

agency we are testing and developing the technique to produce steel by using hydrogen instead of coal and coke. Construction of the project was started in June 2018. We hope it will lead to a historical shift in steel production, creating water as a by-product instead of carbon dioxide.

Hydrogen also plays an important role for Vattenfall in sector coupling. In Hamburg, for example, we have been involved in Germany's most busiest hydrogen fuel station since 2012, and the broader testing of the use of hydrogen as a transport fuel. Moreover, Vattenfall, with the fuel producer Preem, aims to build an 18 MW hydrogen gas plant in Gothenburg. The plant will produce hydrogen gas using biofuel from derived by-products of the Swedish wood pulp industry. This fossil-free hydrogen production will potentially contribute to a CO₂ reduction of 25,000 tons.



