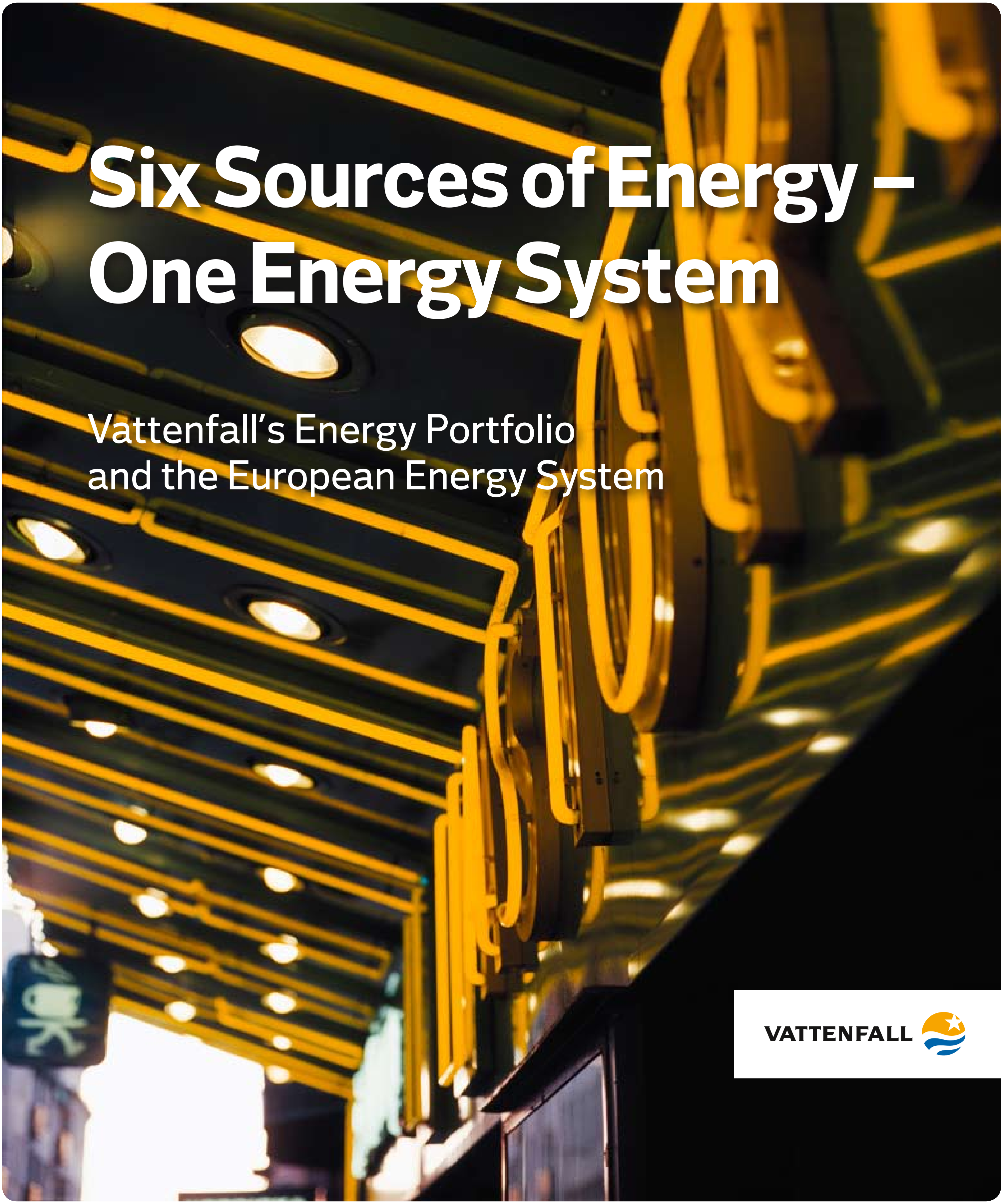


Six Sources of Energy – One Energy System

Vattenfall's Energy Portfolio and the European Energy System

VATTENFALL

Wind Power

Vattenfall AB (publ)
SE-162 87 Stockholm, Sweden
Visitors: Sturegatan 10
Telephone: +46 8 739 50 00

For more information, please visit www.vattenfall.com

WIND POWER

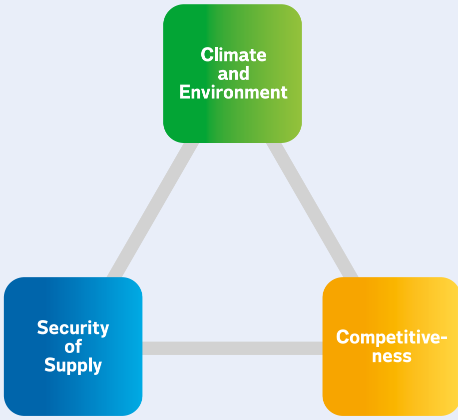
Wind power has no fuel costs and no emissions of CO_2. Total cost per produced kilowatt hour is relatively high due to significant investment costs. Wind power is the fastest growing energy source in Europe and plays a key role in the achievement of the European Union's climate goals.

The Energy Triangle – Wind Power

Climate and environment

All energy sources have environmental impact during their life cycles. Combustion of energy sources, particularly fossil fuels, generates CO_2 emissions and contributes to global warming. In the long run, emissions from power production will need to be close to zero if greenhouse gas levels in the atmosphere are to be stabilised.

Wind power is a renewable energy source that emits essentially no CO_2 across the life cycle. Wind turbines do have an impact on the landscape, which some people may find disturbing.



Security of supply

Fuel shortages and unreliable electricity systems cause societal and economic problems. Securing supply means guaranteeing that primary energy is available, and that delivered energy is reliable, essentially 100 per cent of the time. This is a major political and technical challenge.

Wind resources are renewable, and do not increase import dependency. They can thus be securely developed. But wind power is dependent on available wind, and excessively high wind speeds require temporary stops in electricity generation. New wind power developments must therefore target areas with reliable and predictable winds.

Competitiveness

Energy is a fundamental input to economic activity, and thus to human welfare and progress. The costs of producing energy vary between different energy sources and technologies. A competitive energy mix will keep overall costs as low as possible given the available resources.

Wind power has no fuel costs, though total cost per produced kilowatt hour is high due to significant investment costs and the need for network capacity investments for new wind farms. Today, wind power is therefore largely dependent on support systems. Larger investments are required for offshore wind farms than for land-based ones. Technological development and an increase in the price of CO_2 emissions will make wind power more cost-competitive.

The History of Wind Power

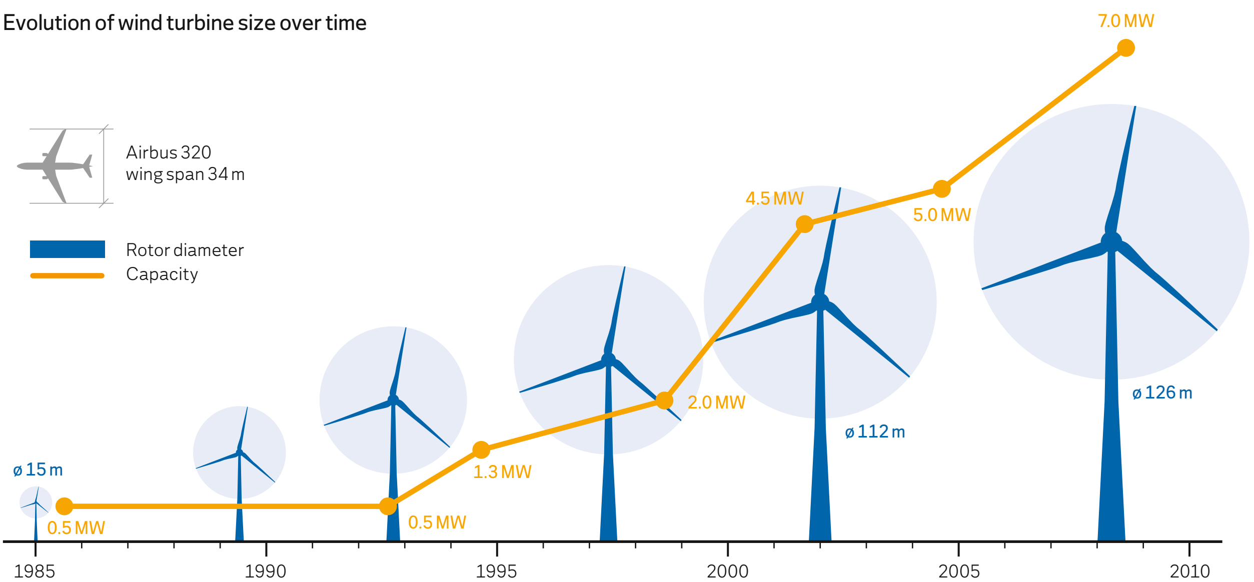
Man has been using wind energy for thousands of years. For a long time wind was harnessed with the help of sails, opening new horizons by allowing boats to travel faster over longer distances.

The first step towards the use of wind power as we know it today was the use of windmills in the Middle Ages. Windmills came to play a major role, particularly in terms of agriculture, in areas that lacked the resources to use hydro power. Wind power also played a crucial role as railways were built across the North American continent during the 1800s. Steam engines needed a continuous supply of water, and small wind turbines were used to pump water into storage tanks from which water could then be loaded into the locomotive.

The history of modern wind power dates back to the 1970s. The 1973 oil crisis was a driving force for technological development. Denmark was one of the European countries that decided early on to utilise wind power technology to reduce its dependency on oil. Today, Denmark remains among the countries where the share of electricity demand that is met by wind power is the highest: in 2008 Danish-produced wind power comprised 19 per cent of the country's electricity generation.[1]

Rapid development has been taking place since the 1980s. Continual technology improvements (e.g., longer blades, improved power electronics, better use of fibre-reinforced plastics) have been carried out over time, aimed at capturing as much energy as possible from the wind. Interconnected wind farms became more prevalent, replacing the use of smaller machines. In 1985, the typical turbine had a rotor diameter of 15 metres. Fifteen years later, the size had increased nearly tenfold, meaning a significant increase in capacity. Large commercial turbines today have a capacity of 5 MW as compared to 0.5 MW in 1985.

Evolution of wind turbine size over time



Source: European Wind Energy Association

How Wind Power Works

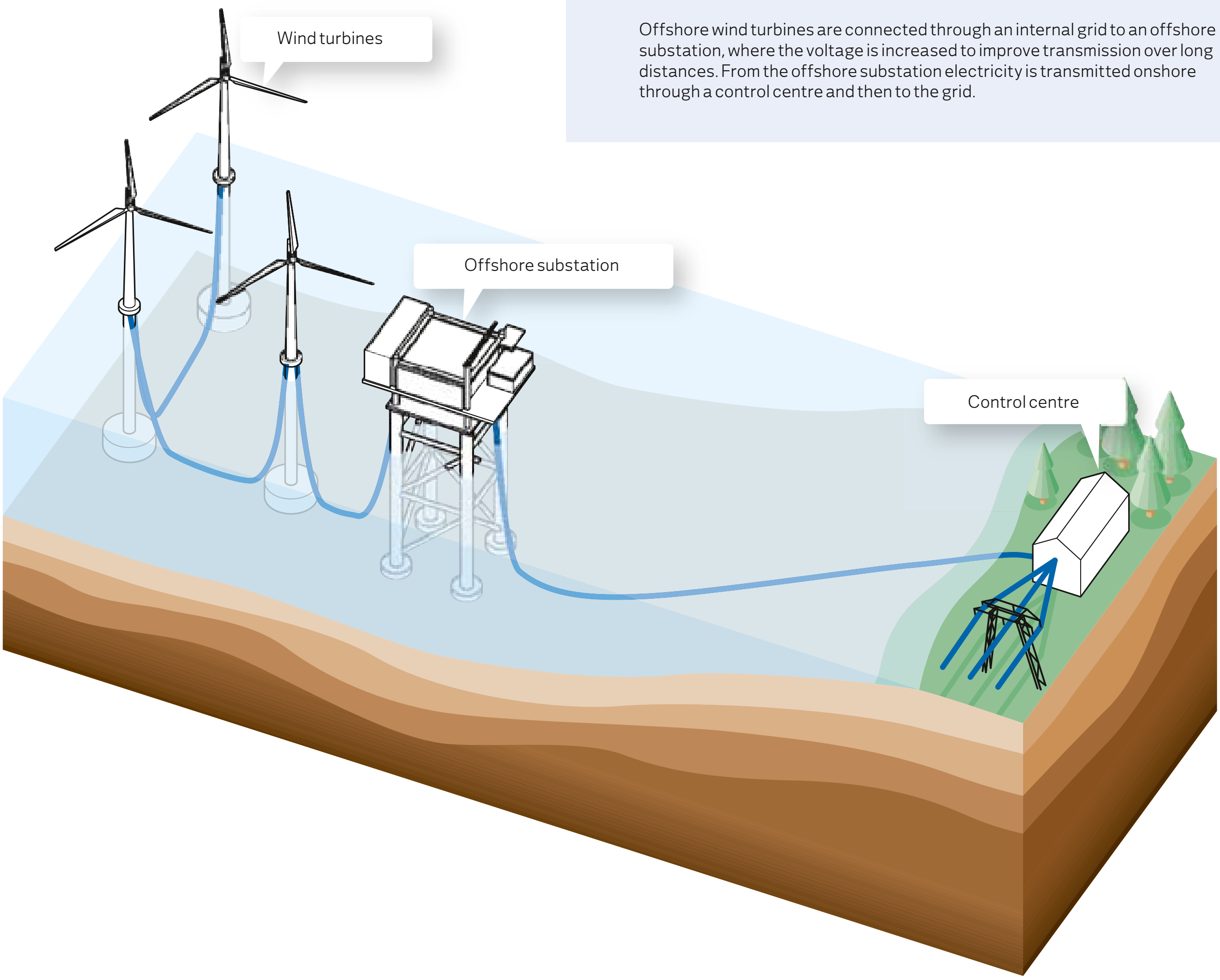
Wind turbines today

A wind turbine converts wind energy (essentially, the kinetic energy in the air) into electricity. Of course, wind power requires favourable wind conditions. Wind drives the turbine's blades and hub, which make up the rotor. The turbine's shaft is connected to a generator inside the nacelle located in the upper part of the tower. A gearbox, normally situated between the rotor and generator, steps up the slow speed of the rotor to a speed that suits the generator.

A yaw system between the nacelle and the tower automatically keeps the turbine pointed into the wind. This allows the utilisation of wind blowing from different directions by automatically keeping the turbine turned into the wind. Turbine blades are normally made of extremely durable fibreglass-reinforced plastic and sometimes of carbon-reinforced fibres. Lightning protection is also built into the blades.

Wind turbines have built-in, automatic control systems, but they are also monitored from a manned control centre. If an

Offshore wind farm



Offshore wind turbines are connected through an internal grid to an offshore substation, where the voltage is increased to improve transmission over long distances. From the offshore substation electricity is transmitted onshore through a control centre and then to the grid.

operational problem arises, the control system can identify it immediately and send an error message to the control centre. Regular inspections are carried out by specially trained staff as part of ongoing operational and security work. These specialists make sure that all equipment is in top condition, replacing various machine components as needed to ensure optimal operation and generation.

Wind farms

Wind turbines are often situated in groups, or wind farms, either on- or offshore. A large wind farm may consist of hundreds of individual wind turbines, interconnected by a transmission system.

Extensive calculations are performed when planning wind farm locations. Parameters studied include wind efficiency at specific locations and above-ground altitude. Factors such as bird life and distance to residential areas are also taken into consideration.

Extensive calculations are performed when planning wind farm locations. Parameters studied include wind efficiency at specific locations and above-ground altitude. Factors such as bird life and distance to residential areas are also taken into consideration.

In wind farms, turbines are ideally spaced four to 10 rotor diameters apart, depending on the prevailing wind. This minimises efficiency losses caused by turbine interference.

Wind power and electricity generation

Wind turbines can only produce electricity when the wind speed is right. When there is light or no wind, turbines rest in standby mode. When wind blows to a sufficient degree, approximately 4 m/s, the turbine starts operating automatically and feeds electricity into the grid. It operates at full power when winds are around 12 to 14 m/s. In strong winds (wind speeds in excess of around 25 m/s) the loads are so great that the turbine is shut off to prevent unnecessary wear and tear.

Wind turbines in a wind farm are connected through an internal grid that feeds the produced electricity to a transformer station. The transformer station increases the electricity's voltage (e.g., from the internal grid's 30 kV to 130 kV for the regional grid) and the electricity is then transported to a nearby regional grid through a connection point. Individual turbines can also be connected directly to local grids.

Special facilities are required for offshore wind farms. In most cases, turbines feed produced electricity to an offshore transformer from which a cable connects the wind farm to the onshore electricity grid.

On those occasions when the wind is not strong enough, other types of energy are used as balancing power. Natural gas is often used as balancing power in Germany and the UK. In Sweden, balancing power is often synonymous with hydro power. More water is drained from reservoirs when the wind is weak. Similarly, water can be conserved when wind is strong.

Good wind position is a project's first step

In order for a wind farm to be profitable, it must have a good wind position. Computer programmes that can calculate theoretical wind energy based on terrain and above-ground altitude are used to identify areas with good wind positions. After an area has been identified, a thorough examination is made of the geographical surroundings, existing roads, electricity grids, proximity to residences, acceptance among local residents, flora and fauna and any restricted areas. Winning the acceptance of nearby residents can sometimes be a major challenge when planning the construction of a new wind farm.

Before deciding on a location for a wind farm, theoretical wind energy calculations must be checked by measuring wind at the location. Wind measurements are normally taken with cup anemometers (wind gauges) mounted in a measuring mast. The anemometer is placed at several different altitudes and measurements are taken over a long period of time in order to assess the site's wind characteristics.

Optimal geographic areas for wind power are often in coastal and open landscape areas where winds are strong. Offshore sites away from the coast are usually optimal in terms of wind strength. At the same time, it is important that turbines are located relatively close to roads and power lines so that they can be serviced and so that cables can be installed to transport the generated electricity.

WIND SPEED

At an average wind speed of seven m/s, a wind turbine produces during approximately 90 per cent of the hours of the year. This is equivalent to an output of approximately 5 to 6 GWh of electricity per year for a turbine with an effect of 2 to 2.5 MW. Translated into household electricity, it corresponds to the consumption of approximately 1,000 households.

Offshore construction presents special challenges

When constructing an offshore wind farm, turbines are assembled on land to the greatest extent possible. They are then transported offshore by special crane-equipped installation vessels. The parts that are not assembled on land are assembled offshore: the tower and its foundation followed by the nacelle with hub and rotor blades mounted on the tower. The trend is towards building the entire turbine on land and transporting it offshore with special vessels. It is important to ensure that the turbine operates throughout its entire useful life (approximately 20 years) without requiring the replacement of too many parts. Compared to land-based wind farms, greater strain is put on offshore equipment due to waves, salt water, ice and stronger winds. Maintenance is also more difficult. However, the fact that average offshore wind speeds are often higher offers greater electricity generation potential.

Another issue is offshore grid connection; turbines located far from the coast present challenges in terms of laying electric cable on the seabed. Regulations on who pays for the connecting lines also differ between European countries; the wind power company is liable in Sweden, while the grid operator is liable in Denmark, the UK and Germany.

Investment costs for offshore turbines are also many times higher than for land-based wind power, since in most cases it is more expensive to draw power lines to land. One technical limitation to offshore turbines is the difficulty of building them in depths exceeding 40 metres. Preliminary location studies for offshore wind farms are extensive and include an examination of the marine ecology. It has been demonstrated that offshore turbines have come to serve as artificial reefs where molluscs can grow and fish can spawn, a tangible positive effect. Other issues that must be taken into consideration include possible impact on shipping lanes, the fisheries industry and bird life.

Wind Power in Europe

Strong growth

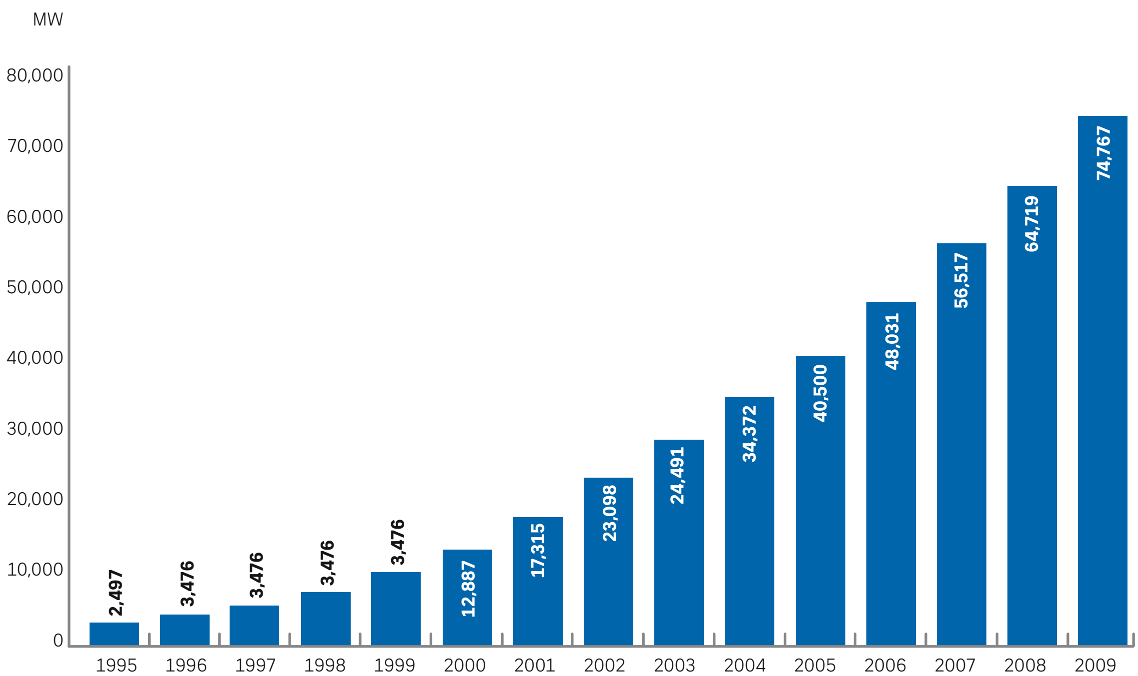
Wind power is the fastest growing source of energy in the EU. In 2009, installed capacity increased 23 per cent and accounted for 39 per cent of total newly-installed electricity generation capacity. In 2008, wind power produced 3.6 per cent of the EU's total electricity generation.[2]

The largest share of new installations were land-based turbines (over 9,500 MW of land-based wind power as compared to nearly 600 MW offshore), though the rate of expansion for offshore was nearly twice that of land-based. The strong growth of wind power is also distinctive in comparison with other energy sources. Natural gas came second in terms of commissioned new capacity, but was far behind wind power with just over 6,500 MW.[3]

In total, renewable energy constituted 62 per cent of all new power generating capacity installed in 2009. This means that, for the second consecutive year, renewable energy accounted for the majority of all new installations. The strong growth in wind power capacity is an important element in efforts to build a sustainable energy system. The EU's goal is to increase the share of renewable energy in the energy mix to 20 per cent and to reduce CO_2 emissions by 20 per cent over 1990 levels by the year 2020.[4] Wind power plays an important role in achieving these targets.

Growth figures for the past 15 years also speak clearly. Wind power has moved from a technology that attracted only a few investors to one that attracts broad-based investments throughout the EU. In 1995, total installed wind power capacity was approximately 2,500 MW. Annual growth has been over 20 per cent since then, and total installed capacity was roughly 75,000 MW by 2009. In a year with normal wind conditions, these turbines produce approximately 200 TWh.[5]

Wind power in Europe - installed capacity over time



Source: European Wind Energy Association, Wind in power 2009 European statistics

Support systems promote expansion of European wind power

Each EU country has its own individual support system for renewable energy. Regardless of how they are designed, the support systems are meant to strengthen the competitiveness of renewable energy sources and thus contribute to the necessary conversion of Europe's energy system. Most European countries, including Germany, Denmark and the Netherlands, use "feed-in" tariffs under which producers of renewable electricity are guaranteed a fixed rate and have a guaranteed market for the electricity produced. These contracts are long-term, often as long as 15 to 25 years.

Sweden uses an electricity certificate system aimed at increasing renewable electricity generation by 25 TWh over 2002 levels by 2020. Practically speaking, producers of renewable electricity receive extra income through electricity certificates that are awarded in proportion to generation. Electricity suppliers buy certificates in proportion to how much they sell ("quota requirement"). This creates demand for certificates, and a market is formed where certificates are traded.

Germany and Spain lead the pack

Germany and Spain are Europe's largest wind power countries in terms of installed capacity, comprising one-third and one-fourth of Europe's wind power, respectively. These two countries are also leaders in terms of installed new capacity; Spain led far and away in 2009, followed by Germany, Italy, France and the UK. Smaller countries such as Sweden and Denmark also had a high rate of expansion. Sweden accounted for five per cent of newly-installed capacity, while Denmark accounted for three per cent in 2009.

The picture changes, however, in terms of wind power's share of the countries' total electricity generation. Here, Denmark emerges as one of Europe's and the world's leading wind power countries. In 2008, 19 per cent of Denmark's electricity generation came from wind power; corresponding figures for Spain and Germany were 10 and 6 per cent, respectively.[5] The corresponding figure for Sweden was just over one per cent.

In a global perspective, several of the largest wind power countries are found in Europe. The global leader, though, is the USA, with an installed capacity of 35,159 MW in 2009, corresponding to over 22 per cent of the world's wind power capacity. Germany comes second just ahead of China; both countries account for roughly 16 per cent of global installed wind power capacity.[6]

As in Europe, wind power's global growth rate has been very strong over the past 15 years. In 1995 there was a total of 7,644 MW installed capacity in the world.[7] This figure increased to 159,213 MW by 2009.[8]

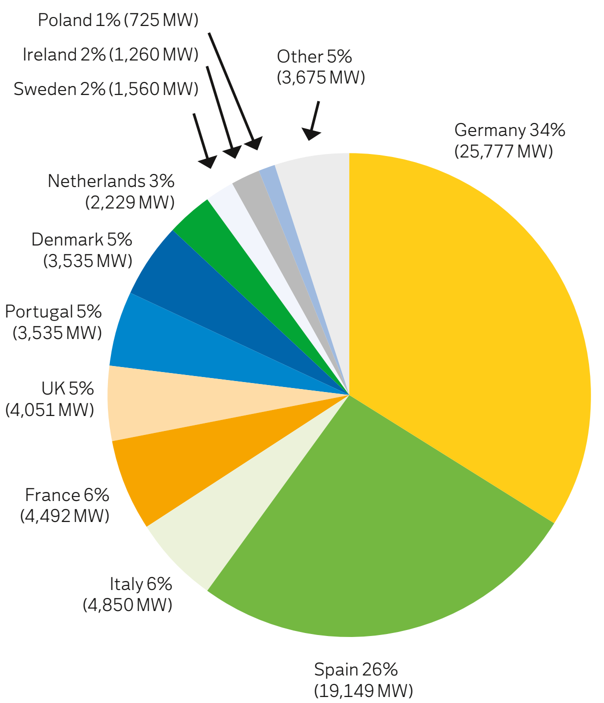
Extensive authorisation process in European countries

To plan, obtain permissions for and build a wind farm is a long-drawn-out process in most European countries. A project may take anywhere from two to 10 years from initial planning to construction start, depending mainly on issues related to obtaining planning permissions. Planning is done in close dialogue and consultation with local authorities, local residents, the general public and other stakeholders. Consideration is taken of the natural and cultural environment. The area where the turbines will stand is thoroughly inspected and possible impact on humans, animals and plants in the area is assessed.

The process of obtaining planning permission differs from country to country. The terms and conditions for obtaining permission can also be difficult to meet. In the Netherlands and Sweden, there is a great degree of local authority over the planning process. In the Netherlands, municipalities need to actively plan to set up a wind farm; if they are passive on the issue, they are saying "No" for all practical purposes. In Sweden, municipalities have the authority to veto planned wind power projects within their own borders.

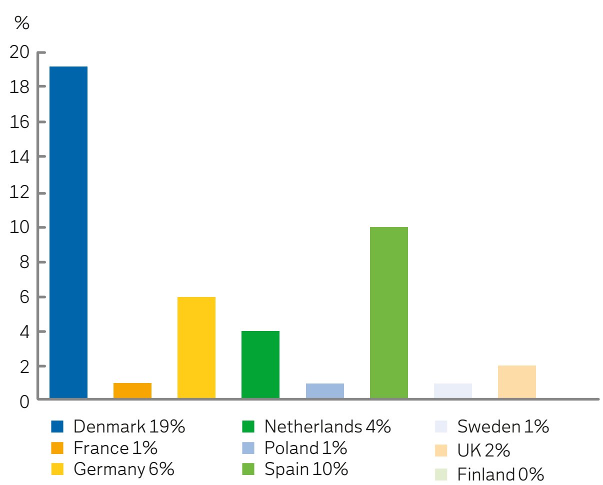
In Denmark, which has seen dramatic wind power expansion, local authorities are legally required to mark out areas for setting up wind turbines. This has worked particularly well in Denmark where municipalities have generally worked co-operatively.

Wind power – installed capacity in Europe (2009)



Source: EWEA Annual Report 2009

Wind power – share of total electricity generation (2008)



Source: IEA Statistics, Electricity Generation, 2010

The Future of Wind Power

Increasingly large wind farms in the future

Far-reaching technological development has taken place since the first wind power stations were constructed in the late 1970s. Wind farms today are larger and produce more electricity. Above all, turbines are now 30 times larger and have a capa-city of around 6 to 7 MW, though 2 to 5 MW turbines are still most prevalent. It is estimated that the average wind farm will have a turbine size of up to 10 MW by the year 2030.

One reason for the increase in turbine size is that more and more wind power facilities are being built offshore. The arguments supporting offshore location are higher wind speeds with greater energy content and the fact that no land area

The Stor-Rotliden wind farm in northern Sweden.

is used (lowering the risk of conflict with nearby residents or other stakeholders). At the close of 2009, offshore wind power accounted for less than three per cent of the EU's total wind power inventory, though forecasts indicate that offshore wind power will be greater than land-based by around 2030.

Future wind power research and development will focus on things such as wind farm optimisation, increased reliability and efficiency. There are also ambitions to reduce wind power's dependence on maintenance and to make it easier to assemble. Finally, extensive research is being conducted on future electricity grids, as increased wind power generation will place new demands on functionality.

New demands on future electricity system – smart grids

The electricity grids across Europe today are primarily adapted to electricity from a few large power plants. They are one-way grids, providing distribution networks with electricity. Future energy systems will place new demands on the electricity system. The increased number of intermittent energy sources, such as wind power, electric vehicles and household-produced electricity, will increase the need for an intelligent, flexible and reliable electricity grid. And as offshore wind power is constructed the need increases for a new, high-capacity grid, as well as advanced networks dedicated to collecting wind energy. If grids aren't constructed at a fast enough pace, the expansion of offshore wind power risks being delayed. The process of grid expansion vis-à-vis offshore power is complicated, however, and differs between European countries.

The European Commission has initiated a research programme aimed at improving the technological performance of turbines while improving economic conditions. The research programme comprises six billion EUR through 2020.

Until now, research on the future electricity system has fallen under the "smart grid" concept. The basic idea of a new electricity grid is that smart management ensures that the electricity system becomes more efficient, both economically and technically. An IT-based control unit manages and makes decisions based on data on generation, demand, use, etc., continuously retrieved from various parts of the electricity system. The control unit collects huge amounts of data that can then be used for more advanced consumption management. The data can also be used to make more reliable forecasts and improve planning.

EU continues to invest in wind power

The EU has set a number of targets to be met by 2020. One of these targets is that renewable energy will constitute 20 per cent of all energy consumed within the EU by 2020. In a recent EU Commission scenario, wind power is expected to account for 14 per cent of electricity consumed within the EU by 2020.[9] As an increasingly large share of the EU's electricity is derived from wind power as opposed to fossil fuels, relative carbon emissions are reduced.

The European Commission has initiated a research programme aimed at improving the technological performance of turbines while improving economic conditions. The research programme comprises six billion EUR through 2020.[10] In addition to increasing the share of renewable energy and lowering CO_2 emissions, the programme will create several thousand new jobs within the wind power industry. At the same time, the number of jobs in the fossil fuel sector will decrease as demand falls.[11] The wind power industry currently employs 192,000 people within the EU.[12]

In 2008, the share of renewable electricity in the EU was roughly 18 per cent, and wind power constituted four per cent of the total electricity generation.[13] Renewables accounted for 62 per cent of new electricity generation capacity installed in the EU in 2009. With more than 74 GW of total installed wind power capacity in 2009, the installations exceeded the 2010 target of 40 GW.[14] According to the European Renewable Energy Council, renewables will account for 34 to 40 per cent of total EU electricity generation by 2020.[15]

With its increasingly important role in Europe's energy supply, wind power has a bright future. But it does face challenges. One of these, described above, is to simplify the process for obtaining planning permissions without sacrificing dialogue with all interested parties. Another challenge is operational security. A wind turbine has a useful life of approximately 20 years, and must produce electricity during most of this time to be profitable. Availability (the amount of time a wind farm can produce if winds are sufficient) is a key measure. For example, the offshore Lillgrund wind farm off Sweden's southern coast produces electricity between 98 and 99 per cent of the time, and thus has an availability of between 98 and 99 per cent.

Generation disturbances must also be kept at a minimum; repairs or replacement of vital parts reduces availability and directly impacts profitability. In many cases, a slightly smaller turbine with long-proven technology may be a better choice than one of the largest turbines on the market that hasn't yet had as long an operating life.

Vattenfall and Wind Power

Wind power is the fastest growing energy source in Europe and plays a key role in the achievement of the European Union's 20-20-20 targets. Vattenfall is Sweden's largest wind power operator and Europe's largest offshore wind power operator. Vattenfall will continue to expand its offshore wind operations in North Sea countries (UK, Germany, Netherlands) and its onshore operations in prioritised markets.

Vattenfall's wind power operations

Vattenfall is one of the largest wind power generators in Europe. Vattenfall operates around 900 turbines in Sweden, Denmark, Germany, Poland, the Netherlands, Belgium and the UK. Together, these turbines generate approximately 2.2 TWh of electricity annually.

Vattenfall is the proud owner of many of the world's largest offshore wind farms: Horns Rev off the west coast of Denmark, Lillgrund in the Öresund Strait in Sweden, Kentish Flats and Thanet just off the southeast coast of England, Egmond aan Zee off the Dutch coast in the North Sea, and Alpha Ventus off the coast of northwest Germany.

For a full list of Vattenfall's wind farms, please see the production site at www.vattenfall.com/powerplants.

Vattenfall's wind power operations going forward

Vattenfall sees significant growth opportunities within wind power, though profitability is dependent upon support systems. In terms of offshore wind power, Vattenfall has a competitive advantage and intends to grow further.

Vattenfall is investing to increase its electricity generation from wind power. Between 2009 and 2011, Vattenfall has had nine wind farms in six countries under construction. This represents an investment of 20 billion SEK in these facilities and

Thanet offshore wind farm off the coast of southeast England.

a near doubling of Vattenfall's wind power electricity generation to 4 TWh (the amount needed to power 800,000 households). Vattenfall has also entered into a joint venture with Stadtwerke München (SWM) for construction of the Dan Tysk offshore wind farm in the North Sea, one of the world's largest offshore wind power projects. With a capacity of 288 MW and an output of approximately 1,320 GWh, the wind farm will produce enough renewable power to supply electricity to more than 500,000 homes.

Vattenfall is continuously exploring possibilities for on- and offshore wind power projects in several countries. In early 2010 Vattenfall and Scottish Power Renewables were awarded one of the zones in the British "Round Three" for expanding offshore wind power. Vattenfall's zone has the potential to deliver 25 TWh on an annual basis, equivalent to the consumption of four million households. The Thanet wind farm, the world's largest offshore wind farm, opened in September 2010 and increased the UK's wind power generation by 30 per cent.

Smart grids – an important tool for increasing the share of wind power in the energy mix

As electricity generation from wind power and other energy sources with fluctuating generation increases, the need arises for an intelligent, flexible and reliable network. Today's European electricity networks were originally planned and constructed for centralised, large-scale electricity generation and distribution. Demands placed on electricity networks have changed, and these networks are no longer suitable for current and future energy systems. This fact, along with societal, energy usage and political trends, has resulted in the development of smart grid technology. Smart grids enhance possibilities to control and store electricity, making it an important tool for efficiently integrating small- and large-scale wind power generation in European electricity networks. Vattenfall is conducting several smart grid technology R&D projects aimed at ensuring secure and reliable network services, today and in the future.

Footnotes – Wind power

1 International Energy Association (IEA) Statistics, Electricity Generation 2008, www.iea.org
2 IEA World Energy Outlook 2010
3 IEA Wind Energy Annual Report 2009
4 Read more about the EU Climate Change Policy on www.energy.eu
5 IEA Statistics, Electricity Generation, 2010, www.iea.org
6 World Wind Energy Association, www.wwindea.org
7 U.S. Energy Information Administration, www.eia.doe.gov
8 World Wind Energy Association, op. cit.
9 European Commission, EU energy trends to 2030.
10 European Commission (2009), SE C (2009) 1295
11 European Climate Foundation (2010), Roadmap 2050, Technical Analysis
12 EWEA (2010), Wind Energy Factsheets
13 IEA Statistics, op. cit.
14 European Commission (2010), www.europa.eu
15 European Renewable Energy Council, Renewable Energy Technology Roadmap

SUMMARY

- **Wind power is the fastest growing renewable energy source and plays a key role in the attainment of the European Union's 20-20-20 targets**
- **At year-end 2009, installed wind power capacity produced 3.6 per cent of the electricity consumed within the EU**
- **Wind power has no fuel costs. Total cost per produced kilowatt hour is relatively high due to significant investment costs and the need for network capacity investments for new wind farms. Wind power is therefore largely dependent on support systems**
- **As electricity generation from wind power and other energy sources with fluctuating generation increases, the need arises for an intelligent, flexible and reliable network. Smart grid technology enhances possibilities to control and store electricity, making it an important tool for efficiently integrating small- and large-scale power generation in European electricity networks**
- **Wind power emits low levels of carbon dioxide. Wind turbines do have an impact on the landscape, which some people may find disturbing**
- **Vattenfall is one of the biggest wind power generators and developers in Europe. Vattenfall operates around 900 turbines in Sweden, Denmark, Germany, Poland, the Netherlands, Belgium and the UK**
- **Vattenfall sees significant growth opportunities within wind power. In terms of offshore wind, Vattenfall has a competitive advantage and intends to expand further**