



# WIND POWER **TECHNOLOGY**



**OPERATION, COMMERCIAL DEVELOPMENTS, WIND PROJECTS, GRID DISTRIBUTION**



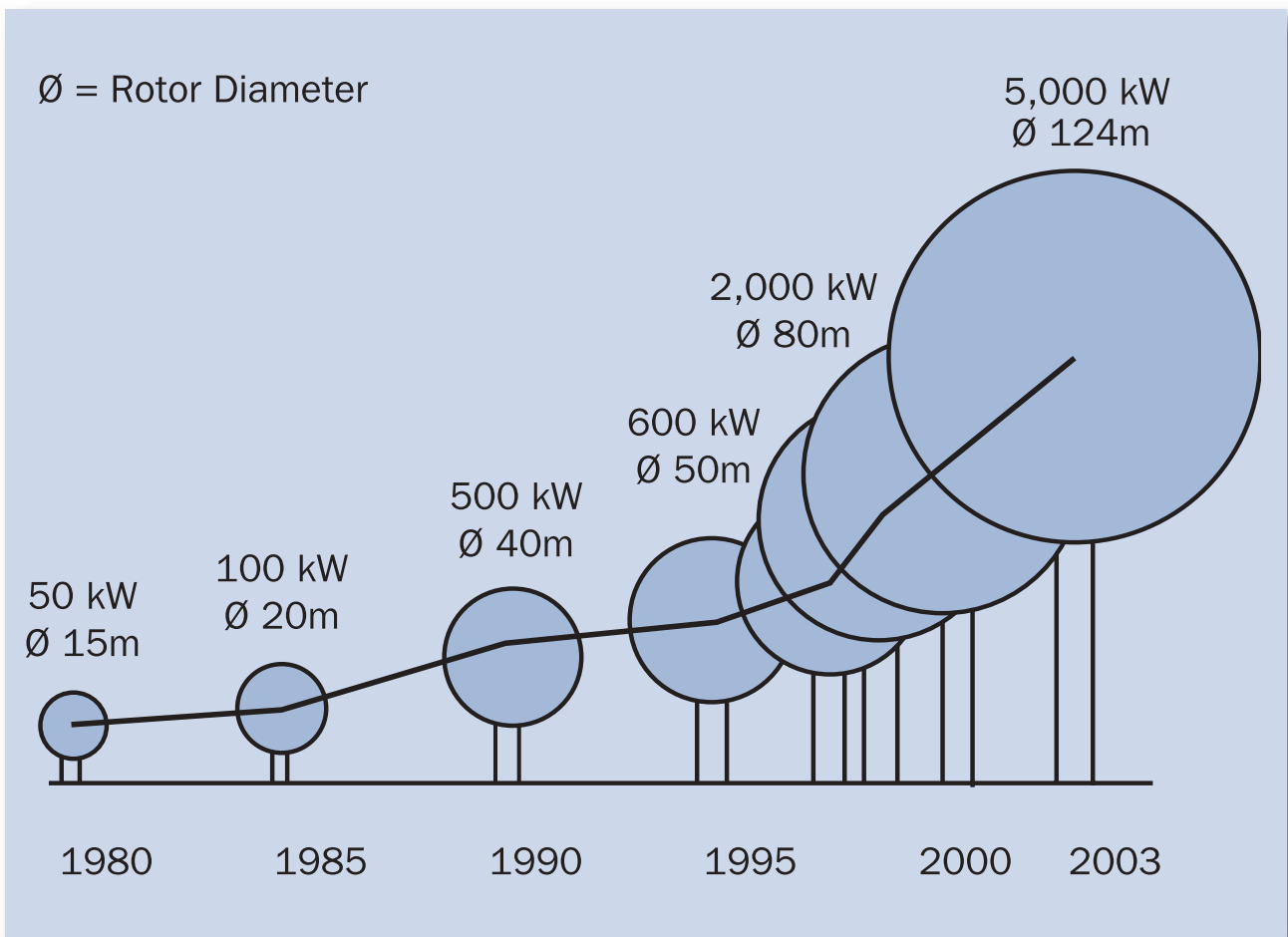
Since the beginning of the 1980s, the power of a wind turbine has increased by a factor of more than 200.

**“Developing Europe’s potential for using renewable energy will contribute to security of energy supply, reduce fuel imports and dependency, reduce greenhouse gas emissions, improve environmental protection, decouple economic growth from resource use, create jobs, and consolidate efforts towards a knowledge-based society”**

- The share of renewable energy in the EU' Communication from the Commission to the Council and the European Parliament Brussels 26.5.2004

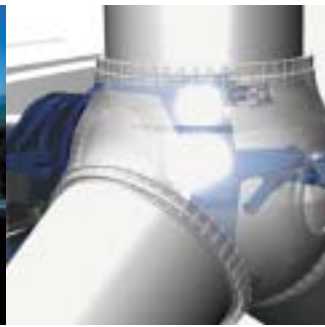


### Growth in Size of Commercial Wind Turbine Designs





Depending on its siting, a 1 MW turbine can produce enough electricity for up to 650 households



## How wind turbines operate

In contrast to the windmills common in the nineteenth century, a modern power generating wind turbine is designed to produce high quality, network frequency electricity whenever enough wind is available. Wind turbines can operate continuously, unattended and with low maintenance with some 120,000 hours of active operation in a design life of 20 years. By comparison, a typical car engine has a design lifetime of the order of 6,000 hours.

The rotors of modern wind turbines generally consist of three blades, with their speed and power controlled by either stall or pitch regulation. Stall regulation involves controlling the mechanical rotation of the blades, pitch regulation (now more commonly used) involves changing the angle of the blades themselves. Rotor blades are manufactured from composite materials using

fibreglass and polyester or fibreglass and epoxy, sometimes in combination with wood and carbon.

Energy captured by the steadily rotating blades is transferred to an electrical generator via a gearbox and drive train. Alternatively, the generator can be coupled directly to the rotor in a “direct drive” arrangement. Turbines able to operate at varying speeds are increasingly common, a characteristic which improves compatibility with the electricity grid.

The gearbox, generator and other control equipment are housed within a protective nacelle. Tubular towers supporting the nacelle and rotor are usually made of steel, and taper from their base to the top. The entire nacelle and rotor are designed to move round, or “yaw”, in order to face the prevailing wind.





From units of 20-60 kilowatts (kW) with rotor diameters of around 20 metres (m), wind turbine generators have increased in capacity to 2 megawatts (MW) and above, with rotor diameters of 60-90 m.



## Commercial developments

Manufacture of commercial wind turbines started in earnest in the 1980s, with Danish technology leading the way. From units of 20-60 kilowatts (kW) with rotor diameters of around 20 metres (m), wind turbine generators have increased in capacity to 2 megawatts (MW) and above, with rotor diameters of 60-90 m. The largest machine being manufactured now has a capacity of 4,500 kW and a rotor diameter of 112 m. Some prototype designs for offshore turbines have even larger generators and rotors.

Continual improvements are being made in the ability of wind turbines to capture as much energy as possible from the wind. These include more powerful rotors, larger blades, improved power

electronics, better use of composite materials and taller towers. One result is that many fewer turbines are required to achieve the same power output, saving land use. Depending on its siting, a 1 MW turbine can produce enough electricity for up to 650 households.

Since the beginning of the 1980s, the power of a wind turbine has increased by a factor of more than 200.

Wind turbines are highly reliable, with operating availabilities (the proportion of the time in which they are available to operate) of 98%. No other electricity generating technology has a higher availability.





**“More installations exploiting wind power can help to plug the growing gap in European electricity supply and at the same time dovetail with the Lisbon Strategy providing the EU with high-tech world-class technology”**

–Introduction to Wind Energy The Facts, DGTREN, European Commission, May 2004



## Wind resources and monitoring

The wind resource is the fuel for a wind power station, and just small changes have large impact on the commercial value of a farm.

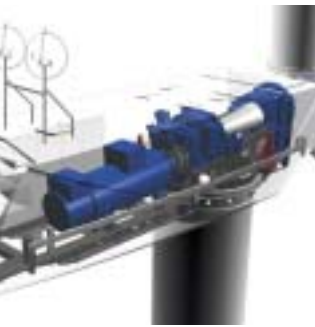
Every time the average wind speed doubles, the power in the wind increases by a factor of eight, so even small changes in average speed can produce large changes in performance. If the average wind speed at a given site increases from 6 metres per second (m/s) to 10 m/s, for example, the amount of energy produced by a wind farm will increase by over 130%. Detailed and reliable information about how strongly, from which direction and how regularly the wind blows, is therefore vital for any prospective development.

At a national and regional level, European wind atlases have been produced which record the

wind speed to be expected in particular areas. For specific sites, more detailed assessment is required using data from nearby weather stations and specialist computer software to model the wind resource. Finally, site specific measurements are carried out using an anemometry mast on which a number of anemometers measure the wind speed and direction at different heights above ground.

Overall, the exploitable onshore wind resource for the European Union (EU-25) is conservatively estimated to be capable of generating an output of 600 Terawatt hours (TWh). The wind resource in offshore waters has been assessed at up to 3,000 TWh. This alone would exceed Europe's entire current electricity consumption.





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## Wind farms

A number of constraints affect the siting of a cluster of wind turbines, usually described as a wind farm or park. These include land ownership, positioning in relation to buildings and roads, and avoidance of sites of special environmental importance. Once these constraints have been determined, the layout of the wind turbines themselves can be planned. The overall aim is to maximise electricity production whilst minimising infrastructure, operation and maintenance (O&M) costs, and environmental impacts. Specialist software has been developed to produce visualisations of how the turbines will appear in the landscape, enabling developers and planners to choose the best visual impact solutions before the project is constructed.

Apart from the turbines themselves, the other principal components of a wind farm are the foundations to support the turbine towers, access roads and the infrastructure to export the electrical output to the grid network. A 10 MW wind farm can easily be constructed within two months, producing enough power to meet the consumption of over 5,000 average European households. Once operating, a wind farm can be monitored and controlled remotely. A mobile team carries out maintenance work, with roughly two personnel for every 20 to 30 turbines. Typical maintenance time for a modern wind turbine is about 40 hours per year.

Wind farms can vary in size from a few megawatts up to the largest so far - 300 MW in the western United States.





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## Transmission and distribution

A key strategic element in the successful penetration of wind power is its efficient integration into the European electricity transmission and distribution network.

The increase in the penetration of wind power production into the grid raises a number of issues. Most are matters of utility attitude rather than engineering imperative.

- The output from a wind farm fluctuates to a certain degree according to the weather.
- Wind farms are often located at the end of the distribution networks. Most European grids have been designed for large-scale electricity generation from a relatively small number of large plants, sending power outwards towards the periphery, rather than in the opposite direction.
- The technical characteristics of wind generation are different to those of conventional power stations, around which the existing systems have evolved.

The requirement for grid network operators to handle an increasing proportion of such “distributed generation” is coming not only from wind energy. Environmental considerations and the liberalisation of the electricity market have increased interest in smaller scale commercial generation; a shift in both the attitude of utilities, and grid operation, is required to accommodate this development.

Intermittency issues require an understanding of **variability** and **predictability**.

Wind prediction techniques are at an early stage of development, and improvements can help firm up wind power for system operators by reducing and specifying forecast error.

Because of its intermittency, it has been suggested that grid stability issues might arise with the penetration of wind power above a certain level. Such concerns need to be weighed against the potential benefits, including local reinforcement of grids and the ability of variable speed turbines to contribute to grid stability. As more wind farms are connected to the system across a wide geographical area, their aggregate output is likely to even up the overall pattern of generation, resulting in less requirement for backup use of conventional power stations.

In balancing a system to accommodate the fluctuating input from wind power, a range of techniques are available to the grid operator. In a situation where a lot of wind is available, for example, the operator can maintain other types of generation plant at a low output. Other solutions are likely to become increasingly significant as wind energy’s penetration expands. These include forecasting and the use of interconnectors to neighbouring electricity networks, as described below. Using such techniques, as well as reinforcement of the grid network itself and increased geographical dispersion of wind power, it is feasible to have a very high level of wind penetration in the European electricity systems without affecting the quality of supply.

### • Forecasting

Much progress has been made in recent years in forecasting the energy output from wind farms. It has generally been found that with short measurement periods on a site, it is possible to predict output very accurately using a correlation with measured meteorological data from nearby weather stations.





The wind resource in offshore waters has been assessed at up to 3,000 TWh. This alone would exceed Europe's entire current electricity consumption.



• **Interconnectors**

An essential element in establishing wind energy is to ensure that the electricity generated can feed into the grid system, and reach electricity consumers. Experience has shown that combining a diverse mix of creative demand and supply solutions allows large wind power penetration in an electricity grid without adverse effect. In the Eltra system in West Denmark, for example, use of interconnectors to the large hydropower generators in Norway to the north and Germany in the south has allowed 30% wind energy penetration, with minor adjustments in grid operation.

The variability of the wind has produced far fewer problems for electricity grid management than sceptics had anticipated. On a few windy winter nights, wind turbines can account for up to 100% of power generation in the western part of Denmark, for example, but the grid operators have managed it successfully.

The majority of wind farms in Europe are presently connected to the local distribution system. With larger onshore and offshore parks being built, however, connection to the main transmission network will increasingly be sought.





**With turbines available of 2 MW rating and above, and projects of over 150 MW capacity already constructed, there is real progress in offshore wind farms.**



## Offshore technology

A growing market for offshore wind power is now the main driver for the development of larger turbine sizes. This has raised new technical demands, with the logistics involved in the manufacture, transport, erection and maintenance of offshore multi-megawatt turbines presenting a severe challenge.

Offshore wind turbines must be firmly positioned on the sea bed by using one of several foundation designs – steel monopiles driven deep into the sub-soil, gravity-based concrete caissons or tripod supports. Many kilometres of cables have to be laid both between individual turbines in an array and then back to shore to feed the electricity output into

the grid. Since turbine reliability is of paramount importance, effective maintenance requires the ready availability of service vessels which can access the turbines in rough sea conditions.

Initial designs for offshore turbines were essentially “marinised” versions of land-based technology, with extra protection against sea salt incursion. Machines now being designed include more substantial changes, such as higher blade tip speeds and built-in handling equipment for maintenance work. With turbines available of 2 MW rating and above, and projects of over 150 MW capacity already constructed, there is real progress in offshore wind farms.





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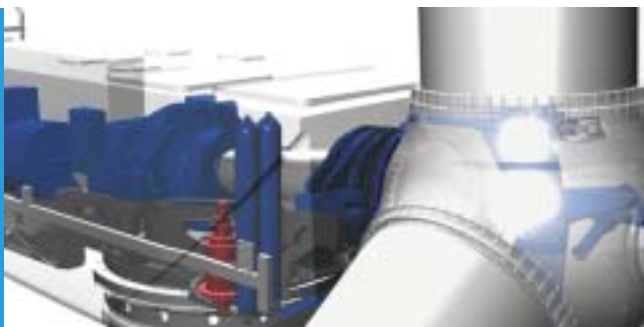
## The advantages of wind power

- 👉 **Low cost – can be competitive with nuclear, coal and gas on a level playing field**
- 👉 **The fuel is free, abundant and inexhaustible**
- 👉 **Clean energy - no resulting carbon dioxide emissions**
- 👉 **Provides a hedge against fuel price volatility**
- 👉 **Security of supply - avoids reliance on imported fuels**
- 👉 **Modular and rapid to install**
- 👉 **Provides bulk power equivalent to conventional sources**
- 👉 **Land friendly - agricultural/industrial activity can continue around it**

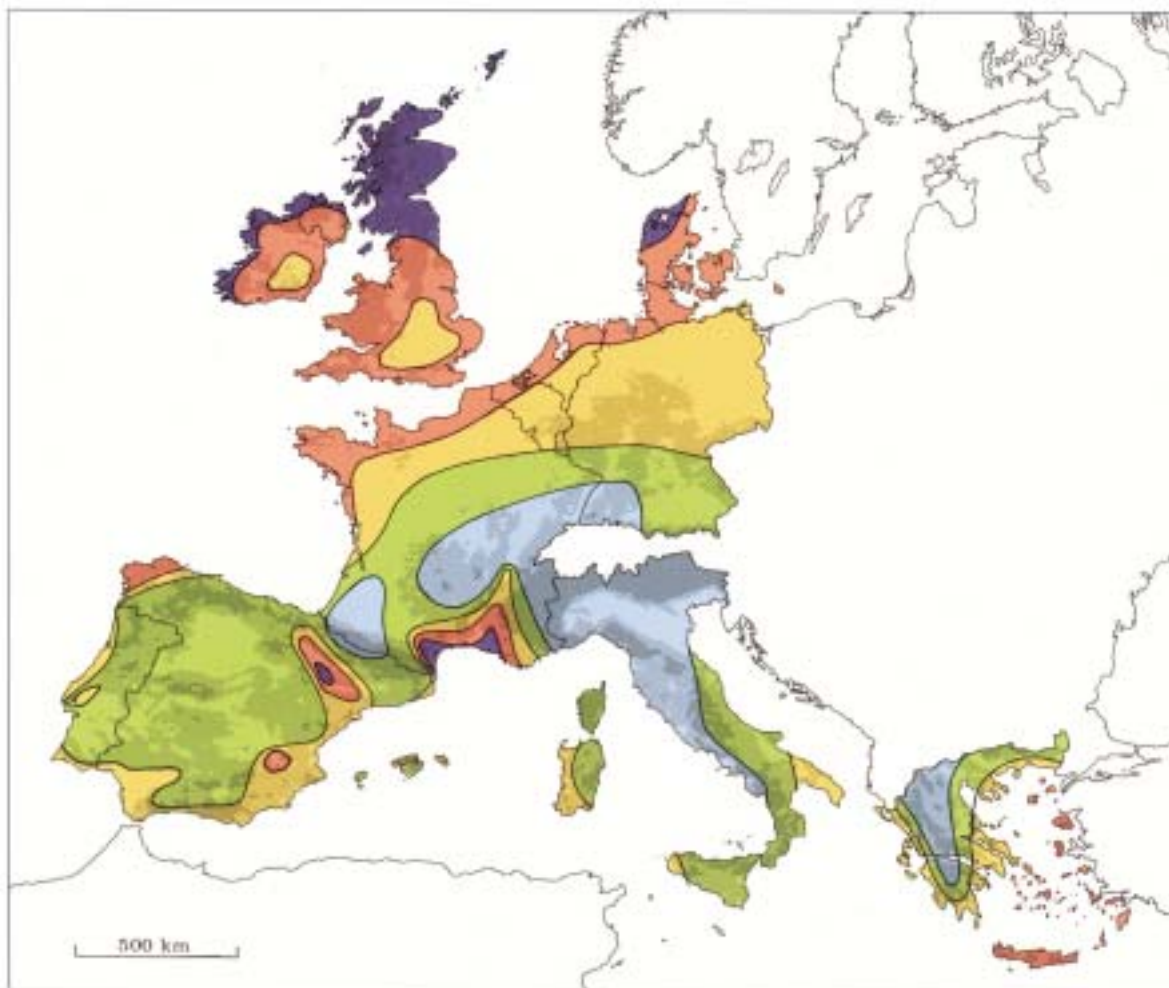




it is feasible to have a very high level of wind penetration in the European electricity systems without affecting the quality of supply.



**European Wind Atlas, Onshore (EU-12)**



**Wind resources at 50 metres above ground level for five different topographic conditions**

	Sheltered terrain		Open plain		At a sea coast		Open sea		Hills and ridges	
	$m s^{-1}$	$Wm^{-2}$	$m s^{-1}$	$Wm^{-2}$	$m s^{-1}$	$Wm^{-2}$	$m s^{-1}$	$Wm^{-2}$	$m s^{-1}$	$Wm^{-2}$
Dark Purple	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
Orange	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
Yellow	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
Light Green	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
Light Blue	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Source: Risø National Laboratory





## About EWEA

**EWEA is the voice of the wind industry - promoting the best interest of the sector in Europe and worldwide.**

EWEA members include manufacturers covering 98% of the global wind power market, as well as component suppliers, research institutes, national wind and renewables associations, developers, electricity providers, finance and insurance companies and consultants. The combined strength of more than 200 members from over 40 countries makes EWEA the world's largest renewable energy association.

Located in Brussels, close to key EU institutions and players, the EWEA Secretariat co-ordinate international policy, communications, research and analysis. The first stop for external enquiries about wind power from around the world, EWEA manages European programmes, hosts events and supports the needs of its members.

For further information and details of membership:

**[www.ewea.org](http://www.ewea.org)**



**EWEA**  
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More detailed information than this fact sheet can be found in the full version of Wind Energy the Facts