Wind energy is an attractive alternative to fossil fuels. It is plentiful, renewable, widely distributed, clean and produces no greenhouse gas emissions.

Europe remains a global leader in wind energy, although the global market share of top European turbine manufacturers dropped from 67% in 2007 to around 43% in 2012, as Chinese manufacturers take advantage of their stronger market. Even so, in 2013, three of the top five wind turbine manufacturers were European and the world leader (Vestas) is based in Denmark, with a 13.7% market share in 2013. During 2013, an estimated 35.5 GW of new wind power capacity was installed globally, bringing the total (cumulative) global installed capacity to approximately 318 GW (GWEC, 2014).

The EU-28 installed 11 159 MW of wind power capacity in 2013, of which 9 592 MW was onshore and 1 567 MW offshore (EWEA 2014). Overall, however, the European wind energy market decreased by 8% compared to 2012. Of the total 35.2 GW of new power generating capacity installed in the EU-28 in 2013, wind power accounted for 32% (11.2 GW), the largest share ahead of solar PV (31%) and gas (21%). Annual installations of wind power increased from 3.2 GW in 2000 to 11.2 GW in 2013, a compound annual growth rate of over 10%.

Wind's share of total installed power capacity has increased five-fold from 2.2% in 2000 to 13% in 2013. Over the same period, renewable capacity increased from 24.5% of total power capacity in 2000 to 39.6% in 2013.

Onshore wind energy is a mature technology that is nevertheless undergoing continuous improvements. Currently, R&D is primarily focused on maximising the value of wind energy and on taking the technology offshore, where public opinion is more supportive of new wind farm installations.

Although its share of total wind capacity remains small, the offshore wind sector saw another record year in 2013, with 1.6 GW of new capacity connected to the grid. Offshore wind power installations accounted for nearly 14% of total EU wind power installations in 2013, up 4% from 2012. The outlook for 2014 and 2015 seems stable, even if it is not growing (EWEA, 2014).

The trend for offshore wind farms is to build them further away from shore and in deeper water.

### EU 28 Electricity Production by Source, 2013

- **Conventional thermal**: 50%
- **Nuclear**: 27%
- **Hydro**: 12%
- **Wind**: 8%
- **Other**: 3%

Source: Eurostat
The Technology

The rotors of wind turbines (WT) transform the kinetic energy of the wind into mechanical energy, and then into electricity. Wind turbines are normally grouped together in wind farms in order to obtain economies of scale.

The main technological development in recent years is a trend towards ever larger wind turbines. Since the first commercial WT in the 1980s, WT size has evolved from 0.022 MW to machines of a maximum of 8 MW today. For this to be achieved, rotor diameters grew from 10 m to 120 m in 2002, then stabilising and only picking up significantly again from 2011. Several companies have machines, mostly prototypes, with rotors up to 171 m diameter already in operation. Turbine towers also grew significantly, from around 20 m in the early 1990s to just above 140 m today.

Currently, the turbine size of new projects in the EU is around 2.5 – 3 MW onshore and 6 MW offshore. The largest wind turbine now in commercial operation has a capacity of 7.58 MW and many manufacturers are introducing turbines in the 4.5 – 8 MW range, mostly for offshore use. Interest in 10 MW designs seems to have declined for the time being, although academia and the industry still foresee 10 – 20 MW turbines in the future.

This recent scaling-up of turbine size is driven primarily by the move to take wind technology offshore. Due to land use constraints, there are more suitable sites offshore than onshore, and wind speeds are higher and less turbulent away from land, leading to more wind energy generation.

Larger wind turbines lead to new challenges in the field of load control and turbine construction materials, while offshore sites require increased technological focus on foundations and materials adapted to the marine environment. The average water depth of offshore wind farms where work was carried out in 2013 was 20 m, slightly lower than in 2012 (22 m). The average distance to shore for those same projects was 30 km, almost the same as in 2012 (29 km).

The further deployment of wind farms will also need to be accompanied by developments in storage technologies and increased grid flexibility in order to be able to accommodate increasing levels of wind energy in the electricity network.

The speed of the tip of the rotor blade is limited by acoustic noise, operating at reduced speed in noise-sensitive areas. However, speeds above 80 m/s can be acceptable for offshore machines.

Fact file

• Wind speed is the most important factor affecting wind turbine performance. A site’s wind speed is measured through wind resource assessment prior to installation.

• Wind speed varies depending on the year, the time of the year, location, orography and other obstacles and it generally increases with height. Surface obstacles, such as forests and buildings, decrease the wind speed.

• For a given site, annual variations in electricity production of around 20% are normal.

• Wind power plants at the scale needed to provide electricity to national grids generally require minimum average wind speeds of 6 metres per second (m/s).

• A small difference in wind speed can bring a large difference in available energy and in electricity produced, as well as its cost. If long-term mean wind speed increases by around 67%, from 6 to 10 m/s, the energy produced increases by 134%.

• The system availability of European wind turbines is above 97%, which is among the best of the electricity generation technologies.

• Wind is already one of the most widely used renewable technologies. Global installed wind capacity has grown during the past decade at an average annual rate of over 28%. During 2013, an estimated 35.5 GW of new wind power capacity was installed globally, with 11.16 GW (32%) located in the EU-28 (GWEC).

• The reduction of Europe’s share of annual new capacity over the past few years is largely due to China and the US overtaking the EU in their rates of installation, which creates an opportunity for local producers.

• Typically, average capacity factors for wind power installations are 1800 – 2200 full-load hours onshore and 3200 – 4000 full-load hours offshore.

“Wind energy is the leading renewable energy technology. Given the right support it could provide up to 34% of EU electricity by 2030. However, this target will not be achieved if the sector and policy makers think with short-term objectives. Long-term, strategic action in technology and policy research, are fundamental.”

European Wind Energy Technology Platform (TF Wind)

Ongoing Research

Analysis shows that both corporate and public R&D investments are higher in countries with high GDP, but also that wind energy market penetration plays a role: countries where wind accounts for a larger share of the energy market tend to invest more in technology development. Consequently, Germany, France, Denmark, Spain and the UK all provided public funding to support private research initiatives through the demonstration stage. Of these countries, the UK has seen the largest increase in public R&D investment in wind technology, with a focus on offshore testing of new wind turbines.

Total European investment in wind technology research in 2010 amounted to almost EUR 882 million, rising to almost EUR 1028 million if European Energy Programme for
Recovery (EEPR) funding is included. According to IEA statistics, public investment in wind technology R&D across EU Member States has more than doubled in the last ten years, from EUR 60 million in 2001 to almost EUR 175 million in 2010. The European Commission has been an important contributor to overall investment, with EUR 146 million in EEPR funding for offshore projects in 2010 and over EUR 10 million through the Seventh Framework Programme (FP7).

The pan-European Twenties project started in 2010 with a total budget of EUR 56.8 million and an EU contribution of EUR 31.8 million under FP7 for three years. The EEPR also provided EUR 565 million for the deployment of large-scale offshore wind farms. The main driver of wind R&D in Europe is the European Wind Initiative (EWI) of the SET-Plan, bringing together industry, EU Member States and the EC. The EWI has an estimated investment of EUR 6 billion, shared between industry and public funding.

SETIS estimates an R&D intensity for the wind sector of 2.6 – 3.0%, which is considerably above the low R&D intensities of companies active in the electricity sector in general (0.6%) or oil and gas producers (0.5%). Funding should focus on actions that eventually reduce the cost of energy such as larger turbines, materials reduction, improved offshore installation vessels and other technological barriers. Better adaptation of power electronics to the marine environment is needed for offshore. Even though the overall financing needs for wind technology development have been met, it is unclear whether this funding has been used to attain the specific SET-Plan priorities for wind technology.

New system concepts include experimental technologies, such as floating turbines (e.g. HyWind by StatoilHydro/Siemens and SWAY/ AREVA-Multibrid) for deep waters, and even more experimental concepts such as airborne turbines (kite, balloon or auto-giros, including Magenn and MAGLEV) or the electrostatic generator (TU Delft).

The Industry

Wind energy has two distinct market sectors: onshore wind, which includes both inland and shoreline installations, and offshore wind, installed away from the coast. There are large differences between offshore and onshore due to the different access and working environments. It is more difficult to install and maintain wind farms at sea.

### Fact file

**Deployment costs**
- Average investment costs for onshore projects showed a reduction to EUR 1020/kW in 2004, then climbed to EUR 1410/kW for 2009 deliveries. However, lower WT demand led to an 18% turbine price reduction at the beginning of 2009, which drove down investment costs to EUR 1050 – 1400/kW by mid-2014.
- Offshore investment costs have been even more affected by supply-chain limitations. They climbed from EUR 2 200/kW in 2007 to peak at EUR 3 000/kW – EUR 4 200/kW in 2011 before initiating a reduction. Investment costs are expected to be 20 – 40% lower by 2020.
- Average onshore operational costs (OpEx) are around EUR 18/MWh all included and, over a 20-year operation period, constitute 30 – 40% of total costs. The pure maintenance component (O&M) has shown a declining trend from the EUR 35/MWh for the old 55 kW turbines to around EUR 10/MWh.
- Offshore OpEx costs, at EUR 25 – 40/MWh, with a European average of EUR 30/MWh, are higher mainly due to the high cost of access, even if higher production partly compensates.
- In 2012, off shore O&M costs were down significantly (EUR 23 MWh), compared to EUR 36/MWh two years earlier.
- Improved supply-chain and competition could lead to a reduction in costs of 15 – 20% for offshore wind by 2015.

**Anticipated greenhouse gas savings**
- According to EWEA calculations, wind energy avoided 140 Mt of CO2 in 2011; by 2020 the annual CO2 avoided from wind energy will increase to 342 Mt and by 2030 to 646 Mt.

**Employment**
- If the EWEA targets are met, over 520 000 people will be employed in the wind energy sector by 2020. By 2030, over 794 000 people are expected to be employed in the sector, of which 62% will be employed offshore.
The average offshore wind farm size was 485 MW in 2013, 78% more than the previous year.

According to the European Wind Energy Association (EWEA), investment in EU wind farms was between EUR 13 billion and EUR 17 billion in 2013. The onshore sector attracted investments of between EUR 8 billion and EUR 12 billion, with the offshore sector receiving between EUR 4.6 billion and EUR 6.4 billion. Offshore wind accounted for 14% of total EU wind power installations in 2013.

The wind market is affected by supply/demand imbalance and changes in raw material and component prices. Wind turbine prices, which were expected to continue in a downward trend through technological innovation, began to increase in 2004 and had risen by up to 40% by 2006. By 2008, onshore turbine prices reached a high of EUR 410/kW installed before dropping to EUR 1 150/kW in 2009. In recent years, over-capacity among manufacturers, increased competition, increasing scale, and greater efficiency have combined to drive down turbine costs even further, to around EUR 890/kW by mid-2013 (JRC, 2013). Offshore turbine prices are currently around EUR 1 320 – 1 540 /kW.

In spot-priced, wholesale electricity markets, zero-fuel-cost technologies, such as wind energy, reduce marginal costs. In periods when prices for fossil fuels are high, the resulting multiplying effect overcompensates for the subsidies that wind power receives.

Top European wind turbine manufacturers have suffered a reduction in their global market share from 67% in 2007 to 37% in 2011, before a slight recovery to 46% in 2013. Chinese manufacturers have also fallen victim to increased international competition and to the contraction of their domestic market.

Barriers

A significant obstacle to deploying wind energy is still the high up-front capital cost, which makes wind electricity prices uncompetitive with conventional sources of energy at low fuel prices.

This is exacerbated by a lack of vision by certain governments regarding the future deployment of renewables in general, and wind in particular. Support policies have not taken into account the rapid rate at which equipment costs have been falling.

From a system point of view, the main barrier to large-scale wind deployment is grid integration. Current electricity transmission and distribution systems have been designed and developed to manage more traditional generation technologies, and are not appropriate for large-scale wind penetration, whether centralised or distributed. Increasing shares of wind energy will require a new grid philosophy and operational procedures, and flexible, robust transmission and distribution grid infrastructures. Energy storage mechanisms to compensate for the fluctuating nature of wind generation will also be critical enablers for large-scale deployment.

Technological challenges for wind energy include improved interconnections to the grid, as well as a better service to the grid in terms of support and quality of the electric signal. Barriers that need to be overcome in scaling up turbines include reducing the weight (and cost) of drive trains and the nacelle mass so that mechanical loads are reduced.

Maintenance requirements and facilitating access are a challenge, particularly for offshore wind farms, which are inherently high-risk installations from an operational health and safety point of view. Offshore installations also need new, economic support structures, designed for waters with depths of more than 30 metres.

Social barriers preventing energy uptake include the perception that wind farms spoil the landscape and a shortfall of trained, experienced staff, particularly for the expected growth in offshore development.

The limitation of existing EU research facilities (both public and industry-housed), for testing wind technology at an appropriate (large) scale, and under relevant climatic conditions, poses a potential barrier to scaling up turbine sizes and to offshore deployment.

Needs

The conditions for wind energy operation need to be more fair and flexible in all Member States. Grid compliance comes at a cost and if grid codes were harmonised in Europe this cost would be reduced. Some Member States still have slow, cumbersome and expensive permit procedures.

The EU should create an appropriate framework for the development and integration of the electricity grid to support renewable energy penetration. The reinforcement of grid interconnections and the facilitating of legal or institutional conditions for market integration are consistent with general EU energy policy and support the internal market.

It is important to ensure the channelling of R&D support to the thousands of small and medium enterprises (SMEs) making up the component supply chain, to enable them to keep the required innovation pace and expand their manufacturing capacities.

Installed capacity

With 117.3 GW of installed wind capacity at the end of 2013, the EU-28 has more than one-third of the 318.1 GW of wind capacity installed globally (Global Wind Energy Council, 2014). Wind is expected to be one of the main contributors of electricity production from renewable sources (RES-E). Installed wind capacity has grown at an average rate of 25% per year over the last ten years. Wind capacity installed by the end of 2013 would produce 230 TWh of electricity in a normal year, representing about 8% of EU electricity consumption.

The European wind industry association, EWEA, in its 'central scenario', has recently revised its 2020 target downwards from 230 GW of installed capacity in Europe, including 40 GW offshore, to 192 GW of wind power, producing 442 TWh of electricity, meeting 14.9% of electricity consumption. By 2030, EWEA predicts an increase to 400 GW, of which 150 GW will be offshore.

For further information:

SETIS section on wind energy
http://setis.ec.europa.eu/technologies/wind-energy

European Wind Energy Technology Platform
http://www.windplatform.eu/

European Wind Energy Association (EWEA)
http://www.ewea.org/