Geofile Online
SEPTEMBER 2012
674

NEIL PUNNETT

WIND ENERGY

Harnessing the kinetic energy of the wind and converting it to mechanical energy and electricity is one of the most rapidly growing, cost-effective and proven renewable energy technologies. By 2012, 22 countries had installations of more than 1,000 megawatts, compared with just 11 countries in 2006. Both China and the USA have over 50,000 MW of installed wind energy, and total world wind energy installation amounted to over 250,000 MW in 2012. This represents a ten-fold increase since 2001, yet wind energy still amounts to only 3% of total world electricity production. This **Geofile** looks at the current situation, focusing on case studies from the UK, USA and Germany, and considers the future for wind energy.

Until recently most wind turbines have been sited on land, either individually or grouped together in wind farms. The pace of technological development within the wind energy sector has been rapid and wind turbine power units are increasingly efficient. Even so, the average efficiency rating for wind turbines is only 30%, ie the turbine will generate 30% of the potential maximum available energy from the wind; this compares with over 40% efficiency for nuclear and fossil-fuel power stations. Wind turbines will operate for 70-90% of the time, depending on the site characteristics, but not at full capacity. Most wind turbines start generating electricity at wind speeds of around 12 km per hour, and at around 55 km/hr

Figure 1: Windpower capacity in 2010 (MW)

Country	Capacity (MW)
China	44,733
United States	40,180
Germany	27,215
Spain	20,676
India	13,066
Italy	5,797
France	5,660
United Kingdom	5,204
Canada	4,862
Denmark	3,752
Netherlands	2,270
Japan	2,304
Sweden	2,019
Australia	1,880

Figure 2: The advantages and disadvantages of wind power

ADVANTAGES	DISADVANTAGES
• Wind energy is a renewable source of energy which produces no carbon or sulphur dioxide emissions and replaces generation from conventional power stations. Wind energy thus does not contribute to the greenhouse effect which is thought to be causing climate change. The UK government estimates that the net savings from wind power in 2010 were 6 million tonnes of carbon dioxide. This takes account of the effect of fossil fuel power used for back-up during times that wind power was not available. • Although wind turbines can be very tall (over 160m high), each takes up only a small plot of land. This means that the land below can still be used for agricultural purposes. • Wind turbines are available in a wide variety of sizes, which means that users can range from single households and businesses to vast wind farms supplying whole regions. • Wind energy is freely available and secure, countries do not have to depend upon supplies of fuels from other countries which may be insecure. • Unlike many other power stations, wind energy systems require minimal maintenance and have low operating expenses. • Decommissioning of wind farms is straightforward and leaves no toxic residues or environmental damage. • Wind energy can bring wider economic benefits to a country. For example, there are an increasing number of companies around the UK involved in manufacturing turbine components and installing, operating and maintaining turbines. A survey published in January 2011 by trade body RenewableUK showed 10,800 full-time employees working in the wind energy sector at the start of 2010. 56% were associated with large-scale onshore wind, 29% in offshore wind, 15% in small-scale wind energy.	• Some people find wind turbines visually unattractive, spoiling the countryside and altering its natural form. • Wind turbines are noisy. Precisely how noisy is a subject of controversy. One group opposing wind energy states: a researcher from the Daily Telegraph recorded 65dB at a distance of 800m from a wind farm near Peterborough. This rose to 76 dB standing beneath a turbine, which is not as loud as a busy main road (80 dB). Technological development means many modern turbines have no gearbox, resulting in reduced noise. • Wind turbines can create turbulence and vibrations. Acoustic scientists estimate a fifth of Britain's wind farms generate a low frequency hum that can be audible for more than a kilometre and can be very intrusive. The pulsating sound, a phenomenon called amplitude modulation, is probably caused by turbine blades striking patches of turbulent air. • Suitable sites for wind turbines are often in remote locations, distant from areas of demand for electricity. Thus there is an additional expense in connecting to the National Grid so the electricity can be distributed to the appropriate areas, and obtrusive pylons and power lines cross the countryside. • Wind power receives high subsidies from some governments. For example, the UK government estimates that the impact of the Renewables Obligation (the Government's main subsidy for large-scale renewable electricity) on average household electricity bills in 2011 was £20, of which half is accounted for by wind power. • Because wind turbines cannot provide a constant supply of electricity, other types of power station have to be built to provide cover for less windy periods. In practice this means fossil-fuelled or nuclear stations. Some of them have to be kept expensively operating at less than full load in order to be ready to cover periods of lower wind speeds. • Wind turbines kill birds, especially at higher rotation speeds when the turbine blades can become invisible. • Windfarms can interfere with the radar the aviation industry needs to operate safely. RenewableUK reported that in 2010, at least 66% of all wind farm applications were subject to objections from the aviation sector. • Offshore wind turbines have a design life of 20 years, but several of the earliest turbines have had to be replaced after only eight years in the North Sea environment. A number of onshore wind turbines have also proved vulnerable to damage. On 6 January 2012 three wind turbines in West Yorkshire shed blades in gale force winds. Debris was blown across a road into a neighbouring property. The damage occurred when wind speeds peaked at 125 km/hr during fierce storms. In December 2011 a 90m turbine in Ardrossan, North Ayrshire, erupted in flames during gales of 265 km/hr. It was said to have been switched off, but experienced a brake system failure.

Geofile Online © Nelson Thornes 2012

they generate their maximum output. At wind speeds greater than 90 km/hr they have to be shut down in order to prevent storm damage. The term **capacity factor** is used to represent the extent to which the generator is producing electricity over a period of time, usually a year. Wind turbines have capacity factors of between 30 and 45%, whilst nuclear and fossil-fuel stations have capacity factors above 90%.

Wind energy has both advantages and disadvantages, as shown in Figure 2.

Wind energy in Germany

Germany has been at the forefront in the development of wind power. In 2010 the installed capacity was 27.2 GW (Figure 3). Wind power currently produces about 6% of Germany's total electricity and employs 80,000 people. The renewable energy sector benefited when the Green Party joined the Federal Government between 1998 and 2005. The Renewable Energy Sources Act promotes renewable energy, mainly by feed-in tariffs that grid operators must pay for renewable energy fed into the power grid. People who produce renewable energy can sell their 'product' at fixed prices for a period of 20 or 15 years. This has created a surge in the production of renewable energy. In 2001 a law was passed requiring the closure of all nuclear power plants within a period of 32 years. The shutdown time was extended to 2040 by a new government in 2010, but following the Fukushima incident in Japan, the law was abrogated and the end of nuclear energy was set for 2022.

The cost of replacing Germany's nuclear power with renewable energy has been estimated by the German Ministry of Economics at £0.01/kWh (£50 bn over the next decade), on top of the £12 bn per year already devoted to subsidising renewables. However, unofficial estimates put the cost several times higher, at about £220 bn over the next decade.

The development of wind power has been enthusiastically welcomed by politicians in Germany's north-eastern region. The region's depressed economy stands to benefit from a rush to tap the potential of wind energy. There are more than 1200 wind turbines on land, and a new push into offshore wind energy in the Baltic will further fuel that growth. Germany's first commercial offshore wind farm, 'Baltic 1', lies16 km north of the Darss-Zingst peninsula and covers about 7 sq km. This 48.3 MW project with 21 turbines began generating in May 2011. By 2013, Baltic 1's owner, Energie Baden-Württemberg AG, aims to complete 80 more wind turbines in the 'Baltic 2' development, 32 km offshore, with a capacity of 288 MW.Germany expects to have some 25 MW of offshore wind energy capacity by 2030.

Many new jobs have been created at firms such as Nordex, which employs 1,000 in Rostock making lightweight wind turbine rotor blades up to 65 metres long. The firm has invested £100 m expanding its plant, and exports some 95% of its output. These highly skilled jobs are sorely needed, in a sparsely populated state whose industrial base was devastated by the economic upheaval accompanying Germany's reunification in 1990. There were 32,800 jobs in the shipyards around the port of Rostock when the Berlin Wall fell in 1989. Most were lost when the East German shipbuilding industry collapsed in the face of surging labour costs and fierce western competition. There are only 3,300 shipyard jobs left and the industry's demise epitomised the east's decline. Mecklenburg-Vorpommern became one of Germany's poorest regions. The jobless rate soared to 20% in 2004 – double the national average – and the population fell by 250,000 to 1.6 million as mostly young, well educated people moved to the more prosperous west in search of employment. Since then the gloom has lifted as unemployment has nearly halved. More than 8,000 left the state in 2008, but only 3,500 moved away in 2010, at least partly due to the increasing job opportunities brought by the wind energy sector.

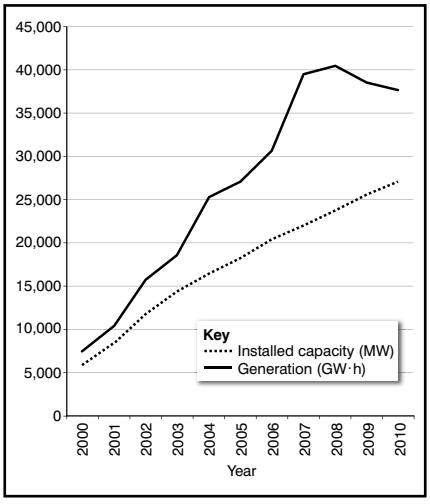
Wind energy in the USA

By 2012 the installed wind power capacity in the United States was 50.1 GW, making it second in the world behind China. In 2010 wind power accounted for 2.3% of the electricity generated in the United States. The federal government has given special incentives for investment in wind farms and, in addition, many US states have adopted favourable legal frameworks for wind energy in order to attract investment.

The Roscoe Wind Farm in Texas, 45 miles south-west of Abilene, is owned and operated by the German power company EON. It was the world's largest capacity wind farm in 2011, with 627 wind turbines and a total installed capacity of 781.5 MW. The wind farm is situated on 40,000 ha of land, primarily used for cotton farming. Construction began in May 2007, and the wind farm has been operational since October 2009. The Roscoe wind complex provides the community with 70 full-time jobs.

The project cost more than £0.65 billion, but it benefits from state subsidies. The Texas Economic Development Act allows districts to cap property rates so that businesses pay taxes on less than the full value of the property while the state largely offsets any revenue loss. For Roscoe, EON pays property taxes on £7 million, instead of on the estimated value of £240 million.

Figure 3: (a) Wind energy capacity and generation in Germany 2000–2010



(b) Wind energy's share of renewable electricity generation in Germany in 2010 (101 TwH, or 17% of total electricity production)

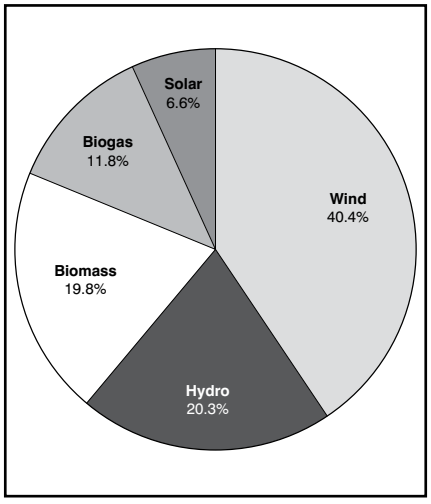


Figure 4: UK electricity generating costs

Energy Source	£/MWh
Gas (not including carbon costs)	65-105
Gas (including carbon costs)	80-110
Coal (not including carbon costs)	65-130
Coal (including carbon costs)	105-145
Nuclear	100
Onshore wind	95
Offshore wind	160-190

Source: UK Electricity Generating Costs Update June 2010 Mott MacDonald

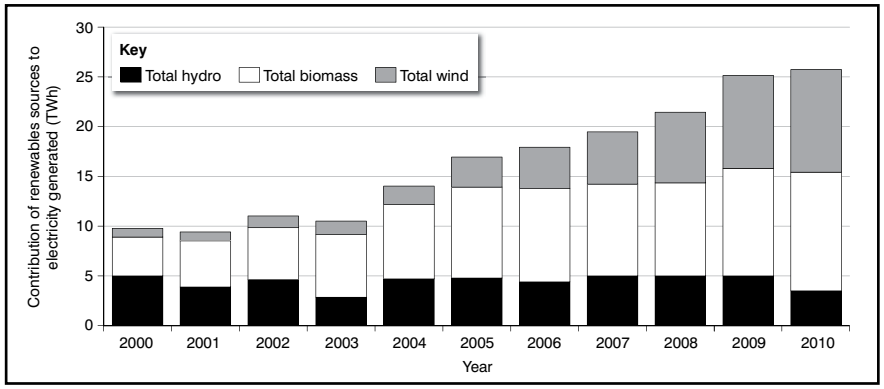
The US Department of Energy has predicted that wind power could supply 20% of all US electricity by 2030, which includes a contribution of 4% from offshore wind power.

UK wind power

The UK government reaffirmed its commitment to wind energy in 2011 as part of its strategy to move away from finite, high-carbon fossil fuels to cleaner, more secure energy sources. The 'Renewables Obligation' is designed to encourage generation of electricity from renewable sources. Introduced in 2002, the RO places an obligation on electricity suppliers to source an increasing proportion of electricity from renewable sources. In 2011 this figure was 11.1%, having been set at 3% in 2002, and under current political commitments will rise to 15.4% by 2015 and then run until 2037.

The government stated that wind will be a key component in meeting the UK's 2020 target to derive 15% of its energy from renewable sources: 'The Government believes wind power has a vital contribution to make both to our energy security and our low-carbon goals, as part of a diverse energy mix with other renewable sources, nuclear, clean coal and gas.' A report published in June 2010 establishes onshore wind power as one of the cheapest sources of energy for the UK (Figure 4). 58% of renewable electricity capacity in 2010 was from wind, 18% from hydro and 11% from landfill gas (Figure 5). By 2012 there was an installed capacity of 4.1 GW of onshore wind in over 600 sites (Figure 6).

Figure 5: UK Electricity generation by main renewable sources 2000-2010



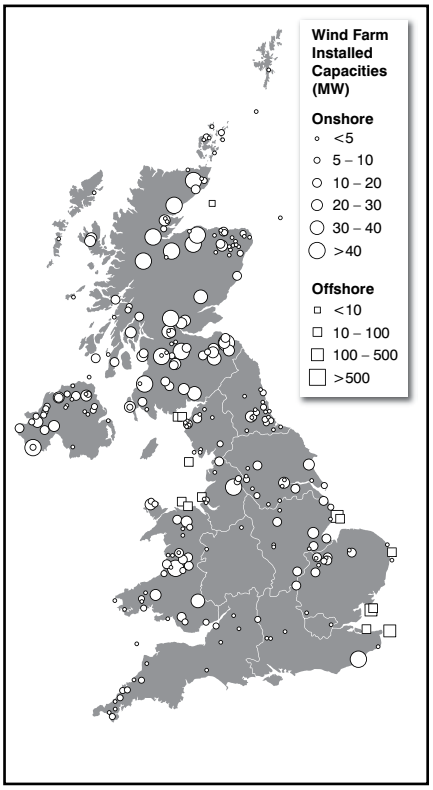
An example of smaller scale onshore wind energy is provided by the Ford Motor Company's Dagenham Diesel Engine factory. Three turbines with a capacity of 4.6MW produce all the electricity used by the factory, 12 million kWh per year. This saves 5000 tonnes of carbon emissions per year.

On a much larger scale, Scout Moor Wind Farm is the largest onshore wind farm in England. Built for Peel Wind Power Ltd, it produces electricity from 26 wind turbines. It has a total capacity of 65MW of electricity, providing 154,000MWh per year (a capacity factor of 27%), enough to serve the average needs of 40,000 homes. The site occupies 545 ha of open moorland between Rawtenstall and Rochdale. The 80 metre diameter turbines and 60 metre high towers are visible from as far away as south Manchester, over 30 km away.

The DECC estimated that further onshore wind projects will make up 15% of the growth in renewable energy capacity required to reach the 2020 target. The bulk of the remainder will come from offshore wind farms, a more recent development on the UK energy scene, but embraced with such enthusiasm that the UK now produces more electricity from offshore wind turbines than the rest of the EU put together.

Offshore winds tend to blow at higher speeds and are more consistent than on land, thus allowing turbines to produce more electricity (the potential energy produced from the wind is directly proportional to the cube of the wind speed, so wind speeds a few km per hour higher can produce a significantly larger amount of electricity). In the Irish Sea, 10 km from Barrow-in-Furness is Ormonde offshore wind farm. Thirty turbines with rotors of 126m diameter have a

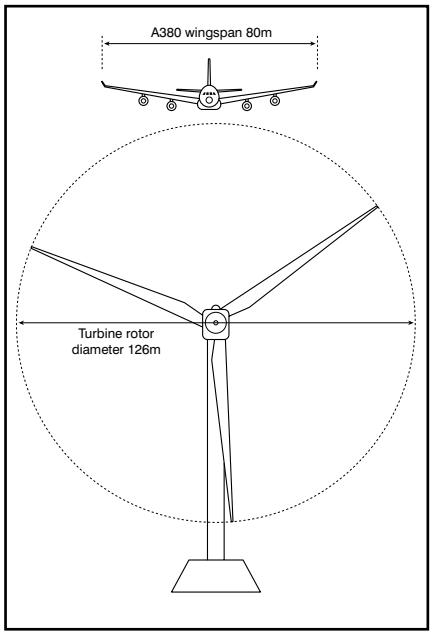
Figure 6: The location of wind farms in the UK as at January 2011



total capacity of 150 MW. The wind farm occupies nearly 9 sq km of sea, with depths of up to 30m at high tide. Each giant turbine weighs 661 tonnes, which dwarfs the world's largest airliner, the Airbus A380 Superjumbo (Figure 7).

Ormonde's electricity is carried by underwater cable to Half Moon Bay and on to a substation at Heysham. The completion of Ormonde in early 2012 boosted the UK's wind energy installed capacity to over 6 GW. The growth of wind energy is vital to the UK, because 11.4 GW of the UK's coal-fired power stations will be decommissioned by 2015, and 7 GW of nuclear power by 2020, 23% of the total generating capacity connected to the national grid.

Figure 7: Comparative Dimensions of an Airbus A380 and an Ormonde Wind Farm 5 MW turbine



Ormonde is owned by the Swedish company Vattenfall, which also owns the UK's largest offshore wind farm, Thanet, which opened in 2010 and has a capacity of 300 MW. Thanet has one hundred 3 MW turbines, smaller than those at Ormonde but still an impressive size with rotors of 90 m diameter. Located 12 km off Foreness Point in Kent, the entire Thanet wind farm covers 35 sq km. Vattenfall invested £800 m in the Thanet project. It is calculated that Vattenfall will receive £30-£40 million per year for Thanet's electricity, plus a subsidy of £60 million per year from the UK government via the Renewable Obligation. Vattenfall estimates a capacity factor of 35-40% for the Thanet Offshore Wind Farm, or 105-120 MW. The wind farm was expected to create 90 permanent jobs, but actually only 21 have resulted.

Official figures from the Department for Energy and Climate Change show up to 32,000 more wind turbines could be erected over the next 20 years, of which 26,000 would be offshore sites. This will not happen without some fierce opposition from some quarters. A report published in late 2011 by the Scientific Alliance and the Adam Smith Institute described Britain's renewable energy ambitions as a 'mirage'. The report claimed that placing heavy reliance on wind power to deliver a large part of our electricity in the future is unrealistic. The Adam Smith Institute claimed the purpose of the report was to prevent Britain from 'sleepwalking' into a future energy system that it claimed will not work. Instead, the Institute promoted nuclear and increased use of combined-cycle gas-fired generating power stations.

Each onshore wind farm development has to receive planning permission, and opponents say that the political imperative to introduce wind energy as swiftly as possible is leading to unreasonable projects being approved. One example is the Kelmarsh wind farm project near Naseby in Northamptonshire. The proposal for 7 wind turbines rising to 126 metres would have a capacity of 13.8MW, but it would be built close to the site of the Battle of Naseby, fought in 1645, which marked the end of the English Civil War and the defeat of King Charles 1. It has been called the most significant battlefield in the UK, because it marks the overthrow of autocratic monarchy and the beginning of parliamentary democracy. Daventry District Council refused consent in May 2011. EON appealed, producing a revised proposal for six turbines, and a public enquiry was held in September 2011. On 19 December 2011 the Planning Inspectorate indicated that planning permission would be granted for the wind farm, despite acknowledging that the wind farm would detract from the significance of the battlefield and harm its setting. This led to questions in Parliament and the establishment of a pressure group of MPs seeking to prevent any more onshore wind farms being constructed in the UK. The Conservative MP for Daventry, Chris Heaton-Harris, is the driving force behind the new group. He said: 'Ministers need to look at this policy again. It is an inefficient technology, it adds to the bills of consumers, it harms the balance of the National Grid, it is the wrong renewable for the UK. We need a change of policy.'

Future developments in wind energy

Two technological developments currently being tested could help to overcome some of the main disadvantages of wind energy. First, the Dynamic Power Resource dry cell battery system designed by xTreme Power Inc is a system to store large amounts of electricity generated during windy periods, which can be released at times of lower or no wind. The system enables wind energy's power generation to be more consistent. Small versions up to 10 MW are already in operation, but aDPR system designed to store 36 MW of electricity is being built alongside the 153 MW Notrees wind farm in Texas and is planned to be in operation by early 2013. Storage on this scale could significantly enhance wind energy's future.

Secondly the effect of wind turbines on aviation radar systems has been tackled by Cambridge Consultants in the UK, which has developed a holographic radar infill sensor system to be located at wind farms which would eliminate the false signals which currently appear on air traffic control radars. If this system is successful it will overcome objections to many proposed wind farm locations.

Useful Websites

http://www.wwindea.org/home/images/stories/worldwindenergyreport2009_s.pdf

http://www.texastribune.org/library/multimedia/wind-farm-money-spending-schools/

http://www.renewableenergyfocus.com

http://www.bwea.com

http://www.ukoffshorewind.com

www.decc.gov.uk/

www.eon.com

www.vattenfall.co.uk/

Focus Questions

1 Some communities welcome the development of wind farms in their area, while others have resisted them. Suggest reasons for these different attitudes.

2 With reference to one named country, describe and explain the increase in the exploitation of wind energy.

3 Assess the future potential of wind energy in securing sustainable energy.