Energy Briefing Sheet: Wind Energy

ICE's energy briefing sheets provide an informative guide to the various sub-sectors, issues and challenges within the energy industry. Authored by members of our Energy Expert Panel, our briefings are updated regularly and are intended to provide accurate information to a varied audience.

This briefing sheet focuses on wind energy.

1.0 Electricity from Wind Worldwide (2013)

Commercial wind turbines are being installed worldwide by all the main industrialised countries as part of an international drive to reduce atmospheric pollution (which causes climate change), to provide indigenous energy and to reduce dependency on finite oil and gas reserves.

Global installed wind turbine capacity at the end of 2013 was 318,105MW across 116 countries, primarily, 38% in Europe, 36% in Asia and 19% in USA. European country installations have lost place to US and Chinese interests (GWEC).

With 75,000MW of capacity, China is now the largest by country, overtaking the USA in 2008. China also boasts the largest wind farm in the world, Gansu Wind Park, at over 5,000MW – it is in fact a combination of smaller separate wind farms in the same region.

The UK is a leader in the development of larger offshore wind farms due to high wind speeds and a large area of relatively shallow coastal water. The largest individual offshore wind farm in the world is the London Array with 630MW capacity. Others are planned up to 2,500MW.

Global investment in wind energy for 2010-20 is estimated at $980 billion (IEA).

2.0 Renewable Energy in the UK (2013)

UK national policy is "to put ourselves on a path to cutting CO_2 emissions by some 80% by about 2050, with real progress by 2020" (Energy White Paper).

Current EU policy requires member states to achieve 20% of all EU energy to come from renewable sources by 2020. The UK's contribution to this has been agreed at 15% of energy (currently electricity accounts for ~19% of UK energy consumption).

A UK contribution of 15% of all energy by 2020 is being aimed primarily at electricity generation and would require approximately 35-40% of electricity to come from renewables. This could require 35,000MW of wind capacity to be installed (mostly offshore – see Section 6.0).

As of 2013 the current contribution to electricity of all renewables is approximately 14.9%, of which wind provides 7.9% (DECC).

As of the end of 2013 there is approximately 11,187MW of operational wind capacity in the UK, across 657 projects. Offshore accounts for approximately 35% of this capacity across a small number of large projects.

There is approximately 3,128MW capacity under construction (44% offshore), 11,462MW consented (54% offshore) and 17,329MW in planning (60% offshore) (UKWED).

3.0 Wind Turbine Technology

Wind turbines for current UK onshore wind farms are typically three-bladed, of 70-90m rotor diameter, a 70-80m tower, and with a generating capacity of up to 3MW. Several smaller commercial turbines are available for constrained areas. In Europe some larger turbines are installed, some as pre-production offshore prototypes.

Wind energy involves the cube law whereby a 10% increase in wind speed yields about a 30% increase in available energy. High wind speed locations, large rotors and high towers therefore yield more energy, but are subject to other constraints.

Turbine sizes for offshore wind farms have been in the 90-126m rotor diameter range with a generating capacity of at least 3MW, but designs are being driven to much larger units, due to the increased unit cost of foundations and installation. The largest current prototype has a 164m diameter rotor (each blade weighing 35 tonnes) and is of 8MW rating.

All current large commercial turbines in use are horizontal axis machines. A few smaller vertical axis machines remain but the technology for large machines has proved not to be cost-effective.

Wind turbines are designed to reach maximum rated power at a hub height wind speed of 12-18m/s (33-40mph). Power is then regulated (usually by full blade pitch, occasionally by stall regulation) up to a designed cut-out wind speed of about 25m/s (56mph, Beaufort Scale Force 9-10).

The capacity factor for wind projects is typically around 25-35%, i.e. the average percentage of continuous output at maximum capacity actually achieved. Figures of approximately 35-40% are achievable on some offshore sites and in exposed northern UK locations. Lower wind speed areas yield 20-30%. Capacity factors can be modified using different turbine configurations (i.e. larger rotor/smaller generator).

3.1 Intermittency

The electrical output of a wind turbine varies with wind speed. Unit variability is smoothed across a large area of wind farm and further by geographical distribution. National Grid has determined that intermittent renewable (or other) generation can be handled within the current transmission system up to around 20% penetration and thereafter is manageable with some capacity cost. European grid interconnection is seen as one way of managing demand and supply variability.

4.0 Costs of wind power

From 2013-14 the UK Government has promoted Electricity Market Reform (EMR) to establish new forms of support for renewable energy. This is based on two main programmes administered by OFCOM:

Feed-in Tariff (FiT) is a mechanism for smaller scale commercial or domestic generators (e.g. roof-top solar panels). For small onshore wind these vary (by capacity) from 7.24p/kWh to 16p/kWh. (OFGEM)

CfD (Contract for Differences) is for all large industrial scale renewables. The CfD programme funds a variable top-up price per MWh of renewable electricity between the wholesale market rate and a "strike price", set by government, designed to ensure sufficient return for investors and operators to build and operate renewable generation plants. The CfD system is still in development but the 2014-15 strike price for onshore wind generation is £95/MWh (9.5p/unit) and the offshore wind price is £155/MWh. The strike price will vary over time depending on the required level of incentive. This strike price is an indicative cost of electricity from wind including an element of incentive payment for new build (DECC).

Previously, and up to around 2017 (subject to government schedule), the main support mechanism is/was the Renewables Obligation (RO), from which existing contracts will continue for up to 20 years. The RO required electricity generators to source an increasing percentage of the UK's total electricity supply from renewable energy sources (wind, biomass, new hydro, solar, tidal, etc.) or pay an equivalent value which is recycled to renewable providers. In 2012-13, renewable energy projects provided 11.2% of electricity in the UK. The RO was always undersubscribed (partly by design and by realities of development) and a "buy-out" payment by underperforming suppliers set a base value of renewable energy. The Renewables Obligation Certificate (ROC) buy-out rate for 2011-12 was £38.69/MWh or 3.89p/kWh (unit) plus the retail price of electricity (approx. 3p/kWh). Auctioning surplus ROCs can also lead to higher prices for renewable generators' output, although this provides a difficult market for financial planning (DECC/OFGEM).

As from 2013, onshore wind receives 0.9 ROCs/MWh; offshore wind, as a new entrant receives 1.9 ROCs/MWh. Both of these are reduced from earlier ROCs.

The cost of wind energy mainly depends on wind speed, the required rate of return on investment (discount price), world turbine prices and infrastructure costs. Current costs are varied and highly subject to location, size, etc.

The latest prices for new build were reviewed by the Royal Academy of Engineering in 2014. This predicted the levelised cost comparisons:

Gas (CCGT)	8-10p/kWh
Gas + CCS [1]	10.5-11.5p/kWh
Coal + CCS	10.5-14p/kWh
Nuclear	7-10.5 p/kWh
Onshore wind	7-12.5 p/kWh
Offshore wind [2]	10-20p/kWh

[1] n.b. gas fuel costs represent 60% of total costs
[2] n.b. carbon emissions costs are difficult to predict

5.0 Onshore Wind Projects

Onshore currently represents over 95% of wind farms globally, dominated by countries with a large, sparsely occupied land mass, e.g. China, India, USA (GWEC, EWEA).

The average size (MW rating) of an individual wind turbine is around 2-3MW.

Foundations and civil costs are relatively low (around 13%) with turbine manufacture making up around 65% of the capital costs.

Turbine size and wind farm layouts are often dictated by environmental or planning constraints, road access for large components or available heavy lift craneage. These factors do not restrict offshore wind farms.

Regions of high electricity demand but with lower wind speeds, e.g. South East England, are often of lower commercial viability than the windier North of England, and Scotland.

6.0 Offshore Wind Projects

Offshore windfarms are relatively new developments (over the last decade) involving more complex foundations in water depths of up to and over 45m.

Projects and components are much larger than onshore to minimize infrastructure costs. A national programme is developing new structures for cheaper, and deeper, foundations.

The Crown Estate owns the seabed and has issued three rounds of leases for development off the coast of the UK. The first round of site allocation issued 18 licenses for projects around the UK of up to 100MW each. These have now been built (e.g. North Hoyle, Kentish Flats).

Development areas for a second round were announced in 2003. Fifteen sites were awarded (7,169MW) – many of these are now operational.

A third round of lease offerings for up to 25,000MW of wind was announced by Crown Estates in June 2008. This was in parallel with a Government announcement of strategic assessment of offshore resources towards 35GW (35,000MW) of offshore wind capacity to help fulfil the EU's 2020 targets for renewable energy.

Other main offshore players in Europe include Denmark (e.g. Horns Rev II, 200MW), Netherlands (e.g. Ijmuiden, 100MW) and Ireland (Kish Bank, 250MW). Eclipsing these, China has adopted a target of 30,000MW of offshore capacity by 2020 (Carbon Trust).

7.0 Key Issues in the UK

As of 2010, the wind energy sector (and marine renewables research) employed 10,800 people (FTE – full time equivalent jobs). The skill base is multidisciplinary, including project management, civil, electrical and mechanical professionals, environmental specialists, supply chain managers and financial modellers.

Many onshore wind farms in the UK have difficulty in getting planning permission, especially in England and also in Wales where there is also a shortage of grid capacity.

Scottish onshore development has been substantial (target is 17.5% of electricity demand) but is constrained by national grid export capacity and infrastructure.

The best sites for wind speed are often in exposed locations, however, higher costs of grid connections and road access works for turbine delivery can make these locations difficult and potentially un-economic, however development of lower wind sites near population centres has increased under the RO.

Environmental considerations, especially visual impact, aviation radar, designated landscapes etc. limit the sites which are suitable.

Offshore siting offers a much larger opportunity for wind power towards meeting the UK renewables targets, but at a greater cost. Current constraints include grid capacity, finance, air defence radar, engineering of deeper foundations and limited availability of components (i.e. supply chain).

7.1 Intermittency

This is often cited as a drawback for wind and other variable renewables. The Select Committee on Science and Technology (SDC) (2004) accepted evidence from National Grid and other experts that any reserve “firm” capacity for 10% penetration of the UK's total generating capacity by wind is "not large". Increasing penetration by wind has no technical limitation but will require proportionately greater reserve costs. SDC (2007) and Cabinet Office (2002) gave cost of back-up for 20% penetration at 0.17and 0.20 p/kWh respectively.

7.2 Microgeneration

There has been publicity for domestic or small commercial generation including relatively small, roof-mounted wind turbines. While these may form part of a useful contribution, along with energy efficiency etc. it would require approximately 5,000 medium sized (1.75m diameter) home turbines to equal the electricity output of a single medium-sized commercial wind turbine (80m diameter).

8.0 Links & sources of reference

Global Wind Energy Council (GWEC)

European Wind Energy Association (EWEA)

Renewables UK

Department for Climate Change (DECC)

Sustainable Development Commission