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Wind

Contents

Strategic insight

1. Introduction

Wind has many applications, including electricity generation. It is available virtually everywhere on earth, although there are wide variations in wind strengths. The total resource is vast; one estimate (Cole, 1992) suggests around a million GW 'for total land coverage'. If only 1% of the area was utilised, and allowance made for the lower load factors of wind plant (15-40%, compared with 75-85% for thermal plant) that would still correspond, roughly, to the total worldwide capacity of all electricity-generating plant. The offshore wind resource is also vast, with European resources, for example, capable of supplying all the European Union's electricity needs, without going further than 30 km offshore.

The location of the 'best' onshore wind resources, based on maps by Czisch (2001), and the analysis of Archer and Jacobson (2005) is summarised in Fig. 10.1, which shows that wind energy resources are well distributed.

Figure 10.1

Summary of locations of the most attractive regions for wind energy

Source: Czisch, 2001

Region	Location
Europe	North and west coasts of Scandinavia and the UK, some Mediterranean regions
Asia	East coast, some island areas, Pacific Islands
Africa	North, southwest coast
Australasia	Most coastal regions
North America	Most coastal regions, some central zones, especially where mountainous
South America	Best towards the south, coastal zones in east and north

The rapid growth of wind energy may be demonstrated by noting that the projection for 2010 set out in the European Commission's White Paper on renewable energy (EC, 1997), was 40 GW. That was 16 times the capacity in 1995, but the target was realised by 2005 and by late 2009, European capacity was over 72 GW.

World wind energy capacity has been doubling about every three and a half years since 1990. It is doubtful whether any other energy technology is growing, or has grown, at such a rate. Total capacity at the end of 2008 was over 120 GW and annual electricity generation around 227 TWh, roughly equal to Australia's annual consumption. The United States, with about 25 GW, has the highest capacity but Denmark with over 3 GW, has the highest level per capita, and production there corresponds to about 20% of Danish electricity consumption.

Wind energy is being developed in the industrialised world for environmental reasons and it has attractions in the developing world as it can be installed quickly in areas where electricity is urgently needed. In many instances it may be a cost-effective solution if fossil fuel sources are not readily available. In addition there are many applications for wind energy in remote regions, worldwide, either for supplementing diesel power (which tends to be expensive) or for supplying farms, homes and other installations on an individual basis.

Most wind capacity is located onshore but offshore wind sites have been completed, or are planned, in China, Denmark, Ireland, Sweden, Germany, the Netherlands, the UK and elsewhere. By end-2009, over 1 500 MW was operational. Offshore wind is attractive in locations where pressure on land is acute and winds may be 0.5 to 1 m/s higher than onshore, depending on the distance from the coast. The higher wind speeds do not presently compensate for the higher construction costs, but the chief attractions of offshore are its larger resource potential and lower environmental impact.

Early machines - 25 years ago - were fairly small (50-100 kW, 15-20 m diameter) but there has been a steady growth in size and output power. Several commercial types of wind turbine now have ratings over 3 MW and diameters around 60-80 m; machines for the offshore market have outputs up to 6 MW and diameters up to 126 m. The average rating of turbines installed in Germany in 1992 was 180 kW and in 2008 it was just under 2 000 kW – over ten times as much.

Machine sizes have increased for two reasons. They are cheaper and they deliver more energy. The energy yield is improved partly because the rotor is located higher from the ground and so intercepts higher-velocity winds, and partly because they are slightly more efficient. Energy yields, in kWh per square metre of rotor area, are now double those of 1990 (Welke and Nick-Leptin, 2006). In 2008, data from the Danish Energy Agency showed that the most productive machines delivered around 1 500 kWh per square metre of rotor area. Reliability has also improved steadily and availabilities of 95% or more are common.

The majority of the world’s wind turbines have three glass-reinforced plastic blades. The power train includes a low-speed shaft, a step-up gearbox and an induction generator, either four- or six-pole. However, the market is evolving and there are numerous other options. Wood-epoxy is an alternative blade material and some machines have two blades. Variable-speed machines are becoming more common and many generate power using an AC/DC/AC system, but double-fed induction generators are becoming established. These also allow variable-speed operation, which brings several advantages - it means that the rotor turns more slowly in low winds (which keeps noise levels down), it reduces the loadings on the rotor, which can operate with higher efficiency, and the generators are usually able to deliver current at any specified power factor. Direct drive systems are becoming increasingly common. These eliminate the gearbox and are usually of the variable-speed type, with power conditioning equipment.

Towers are usually made of steel and the great majority are of the tubular type. Lattice towers, common in the early days, are now rare, except for small machines in the range 100 kW and below. Recent increases in the price of steel have reawakened interest in concrete towers but there are relatively few examples yet.

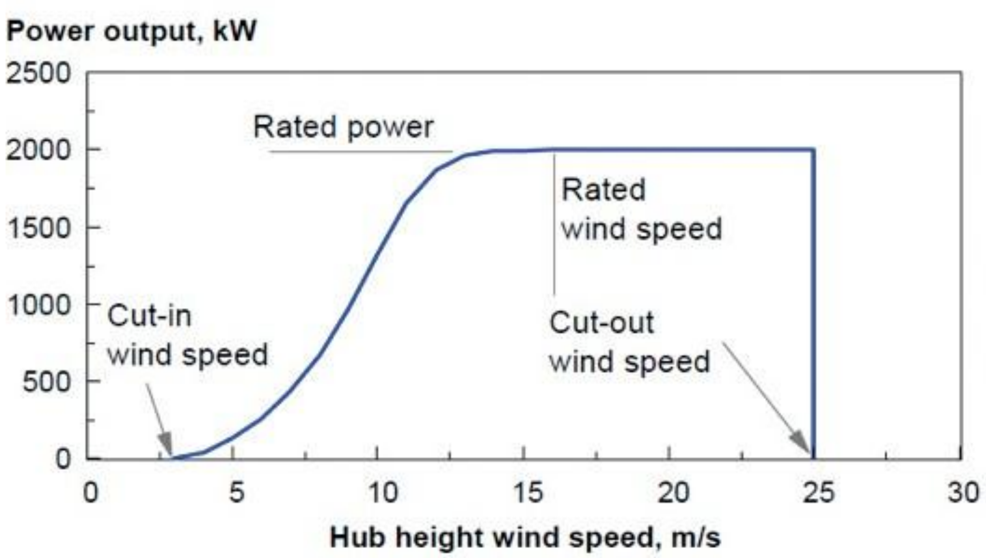
As the power in the wind increases with the cube of the wind speed, all wind turbines need to limit the power output in very high winds. There are two principal means of accomplishing this, with pitch control on the blades or with fixed, stall-controlled blades. Pitch-controlled blades are rotated as wind speeds increase so as to limit the power output and, once the ‘rated power’ is reached; a reasonably steady output can be achieved, subject to the control system response. Stall-controlled rotors have fixed blades which gradually stall as the wind speed increases, thus limiting the power by passive means. These dispense with the necessity for a pitch control mechanism, but it is rarely possible to achieve constant power as wind speeds rise. Once peak output is reached the power tends to fall off with increasing wind speed, and so the energy capture may be less than that of a pitch-controlled machine. The merits of the two designs are finely balanced and until recently roughly equal numbers of each type were being built. Since the turn of the century, however, pitch-controlled machines have become much more popular.

Annual energy production from the turbine whose performance is charted is around 2 457 MWh at a site where the wind speed at 78 m height is 5 m/s, 5 629 MWh at 7 m/s and 6 725 MWh at 8 m/s. Wind speeds around 5 m/s can be found, typically, away from the coastal zones in all five continents, but developers generally aim to find higher wind speeds. Levels around 7 m/s are to be found in many coastal regions and over much of Denmark; higher levels are to be found on many of the Greek Islands, in the Californian passes – the scene of many early wind developments - and on upland and coastal sites in the Caribbean, Ireland, Sweden, the UK, Spain, New Zealand and Antarctica. Offshore wind speeds are generally higher than those onshore – around 8 m/s in European coastal waters, for example.

Figure 10.2

Power curve and key concepts for a 2MW wind turbine

Source: Vestas Wind Systems A/S



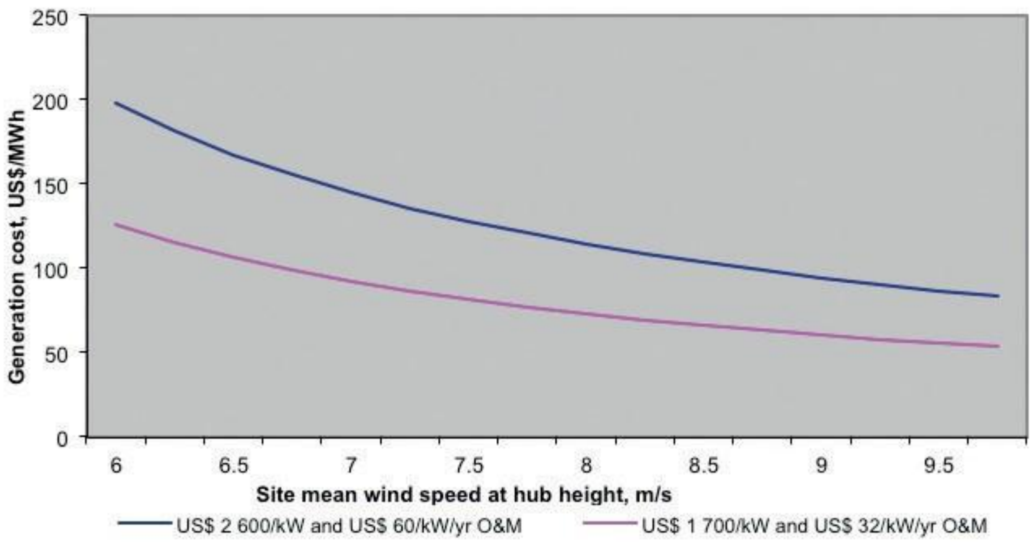
The cost of wind energy plants fell substantially during the period from 1980 to 2004. Prices in the 1980s were around US$ 3 000/kW, or more, and by 1998 they had come down by a factor of three. During that period the size of machines increased significantly - from around 55 kW to 1 MW or more - and manufacturers increased productivity substantially. In 1992, for example, one of the major manufacturers employed over seven people per megawatt of capacity sold, but by 2001 only two people per megawatt were needed. The energy productivity of wind turbines also increased during this period. This was partly due to improved efficiency and availability, but also due to the fact that the larger machines were taller and so intercepted higher wind speeds. A further factor that led to a rapid decline in electricity production costs was the lower operation and maintenance costs.

With capital costs halving between 1985 and the end of the century, and productivity doubling, it could have been expected that electricity production costs would fall by a factor of four. This general trend has been confirmed by data from the Danish Energy Agency; these suggest that generation costs fell from DKK 1.2/kWh in 1982 to around DKK 0.3/kWh in 1998 (Danish Energy Agency, 1999).

Shortly after the turn of the century, the downward trend in wind turbine and wind farm prices halted and prices moved upwards. This was partly due to significant increases in commodity prices and partly due to shortages of wind turbines. Prices appear to have peaked in 2008, with complete wind farms averaging just under US$ 2 200/kW and wind turbines at just under US$ 1 600/kW. Prices may now be falling, based on data available to the autumn of 2009.

No single figure can be quoted for the installed cost of wind farms, as much depends on the difficulty of the terrain, transport costs and local labour costs. Generation costs depend, in addition, on the wind speed at the wind farm site - since this determines the energy productivity - and on the financing parameters. The latter depend on national institutional factors which influence whether wind farm investments are seen as high or low risk. Although there is a broad consensus that wind turbines are now sufficiently reliable to enable depreciation over a 20-year period, the ‘weighted average cost of capital’ (WACC) may lie between 5% and 11%. (The WACC is a weighted average interest rate that takes into account the cost of both bank loans and equity investments).

Figure 10.3
Typical generation costs



Typical generation costs are shown in Fig. 10.3 above, using installed costs between US$ 1 700/kW and US$ 2 600/kW, an 8% interest rate and a 20-year amortisation period. Operating costs, which cover the costs of servicing, repairs, management charges and land leases have been set at US$ 32/kW/yr for the lower capital cost and US$ 60/kW/yr for the higher capital cost. The link between wind speed and energy productivity has been established by examining the performance characteristics of a number of large wind turbines that are currently available. Although there is not a unique link between wind speed and capacity factor, the spread is quite small. All wind speeds refer to hub height. The estimates suggest that generation costs at US$ 2 600/kW range from just under US$ 200/MWh at 6 m/s, falling to US$ 84/MWh at 9.75 m/s. At US$ 1 700/kW, the corresponding range is US$ 125/MWh to US$ 53/MWh, respectively.

The way in which wind energy has developed has been influenced by the nature of the support mechanisms. Early developments in California and subsequently in the UK, for example, were mainly in the form of wind farms, with tens of machines, but up to 100 or more in some instances. In Germany and Denmark the arrangements favoured investments by individuals or small cooperatives and so there are many single machines and clusters of two or three. By building wind farms, economies of scale can be realised, particularly in the civil engineering and grid connection costs and possibly by securing quantity discounts from the turbine manufacturers.

The attractions of offshore wind are the availability of a huge resource, low environmental effects and good wind speeds - often exceeding 8 m/s – which are only found on limited numbers of onshore sites. The downsides are the need to protect the wind turbines from salt spray, the higher foundation and installation costs and the additional expenses of organising operation and maintenance activities.

Offshore wind installations have been built in the waters around Belgium, China, Denmark, Germany, Ireland, the Netherlands and the United Kingdom. A number of projects are being planned in Canada and the USA. The UK Government has recently awarded concessions that allow the development of up to 32 GW of offshore wind; when this is added to awards from licensing rounds, the UK is set to host up to 40 GW in total.

Economies of scale deliver more significant savings in the case of offshore wind farms and many of the developments involve large numbers of machines. Fig. 10.4 gives an indication of typical parameters for offshore and onshore wind farms. The strength of the offshore wind may be gauged by noting that the offshore wind farm is half the capacity of the onshore farm, but delivers well over half the energy output.

Figure 10.4

Key features of an onshore and an offshore wind farm

	Onshore	Offshore
Project name	Hadyard Hill, Scotland	Alpha Ventus, Germany
Project locations	72km south of Glasgow, in the Southern Highlands of Scotland	45km from the coast
Site features	moorland, 250m above sea level	water depth 30m
Turbines	52 x 2.3 MW	12 x 5 MW
Project rating	120 MW	60 MW
Turbine size	58 and 68 m hub height, 82 m diameter	90 m hub height, 116 m diameter (6) 92 m hub height, 126 m diameter (6)
Energy production (annual)	320 000 MWh	220 000 MWh
Construction completed	2005	2009
Source	Scottish and Southern Energy	E.ON Climate and Renewables, EWE and Vattenfall Europe

Small scale wind power

Although the largest wind turbines tend to attract most interest, there is a wide range of sizes available commercially, from small battery-charging machines with ratings of a few Watts, up to, say 100 kW for farm use. A recent review of this market (Frey, 2010) found 124 manufacturers and suggested the term ‘micro SWTs’ be used for machines up to 1 kW output, ‘mini’ up to 10 kW output and ‘midi’ up to 100 kW output. Although such turbines are relatively more expensive than their larger counterparts, they are generally not competing with electricity from large thermal power stations and may be the only convenient source of power - possibly in conjunction with batteries or diesel generators. In developing countries small wind turbines are used for a wide range of rural energy applications, and there are many ‘off-grid’ applications in the developed world as well – such as providing power for navigation beacons and road signs. Since most of these are not connected to a grid, many use DC generators and run at variable speed. A typical 100 W battery-charging machine has a shipping weight of only 15 kg.

A niche market, where wind turbines often come into their own as the costs of energy from conventional sources can be very high, is in cold climates. Wind turbines may be found in both polar regions and in northern Canada, Alaska and Finland.

Environmental impact of wind power

No energy source is free of environmental effects. As the renewable energy sources make use of energy in forms that are diffuse, larger structures, or greater land use, tend to be required and attention may be focused on the visual effects. In the case of wind energy, there is also discussion of the effects of noise and possible disturbance to wildlife - especially birds. It must be remembered, however, that one of the main reasons for developing the renewable sources is an environmental one - to reduce emissions of greenhouse gases. Several studies have shown that wind plants 'repay' the energy used during construction by about 6 months or less, and so electricity generated after that time realises substantial emission savings. In many cases wind generation displaces coal-fired plant, so 1 kWh of wind saves about 0.8-1 kg of carbon dioxide.

Almost all sources of power emit noise, and the key to acceptability is the same in every case – sensible siting. Wind turbines emit noise from the rotation of the blades and from the machinery, principally the gearbox and generator. At low wind speeds wind turbines generate no noise, simply because they do not generate. The noise level near the cut-in wind speed is important since the noise perceived by an observer depends on the level of local background noise in the vicinity, and this has a masking effect. At very high wind speeds, on the other hand, background noise due to the wind itself may be higher than noise generated by a wind turbine. The intensity of noise reduces with distance and it is also attenuated by air absorption. The exact distance at which noise from turbines becomes 'acceptable' depends on a range of factors, especially local planning guidelines.

Wind turbines, like other structures, can sometimes scatter electro-magnetic communication signals, including television. Careful siting can avoid difficulties, which may arise in some situations if the signal is weak. Fortunately it is usually possible to introduce technical measures - usually at low cost - to compensate.

The need to avoid areas where rare plants or animals are to be found is generally a matter of common sense, but the question of birds is more complicated and has been the subject of several studies. Problems arose at some early wind farms that were sited in locations where large numbers of birds congregate - especially on migration routes. However, such problems are now rare, and it must also be remembered that many other activities cause far more casualties to birds, such as the ubiquitous motor vehicle. In practice, provided investigations are carried out to ensure that wind installations are not sited too near large concentrations of nesting birds, there is little cause for concern. Most birds, for most of the time, are quite capable of avoiding obstacles and low collision rates are reported where measurements have been made.

One of the more obvious environmental effects of wind turbines is their visual aspect, especially that of a wind farm comprising a large number of wind turbines. There is no measurable way of assessing the effect, which is essentially subjective. As with noise, the background is important. Experience has shown that good design and the use of subdued neutral colours – 'off-white' is popular – minimises these effects. The subjective nature of the question often means that extraneous factors come into play when acceptability is under discussion. In Denmark and Germany, for example, where local investors are often intimately involved in planning wind installations, this may help to ensure that the necessary permits are granted without undue discussion. Sensitive siting is the key to this delicate issue, avoiding the most cherished landscapes and ensuring that the local community is fully briefed on the positive environmental implications.

Electricity systems in the developed world have evolved so as to deliver power to the consumers with high efficiency. One fundamental benefit of an integrated electricity system is that generators and consumers both benefit from the aggregation of supply and demand. On the generation side, this means that the need for reserves is kept down. In an integrated system the aggregated maximum demand is much less than the sum of the individual maximum demands of the consumers, simply because the peak demands come at different times.

Wind energy benefits from aggregation; it means that system operators cannot detect the loss of generation from a wind farm of, say, 20 MW, as there are innumerable other changes in system demand which occur all the time. Numerous utility studies have indicated that wind can readily be absorbed in an integrated network at modest cost. Several studies have been reviewed by the International Energy Agency (2005). More recent estimates suggest 10% wind energy is likely to incur extra costs in the range GBP 2.5-5/MWh (US$ 4-8/MWh) and 20% wind energy in the range GBP 3-6/MWh (US$ 5-10/MWh), approximately (Milborrow, 2009). Beyond 20%, some wind power may need to be curtailed on a few occasions if high winds coincide with low demand, but there are no ‘cut-off’ points. Practical experience at these levels is now providing a better understanding of the issues involved.

The very rapid growth in Denmark and Germany, up to around 2003/4, has now slowed, but Spain, India, China and the United States are now forging ahead and there are plans for further capacity in Canada, the Middle East, the Far East and South America. The future rate of development will depend on the level of political support from national governments and the level of commitment, internationally, to achieving carbon dioxide reduction targets.

Projections of future capacity vary. The International Energy Agency’s Reference Scenario suggests 422 GW by 2020, but other studies suggest higher values. The European Wind Energy Association suggests there will be 230 GW in Europe by 2020, of which 40 GW will be offshore. The technology has developed rapidly during the past 20 years, is still maturing and further improvements are expected both in performance and cost.

Taking the IEA’s cautious estimate of 422 GW for the installed capacity in 2020 and assuming an installed cost of US$ 2 000/kW suggests investments of around US$ 522 billion will be required over the next 10 years.

Wind Energy today represents the fastest growing technology in the energy production space globally today. Energy is generated from wind in 79 countries around the world and 24 of the countries today already have installed capacity of more than 1000MW. Within the low carbon energy generation technologies, wind has emerged as the top technology of choice, investors are becoming increasingly comfortable backing wind investments and as this chapter will demonstrate, wind energy not only a mainstream energy sector but is already a global industry with large international players dominating the industry. In most parts of the world where generation sources compete on the basis of market reflective pricing of electricity, wind is beginning to offer stiff competitions to the other most preferred low fossil intensity technology gas fired CCGT technology.

The current and likely future trends in wind energy economics, investor sentiment and the strategic conduct and corporate trends in the wind industry suggest a robust belief in the future of wind energy with a forward looking perspective on emerging risks and future challenges. The chart below attempts to capture the high level messages of today’s status quo.

STRATEGIC ASSESSMENT OF GLOBAL WIND ENERGY

Outlook and Growth Drivers:

- Current global installed capacity expected to grow from 282GW to approx. 750 GW by 2020. On shore and sites with lower wind speeds expected to dominate share of new build. Off shore to continue to be a niche play.
- Technology maturity, investor familiarity, high learning rates, rising average turbine ratings are key drivers of growth and are supported by a widespread trend towards low carbon electricity.
- Improvement on low wind speed technology performance will drive wind access sites
- Cost competitive gains may be off set if consolidation trends in the sector continue and global specialists emerge.
- In Off shore- early trends of cooperation between oil and gas and wind industries.

Key Growth Geographies and Source of Expertise:

- US market is expected to be the largest market by 2015 although key EU markets- Germany, UK, Southern EU countries will retain their leadership in the short-medium term.
- China already aggressively competing for global wind leadership, India ramping capacity.
- UK North Sea is already beginning to lead in the deep water off-shore space (Beatrice Field) being developed by a Canadian Oil and Gas company Talisman is the first mover. Other off-shore currently is in shallow waters of Denmark and Germany.
- Other industries esp Oil and gas, shipping and advanced manufacturing are well positioned to develop skills in the sector and capture opportunities in project engineering, development and services.

The Investment case:

- Credible growth track record and increasing technological and management sophistication emerging
- Stability of Governmental policy incentives, improving economics and bias towards carbon free electricity generation
- Global technological plays, emergence of global specialists, increasing cross border transaction activity and yet significant growth potential in regional markets
- Also, as investor comfort with wind technology grows, deployment rates and cost competitiveness is set to increase further, Wind will possibly establish it self as a renewable technology of choice

Key risks and challenges:

- As industry consolidates regional policy makers are demanding greater local content requirements.
- Supply chain discontinuities emerging as turbine manufacturing matures.
- Technical de-risking of projects esp in new offshore environments, new materials and engineering practices is as yet uncharted territory.
- Intermittency of operations, difficulties in siting and consenting regimes, grid availability and back up requirements affect economics of projects considerably- greatest threat comes from energy market design considerations.
- Policy support may move away from wind with further technological maturation in favour of other new technologies

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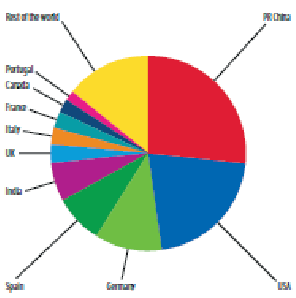
Source: Industry Publications, Expert Interviews and EnerStrat Analyses

The ongoing economic crises and the acuity of the policy uncertainty in the global energy sector, it would seem, has barely registered with the global wind energy industry. The year 2012 was a phenomenal year when the industry added 45GW of new capacity and grew at a little over 10 percent from the previous year. The slide below captures the current cumulative distribution of wind capacity across the world and the most recent capacity additions of 2012.

SNAPSHOT OF GLOBAL DISTRIBUTION OF WIND CAPACITY

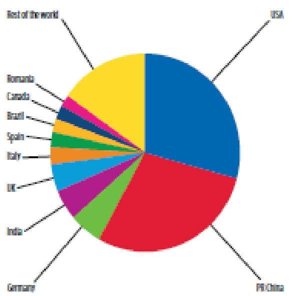
Top 10 Cumulative Capacity (December 2012)



Country	MW	% SHARE
PR China	75,324	26.7
USA	60,007	21.2
Germany	31,308	11.1
Spain	22,796	8.1
India	18,421	6.5
UK	8,445	3.0
Italy	8,144	2.9
France	7,564	2.7
Canada	6,200	2.2
Portugal	4,525	1.6
Rest of the world	39,853	14.1
Total TOP 10	242,734	85.9
World Total	**282,587**	**100.0**

Source: GWEC

Top 10 New Installed Capacity (Jan-Dec 2012)



Country	MW	% SHARE
USA	13,124	29.3
PR China	12,960	28.9
Germany	2,415	5.4
India	2,336	5.2
UK	1,897	4.2
Italy	1,273	2.8
Spain	1,122	2.5
Brazil	1,077	2.4
Canada	935	2.1
Romania	923	2.1
Rest of the world	6,737	15.0
Total TOP 10	38,062	85
World Total	**44,799**	**100.0**

Source: GWEC

US for the first time since 2009 overtaken China in annual capacity additions.

Largely as a result, OECD registered greater growth in wind capacity than Non OECD regions- again a first sine 2009.

India and China continue to lead wind capacity additions.

Source: Global Wind Energy Council 2012 Report

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It remains to be seen if this pole position that the US has wrested from China can be sustained. Tariff and fiscal incentives have played a significant part in the US wind growth story and it is unclear right now if the production tax credits- a key instrument that has contributed to wind growth in the US- will continue into 2014.

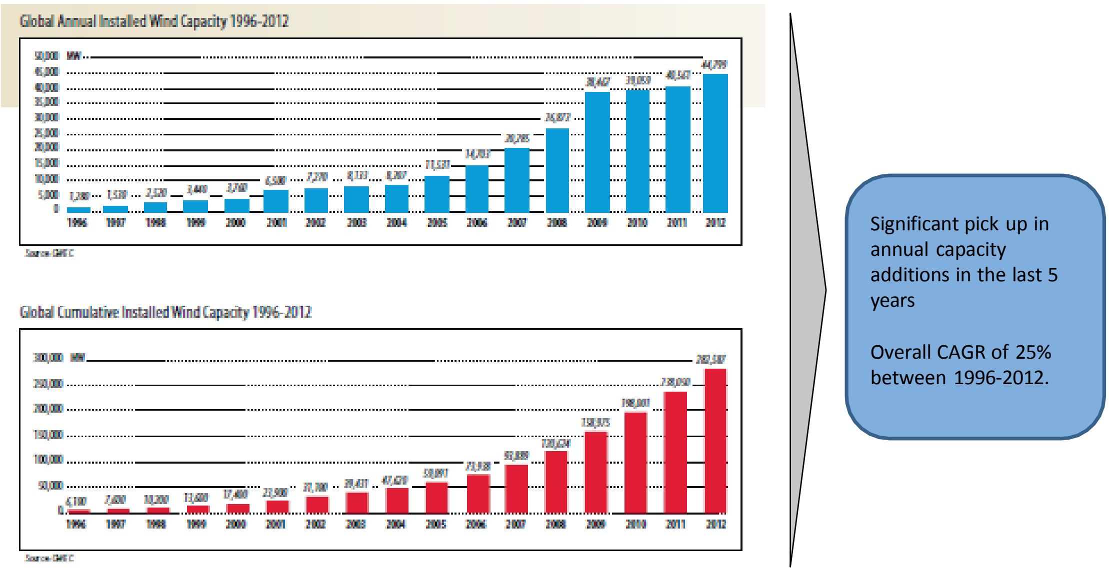
One notable aspect of the top 10 countries from the slide above is that by cumulative or new installed capacity is their dominant 85% market share. The remainder 15% (or 40GW) of cumulative or new capacity is shared by the rest of the 69 countres around the world of which the next 14 contribute more than 1GW of installed capacity implying that 55 countries around the world share the remainder 24GW of capacity. This is an important aspect not only to highlight the concentration of wind capacity while wind resources remain ubiquitous but also to suggest that these 55 countries with nearly 500MW installed capacity on an average represent the next frontier for the growth of wind energy going forward.

Understanding the Growth Trends in Global Wind Energy

Having established the growth potential for wind energy around the world, we now explore historical trends growth outlook and drivers for wind energy growth.

The slide below shows the historical observed trends in the growth of wind power capacity between 1996 -2012.

HISTORICAL GROWTH IN WIND CAPACITY



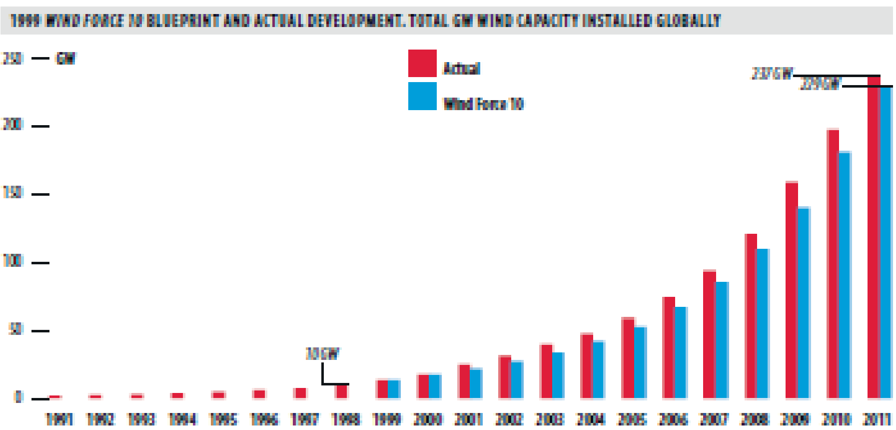
The most interesting aspect of this growth trend is that the industry has grown in the last 18 years at a cumulative average growth rate (CAGR) of nearly 25% and particularly in the last 5 years despite huge capacity additions the growth rate does not appear to be slowing down. As mentioned previously, note also that nearly 55 countries with some wind capacity are eyeing these trends and therefore the high growth rate, albeit from a low base, appears likely to be sustained.

Two key facts about the business of forecasting wind energy growth. In 2009 the IEA published an assessment of installed capacity estimates for global wind by 2030 to be 587 GW; two years later the figure of 587GW capacity appeared in as a forecast for 2020.

The first 2020 forecast of wind capacity was undertaken in 1999- when the year 2020 did indeed sound very far away. In 1999, also remember that the installed wind power capacity stood at a grand 13,600 MW and the industry was celebrating the previous year record of 2500 MW addition the previous year, the highest capacity addition in one year, ever; exuberance would have been forgiven and the group of analysts from the European Wind Energy Association, Greenpeace and Forum for Energy and Development that came together under the banner called Wind 10 published a forecast for wind capacity by 2020 at 229 GW and it was rightly labelled at the time as a “pie in the sky”.

The slide below shows how actual wind power capacity development has in fact exceeded the forecast made for 2020 in 1999 on a year one year basis:

GROWTH PROJECTIONS IN OF THE WIND 10 INITIATIVE *OF 1999-THEN CONSIDERED OUTRAGEOUSLY AMBITIOUS- HAVE BEEN SURPASSED IN REALITY YEAR ON YEAR



The Wind 10 Initiative- comprising European Wind Energy Association, Greenpeace and Forum for Energy and Development- published a first 2020 forecast for Wind in 1999- which was dismissed by many analysts as a”pie in the sky”.

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Source: Global Wind Energy Outlook 2012

It is against the backdrop of these facts that we now explore future growth trends for wind capacity.

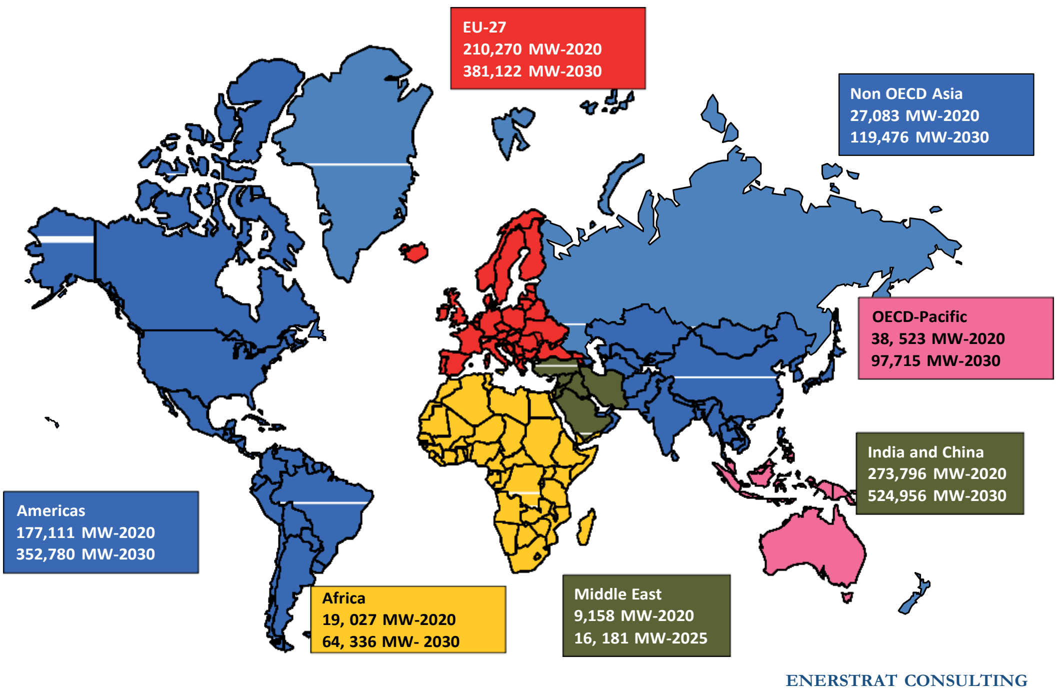
The slide below is based on an assessment carried out by the Global Wind Energy Council on the basis of known projects going out for the next 5 years upto 2017 and is shown broken down by annual additions expected by region. Note that by 2017, according to this assessment the cumulative installed capacity by 2017 already reaches nearly 537GW.

Also note that the installed capacity base nearly doubles by 2017 from 2012 levels for both the US and Asia (primarily driven by China) and reflects the race for global leadership already in evidence in 2012/13 between the two countries. Note also that European growth projections are slightly muted in comparison.

Based on the range of forecasts provided by the IEA in its New Policies Scenario and taking into consideration IEA's latest forecasts for 2020 at 587 GW and the range of forecasts provided by the Global Wind Energy Council and adjusting for the differences in their regional classification methodology and triangulating the actual observed and implied future growth rates developed a consensus or median growth forecasts and these are presented by region for the years 2020 and 2030 in the slide below on the next page.

As the slide suggests, we anticipate 2020 wind capacity to touch about 750GW and to double again by 2030 to about 1550GW. Note that during the period 1990-2012, wind capacity has been doubling every three years, however, the dominant growth regions in this assessment still continue to be Asia (mainly India and China), US and Europe. The bottom 55 countries still do not figure in any major way in this assessment implying that these numbers could be still possibly represent the lower end of the actual growth profile.

ASSESSING GLOBAL CUMULATIVE WIND ENERGY GROWTH



Source: Industry journals, IEA Reports, Global Wind Energy Outlook 2012 and EnerStrat Analyses

Growth Drivers

A number of factors is driving growth in the wind technology space. Chiefly, Wind Resource, Technology Maturity, Bankability, and an irreversible policy trajectory that incentivises investment in low carbon sources of generation –which have provided the much needed initial investment momentum for wind investments.

Wind resource all over the world is phenomenal. As mentioned in the previous version of SER 2010, the total resource around a million GW 'for total land coverage'. If only 1% of the area was utilised, and allowance made for the lower load factors of wind plant (15-40%, compared with 75-85% for thermal plant) that would still correspond, roughly, to the total worldwide capacity of all electricity-generating plant.

In terms of technological maturity, the average turbine rating in the 1980s was 50KW while the comparable figure in 2000 was 2MW and currently turbine sizes of 5MW and 10MW are possible. This is a huge shift in addition to the improvements in rotor and tower design that have allowed rotor diameters of 80 mtrs to be considered “standard” whereas the comparable figure in the 80s was 15 mtrs. Improvements in advanced drivetrain designs that improve reliability and reduce cost, greater production volumes, improved power electronics that allows greater frequency and voltage control in operations have all played –and continue to play- a part in enhancing the competitiveness of wind power.

As we shall see in the chapter on investment economics, learning rates and various other techniques to predict the future cost of energy from wind play an important role in understanding the growth drivers in this industry.

Offshore Wind

A total of 5,415 MW of offshore wind power has been installed globally as on today- representing about 2% of total installed wind power capacity. More than 90% of it is installed off northern Europe, in the North, Baltic and Irish Seas, and the English Channel; and most of the rest is in a number of demonstration projects off China’s east coast. However, there is also great interest elsewhere: Japan, Korea, the United States, Canada, Taiwan and India have shown enthusiasm for developing offshore wind in their waters. According to the more ambitious projections, a total of 80 GW could be installed by 2020 worldwide, with three quarters of this in Europe. The table below gives a breakdown of installed off shore wind capacity by region.

Global offshore wind power in the end of 2012

	2012 (MW)	Cumulative (MW)
UK	854	2,947.9
Denmark	46.8	921
China	127	389.6
Belgium	185	379.5
Germany	80	280.3
Netherlands	0	246.8
Sweden	0	163.7
Finland	0	26.3
Japan	0.1	25.3
Ireland	0	25.2
Korea	3	5
Norway	0	2.3
Portugal	0	2
Total	**1,296**	**5,415**

One aspect of the step out in off shore wind will likely be the unlikely technological collaboration between the off-shore oil and gas industry and the wind industry. The key benefit of off shore wind farms is the higher wind velocity that is available, less turbulence, greater swept area for larger farms, fewer environmental and planning constraints and the possibility of larger scale developments. Off shore oil and gas platforms have a long established track record in operating in harsh marine environments and have the technology and resource pool that can benefit the wind industry. An early example of such a oil and gas-wind energy collaboration is the Beatrice Field Windfarm Project due to be commissioned in 2017 which has come out of a previous demonstration project started in 2007.

The Beatrice Wind Farm Demonstrator Project was a joint venture between Scottish and Southern Energy and Talisman Energy (UK) to build and operate an evaluation wind farm in the deep water close to the Beatrice Oil field in the North Sea. Built in 2007, with 2 turbines and a total capacity of 10 MW, it was designed to examine the feasibility of creating a commercial wind farm in deep water and a reasonable distance from the shore. The jacket foundation design was developed by the Norwegian company OWEC Tower AS, and fabricated in Scotland by Burntisland Fabrications. The site is 22 km from the Scottish coast and in 45m of water. The project was proposed to last 5 years. All the electricity generated is fed to a nearby oil rig.

In February 2009, the partnership of SSE Renewables and SeaEnergy Renewables, was awarded exclusivity by The Crown Estate to develop the Beatrice offshore wind farm in the Outer Moray Firth just to the north of the existing 2 demonstrator turbines. The development will cover an approximate area of 131.5 km2, consist of 184 turbines and a total capacity of 920 MW. The project is currently in the planning stage with construction starting in 2014 and fully operational by 2017.

Estimating Future Costs of Wind Energy

Within the electricity sector, particularly in the case of wind, the Levelised Cost of Energy (LCOE) is the most significant metric that impacts the value of the project to the all stakeholders including the wider society although not all societal costs are captured by the LCOE. Capital costs and operational performance are both important components that drive the LCOE. Both measures are also equally difficult to forsee long into the future however established techniques have evolved to predict with a sufficient confidence interval the future costs of energies- including wind energy.

Operational Performance Improvements:
A combination of techniques such as “learning curves”, expert elicitation and engineering modelling studies have been successfully used in the wind industry to estimate future costs. By using learning curves learning rates or percentage reductions associated with every doubling of capacity in the wind industry are calculated and these are used to forecast future costs. A recent exercise carried out for the Inter- Governmental Panel on Climate Changea range of learning rates between 9-19% has been identified to forecast suture wind costs.

Similarly, by another process called “expert elicitation” the European Wind industry and the US DoE has determined a 10% reduction in energy capital costs and a nearly 20% increase in capacity factors to be a sensible range between 2005 and 2030. Similarly the NREL modelling work has also revealed that a performance increases of almost 20% and cost reductions of 10% may be used, similar results were obtained by the European “Upwind Study” to determine future costs of a possible 20MW wind turbine.

As mentioned earlier in the chapter, the rising hub heights and increasing rotor diameters have continued to trend towards larger machines and recent analyses by NREL suggests that “capacity factors for projects to be installed with current state of the art technology will improve significantly within a given wind power class relative to older technology; importantly most significant improvements are occurring in equipments designed for low wind speeds of 7.5m/s” As result of these advances it has been found that the amount of land area that could achieve 35% or higher wind project capacity factors has increased by as much as 270% in the US when going from turbines installed during 2002-03 to current low wind speed offerings. This is a significant finding as from these flow important implications for wind projects irrespective of geography that 1) future capacity factors can be assumed to be higher upto 35% and that 2) that the number of hitherto rejected low wind velocity sites will now come into play thus offering a greater number of sites to accommodate growing capacity. The figure below is reproduced from the IEA Wind Task 26 report of 2012 that graphically illustrates the commercial materiality of these findings:

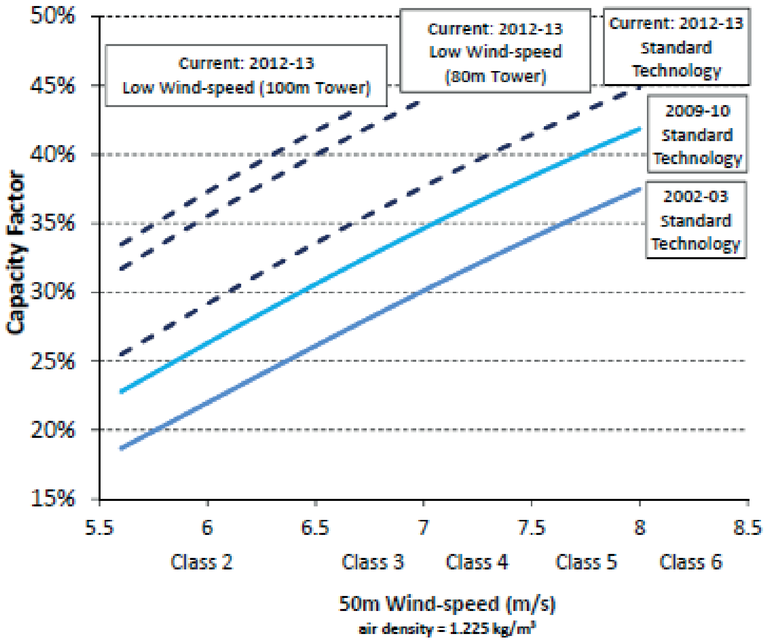
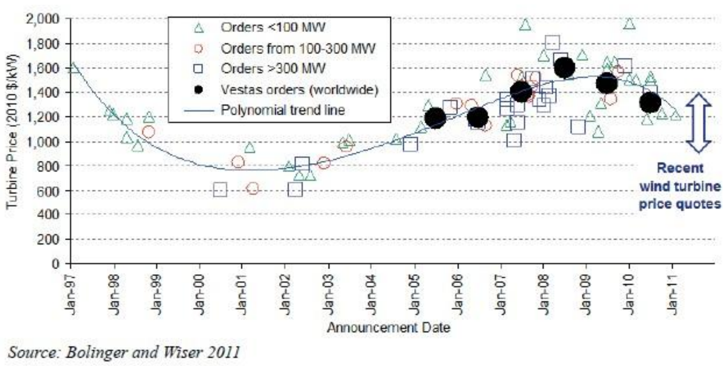


Figure 7. Modeled capacity factors for current turbine models relative to historical technology

Source: Wiser et al. 2012

Capital Cost Improvements:

WIND TURBINE PRICE TRENDS 1997-2012



- The years 2005-2009 were years of tight turbine supply, which now appears to be easing as new manufacturing facilities come on stream and new players emerge esp in the emerging markets in China and India.
- No clear trend of bargaining power of larger (greater than 300MW project orders) developers appears evident, a new "standard" turbine specification appears to be emerging. This standardisation will likely yield further lower prices if industry consolidation slows down providing opportunities for lower project level capex.

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Source: Original Bolinger and Wiser Study quoted in NREL February 2012 Report and NREL own global data set for 2011/12 WTG prices.

As the slide above shows, largely as a function of new manufacturing capacity turbine prices and therefore project capital costs have recently declined since their peak in late 2000s and as a result of continual improvements in turbine technology are expected to result in possibly historic lows in the LCOE of wind particularly in low and medium wind speed sites- 6.0m/s to 8.5m/s.

Applying the above performance measures and projected capital costs the IEA Task 26 working group has obtained results for the LCOE of Wind going forward that is shown in the graphic below.

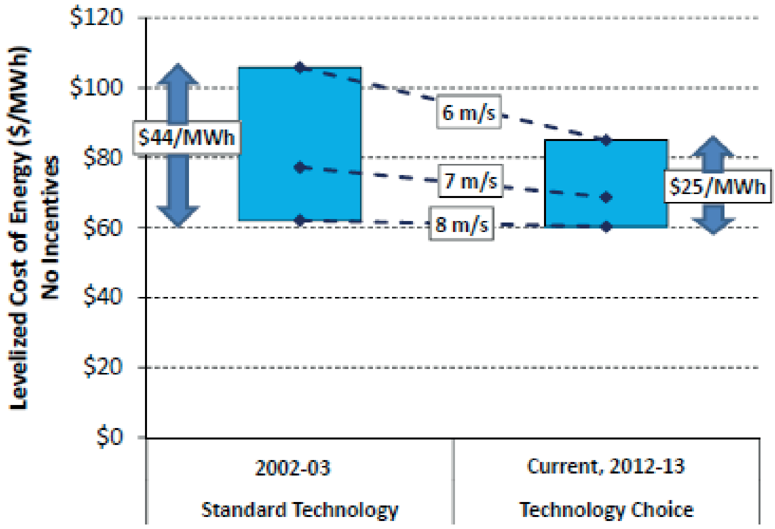
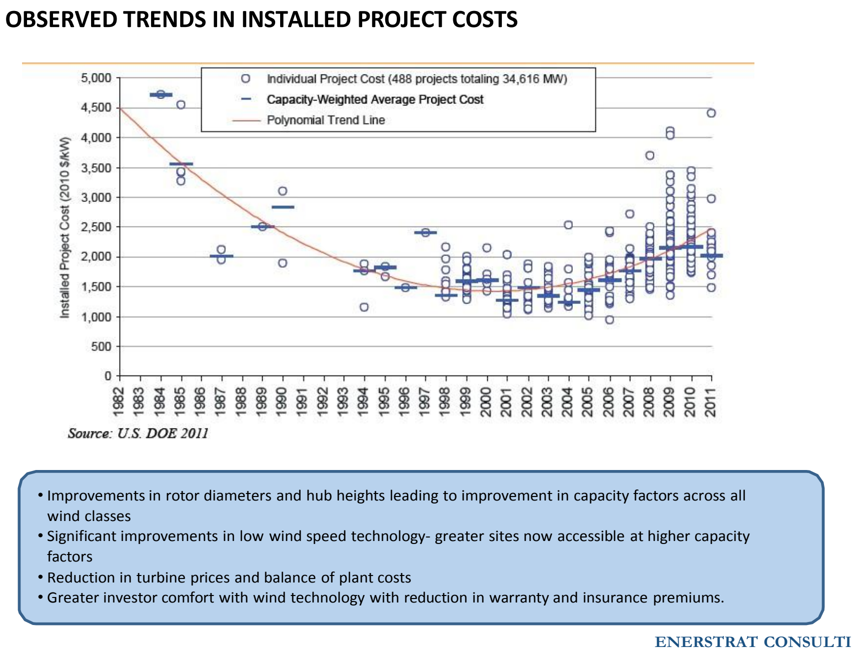


Figure 10. Estimated change in the LCOE between low and high wind speed sites resulting from technological advancement

Source: Wiser et al. 2012

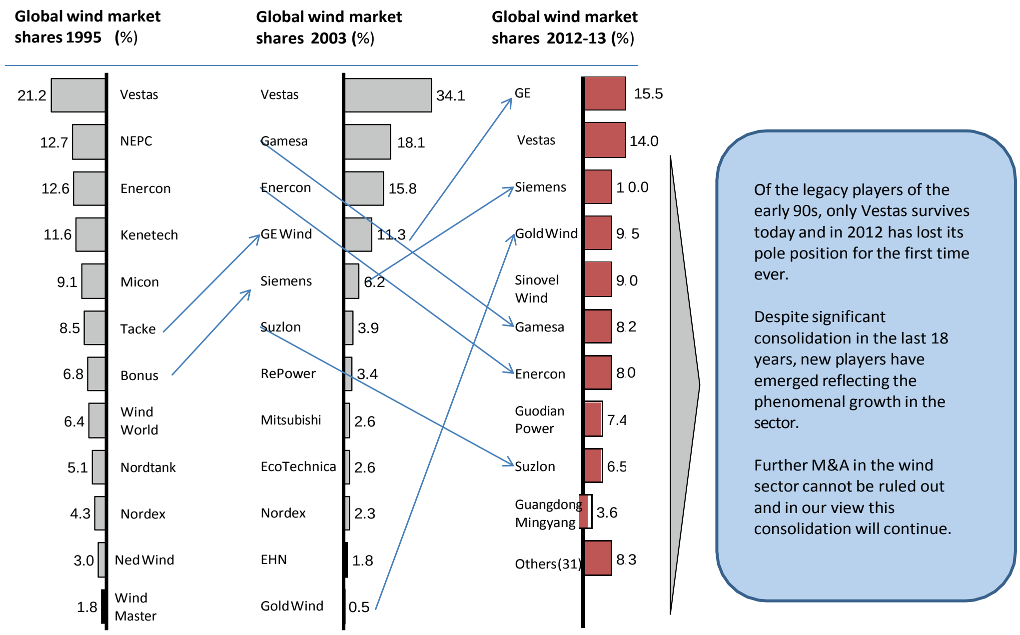
Additionally, the slide below provides a graphical illustration of how the above described factors are leading to a better understanding of project capital and performance metrics and as a result a growing comfort with wind power for current investors and possibly will attract new investors into this space.



Strategic Trends and Industry Outlook

In this final section of the chapter we now focus on the evolving structure and strategic conduct of the wind industry so far. The slide below captures the observed trends in the market shares of players at key points in the industry's history:

GLOBAL CORPORATE ACTIVITY IN WIND 1994-2012/13



Source: Industry Publications, News Clippings, EnerStrat Analyses
market shares are the authors' own estimates based on a number of sources which differ slightly on the relative positions of the 4th to the 7th largest player in the Industry

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In 1995 the top 4 players in the industry comprising 12 players controlled a 60% market share and the size of the industry in MW terms was all of 6100MW thus leading to a median size of a company around 500MW. Of the companies in 1995, Kenentech declared bankruptcy, Enron bought Tacke and was itself subsumed eventually by GE whereas the four smaller companies Micon, Wind World, Nord Tank and Ned Wind merged to form NEG Micon which eventually was acquired by Vestas leading to a jump in the market share for Vestas by the time the acquisitions were completed in 2003.

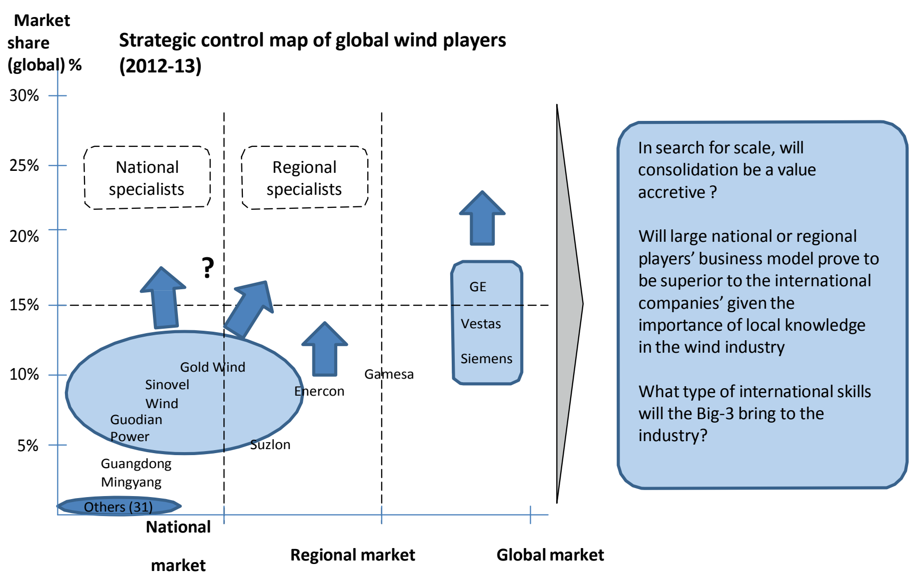
Not only is this a story of rapid consolidation and emergence of global players like GE and Siemens in the top 3 by 2012 but it is also a story of aggressive growth- by 2003 while the number of players remained constant despite the consolidation as new players like Gold Wind of China and Suzlon of India emerged on the scene, the installed capacity of the industry was 39.5GW raising the size of the average player from 500MW in 1995 to 4000MW by 2003 and to a whopping 7100MW by 2012. Wind industry has finally built itself to a global scale.

In 2003 the top 4 players now controlled a whopping 80% of the market share while by 2012, with the emergence of national and regional specialists the industry concentration had come back to 1995 levels where the top 4 companies now control 50% of the market share. This means that for the top 4 companies the average asset portfolio size is now over 35GW- comparable to some of the largest global utility players.

What does this portend for the future? Our assessment is that the next three years (when the next survey will be written, the industry will go through further rounds of consolidation. Note that today nearly 31 smaller, sub-scale companies make up a combined 8% market share. As the global players vie for industry leadership the competition for assets is expected to rise, driving higher valuations though given that the next phase of growth may come from emerging economies of India (already the fifth largest country with wind installations) and China (which already has built local companies with global scale) it remains to be seen if the large international players will be able to maintain their leading positions.

The slide below is a strategic control framework that describes the competing route maps to global leadership in wind.

LIKELY GROWTH VECTORS FOR THE GLOBAL WIND INDUSTRY



Source: EnerStrat Analysis

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Challenges to the industry over the next 3 years

The wind industry faces three main challenges in the near-medium term:

1. Balancing the demands of globalisation with increasing demand for local content requirements will challenge the business models of the wind industry

   Local Content Requirement (LCR) refers to a government requiring companies operating in its jurisdiction to source all or part of the components required from local manufacturers. This sits at cross purposes with the intergrated global supply chains that will be required to be built to sustain benefits of scale economies.

   Furthermore, policy makers, particularly in smaller countries, will find the prospect of introducing renewable energy along with jobs growth tantalising.

   The recent example of Brazil introducing LCR appears to hold a possibility of a slow down in the uptake for renewable energy.

2. As the industry becomes globally competitive the fiscal and policy/tariff support it currently enjoys may come under pressure.

   There is currently no evidence for this but the finite pool of funds that might have to be distributed across the renewable energy technologies, many of which are not as well developed as wind, globally does pose considerable risk.

3. The issue of how large scale wind gets integrated into a national generation mix- especially how newly competitive wind technologies stand up the interfuel competition especially from gas fired generation capacity with which it will certainly compete in most geographies.

   In most electricity markets, where gas fired power generation assets operate along with wind assets, gas capacity is increasingly viewed as a backup to compensate for the no-availability of wind capacity. Typically in the Northern hemisphere, where energy demand shoots up on a cold anti-cyclonic day, it is gas fired generation that is called in to supply. Thus relative to gas assets the delivery risk factor of wind assets is greater.
   The outlook for wind in such circumstances would be predicated upon the market design and pricing mechanisms in the local market.

In conclusion, the wind industry has before it tremendous opportunities for growth but equally daunting are the challenges it faces within and without. Will the wind industry live up to its projections- as it has done thus far for the last two decades- or will this be a different story this decade?

Ashutosh Shastri
Director, Enerstrat Consulting UK

Global tables

Country	"Installed capacity" MW	Annual Output GWh
Albania	42.00	
Algeria	0.10	
Argentina	142.50	450.00
Armenia	2.64	
Australia	2226.00	
Austria	1084.00	1934.00
Azerbaijan	2.00	
Bahrain	1.00	
Bangladesh	2.00	
Belarus	3.50	
Belgium	1078.00	
Brazil	1426.00	2705.00
Bulgaria	539.00	861.00
Canada	5265.00	13800.00
Cape Verde Islands	38.00	
Chile	190.00	
China	62364.30	73200.00
Colombia	18.00	41.30
Costa Rica	148.20	
Croatia	129.75	201.00
Cuba	12.00	
Cyprus	134.00	
Czech Republic	219.00	397.00
Denmark	3927.00	
Dominican Republic	34.00	
Ecuador	3.00	
Egypt	550.00	
Eritrea	1.00	
Estonia	181.00	368.00
Ethiopia	52.00	
Faroe Islands	4.25	
Finland	199.00	481.00
France	6549.40	12100.00
Germany	29071.00	48883.00
Greece	1749.00	117.00
Guadeloupe	26.00	
Guyana	14.00	
Hong Kong	0.80	
Hungary	329.40	
India	15880.00	19475.00
Indonesia	0.93	4.69
Iran	91.00	
Ireland	1738.00	
Israel	6.00	
Italy	6936.10	9856.00
Jamaica	48.00	

Japan	2294.00	4016.00
Jordan	1.90	
Kazakhstan	1.50	0.00
Kenya	5.00	
Korea (Republic)	425.00	
Latvia	30.00	70.00
Libya	20.00	
Lithuania	179.00	
Luxembourg	45.00	
Macedonia	0.00	
Martinique	1.00	
Mauritania	0.00	
Mauritius	0.00	
Mexico	570.00	1300.00
Mongolia	1.30	
Montenegro	0.00	
Morocco	291.00	
Netherlands	2328.00	
New Caledonia	28.00	
New Zealand	622.90	
Nicaragua	102.00	
Niger	2.20	
Nigeria	2.00	
Norway	520.00	
Pakistan	6.00	
Peru	1.00	
Philippines	33.00	
Poland	1799.93	3204.55
Portugal	4336.00	9162.00
Réunion	15.00	
Romania	821.80	1149.00
Russian Federation	15.40	
Slovakia	3.00	
South Africa	10.10	
Spain	21673.00	41790.00
Sri Lanka	14.00	
Swaziland	45.50	
Sweden	2900.00	6100.00
Switzerland	45.51	70.13
Syria	0.60	
Taiwan	564.00	
Thailand	7.28	
Tunisia	104.00	
Turkey	2063.70	5700.00
Ukraine	151.00	
United Kingdom	6488.00	
United States of America	46919.00	120177.00
Uruguay	43.50	
Venezuela	30.00	
Vietnam	31.00	
Total World	**238 049**	**377 613**

Country notes

Australia

Wind energy continues to increase its stake in Australia's clean energy mix following another year of growth in 2012. Wind energy now makes a significant contribution to Australia's energy mix, supplying over 7,700 GWh annually. This equates to around 3.4% of the nation's overall electricity needs and the equivalent of more than one million average Australian households.

Australia's 20% by 2020 Renewable Energy Target (RET) continues to provide the greatest incentive for the development of wind energy in Australia and has driven installed wind capacity from approximately 71 MW in 2001 to 2,584 MW as at the end of 2012. The RET is now complemented by Australia's carbon price mechanism, which commenced on 1 July 2012 with the aim of reducing emissions in the stationary energy sector.

Austria

With nearly 70% of renewable energy in its electricity mix, Austria is among the global leaders in this respect. Without any doubt, it is the natural conditions in Austria—hydropower, biomass, and a high wind energy potential—that allowed such a development. Due to the new Green Electricity Act (GEA 2012) (Ökostromgesetz 2012), annual wind power installations in Austria increased to 296 MW in 2012. This represents an annual growth rate of 27% compared to the previous year.

By the end of 2012, nearly 1,400 MW of wind power was operating in Austria. An additional 420 MW of wind power will be constructed in Austria in 2013

Canada

Canada is the ninth largest producer of wind energy in the world. It has more than 6 GW of wind energy capacity, which produces enough power to meet about 2.8% of the country's total electricity demand. Canada has more than 170 wind farms, spread across ten provinces and two territories.

In 2012, Canada placed ninth globally, in terms of new wind energy capacity installed. Nearly 940 MW of new wind capacity were installed in six provinces and one territory. The province of Quebec led the way, with 430 MW of new installations. The world's most northern large-scale wind-diesel hybrid power facility was commissioned in Canada's Northwest Territories.

The government of Canada continues to fund the growth of Canada's wind power sector through its ecoENERGY programs. Provinces across Canada continue to offer a range of incentives for renewable power, including wind. In some cases, existing programs have or will undergo reviews and changes. Ontario, for example, completed a scheduled two-year review of its Feed-in Tariff (FIT) program. A rate reduction in the price paid for wind generated electricity was one of several recommendations put forward, as a result of the review. In Nova Scotia, a review of the province's Community FIT (COMFIT) program is under way.

Community power was given a boost in 2012 with the approval of 46 community projects under Nova Scotia's COMFIT program. The projects range in size from 50 KW–6 MW, and are located in over 40 different communities across Nova Scotia. In Ontario, the M'Chigeeng First Nation Band celebrated the grand opening of its 4-MW Mother Earth Renewable Energy (MERE) wind farm in northern Ontario. MERE is Ontario's first wind farm owned entirely by a First Nation Band.

China

In 2012, 12,960 MW of new wind capacity was installed in China, increasing the accumulated capacity to 75,324.2 MW. During the year, wind power generated 100.4 TWh of electricity replacing nuclear power as the third largest electricity source in China. But compared to conventional power, wind power only accounted for 2% of generation, so there is a high potential for growth. In the future, wind power could and should play a more important role in the clean and sustainable energy and electricity supply.

After years of rapid development, China's wind power industry has entered an adjustment period and development has slowed. The industry has shifted from expansion of quantity to the improvement of quality. The government and enterprises are paying attention to improving the quality of the Chinese wind power industry. In 2012, grid integration and consumption were the most important bottlenecks that restrict China's wind power development. The government is taking policy, management, and technical measures to overcome these problems.

Germany

Wind energy continues to be the most important renewable energy source in Germany in medium term. Within the German federal government, the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) is in charge of renewable energy policy as well as of the funding of research for renewable energies.

The share of renewable energy sources in Germany's gross electricity consumption rose significantly in 2012 to reach 22.9%. This represents an increase of nearly two and a half percentage points against the previous year (20.5%). At 136 billion kWh, electricity generation from solar, wind, hydro, and biomass was around 10% higher than in 2011. This upward trend was largely due to the sharp increase in electricity generation from photovoltaic systems. Biogas was another growth area, and generation from hydropower increased from the previous year due to high rainfall.

Relatively poor wind conditions led to a decline in electricity generation from wind (2012: 46 TWh; 2011: 48.9 TWh) despite of the fact that 2012 also saw a strong upward trend in the expansion of wind energy capacity, and 675 MWh were generated by offshore wind. Construction of new turbines added 2,440 MW, a clear increase from the previous year (2,007 MW). Repowering measures accounted for 541 MW, while installations with a capacity of 196 MW were dismantled, giving a net capacity in 2012 of 2,244 MW. At the end of the year total installed wind capacity in Germany was nearly 31,315 MW, of which 280 MW were offshore.

Greece

In 2012, 117 MW of new wind capacity were installed in Greece the total installed wind capacity is 1,749 MW, a 7% increase from 2011. There are 121 wind farms in Greece. Almost 150 million EUR (197 million USD) was spent in the wind energy industry in 2012.

The Hellenic Wind Energy association (HWEA) still expects roughly 150 MW of new capacity could be added in Greece in 2013 after capacity increased 117 MW to 1,746 MW in 2012. The pace of installation must increase to reach the 2020 target of 7,500 MW of wind capacity as included in the national renewable energy action plan.

The government has many issues to consider in reaching this target. As part of a package of austerity measures approved in November 2012, wind and other renewable producers will be charged a 10% extraordinary tax on revenues for 12 months, dated back to 1 July 2012.

Denmark

Approximately 23.7% of Denmark's energy consumption came from renewable sources in 2012, 38.3% from oil, 19.4% from natural gas, and 13.8% from coal. The production from wind turbines alone corresponded to 30% of the domestic electricity supply, compared to 28.2% in 2011. The total domestic supply was nearly the same in 2012 as in 2011.

Wind power capacity in Denmark increased by 210 MW in 2012, bringing the total to 4,162 MW (Table 1). There were 220.6 MW in new turbines installed while 10.7 MW were dismantled. Most of the installed wind turbines in 2012 were onshore, while 14 of the 111 planned 3.6-MW turbines were installed offshore in the Kattegat project Anholt. The largest rated turbine to be installed in 2012 was the 6-MW Siemens turbine at the Oesterild Testsite.

Finland

In Finland, 32% of electricity consumption was provided by renewables in 2012. Finland's generating capacity is diverse. In 2012, 26% of gross demand was produced by nuclear, 20% by hydropower, 27% from combined heat and power (coal, gas, biomass, and peat), 7% from direct power production from mainly coal and gas, and 20% from imports. Biomass is used intensively by the pulp and paper industry, raising the share of biomass-produced electricity to 12% in Finland. The electricity demand, which is dominated by energy-intensive industry, was 85 TWh in 2012.

Finland aims to increase the share of renewables from 28.5% to 38% of gross energy consumption to fulfill the EU 20% target by 2020. The national energy strategy foresees biomass as providing most of the increase in renewables. Wind power is the second largest source of new renewables in Finland, with a target of 6 TWh/yr by 2020. The new energy strategy set a target of 9 TWh/yr for 2025.

A market-based feed-in system with a guaranteed price of 83.50 EUR/MWh (110.05 USD/MWh) entered into force in 2011. There will be an increased tariff of 105.30 EUR/MWh (138.80 USD/MWh) through the end of 2015. The difference between the guaranteed price and spot price of electricity will be paid to the producers as a premium.

Korea, Rep.of

The cumulative installed wind power in the Republic of Korea was 406 MW in 2011 and 487 MW in 2012, increasing by 17% from the previous year. Most wind turbine systems installed in 2012 were supplied by local turbine system manufacturers. A Renewable Portfolio Standard (RPS) proposal for new and renewable energy was enacted in 2012. The required rate of RPS in 2012 was 2% and will increase to 10% by 2022. In 2012, the first year of RPS, more than 60% of the target rate was achieved. A nine-year plan for construction of a 2.5-GW offshore wind farm off the west coast was announced in 2010. The first stage of the project, construction of 100-MW wind farm, was initiated in 2011 and is in progress.

The 2.5-GW offshore wind farm construction and RPS are expected to accelerate the growth of wind energy in Korea. Since 2009, the government has concentrated on developing Korean production of components to secure the supply chain for wind projects. More government R&D budget has been allocated to localize component supply and develop Ireland's official commitment to achieving ambitious 2020 renewable electricity targets primarily from wind power remained unchanged in 2012. A significant challenge in 2012 was the proposed implementation of arrangements for curtailment of wind farms. The associated market uncertainty may have contributed to the relatively low new wind capacity addition of 153 MW. This is below the estimated 200 MW/yr required to deliver upon the 2020 targets.

Italy

Although production capacity increased (slightly), wind energy output in 2012 did not exceed 2011 levels. Installation of new wind farms in Italy slowed its pace in 2010. Total online grid-connected wind capacity reached 5,797 MW at the end of the year, with an increase of 948 MW over 2009. As usual, the largest development took place in the southern regions, particularly in Apulia, Calabria, Campania, Sardinia, and Sicily. In 2010, 615 new wind turbines were deployed in Italy and their average capacity was 1,541 kW. The total number of online wind turbines thus became 4,852, with an overall average capacity of 1,195 kW. All plants are based on land, mostly on hill or mountain sites.

Japan

The 2010 production from wind farms could provisionally be put at about 8.4 TWh, which would be about 2.6% of total electricity demand on the Italian system. In 2012, the total installed wind capacity in Japan reached 2,614 MW with 1,887 turbines, including 25.3 MW from 15 offshore wind turbines. The annual net increase was 78 MW. Total energy produced from wind turbines during 2012 was 4.5 TWh, and this corresponds to 0.54% of national electric demand (861 TWh).

In response to the great East Japan earthquake and tsunami of March 2011, the decision was taken to dismantle four nuclear power plants in FukushimaThe cumulative installed wind power in the Republic of Korea was 406 MW in 2011 and 487 MW in 2012, increasing by 17% from the previous year. Most wind turbine systems installed in 2012 were supplied by local turbine system manufacturers. A Renewable Portfolio Standard (RPS) proposal for new and renewable energy was enacted in 2012. The required rate of RPS in 2012 was 2% and will increase to 10% by 2022. In 2012, the first year of RPS, more than 60% of the target rate was achieved.

Mexico

During 2012, 645 MW of new wind turbines were commissioned in México, bringing the total wind generation capacity to 1,212 MW. The Law for Renewable Energy Use and Financing of Energy Transition (enacted in November 2008) is successfully achieving its main objectives. Wind energy is now a competitive option within the Mexican electricity market, and the Secretariat of Energy issued a Special Program for the Use of Renewable Energy. A 2000-MW, 400-kV, 300-km electrical transmission line was commissioned for wind energy projects in the Isthmus of Tehuantepec. Presently, the construction of 276 MW of new wind power capacity has been secured. This will bring the total generation capacity to at least 1,488 MW by the end of 2013. It is expected that public and private companies will be capable of managing appropriately pending social requirements. In 2012, 195.3 MW of new wind power capacity was installed in Norway, which is more than has ever been installed in one year before. Total installed capacity was 704 MW at the end of the year and production of wind power in 2012 was 1,569 GWh compared to 1,308 GWh in 2011.

Norway

The calculated wind index for Norwegian wind farms in 2012 was 103%, corresponding to a production index of 107%. The average capacity factor for Norwegian wind farms in normal operation was 31.2%.Wind generation amounted to 1.1% of the total electric production in the country.

Portugal

In Portugal, 2012 was an atypical year in Portugal with regards to energy. Due to the efficiency measures implemented in recent years, but also due to the economic recession, electricity consumption in Portugal dropped 3.6% to 49.1 TWh. This represents a reduction of 6% of electricity demand in the last two years. It was also an extremely dry year, the fifth driest hydro year of the past 80 years (63% below the normal climate). Therefore, due to the reduced hydro production, the renewable contribution for the energy mix decreased 17% compared to 2011.

Spain

Installed wind capacity in Spain reached 22,785 MW in 2012 with the addition of 1,112 MW, according to the Spanish Wind Energy Association's (AEE) Wind Observatory. The growth has been similar to 2011, which had an increase of 1,050 MW. Spain is the fourth country in the world in terms of installed capacity and produced 48,156 GWh of electricity from wind in 2012.

In 2012, Spain's electrical energy demand decreased 1.8% from 2011 to 269.16 TWh. Wind energy met 17.8 % of this demand and was the third largest contributing technology in 2012. Other big contributors to the system were nuclear power plants (22.2%), coal (19.8%) and gas combined-cycle power plants (13.9%) .

During 2011, the government implemented new decreases to incentives for wind energy so that the wind sector would share the burden of helping the country to reduce its subsidy bill for green energy. Spain's landmark renewable energy law, 661/2007, only governs wind power prices for new projects through 2012. A draft decree sent to the national energy commission in September sets out the proposed regulations after 2012. However, lobbyists are arguing that the 2020 target will not be achieved if the bill is passed.

Sweden

The new wind energy installations in 2012 had a capacity of 755 MW (765 MW were installed in 2011). The goal is to increase renewable generation by 25 TWh compared to the level in 2002 by 2020. A major part of wind power research financed by the Swedish Energy Agency is carried out in the research programs Vindforsk III, Vindval, and the Swedish Wind Power Technology Center (SWPTC). The technical program Vindforsk III runs from 2009–2012 and has a total budget of about 80 million SEK (9.3 million EUR; 12.3 million USD). Vindval is a knowledge program focused on studying the environmental effects of wind power.

Vindval runs from 2009–2012 with a budget of 35 million SEK (4.1 million EUR; 5.4 million USD). The SWPTC at Chalmers Institute of Technology runs from 2010–2014 and has a total budget of 100 million SEK (11.6 million EUR; 15.4 million USD). The center focuses on complete design of an optimal wind turbine, which takes the interaction among all components into account

Switzerland

By the end of 2012, 32 wind turbines of considerable size were operating in Switzerland with a total rated power of 49 MW. These turbines produced 88 GWh of electricity. Since 1 January 2009, a cost-covering feed-in-tariff (FIT) for renewable energy has been implemented in Switzerland . This policy in promoting wind energy led to a boost of new wind energy projects. Financing is requested today for additional 3,343 GWh under the FIT scheme. Due to continuous obstacles in the planning procedures and acceptance issues, only two new turbines with a rated power of 3.9 MW were installed in 2012

The United Kingdom (UK) has approximately 40% of Europe's entire wind resource and significant potential for both onshore and offshore wind. The UK government has put in place a range of measures to enable the deployment of that potential resource and is committed to ensuring the further growth of wind generation in the UK. The UK signed up in 2009 to a European Union (EU) target of 20% of primary energy (electricity, heat, and transport) from renewables sources. The UK contribution to that target is 15% by 2020. Wind will be an important contributor to this target. Figure 1 shows Griffin wind farm near Perth, Scotland, completed in 2012 with a total installed capacity of 156.4 MW. In 2012, total wind capacity in the UK was 8.29 GW, representing approximately 6% of the UK's national electricity demand, an increase of 1.8 GW from the 2011 figure (a 27% increase). A significant increase in electricity generation from wind was seen in 2012 in the UK, from 15.5 TWh in 2011 to 21.8 TWh in 2012 (40% increase)

United States of America

In the United States, 13,131 MW of wind power capacity came online in 2012, more than any other year and nearly twice as much as was installed in 2011. This added wind capacity represented 43% of new U.S. electricity generation capacity for 2012, surpassing the 33% of new generation represented by natural gas.

Wind energy now accounts for nearly 3.5% of national electricity consumption in the United States and is deployed in 39 states and territories. The state of Texas alone has more installed wind power than all but five countries around the world.

The record installations in 2012 represented a rush to complete projects before the pending expiration of a key federal incentive for wind energy—the Production Tax Credit (PTC). In January 2013, as part of the American Taxpayer Relief Act of 2012, the U.S. Congress extended the incentive for one year and changed the eligibility requirement so that rather than being in operation, farms must be under construction by the end of the year.