GLOBAL WIND ENERGY OUTLOOK 2008

GREENPEACE

GWEC
GLOBAL WIND ENERGY COUNCIL

WIND POWER WORKS

OCTOBER 2008

Contents

Foreword

OVER THE PAST YEAR OR SO it seems that the extraordinary success of the wind industry has finally caught the attention of the main players in the energy policy arena. Whether it is in the reports of the IPCC, the IEA or in the energy debate in an increasing number of countries around the world, the idea that wind power is going to play a significant role in our energy future has begun to take hold. Clean, emissions free wind power is now correctly regarded as an increasingly important part of the answer to the twin global crises of energy security and climate change.

But how important a role will it play? What share of the global electricity 'pie' can and will (and some might say: must) wind occupy in the future? That is the question that the Global Wind Energy Outlook seeks to answer.

Prognostication is a dangerous business at this point in history. We are in the midst of a period of fundamental change as to how we produce and consume energy, and nowhere is this clearer than in the explosive growth in investment in the clean energy sector, with wind power taking by far the largest share of that investment, some 50 billion US dollars in 2007 alone. More wind power was installed in Europe in 2007 than any other technology, some 40% of all new power generation capacity, and it also accounted for 30% of all new generation capacity installed in the United States during that same period. Of equal significance is the fact that for the first time in decades, the majority of the 2007 market was outside Europe, concentrated primarily in the United States and China.

The increased confidence in wind power is also reflected in the names of the largest investors in the sector. These are no longer the pioneers who built the industry in its early days, but major national and international utilities, manufacturers and companies who have created their empires in the traditional energy sector. At the same time, local and regional governments are increasingly mounting campaigns to attract manufacturers, suppliers and developers to their town, their county, their state or province for the economic benefits that wind power brings, providing large numbers of quality jobs and development or redevelopment opportunities, particularly in rural areas. From Sweetwater, Texas, to Urumqi in China's Xinjiang province; from Chennai in India to Fortaleza in NE Brazil, and from Schleswig Holstein to Turkey's Black sea coast, the wind power industry is creating new jobs and economic opportunity at an extraordinary pace; as well, of course, as clean, emissions-free electricity.

As governments struggle to come up with a viable international climate agreement, it is important that they keep their eyes on the goal. As clearly shown in last year's IPCC 4th Assessment Report, that goal must be to ensure that global greenhouse gas emissions peak, and begin to decline by 2020 at the latest. This is the minimum necessary if we are to give the next generation the chance to avoid the worst ravages of climate change. That must be the focus, and the objective of the new climate agreement.

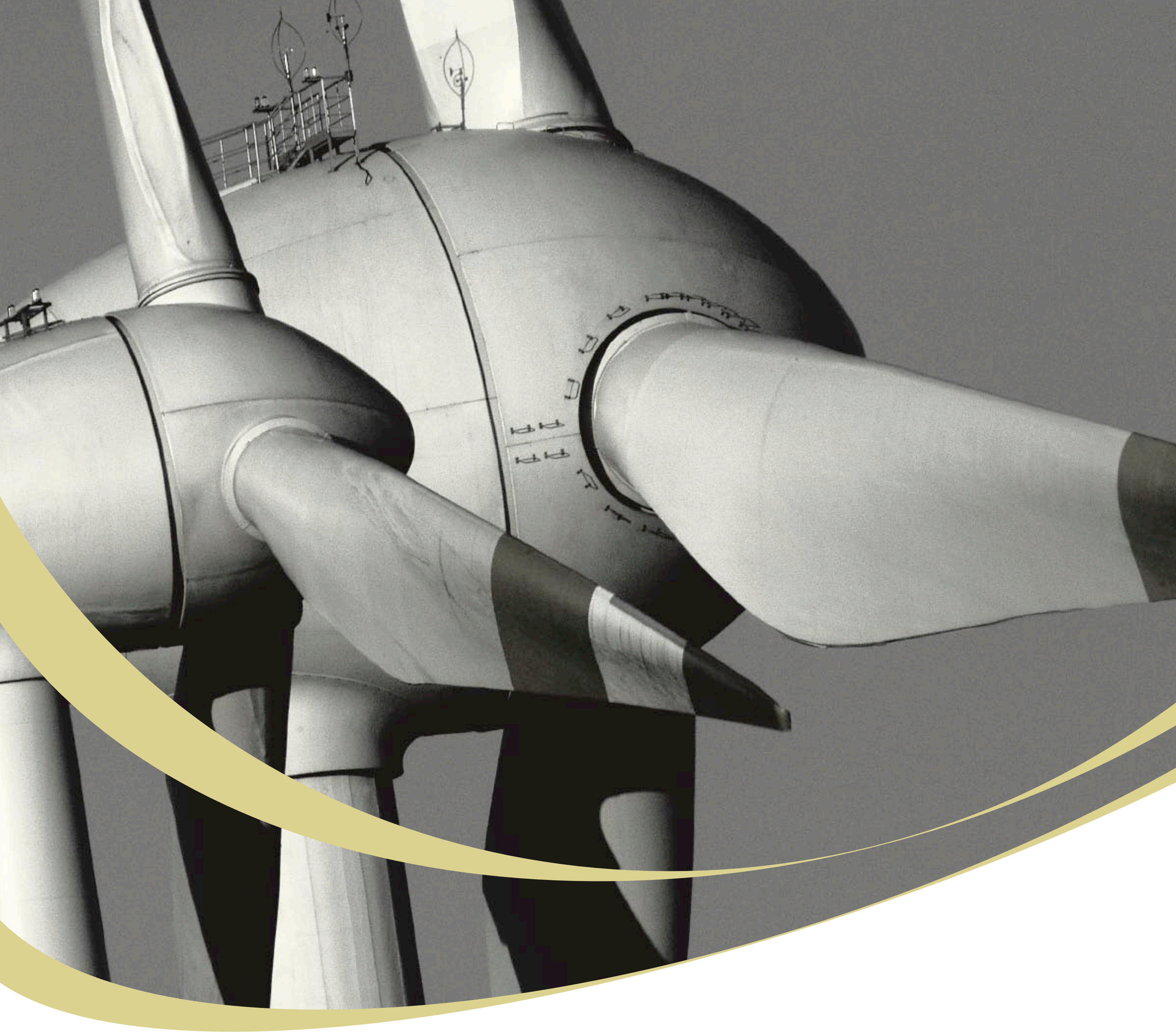
The power sector is by no means the only culprit when it comes to greenhouse gas emissions, but it is still the largest, contributing about 40% of global carbon dioxide emissions. If we want to make a major difference in power sector emissions between now and 2020, there are three options: one, efficiency; two, fuel switching from coal to gas; and three, renewables, which means mostly wind power in this time frame.

As can be seen from the Global Wind Energy Outlook, the wind industry stands ready to do its part in what the UN Secretary General has described as 'the defining struggle of the 21st century'. With sufficient political will and the right frameworks, it could do even more.

ARTHOUROS ZERVOS
Chairman –
Global Wind Energy Council

SVEN TESKE
Director Renewable Energy Campaign –
Greenpeace International

STEVE SAWYER
Secretary General –
Global Wind Energy Council



1. DRIVERS FOR WIND ENERGY

THE GROWTH OF THE MARKET for wind energy is being driven by a number of factors, including the wider context of energy supply and demand, the rising profile of environmental issues, especially climate change, and the impressive improvements in the technology itself. These factors have combined in many regions of the world to encourage political support for the industry's development.

Security of supply

Global demand for energy is increasing at a breathtaking pace, and this is particularly true in China, India and other rapidly developing economies. This sharp increase in world energy demand will require significant investment in new power generating capacity and grid infrastructure, especially in the developing world.

Industrialised countries face a different but parallel situation. While demand is increasing, the days of overcapacity in electricity production are coming to an end. Many older power plants will soon reach the end of their working lives. The IEA predicts that by 2030, over 2,000 GW of power generation capacity will need to be built in the OECD countries, including the replacement of retiring plants.

Just as energy demand continues to increase, supplies of the main fossil fuels used in power generation, are becoming more expensive and more difficult to extract. One result is that some of the major economies of the world are increasingly relying on imported fuel at unpredictable cost, sometimes from regions of the world where conflict and political instability threaten the security of that supply.

In contrast to the uncertainties surrounding supplies of conventional fuels, and volatile prices, wind energy is a massive indigenous power source which is permanently available in virtually every country in the world. There are no fuel costs, no geo-political risk and no supply dependence on imported fuels from politically unstable regions.

Every kilowatt/hour generated by wind power has the potential to displace fossil fuel imports, improving both security of supply and the national balance of payments, which is not only an issue for the United States which sends more than half a trillion dollars a year out of the country to pay its oil bill. This is an even larger issue for poor countries in Africa, Asia and South America whose economies have been devastated by recent oil price hikes.

Wind power also has the advantage that it can be deployed faster than other energy supply technologies. Even large offshore wind farms, which require a greater level of infrastructure and grid network connection, can be installed from start to finish in less than two years. This compares with the much longer timescale for conventional power stations such as nuclear reactors.

Economic considerations

Wind energy makes sound economic sense. In contrast to new gas, coal or even a nuclear power plants, the price for fuel over the total lifetime of a wind turbine is well known: it is zero. For conventional generation technologies, future price developments are a significant risk factor, and if current trends are any indication, they are likely to continue rising into the unforeseeable future.

Wind farm owners, however, know how much the electricity they generate is going to cost. No conventional technology (except hydro – the 'established' renewable power generating technology) can make that claim. This is of fundamental concern not only to individual utilities and power plant operators, but also to government planners seeking to mitigate their vulnerability to macroeconomic shocks associated with the vagaries of international commodity markets.

In addition, at many sites, wind power is already competitive with new-built conventional technologies, and in some cases much cheaper. Although nothing can compete with existing, embedded conventional generation plant that has already been paid off (and was mostly constructed with significant state subsidies: governments still subsidize conventional technologies at the rate of about 250 billion USD/year), wind power is commercially attractive, especially when taking into account the price of carbon, which is a factor in a growing number of markets.

Regional economic development is also a key factor in economic considerations surrounding wind energy. From Schleswig-Holstein in northern Germany, to Andalucía in Spain; from the US Pacific Northwest to west Texas to

Pennsylvania; and from Xinjiang and Inner Mongolia in China to Tamil Nadu and Gujarat in India, the wind power industry is revitalising regional economies, providing quality jobs and expanding tax bases in rural regions struggling to keep their economies moving ahead in the face of the global flight to the cities.

Environmental concerns

Climate change is now generally accepted to be the greatest environmental threat facing the world, and keeping our planet's temperature at sustainable levels has become one of the major concerns of policy makers. The UN's Intergovernmental Panel on Climate Change projects that average temperatures around the world will increase by up to 5.8°C over the coming century. This is predicted to result in a wide range of climate shifts, including melting ice caps, flooding of low-lying land, storms, droughts and violent changes in weather patterns.

One of the main messages from the Nobel Prize winning IPCC's 4th Assessment Report released in 2007 was that in order to avoid the worst ravages of climate change, global greenhouse gas emissions must peak and begin to decline before 2020.

While the power sector is far from being the only culprit when it comes to climate change, it is the largest single source of emissions, accounting for about 40% of CO_2 emissions, and about 25% of overall emissions. The options for making major emissions reductions in the power sector between now and 2020 are basically three: energy efficiency and conservation; fuel switching from coal to gas; and renewable energy, primarily wind power.

Wind power does not emit any climate change inducing carbon dioxide nor other air pollutants which are polluting the major cities of the world and costing billions in additional health costs and infrastructure damage. Within three to six months of operation, a wind turbine has offset all emissions caused by its construction, to run virtually carbon free for the remainder of its 20 year life. Further, in an increasingly carbon-constrained world, wind power is risk-free insurance against the long term downside of carbon intense investments.

Given the crucial timeframe up to 2020 during which global emission must start to decline, the speed of deployment of wind farms is of key importance in combating climate change. Building a conventional power plant can take 10 or 12 years or more, and until it is completed, no power is being generated. Wind power deployment is measured in months, and a half completed wind farm is just a smaller power plant, starting to generate power and income as soon as the first turbines are connected to the grid.

Another consideration of wind energy deployment concerns water. In an increasingly water-stressed world, wind power uses virtually none of this most precious of commodities in its operation. Most conventional technologies, from mining

and extraction to fuel processing and plant cooling measure their water use in the millions of liters per day.

Other environmental effects resulting from the range of fuels currently used to generate electricity include the landscape degradation and dangers of fossil fuel exploration and mining, the pollution caused by accidental oil spills and the health risks associated with radiation produced by the routine operation and waste management of the nuclear fuel cycle. Exploiting renewable sources of energy, including wind power, avoids these risks and hazards.

2. THE WORLD'S WIND RESOURCES

ONE OF THE QUESTIONS most often asked about wind power is 'what happens when the wind doesn't blow'. While on a local level this question is answered in chapter 5 (Grid integration), in the big picture wind is a vast untapped resource capable of supplying the world's electricity needs many times over. In practical terms, in an optimum, clean energy future, wind will be an important part of a mix of renewable energy technologies, playing a more dominant role in some regions than in others. However, it is worthwhile to step back for a minute and consider the enormity of the resource.

Researchers at Stanford University's Global Climate and Energy Project recently did an evaluation of the global potential of wind power, using five years of data from the US National Climatic Data Center and the Forecasts Systems Laboratory[1]. They estimated that the world's wind resources can generate more than enough power to satisfy total global energy demand. After collecting measurements from 7,500 surface and 500 balloon-launch monitoring stations to determine global wind speeds at 80 metres above ground level, they found that nearly 13% had an average wind speed above 6.9 metres per second (Class 3), sufficient for economical wind power generation. Using only 20% of this potential resource for power generation, the report concluded that wind energy could satisfy the world's electricity demand in the year 2000 seven times over.

North America was found to have the greatest wind power potential, although some of the strongest winds were observed in Northern Europe, while the southern tip of South America and the Australian island of Tasmania also recorded significant and sustained strong winds. To be clear, however, there are extraordinarily large untapped wind resources on all continents, and in most countries; and while this study included some island observation points, it did not include offshore resources, which are enormous.

For example, looking at the resource potential in the shallow waters on the continental shelf off the densely populated east coast of the US, from Massachusetts to North Carolina, the average potential resource was found to be approximately four times the total energy demand in what is one of the most urbanized, densely populated and highest-electricity consuming regions of the world[2].

A study by the German Advisory Council on Global Change (WBGU), "World in Transition – Towards Sustainable Energy Systems" (2003) calculated that the global technical potential for energy production from both onshore and offshore wind installations was 278,000 TWh (Terawatt hours) per year. The report then assumed that only 10–15% of this potential would be realisable in a sustainable fashion, and arrived at a figure of approximately 39,000 TWh supply per year as the contribution from wind energy in the long term, which is more than double current global electricity demand.

The WBGU calculations of the technical potential were based on average values of wind speeds from meteorological data collected over a 14 year period (1979–1992). They also assumed that advanced multi-megawatt wind energy converters would be used. Limitations to the potential came through excluding all urban areas and natural features such as forests, wetlands, nature reserves, glaciers and sand dunes. Agriculture, on the other hand, was not regarded as competition for wind energy in terms of land use.

Looking in more detail at the solar and wind resource in 13 developing countries, the SWERA (Solar and Wind Energy Resource Assessment) project, supported by the United Nations Environment Programme, has found the potential, for instance, for 7,000 MW of wind capacity in Guatemala and 26,000 MW in Sri Lanka. Neither country has yet started to seriously exploit this large resource.

After this initial pilot programme, SWERA has expanded since 2006 into a larger programme with the aim of providing high quality information on renewable energy resources for countries and regions around the world, along with the tools needed to apply this data in ways that facilitate renewable energy policies and investments. The private sector is also getting into the resource-mapping business, with Seattle based 3Tier launching its 'mapping the world' programme in 2008, with the goal of making accessible resource assessments available for the entire world by 2010.

In summary, wind power is a practically unlimited, clean and emissions free power source, of which only a tiny fraction is currently being exploited.

1 *Archer, C. L., and M. Z. Jacobson (2005), Evaluation of global wind power, J. Geophys. Res., 110, D12110, doi:10.1029/2004JD005462.*

2 *Kempton, W., C. L. Archer, A. Dhanju, R. W. Garvine, and M. Z. Jacobson (2007), Large CO_2 reductions via offshore wind power matched to inherent storage in energy enduses, Geophys. Res. Lett., 34, L02817, doi:10.1029/*

3. TECHNOLOGY AND INDUSTRIAL DEVELOPMENT

Modern wind turbines

Since the 1980s, when the first commercial wind turbines were deployed, their installed capacity, efficiency and visual design have all improved enormously.

Although many different pathways towards the ideal turbine design have been explored, significant consolidation has taken place over the past decade. The vast majority of commercial turbines now operate on a horizontal axis with three evenly spaced blades. These are attached to a rotor from which power is transferred through a gearbox to a generator. The gearbox and generator are contained within a housing called a nacelle. Some turbine designs avoid a gearbox by using direct drive. The electricity is then transmitted down the tower to a transformer and eventually into the grid network.

Wind turbines can operate across a wide range of wind speeds - from 3-4 metres per second up to about 25 m/s, which translates into 90 km/h (56 mph), and would be the equivalent of gale force 9 or 10. The majority of current turbine models make best use of the constant variations in the wind by changing the angle of the blades through 'pitch control', by turning or "yawing" the entire rotor as wind direction shifts and by operating at variable speed. Operation at variable speed enables the turbine to adapt to varying wind speeds and increases its ability to harmonise with the operation of the electricity grid. Sophisticated control systems enable fine tuning of the turbine's performance and electricity output.

Modern wind technology is able to operate effectively at a wide range of sites – with low and high wind speeds, in the desert and in freezing arctic climates. Clusters of turbines collected into wind farms operate with high availability, are generally well integrated with the environment and accepted by the public. Using lightweight materials to reduce their bulk, modern turbine designs are sleek, streamlined and elegant.

The main design drivers for current wind technology are:

- reliability
- grid compatibility
- acoustic performance (noise reduction)
- maximum efficiency and aerodynamic performance
- high productivity for low wind speeds
- offshore expansion

Wind turbines have also grown larger and taller. The generators in the largest modern turbines are 100 times the size of those in 1980. Over the same period, their rotor diameters have increased eight-fold. The average capacity of turbines installed around the world during 2007 was 1,492 kW, while the largest turbine currently in operation is the Enercon E126, with a rotor diameter of 126 metres and a power capacity of 6 MW.

The main driver for larger capacity machines has been the offshore market, where placing turbines on the seabed demands the optimum use of each foundation. Fixing large foundations in the sea bed, collecting the electricity and transmitting it to the shore all increase the costs of offshore development over those on land. Although the offshore wind farms installed so far have used turbines in the capacity range up to 3.6 MW, a range of designs of 5 MW and above are now being deployed and are expected to become the 'standard' in the coming years.

For turbines used on land, however, the past few years have seen a levelling of turbine size in the 1.5 to 3 MW range. This has enabled series production of many thousands of turbines of the same design, enabling teething problems to be ironed out and reliability increased.

Ongoing innovations in turbine design include the use of different combinations of composite materials to manufacture blades, especially to ensure that their weight is kept to a minimum, variations in the drive train system to reduce loads and increase reliability, and improved control systems, partly to ensure better compatibility with the grid network.

Manufacture and installation

Complete wind turbines and their support components are manufactured in factories spread throughout the world. The leading turbine manufacturers are based in Denmark, Germany, Spain, the United States, India and China. Although the mass production of turbines started in Europe, global demand for the technology has now created a market in many other countries, most recently China, which is now host to the largest turbine manufacturing industry in the world.

Manufacture of wind turbines has benefited from increasing understanding of their aerodynamics and load factors and from the economic drive towards mass production techniques.

Modern turbines are modular and quick to install; the site construction process can take a matter of months. This is of particular importance for countries in need of a rapid increase in electricity generation. Wind farms can vary in size from a few megawatts up to several hundred. The largest wind farm in the world is the Horse Hollow Wind Energy Center in Texas. A total of 421 wind turbines spread across a large area have an installed capacity of 735.5 MW.

Already the leading US state for wind energy, Texas is now planning to invest $4.9 billion towards building a new transmission grid 'superhighway' mainly to transport the output from rural wind farms to centres of demand. This new grid will be able to harness up to 18,000 MW of wind capacity, enough to power more than four million US homes.

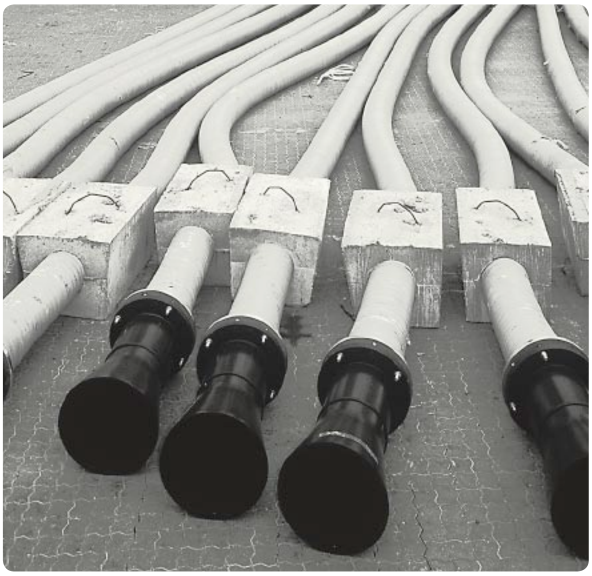
The variability of the wind has produced far fewer problems for electricity grid management than skeptics had anticipated. In very windy periods, for example, wind turbines can cover more than the entire power demand in the western part of Denmark, and the grid operators are able to manage this successfully (see *chapter 5: Grid integration*).

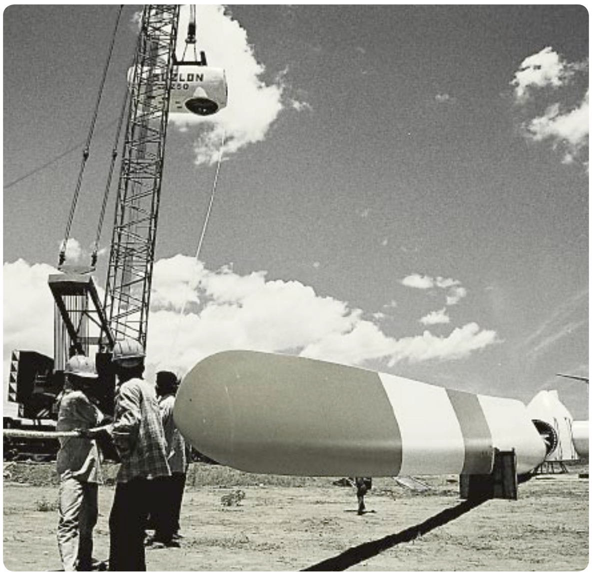
Investment opportunity

As its economic attractiveness has increased, wind energy has become big business. The major wind turbine manufacturers are now commissioning multi-million dollar factories around the world in order to satisfy demand.

As importantly, the wind energy business is attracting serious interest from outside investors. In 2002, for instance, turbine manufacturer Enron Wind was bought by a division of General Electric, one of the world's largest corporations. This lead was followed by Siemens, which took over Danish manufacturer Bonus Energy in 2004. More recently, the large European companies Alstom and Areva have both invested in wind turbine manufacture.

On the electricity supply side, several large conventional power companies have now become major owners and operators of wind farms. Spanish utility Iberdrola is the





market leader with over 8,000 MW of wind power in it is portfolio. FPL Energy in the United States is next with over 5,500 MW, but the growing list of established utilities investing heavily in wind now includes, UK's Southern Electric, RWE, E.ON, EDF and many others.

Also significant is the decision by a number of oil companies to take a stake in wind power. BP, for example, has just made major investments in the wind sector in both the United States and China. These acquisitions are evidence that wind has become established in the mainstream of the energy market.

4. GLOBAL STATUS OF THE WIND ENERGY MARKET

IN ITS BEST YEAR YET, the global wind industry installed close to 20,000 MW of new capacity in 2007. This development, led by the United States, Spain and China, took the worldwide total to 93,864 MW. This was an increase of 31% compared with the 2006 market and represented an overall increase in global installed capacity of about 27%.

The top five countries in terms of installed capacity at the end of 2007 were Germany (22.3 GW), the US (16.8 GW), Spain (15.1 GW), India (7.8 GW) and China (5.9 GW). In terms of economic value, the global wind market in 2007 was worth about €25 billion (US$37 bn) in new generating equipment and attracted about €34 bn (US$50.2 bn) of total investment.

While Europe remains the leading market for wind energy, new European installations represented just 43% of the global total, down from nearly 75% in 2004. For the first time in decades, more than half of the annual wind market was outside Europe. This trend is likely to continue.

Europe

EUROPEAN UNION

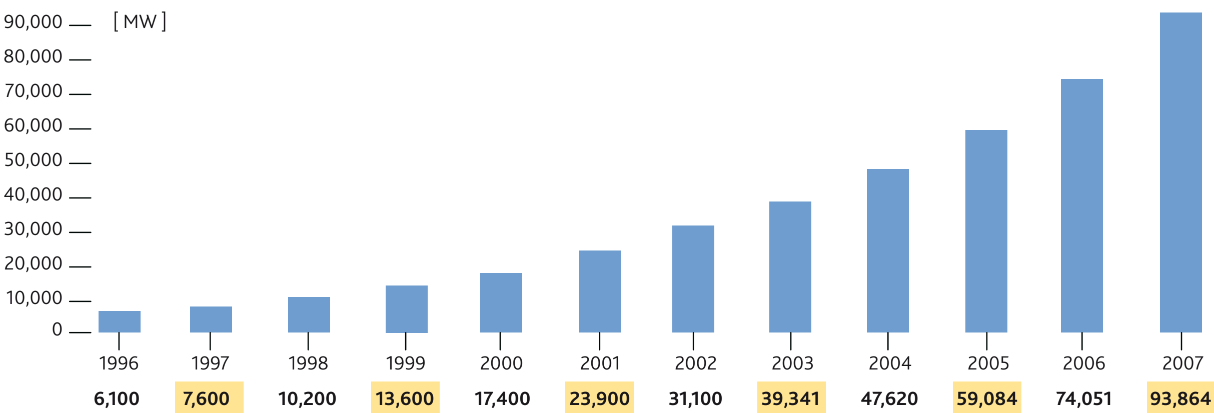
The European Union continues to be the world's strongest market for wind energy development, with over 8,500 GW of new installed capacity in 2007. Cumulative wind capacity increased by 18% last year to reach a level of 56,535 MW. Wind power has accounted for 30% of new electricity generation installations in the EU since the year 2000 and in 2007 more wind power was installed than any other generating technology.

The total wind power capacity installed by the end of 2007 will avoid about 90 million tonnes of CO_2 annually and produce 119 Terawatt hours in an average wind year. This is equal to 3.7% of EU power demand.

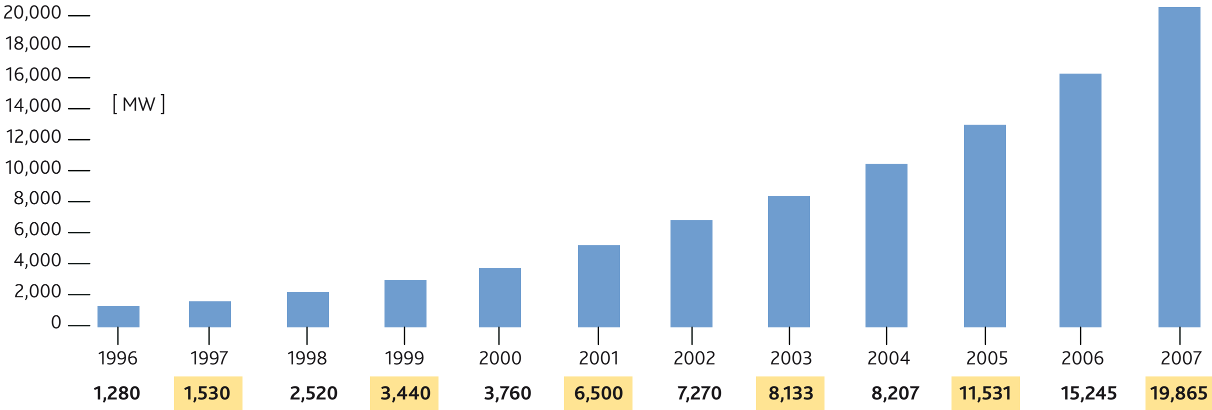
Renewable energy has been supported in Europe by a Kyoto-led target for 22% of electricity supply to come from renewables by 2010 and country by country support measures encouraged by the 2001 EU Renewable Energy Directive. This has now been extended into a new target for 20% of final energy consumption to be renewable by 2020, which will be binding on all 27 member states.

The main markets for wind energy in Europe include Germany, Spain, France, Italy and the UK, with Poland and Turkey both examples of countries with strong future potential.

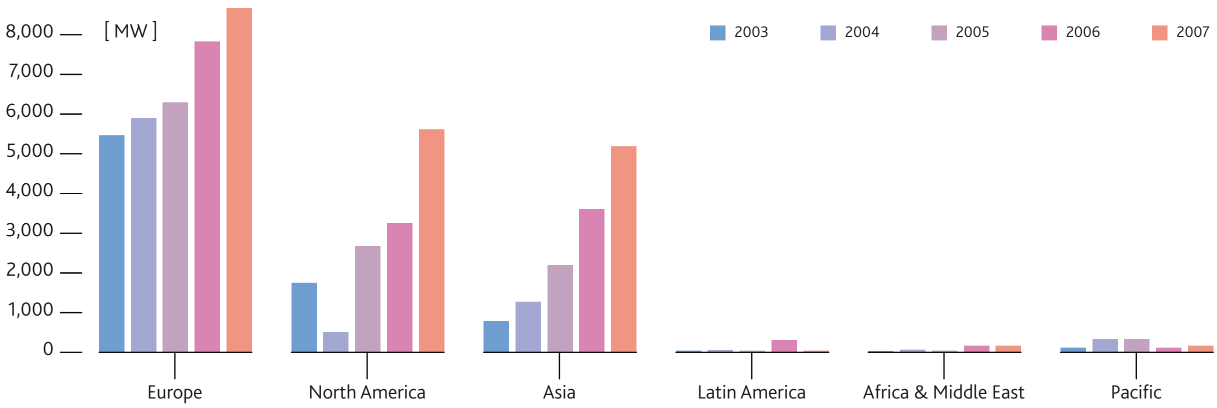
GLOBAL CUMULATIVE INSTALLED CAPACITY 1996-2007



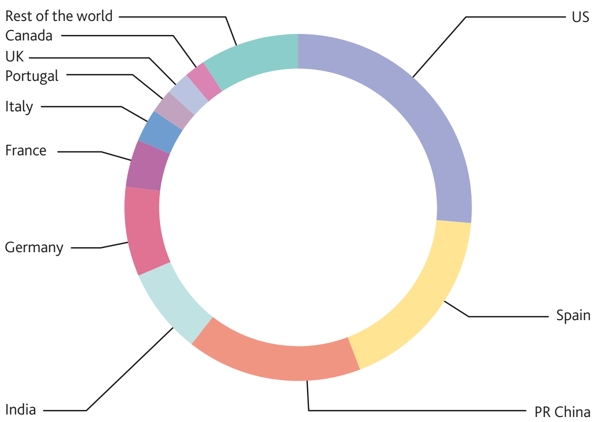
GLOBAL ANNUAL INSTALLED CAPACITY 1996-2007



ANNUAL INSTALLED CAPACITY BY REGION 2003-2007



TOP 10 NEW INSTALLED CAPACITY (JAN.-DEC. 2007)



New capacity	MW	%
US	5,244	26.4
Spain	3.522	17.7
PR China	3,304	16.6
India	1,575	7.9
Germany	1,667	8.4
France	888	4.5
Italy	603	3.0
Portugal	434	2.2
UK	427	2.1
Canada	386	1.9
Rest of the world	**1,815**	**9.1**
Top 10 – Total	**18,050**	**90.9**
World total	**19,864**	**100.0**

GERMANY

Wind power is the leading renewable energy source in Germany, providing around 7% of the country's electricity consumption. Installed capacity has reached 22,247 MW, the largest of any country in the world. The target is for 25-30% of electricity to come from all renewables, mainly wind, by 2020.

The market has been encouraged by a law introduced originally in 1991, which includes a guaranteed 'feed-in tariff' for all renewable power generators. German turbine manufacturers are among the market leaders, with a global market share of 22%. The sector currently employs more than 80,000 people.

Although the installation rate slowed down in 2007 to 1,667 MW, it is expected to pick up when larger wind farms planned off the German coast start to be constructed in the next few years.

SPAIN

The Spanish wind energy market saw spectacular growth in 2007. A record 3,522 MW of new capacity was installed, bringing the total up to 15,145 MW. Wind power now supplies 10% of total electricity demand.

The Spanish industry is on course to meet the government's target for 20,000 MW of wind energy capacity by 2010. Moreover, the Spanish Wind Energy Association (AEEolica) estimates that 40,000 MW of onshore and 5,000 MW of offshore capacity could be operating by 2020, providing close to 30% of Spain's electricity.

ITALY

The Italian wind energy market grew in 2007 by 30 % to reach a total of 2,726 MW. If the present trend continues a national target for 12,000 MW by 2020 should already be met in 2015.

The main barriers to the development remain the regional authorisations, especially over landscape issues, and grid connection difficulties. In 2007, however, the Italian government introduced a Financial Law which will require the individual regions to produce a set share of total power consumption from renewable energy sources.

FRANCE

France enjoys an abundant wind potential, and after a slow start, the wind energy market has been progressing steadily. In 2000 there was only 30 MW of capacity; by the end of 2007 the total had reached 2,454 MW, while a further 3,500 MW has been approved for construction.

The current healthy growth of wind energy in France can be explained by the implementation of a feed-in tariff system in 2001. The government's target is for 25,000 MW of wind capacity, including offshore, by 2020.

UNITED KINGDOM

The United Kingdom has a new target to source 15% of its energy from renewables by 2020. In the windiest country in Europe wind power is expected to play a major part in achieving this; the British Wind Energy Association estimates that 13 GW of wind capacity onshore and 20 GW offshore by 2020 is achievable.

By the end of 2007 the UK's installed capacity had reached 2,389 MW, with a further 1,373 MW under construction. In addition, a total of 1,974 MW has consent to be built and 7,579 MW is in the planning system. Several very large offshore wind parks are planned.

POLAND

Although the installed capacity is still modest, at 276 MW, large areas of Poland have favourable conditions for wind power generation. The onshore target is for 12,000 MW by 2020, according to the Polish Wind Energy Association.

In 2005, the Polish government introduced a stronger obligation for all energy suppliers to source a percentage of their supply from renewable energy sources. Under the new EU proposals, Poland needs to reach a renewable energy target of 15% by 2020.

TOP TEN US STATES BY MEGAWATTS OF WIND POWER GENERATING CAPACITY (AS OF 30 JUNE 2008)				
State	Existing	Under construction	% of total installations (existing)	Rank (existing)
Texas	5,604.65	3,162.35	28.67	1
California	2,483.83	295	12.71	2
Iowa	1,375.28	1,586.60	7.03	3
Minnesota	1,366.15	249.5	6.99	4
Washington	1,289.38	77.2	6.60	5
Colorado	1,066.75	0	5.46	6
Oregon	964.29	298.2	4.93	7
Illinois	735.66	171	3.76	8
New York	706.8	588.5	3.62	9
Oklahoma	689	18.9	3.52	10

Source: AWEA

TURKEY

Turkey has very limited oil and gas reserves and is therefore looking to renewable energy as a means of improving its energy security and independence from imports. In 2007 a record 97 MW of new wind energy capacity was installed, taking the total to 146 MW. As of May 2008, there were about 1300 MW under construction, 1100 MW of new licenses issued and 1500 MW licenses pending. There are also a whopping 78,000 MW of new license applications from the government's latest call.

North America

UNITED STATES

The US reported a record 5,244 MW installed in 2007, more than double the previous year's figure and accounting for about 30% of the country's new power-producing capacity. Overall US wind power generating capacity grew 45% last year, with total installed capacity now standing at 16.8 GW.

The American wind farms installed by the end of 2007 will generate an estimated 48,000 GWh in 2008, just over 1% of US power demand. The current US electricity mix consists of about 50% coal, 20% nuclear, 20% natural gas and 6% hydropower, with the rest generated from oil and non-hydro renewables, according to the US Energy Information Administration.

Most interesting is how quickly wind is growing as a share of current investment: wind projects accounted for about 30% of the entire new power-producing capacity added in the US in 2007, establishing wind power as a mainstream option for new electricity generation.

In 2007, wind power production was extended to 34 US states, with Texas consolidating its lead and the Midwest and Northwest also setting a fast pace. The states with the most cumulative wind power capacity installed are Texas (4,356 MW), California (2,439 MW), Minnesota (1,299 MW), Iowa (1,273 MW) and Washington (1,163 MW).

This sustained growth is the direct result of policy stability due to the continued availability of the federal production tax credit (PTC) over the past three years. The PTC is the only federal incentive in the US for wind power, providing a 1.9 US cents per kilowatt hour tax credit for electricity generated with wind turbines over the first ten years of a project's operations, and is a critical factor in financing new wind farms. In order to qualify, a project must be completed and start generating power while the credit is in place. The energy sector is one of the most heavily subsidised in the US economy; this incentive is needed to help level the playing field for renewable energy sources.

The PTC was extended in October 2008 to run through the end of 2009, but the uncertainty created by the last minute measure has already had some effect on 2009 orders. It is hoped that a more stable, long term system will be established by the new Administration working with the new Congress during 2009. Previously, when the credit was not extended well before its expiration date, installation growth rates fell by 93% (2000), 73% (2002) and 77% (2004).

It is expected that the US will overtake Germany as the leading wind energy country by the end of 2009. The American Wind Energy Association's initial estimates indicate that another 7.5 GW of new wind capacity will be installed in 2008.

CANADA

Canada's wind energy market experienced its second best year ever in 2007. A total of 386 MW of new capacity was installed, increasing the total by 26%. Canada now has 1,856 MW of installed wind capacity.

Ten wind projects were installed during 2007 in five different Canadian provinces. The largest was the 100.5 MW Anse-a-Valleau wind farm in Quebec, part of a commitment by utility Hydro-Quebec to commission a total of 1,000 MW.

Canada entered 2008 with signed contracts in place for the installation of an additional 2,800 MW, most of which should be up and running by no later than 2010. In addition, several new competitive tendering processes were launched in 2007 in the provinces of Manitoba, Quebec, New Brunswick and Nova Scotia which should see 4,700 MW of wind projects constructed in the period 2009–2016.

The Canadian Wind Energy Association forecasts that Canada will have 2,600 MW of installed capacity by the end of 2008. Provincial government targets and objectives in Canada, if met, add up to a minimum of 12,000 MW to be commissioned by 2016.

Asia

CHINA

China added 3,304 MW of wind capacity during 2007, a market growth of 145% over 2006, and now ranks fifth in total installed capacity - with 5,906 MW at the end of last year. Experts estimate, however, that this is just the beginning, and that the real growth in China is yet to come. The regions with the best wind regimes are located mainly along the southeast coast and the north and west of the country. Key provinces include Inner Mongolia, Xinjiang, Gansu Province's Hexi Corridor, some parts of North-East China, and the Qinghai-Tibetan Plateau.

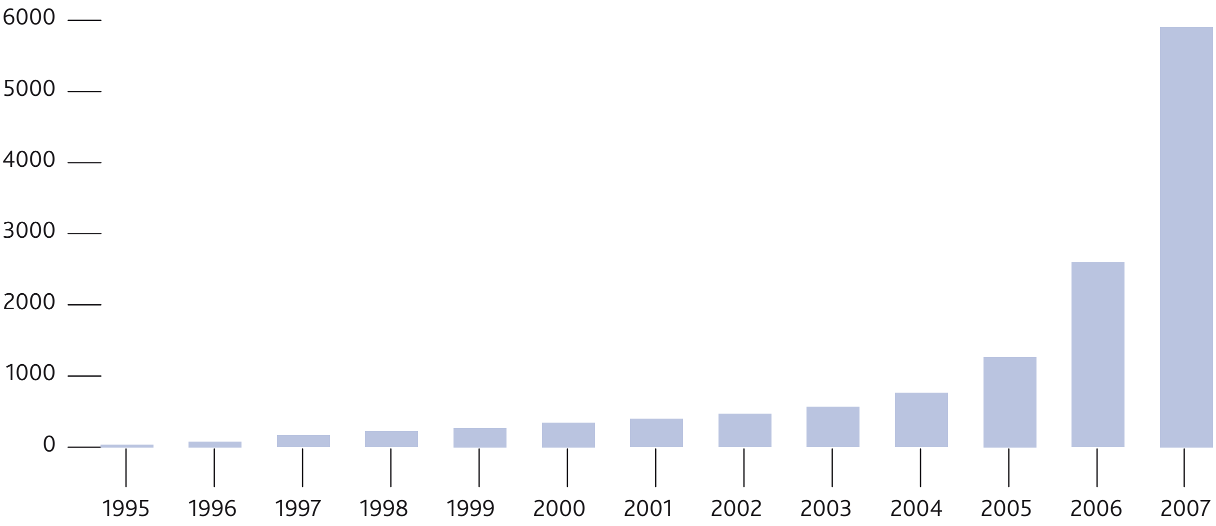
Satisfying rocketing electricity demand and reducing air pollution are the main driving forces behind the development of wind energy in China. Given the country's substantial coal resources and the still relatively low cost of coal-fired generation, cost reduction of wind power is an equally crucial issue. This is being addressed through the development of large scale projects and boosting local manufacture of turbines.

The Chinese government believes that the localisation of wind turbine manufacture brings benefits to the local economy and helps keep costs down. Moreover, since most good wind sites are located in remote and poorer rural areas, wind farm construction benefits the local economy through the annual income tax paid to county government, local economic development, grid extension for rural electrification as well as employment in wind farm construction and maintenance.

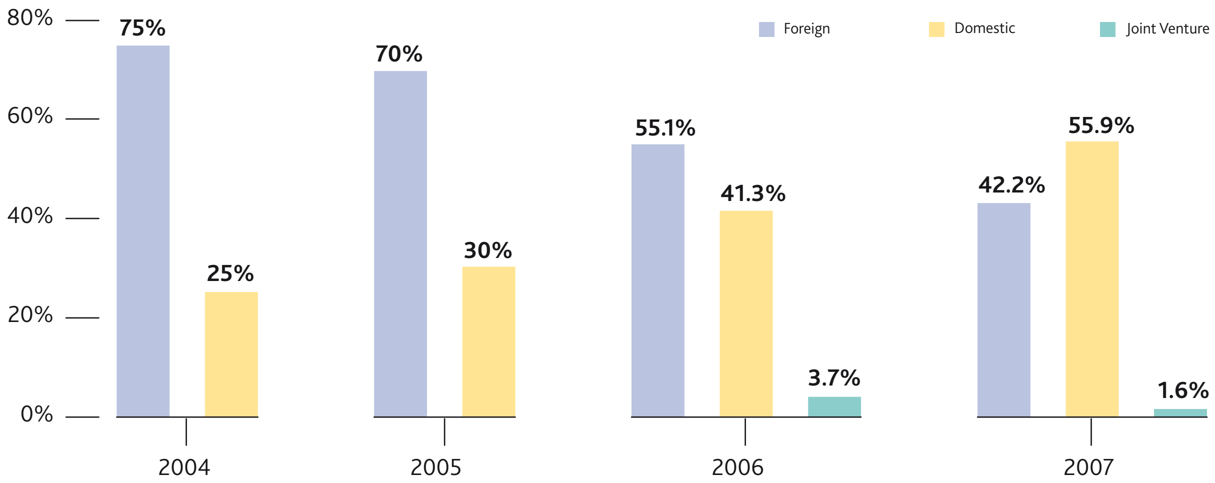
The wind manufacturing industry in China is booming. In the past, imported wind turbines dominated the market, but this is changing rapidly as the growing market and clear policy direction have encouraged domestic production.

At the end of 2007 there were 40 Chinese manufacturers involved in wind energy, accounting for about 56% of the equipment installed during the year, an increase of 21% over 2006. This percentage is expected to increase substantially in the future. Total domestic manufacturing capacity is now about 8,000 MW, and expected to reach about 12 GW by 2010. Established major Chinese manufacturers include Goldwind, Sinovel, Dongfang, Windey and Sewind. .

GROWTH OF THE CHINESE MARKET 1995-2007



FOREIGN AND DOMESTIC PLAYERS IN THE CHINESE MARKET (ANNUAL INSTALLED CAPACITY)



Source: 2007 China Wind Power Report (Li Junfeng, Gao Hu); GWEC

INDIA

Wind energy is continuing to grow strongly in India, with over 1,500 MW of new installed capacity in 2007, reaching a total of 7,845 MW. This represents a year on year growth of 25%.

The development of Indian wind power has so far been concentrated in a few regions, especially the southern state of Tamil Nadu, which accounts for more than half of all installations. This is beginning to change, with other states, including Maharashtra, Gujarat, Rajasthan and Karnataka, West Bengal, Madhya Pradesh and Andhra Pradesh starting to catch up. As a result wind farms can be seen under construction right across the country, from the coastal plains to the hilly hinterland and sandy deserts.

The Indian government envisages an annual capacity addition of up to 2,000 MW in the coming years.

While the first country-wide support for wind power was just announced in June of 2008, the Indian Ministry of New and Renewable Energy (MNRE) has issued guidelines to all state governments to create an attractive environment for the export, purchase, wheeling and banking of electricity generated by wind power projects. State Electricity Regulatory Commissions (SERC) were set up in most of the states with the mandate of promoting renewables, including wind, through preferential tariffs and a minimum obligation on distribution companies to source a certain share of electricity from renewable energy. Ten out of India's 29 states have set up renewable purchase obligations, requiring utilities to source up to 10% of their power from renewables.

The Indian government is considering accelerating depreciation, and replacing the ten year tax holiday with tradable tax credits or other instruments. While this would be an issue for established companies, new investors are less reliant on the tax holiday, since they often have little or no tax liability.

India has a solid domestic manufacturing base, including global player Suzlon, which accounts for over half of the market. In addition, other international companies have set up production facilities in India, including Vestas, Repower, Siemens, LM Glasfiber and Enercon.

Latin America

BRAZIL

Wind energy capacity in Brazil has increased relatively slowly, reaching 247 MW by the end of 2007. The country has also prioritised the development of its biomass potential in the past few years. Wind power, however, is expected to grow substantially in the near future.

In 2002, the Brazilian government passed a programme called PROINFA to stimulate the development of biomass, wind and small hydro power generation. This law was revised in November 2003.

In the first stage (up to 2008/9), the programme guaranteed power sale contracts for 3,300 MW of projects, originally divided into three equal parts of 1,100 MW for each of the three technologies. Wind's share was later increased to 1,400 MW. The Brazilian state-controlled electricity utility Eletrobrás buys power produced by renewable energy under 20 year power purchase agreements at pre-set preferential prices.

Originally a second stage of PROINFA was envisaged with the aim of increasing the share of the three renewable sources to 10% of annual electricity consumption within 20 years.

Renewable energy generators would then have been required to issue Renewable Energy Certificates proportional to the amount of clean energy produced. However, despite the high expectations raised by the PROINFA programme, the scheme has to date failed to deliver the large number of wind projects the government had aimed for.

Predictions for 2008 are nonetheless optimistic: 14 wind farms are under construction financed by the PROINFA programme, with a total capacity of 107.3 MW. In addition, a further 27 wind farms representing 901.29 MW could be added to the grid in 2009.

More than 5,000 MW of wind energy projects have already been registered with Brazilian electricity Regulatory Agency (ANEEL), awaiting approval for supply contracts with utilities in order to move forward with planning and construction. These projects are non-PROINFA, but they are being developed in the anticipation of an auctions scheme, despite the fact that the conditions of this scheme are as yet unknown.

MEXICO

Despite the country's tremendous potential, the uptake of wind energy in Mexico has been slow, mainly due to the lack of government incentives and the lack of a clear regulatory framework encouraging private sector participation. At present, the total installed capacity is 85 MW, with the largest wind farm currently under development the 83.3 MW

La Venta project developed by the Spanish consortium Iberdrola-Gamesa.

A number of private sector companies are still involved in wind energy development in Mexico, including major players such as Cisa-Gamesa, Demex, EDF-EN, Eoliatec, Fuerza Eólica, Iberdrola, Preneal, and Unión Fenosa. According to the Mexican Wind Energy Association (AMDEE), their combined development portfolio could reach 2,600 MW in Oaxaca province and 1,000 MW in Baja California over the period from 2008-2010.

The monopolistic position of the state suppliers is the main obstacle to more widespread renewable energy use in Mexico. In addition, larger projects have failed to materialise due to the lack of favourable building and planning legislation, as well as the lack of experienced developers. Moreover, strong pressure to provide electricity at very low prices has made wind energy installations economically unviable.

Middle East & Africa

EGYPT

Egypt enjoys an excellent wind regime, particularly in the Suez Gulf, where average wind speeds reach over 10 m/sec. Egyptian wind energy capacity has increased from just 5 MW in 2001 to 310 MW at the end of 2007, with 80 MW of new capacity added in 2007.

The Zafarana project on the Gulf of Suez is the showpiece of Egypt's wind industry. Overall, 305 MW has been installed in stages from 2001 through to 2007. Electricity production from Zafarana has now reached more than 1,000 GWh at an average capacity factor of 40.6%. A further 240 MW extension is presently under implementation.

In addition to this, an area of 656 km^2 has been earmarked to host a 3,000 MW wind farm at Gulf of El-Zayt on the Gulf of Suez coast. Studies are being conducted to assess the site potential to host large wind farms of about 200 MW in cooperation with the German government, 220 MW in cooperation with Japan and 400 MW as a private sector project.

In April 2007, Egypt's Supreme Council of Energy announced an ambitious plan to generate 20% of the country's electricity from renewable sources by 2020, including a 12% contribution from wind. This would translate into 7,200 MW of grid-connected wind farms. In addition a new draft energy act has been submitted to the Egyptian parliament to encourage renewable energy deployment and private sector involvement; this includes a guarantee of priority grid access for renewable energy.

MOROCCO

With 3,000 km of coastline and high average wind speeds (7.5-9.5 m/s in the south and 9.5-11 m/s in the north), wind power is one of the most promising sectors for renewable energy generation in Morocco. The Moroccan government has therefore decided to increase wind capacity from its current 124 MW, providing 2% of the country's electricity, to 1,000 MW by 2012. As a start, the government is planning to encourage developers to add 600 MW near the towns of Tetouan, Tarfaya and Taza.

The Moroccan National Programme for Development of Renewable Energies and Energy Efficiency (PNDEREE) meanwhile has an overall aim to raise the contribution of renewable energies to 20% of national electricity consumption and 10% of primary energy by 2012 (currently 7.9% and 3.4 % respectively).

Pacific Region

AUSTRALIA

With some of the world's best wind resources, Australia is a prime market for wind energy. The growing industry can take advantage of a stable economy, good access to grid infrastructure and well organised financial and legal services. Although development has been slower than anticipated, the change of government at the end of 2007 spurred hopes for a brighter future for wind energy. Within hours of being sworn into office, the new Labour Prime Minister Kevin Rudd ratified the Kyoto Protocol, thereby dramatically changing Australia's commitment to reducing greenhouse gas emissions. This is likely to have a positive long-term impact on wind energy development.

Total operating wind capacity at the end of 2007 was 824 MW. In addition, nine projects with a total capacity of over 860 MW were in various stages of construction. Significant wind capacity is also moving through the planning stage, with over 400 MW receiving planning approval during 2007.

The new government has increased Australia's national target for 2% of electricity to come from renewable energy by 2020 up to 20%. This target will require around 10,000 MW of new renewable energy projects to be built over the next decade. The wind industry is poised to play a major role in meeting this demand.

NEW ZEALAND

New Zealand's wind energy industry is small but growing steadily. Capacity almost doubled in 2007, from 171 MW to 322 MW.

The wind industry does not receive direct financial support from the government, but experience has shown that with the right conditions it is competitive with other forms of electricity generation. One reason is that the country's exceptional wind resource results in very high capacity factors. In 2006 the average capacity factor for New Zealand's wind farms was 41%. The estimate for 2007 is 45%, with turbines in some wind farms achieving up to 70% in the windier months.

In 2007 the government announced a target for New Zealand to generate 90% of its electricity from renewable sources by 2025. It currently generates about 65%, primarily from hydro. To reach the target, renewable energy needs to grow by about 200 MW each year.

Wind provides about 1.5% of New Zealand's current electricity needs, but with limited opportunities for the expansion of hydro and geothermal generation, its contribution is set to grow. Developers are seeking consent to build projects with a combined capacity of more than 1,800 MW.

5. INTEGRATING WIND ENERGY INTO ELECTRICITY GRIDS

WIND POWER AS A GENERATION SOURCE has specific characteristics, which include variability and geographical distribution. These raise challenges for the integration of large amounts of wind power into electricity grids.

In order to integrate large amounts of wind power successfully, a number of issues need to be addressed, including design and operation of the power system, grid infrastructure issues and grid connection of wind power [1].

Variability of wind power

Wind power is often described as an "intermittent" energy source, and therefore unreliable. In fact, at power system level, wind energy does not start and stop at irregular intervals, so the term "intermittent" is misleading. The output of aggregated wind capacity is variable, just as the power system itself is inherently variable.

Since wind power production is dependent on the wind, the output of a turbine and wind farm varies over time, under the influence of meteorological fluctuations. These variations occur on all time scales: by seconds, minutes, hours, days, months, seasons and years. Understanding and predicting these variations is essential for successfully integrating wind power into the power system and to use it most efficiently.

Electricity flows – both supply and demand – are inherently variable, as power systems are influenced by a large number of planned and unplanned factors, but they have been designed to cope effectively with these variations through their configuration, control systems and interconnection.

Changing weather makes people switch their heating, cooling and lighting on and off, millions of consumers expect instant power for TVs and computers. On the supply side, when a large power station, especially, if it is a nuclear reactor, goes offline, whether by accident or planned shutdown, it does so instantaneously, causing an immediate loss of many hundreds of megawatts. By contrast, wind energy does not suddenly trip off the system. Variations are smoother because there are hundreds or thousands of units rather than a few large power stations, making it easier for the system operator to predict and manage changes in supply. Especially in large, interconnected grids, there is little overall impact if the wind stops blowing in one particular place.

Predictability is key in managing wind power's variability, and significant advances have been made in improving forecasting methods. Today, wind power prediction is quite accurate for aggregated wind farms and large areas. Using increasingly sophisticated weather forecasts, wind power generation models and statistical analysis, it is possible to predict generation from five minute to hourly intervals over timescales up to 72 hours in advance, and for seasonal and annual periods. Using current tools, the forecast error for a single wind farm is between 10 and 20% of the power output for a forecast horizon of 36 hours. For regionally aggregated wind farms the forecast error is in the order of 10% for a day ahead and less than 5% for 1-4 hours in advance.

The effects of geographical distribution can also be significant. Whereas a single wind farm can experience power swings from hour to hour of up to 60% of its capacity, monitoring by the German ISET research institute has shown that the maximum hourly variation across 350 MW of aggregated wind farms in Germany does not exceed 20%. Across a larger area, such as the Nordel system covering four countries (Finland, Sweden, Norway and Eastern Denmark), the greatest hourly variations would be less than 10%, according to studies. [3]

Design and operation of power systems

One of the most frequent misunderstandings occurring in the public discussion about integrating wind energy into the electricity network is that it is treated in isolation. An electricity system is in practice much like a massive bath tub, with hundreds of taps (power stations) providing the input and millions of plug holes (consumers) draining the output. The taps and plugs are opening and closing all the time. For the grid operators, the task is to make sure there is enough water in the bath to maintain system security. It is therefore the combined effects of all technologies, as well as the demand patterns, that matter.

Power systems have always had to deal with these sudden output variations from large power plants, and the procedures put in place can be applied to deal with variations in wind power production as well. The issue is therefore not one of variability in itself, but how to predict, manage this variability, and what tools can be used to improve efficiency.

1 See also EWEA (2009 - forthcoming): *Wind Energy The Facts, Volume 2*
2 *ibid*

3 Holttinen, H. (2004): *The impact of large scale wind power on the Nordic electricity system*

Experience has shown that the established control methods and system reserves available for dealing with variable demand and supply are more than adequate for coping with the additional variability from wind energy up to penetration levels of around 20%, depending of the nature of the system in question. This 20% figure is merely indicative, and the reality will vary widely from system to system. The more flexible a power system in terms of responding to variations both on the demand and the supply side, the easier the integration of variable generation sources such as wind energy. In practice, such flexible systems, which tend to have higher levels of hydro power and gas generation in their power mix, will find that significantly higher levels of wind power can be integrated without major system changes.

Within Europe, Denmark already gets 21% of its gross electricity demand from the wind, Spain almost 12%, Portugal 9%, Ireland 8% and Germany 7%. Some regions achieve much higher penetrations. In the western half of Denmark, for example, more than 100% of demand is sometimes met by wind power.

Grid operators in a number of European countries, including Spain and Portugal, have now introduced central control centres which can monitor and manage efficiently the entire national fleet of wind turbines.

The present levels of wind power connected to electricity systems already show that it is feasible to integrate the technology to a significant extent. Experience with almost 60 GW installed in Europe, for example, has shown where areas of high, medium and low penetration levels take place in different conditions, and which bottlenecks and challenges occur.

Another frequent misunderstanding concerning wind power relates to the amount of 'back up' generation capacity required, as the inherent variability of wind power needs to be balanced in a system.

Wind power does indeed have an impact on the other generation plants in a given power system, the magnitude of which will depend on the power system size, generation mix, load variations, demand size management and degree of grid interconnection. However, large power systems can take advantage of the natural diversity of variable sources, however. They have flexible mechanisms to follow the varying load and plant outages that cannot always be accurately predicted.

Studies and practice demonstrate that the need for additional reserve capacity with growing wind penetration very modest. Up to around 20% of wind power penetration, unpredicted imbalances can be countered with reserves existing in the system. Several national and regional studies indicate additional balancing costs in the order of 0 to 3 €/MWh for levels of wind power up to 20%. In Spain, with 12% of wind penetration, the cost of balancing power was assessed in 2007 at 1.4 €/MWh [4].

The additional balancing costs associated with large-scale wind integration tend to amount to less than 10% of wind power generation costs [5], depending on the power system flexibility, the accuracy of short-term forecasting and gate-closure times in the individual power market. The effect of this to the consumer power price is close to zero.

In order to reduce the extra costs of integrating high levels of wind, the flexibility of power systems is key. This can be achieved by a combination of flexible generation units, storage systems, flexibility on the demand side, interconnections with other power systems and more flexible rules in the power market.

Storage options

There is increasing interest in both large scale storage implemented at transmission level, and in smaller scale dedicated storage embedded in distribution networks. The range of storage technologies is potentially wide.

For large-scale storage, pumped hydro accumulation storage (PAC) is the most common and best known technology, which can also be done underground. Another technology option available for large scale is compressed air energy storage (CAES).

On a decentralised scale storage options include flywheels, batteries, possibly in combination with electric vehicles, fuel cells, electrolysis and super-capacitors. Furthermore, an attractive solution consists of the installation of heat boilers at selected combined heat and power locations (CHP) in order to increase the operational flexibility of these units.

4 IEA Task 25/VTT (October 2007): State of the art of design and operation of power systems with large amounts of wind power
5 EWEA (2009 - forthcoming): Wind Energy – The Facts, Volume 2

However, it has to be pointed out that storage leads to energy losses, and is not necessarily an efficient option for managing wind farm output. If a country does not have favourable geographical conditions for hydro reservoirs, storage is not an attractive solution because of the poor economics at moderate wind power penetration levels (up to 20%). In any case, the use of storage to balance variations at wind plant level is neither necessary nor economic.

Grid infrastructure

The specific nature of wind power as a distributed and variable generation source requires specific infrastructure investments and the implementation of new technology and grid management concepts. High levels of wind energy in system can impact on grid stability, congestion management, transmission efficiency and transmission adequacy.

In many parts of the world, substantial upgrades of grid infrastructure will be required to allow for the levels of grid integration proposed in this report. Significant improvements can be achieved by network optimisation and other 'soft' measures, but an increase in transmission capacity and construction of new transmission lines will also be needed. At the same time, adequate and fair procedures for grid access for wind power need to be developed and implemented, even in areas where grid capacity is limited.

However, the expansion of wind power is not the only driver. Extensions and reinforcements are needed to accommodate whichever power generation technology is chosen to meet a rapidly growing electricity demand. The IEA estimates that by 2030, over 1.8 trillion USD will have to be invested in transmission and distribution networks in the OECD alone.

In the present situation wind power is disadvantaged in relation to conventional sources, whose infrastructure has been largely developed under national vertically integrated monopolies which were able to finance grid network improvements through state subsidies and levies on electricity bills. But while a more liberalised market has closed off those options in some countries, numerous distortions continue to disadvantage renewable generators in the power market – from discriminatory connection charges to potential abuse of their dominant power by incumbent utilities.

Wind power's contribution to system adequacy

The 'capacity credit' of wind energy expresses how much 'conventional' power generation capacity can be avoided or replaced by wind energy. For low wind energy penetration levels, the capacity credit will therefore be close to the average wind power production, which depends on the capacity factors on each individual site (normally 20-35% of rated capacity). With increasing penetration levels of wind power, its relative capacity credit will decrease, which means that a new wind plant on a system with high wind power penetration will replace less 'conventional' power than the first plants in the system.

Aggregated wind plants over larger geographical areas are best suited to take full advantage of the firm contribution of wind power in a power system.

Grid connection issues

A grid code covers all material technical aspects relating to connections to, and the operation and use of, a country's electricity transmission system. They lay down rules which define the ways in which generating stations connecting to the system must operate in order to maintain grid stability.

Technical requirements within grid codes vary from system to system, but the typical requirements for generators normally concern tolerance, control of active and reactive power, protective devices and power quality. Specific requirements for wind power generation are changing as penetration increases and as wind power is assuming more and more power plant capabilities, i.e. assuming active control and delivering grid support services.

In response to increasing demands from the network operators, for example to stay connected to the system during a fault event, the most recent wind turbine designs have been substantially improved. The majority of MW-size turbines being installed today are capable of meeting the most severe grid code requirements, with advanced features including fault-ride-through capability. This enables them to assist in keeping the power system stable when disruptions occur. Modern wind farms are moving towards becoming wind energy power plants that can be actively controlled.

6. WIND POWER AND THE ENVIRONMENT

Environmental Benefits

CO_2 EMISSIONS

Wind power is a clean, emissions-free power generation technology. Like all renewable sources it is based on capturing the energy from natural forces and has none of the polluting effects associated with 'conventional' fuels.

First and foremost, wind energy produces no carbon dioxide - the main greenhouse gas contributing to climate change – during its operation, and minimal quantities during the manufacture of its equipment and construction of wind farms. By contrast, fossil fuels such as coal, gas and oil are major emitters of carbon dioxide.

The International Panel on Climate Change's (IPCC) 4th Assessment Report (2007) leaves no doubt that climate change is both man-made and already happening. It also warned that in order to avert the worst consequences, global emissions must peak and start to decline before 2020. The potential of wind energy to curb global emissions within this timeframe is therefore key for the long-term sustainability of the power sector.

The power sector today accounts for about 40% of global CO_2 emissions, while any improvements in the efficiency of thermal power stations are being offset by the strong growth in global power demand. To generate the same amount of electricity as today's global installed capacity of wind power would require burning more than 25 million tonnes of coal or more than 17 million tonnes of oil every year.

According to the scenarios presented in this report, global wind energy capacity could reach more than 1,000 GW by the end of 2020, producing about 2,600 TWh of electricity per year. This would save as much as 1,500 million tonnes of CO_2 every year.

AIR POLLUTION

Wind power also has a positive effect on the quality of the air we breathe. The combustion of fossil fuels also produces the gases sulphur dioxide and nitrogen oxide, both serious sources of pollution. These gases are the main components of the 'acid rain' effect - killing forests, polluting water courses and corroding facades of buildings; not to mention the human health effects.

In China, which depends for more than 80% of its electricity on coal-fired power stations, pollution is so serious that the World Health Organisation estimates that it kills upwards of 650,000 Chinese people per year.

Wind energy avoids the numerous issues associated with the discovery and exploitation of fossil fuels. Deaths from mining, the massive destruction of strip mining and 'hill-top removal' and fuel spills are just some of the consequences of dependence on recovering raw materials for electricity generation from under the ground.

According to the Canadian government's environment department, air pollution causes an estimated 5,000 premature deaths in Canada per year. Children and elderly people face the greatest risk. Nearly 12% of Canada's smog is the result of burning fossil fuels to produce electricity.

OTHER BENEFITS

The American Bird Conservancy estimates that mining operations in the states of West Virginia, Tennessee, Kentucky, and Virginia are having a massive and permanent impact on mature forest birds, including the loss of tens of thousands of breeding Cerulean Warblers.

Shortage of supplies of natural gas in the US has resulted in a growing demand for coal-bed methane extraction of gas. This is covering the country's western prairie with drilling wells, noisy compressor stations and wastewater pits, all of which threatens wildlife habitats.

The European Union-funded research study 'ExternE' [1)] has examined in detail the economic consequences for both the environment and human health of the different ways in which electricity is produced in the EU, and found that all renewable energy sources have environmental and social benefits compared to conventional energy sources such as coal, gas, oil and nuclear. These benefits can be translated into costs for society. The EU study estimated the external cost of gas fired power generation at around 1.1-3.0 €cents/kWh and that for coal at as much as 3.5-7.7 €cents/kWh, compared to just 0.05-0.25 €cents/kWh for wind.The study concluded that the cost of producing electricity from coal or oil would double, and from gas increase by 30%, if their external costs were taken into account.

1 *http://www.externe.info/externpr.pdf*

Environmental Impacts

The construction and operation of wind farms, often in rural areas, raises issues of visual impact, noise and the potential effects on local ecology and wildlife. Most of these issues are addressed during consultation with local authorities,

VISUAL IMPACT

Wind turbines are highly visible elements in the landscape. They need to be tall in order to catch the prevailing wind and work effectively. How people perceive them varies, but many see wind farms as elegant and graceful symbols of a better, less polluted future.

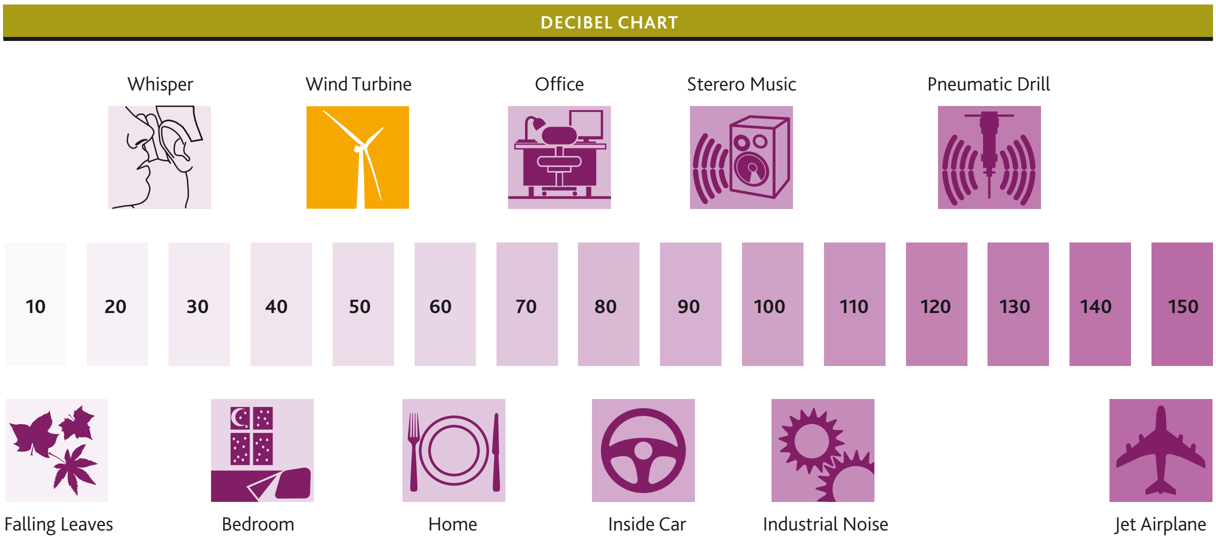
In comparison to other energy developments, however, such as nuclear, coal and gas power stations or open cast coal mining, wind farms have relatively little visual impact. Nevertheless, most countries with a wind power industry have established rules which exclude certain areas from development, such as national parks or nature reserves. Others have identified priority areas where wind power is specifically encouraged.

Wind farm developers recognise that visual impact can be a concern for neighbouring communities. Considerable effort is therefore committed to the planning stages in order to reduce the impact and gain their consent. This includes the use of computer modelling programs to show residents exactly how the turbines will appear from numerous different viewpoints.

A number of national wind energy associations have established detailed best practice guidelines for the development of wind farms, including their visual impact. In Australia, for example, the guidelines produced by Auswind cover construction, operation and decommissioning, including safety, noise, birds and community involvement. In Italy, the Italian Wind Energy Association has developed guidelines together with the main environmental associations - WWF, Legambiente and Greenpeace.

Surveys of public opinion show that most people who live near wind developments find them less intrusive once they are operating than they might have feared beforehand. Other surveys, for instance in Scotland, have shown that there is no evidence that tourism is seriously affected by the presence of wind farms. It is also worth emphasising that wind turbines are not permanent structures. Once removed, the landscape can quickly return to its previous condition.

Although a wind energy project can spread across a large total land area, it does not occupy all that space. Farming or leisure activities can still continue around the turbines. The European Wind Energy Association has estimated that the number of wind farms required to contribute 20% of Europe's electricity supply would take up only a few hundred square kilometres.



Source: AWEA

NOISE

Compared to other types of industrial plants, wind farms are extremely quiet. Even though turbines are commonly located in rural areas, where background noise is lower, the roar of the wind often masks any sound their operation might make. Measured in a range of 35 to 45 decibels at a distance of 350 metres from the turbines, their sound is similar to the background noise found in a typical home.

The sounds emitted from wind turbines can either be mechanical, from internal equipment such as the gearbox or yaw drive, or aerodynamic, from air moving past the rotor blades. Modern turbine designs have effectively reduced mechanical sound through sound proofing so that the "whooshing" aerodynamic sound is what can normally be heard.

Permitted sound levels, including the distance between turbines and the nearest house, are determined at a local level. All wind farms must comply with operating rules laid down by the appropriate authorities, normally based on national recommendations.

Thousands of wind turbines have been installed around the world, many in close proximity to other types of land use, with minimal sound issues. The wind industry seeks to be a good neighbour and addresses concerns where they arise.

BIRDS AND BATS

The most significant long term threat to birds and their habitats comes from climate change. Global shifts in the climate are altering the pattern of indigenous plant species and their attendant insect life, making once attractive areas uninhabitable.

According to the UK's Royal Society for the Protection of Birds, "recent scientific research indicates that, as early as the middle of this century, climate change could commit one third or more of land-based plants and animals to extinction, including some species of British birds". Compared to this threat, "the available evidence suggests that appropriately positioned wind farms do not pose a significant hazard for birds," it concludes [1)].

Although birds do collide with wind turbines at some sites, modern wind power plants are collectively far less harmful to birds than numerous other hazards. The leading human-related causes of bird kills in the United States, according to the US Fish and Wildlife Service, are cats (1 billion deaths per year), buildings (up to 1 bn), hunters (100 million), vehicles (60 to 80 m), as well as communications towers, pesticides and power lines. Bird deaths due to wind development will never be more than a very small fraction of those caused by other commonly-accepted human activities, no matter how extensively wind is used in the future.

1 *Royal Society for the Protection of Birds (2005): Wind farms and birds*

CAUSES OF BIRD FATALITIES

Source: CanWEA

Avian studies carried out at many wind farm sites in the US show that bird kills per megawatt of installed capacity average one to six per year or less. These include sites passed by millions of migrating birds each year. At a few sites, no kills have been found at all. In Europe, studies of almost 1,000 wind turbines in the region of Navarra, Spain, showed a detected mortality rate of between 0.1 to 0.6 collisions per turbine per year.

Well publicised reports of bird deaths, especially birds of prey, at sites including the Altamont Pass near San Francisco and Tarifa in southern Spain, are not indicative of the day to day experience at the thousands of wind energy developments now operating around the world.

As a general rule, birds notice that new structures have arrived in their area, learn to avoid them, especially the turning blades, and are able to continue feeding and breeding in the location. Problems are most likely to occur when the site is either on a migration route, with large flocks of birds passing through the area, or is particularly attractive as a feeding or breeding ground. This can be avoided by careful siting. Modern wind turbines, with their slower turning blades, have proved less problematic than earlier models.

Bird studies are routinely carried out at prospective wind sites in order to understand the local pattern of breeding and feeding. Pre-construction wildlife surveys by a professional consultant are common practice. These surveys help reduce the threat to birds to a minimal level.

Fossil fuels and birds

As a result of a single oil shipping accident - the Exxon Valdez oil spill in Alaska's Prince William Sound - more than 500,000 migratory birds were killed, about a thousand times the estimated annual total in California's wind power plants. A study at a coal-fired power plant in Florida, which had four smokestacks, recorded an estimated 3,000 bird deaths in a single evening during the autumn migration period.

SOURCE: UNION OF CONCERNED SCIENTISTS / FLORIDA ORNITHOLOGICAL SOCIETY

Like birds, bats are endangered by many human activities, from pesticide poisoning to collision with structures to loss of habitat. Despite publicity given to bat deaths around wind farms, mainly in the United States, studies have shown that wind turbines do not pose a significant threat to bat populations. A review of available evidence by ecological consultants WEST concluded that "bat collision mortality during the breeding season is virtually non-existent, despite the fact that relatively large numbers of bat species have been documented in close proximity to wind plants. These data suggest that wind plants do not currently impact resident breeding populations where they have been studied."

Monitoring of wind farms in the US indicates that most deaths involve bats that are migrating in late summer and autumn. The American Wind Energy Association has now joined forces with Bat Conservation International, the US Fish and Wildlife Service and the National Renewable Energy

Laboratory to look at why these collisions occur and how they can be prevented. This initiative is focused on finding good site screening tools and testing mitigation measures, including ultrasonic deterrent devices to warn bats away from turbines.

OFFSHORE WIND

As on land, offshore wind developers have to ensure that their turbines and transmission infrastructure do not interfere with marine life and ecosystems. National regulations ensure that project developers assess in both qualitative and quantitative terms the expected environmental impacts on the marine environment. These procedures ensure that projects comply with international and EU law as well as conventions and regulations covering habitat and wildlife conservation.

Within the structure of an environmental impact assessment, an initial baseline study is conducted. Subsequent monitoring is necessary to record any changes within the marine environment which may have been caused by human activity. The monitoring phase may go on for several years, and evaluations and conclusions are updated annually to assess changes over time.

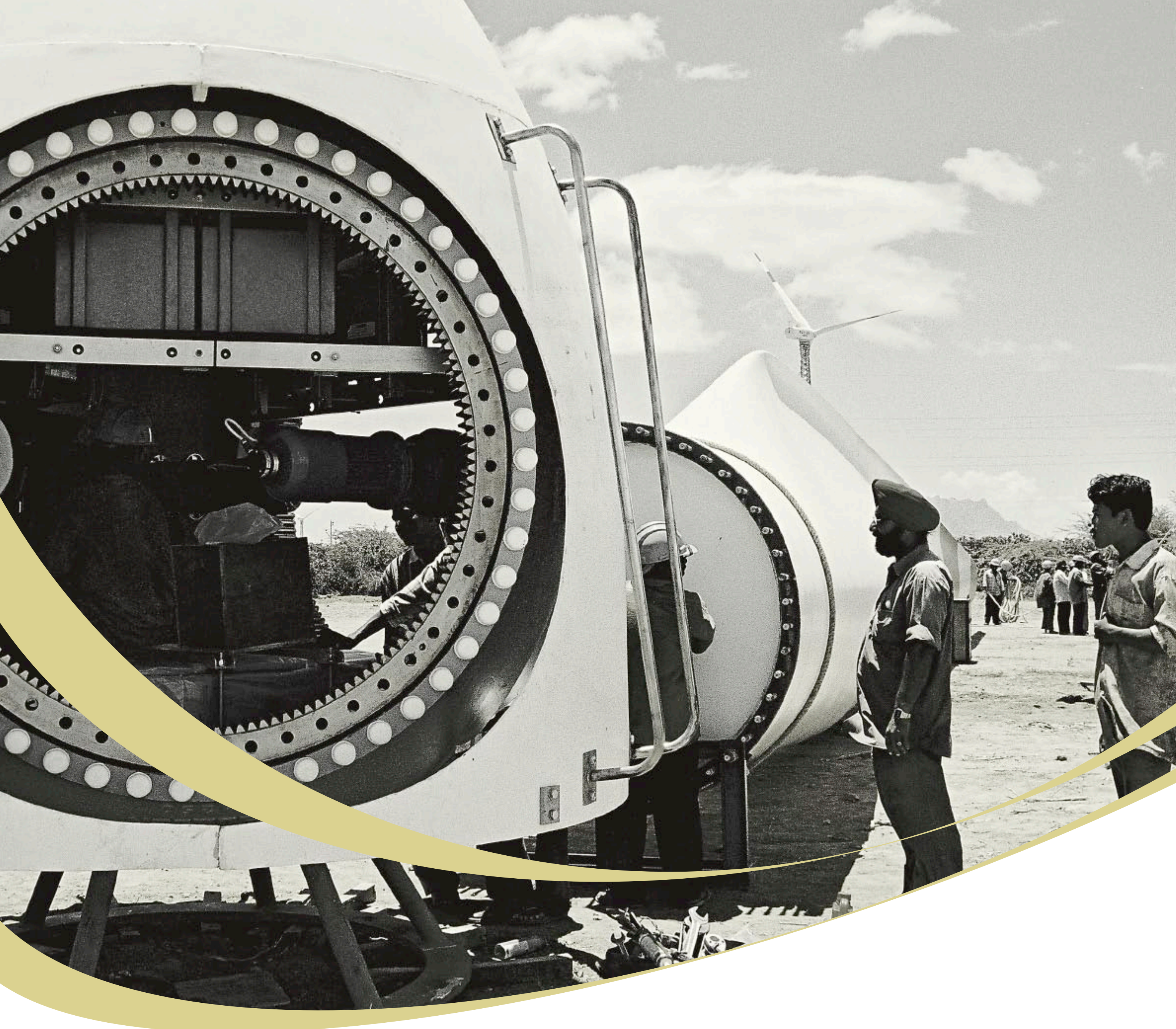
Danish experience over the past 17 years shows that offshore wind farms, if sited correctly, can be engineered and operated without significant damage to the marine environment and vulnerable species. A comprehensive environmental monitoring programme carried out at the Horns Rev (160 MW) and Nysted (165 MW) wind farms by the two developers, together with the Danish Energy Authority and the Forest and Nature Agency, has confirmed that, "under the right conditions, even big wind farms pose low risks to birds, mammals and fish…"

The monitoring showed that neither seals nor harbour porpoises, both of which are active in the area, have been forced to make any substantial changes to their behaviour. Fish and benthic communities have even been attracted to the foundations of the wind turbines after their construction, the latter using them as hatchery or nursery grounds.

Among the most common sea birds frequenting the area of the Nysted wind farm, surveys showed that among a total of 235,000 eider ducks passing by each autumn on migration, the predicted collision rate was just 0.02%. Radar plotting showed that flocks of migrating birds mostly flew round the outside of the block of 72 turbines.

CONCLUSION

Wind energy is arguably the cleanest electricity generation technology, but, like any other industry, does have environmental impacts. The wind industry takes its responsibility to reduce the impacts of wind energy on the environment very seriously, and, since the early days of this relatively young industry, significant improvements have been made with regards to the siting of wind farms and the design of turbines.



7. THE "GLOBAL WIND ENERGY OUTLOOK" SCENARIOS

THE INITIAL SECTIONS of this report have described the current status of wind energy development around the world and the range of drivers behind its expansion, as well as regulatory and grid integration issues which need to be resolved in order for this expansion to continue. The Global Wind Energy Outlook scenarios now examine the future potential of wind power up to the year 2020, and then look out towards 2050, starting from a range of assumptions which will influence the wind energy industry's expected development.

This exercise has been carried out as a collaboration between the Global Wind Energy Council (GWEC), Greenpeace International and the German Aerospace Centre (DLR). Projections on the future of wind energy development have contributed to a larger study of global sustainable energy pathways up to 2050 conducted by DLR for Greenpeace and the European Renewable Energy Council (EREC).

Scenarios

REFERENCE SCENARIO

Three different scenarios are outlined for the future growth of wind energy around the world. The most conservative **"Reference"** scenario is based on the projections in the 2007 World Energy Outlook from the International Energy Agency (IEA). This takes into account only existing policies and measures, but includes assumptions such as continuing electricity and gas market reform, the liberalisation of cross-border energy trade and recent policies aimed at combating pollution. The IEA's figures only go out to the year 2030, but based on these assumptions, DLR has extrapolated both the overall reference scenario and the growth of wind power up to 2050.

MODERATE SCENARIO

The **"Moderate"** scenario takes into account all policy measures to support renewable energy either already enacted or in the planning stages around the world. It also assumes that the targets set by many countries for either renewables or wind energy are successfully implemented. Moreover, it assumes increased investor confidence in the sector as a result of a successful outcome of the current round of climate change negotiations, which are set to culminate at UNFCCC COP-15 in Copenhagen, Denmark, in December 2009.

Up to 2012 the figures for installed capacity are closer to being forecasts than scenarios. This is because the data available from the wind energy industry shows the expected growth of worldwide markets over the next five years based on orders for wind turbines already committed. After 2012 the pattern of development is more difficult to anticipate.

ADVANCED SCENARIO

The most ambitious scenario, the **"Advanced"** version examines the extent to which this industry could grow in a best case 'wind energy vision'. The assumption here is that all policy options in favour of renewable energy, along the lines of the industry's recommendations, have been selected, and the political will is there to carry them out.

While again, the development after 2012 is more difficult to predict, this scenario is designed to show what the wind energy sector could achieve if it were given the political commitment and encouragement it deserves in light of the twin crises of energy security and global climate change.

ENERGY DEMAND PROJECTIONS

These three scenarios for the global wind energy market are then set against two projections for the future growth of electricity demand, one "Reference Demand Projection" and one "Energy Efficiency Demand Projection".

REFERENCE DEMAND PROJECTION

The more conservative of the two global electricity demand projections is again based on data from the IEA's 2007 World Energy Outlook, including its assumptions on population and GDP growth, extrapolated forwards to 2050. It takes account of policies and measures that were enacted or adopted by mid-2007, but does not include possible or likely future policy initiatives.

The IEA's estimation is that in the absence of new government policies, the world's energy needs will rise inexorably. Global demand would therefore almost double from the baseline 15,000 TWh in 2005 to reach over 29,000 TWh by 2030.

ENERGY EFFICIENCY DEMAND PROJECTION

The IEA's expectations on rising energy demand are then set against the outcome of a study on the potential effect of energy efficiency savings developed by DLR and the Ecofys consultancy [1]. This study describes an ambitious development path for the exploitation of energy efficiency measures, based on current best practice technologies, emerging technologies that are currently under development and continuous innovation in the field of energy efficiency.

In reality, of course, constraints in terms of costs and other barriers, such as resistance to replacing existing equipment and capital stock before the end of its useful life, will prevent this 'technical' energy efficiency potential to be fully realised. In order to reflect these limitations, we have used the more moderate **Energy Efficiency demand projection** from the study, which is based on implementing around 80% of the technical potential.

This scenario results in global demand increasing by much less than under the Reference projection to reach 23,937 TWh in 2030, which is 18% lower. By 2050, as much as 28% of global electricity demand or over 12,000 TWh could by saved under the Energy Efficiency demand projection.

Main Assumptions and Parameters

GROWTH RATES

Market growth rates in these scenarios are based on a mixture of historical figures and information obtained from analyses of the wind turbine market. Annual growth rates of more than 20% per annum, as envisaged in the Advanced version of the scenario, are high for an industry which manufactures heavy equipment. The wind industry has experienced much higher growth rates in recent years, however. In the five years up to 2007, the average annual increase in global cumulative installed capacity has been 25%; for the eight year period from 2000-2007, it was over 27%, which was the growth rate in the year 2007, and is in line with what is expected in 2008.

It should also be borne in mind that while growth rates eventually decline to single figures across the range of scenarios, the level of wind power capacity envisaged in 40 years' time means that even small percentage growth rates will by then translate into large figures in terms of annually installed megawatts.

TURBINE CAPACITY

Individual wind turbines have been steadily growing in terms of their nameplate capacity – the maximum electricity output they achieve when operating at full power. The average capacity of wind turbines installed globally in 2007 was 1.49 MW. At the same time the largest turbines on the market are now 6 MW in capacity.

We make the conservative assumption that the average size will gradually increase from today's figure to 2 MW in 2013 and then level out. It is possible that this figure will turn out to be greater in practice, requiring fewer turbines to achieve the same installed capacity.

It is also assumed that each turbine will have an operational lifetime of 20 years, after which it will need to be replaced. This "repowering" or replacement of older turbines has been taken into account in the scenarios.

CAPACITY FACTOR

'Capacity factor' refers to the percentage of its nameplate capacity that a turbine installed in a particular location will deliver over the course of a year. This is primarily an assessment of the wind resource at a given site, but capacity factors are also affected by the efficiency of the turbine and its suitability for the particular location. For example, a 1 MW turbine operating at a 25% capacity factor will deliver 2,190 MWh of electricity in one year.

From an estimated average capacity factor today of 25%, the scenario assumes that improvements in both wind turbine technology and the siting of wind farms will result in a steady increase. Capacity factors are also much higher at sea, where winds are stronger and more constant. The growing size of the offshore wind market, especially in Europe, will therefore contribute to an increase in the average.

The scenario projects that the average global capacity factor will increase to 28% by 2012 and then 30% by 2036.

---

1 www.energyblueprint.info

CAPITAL COSTS AND PROGRESS RATIOS

The capital cost of producing wind turbines has fallen steadily over the past 20 years as turbine design has been largely concentrated on the three-bladed upwind model with variable speed and pitch blade regulation, manufacturing techniques have been optimised, and mass production and automation have resulted in economies of scale.

The general conclusion from industrial learning curve theory is that costs decrease by some 20 % each time the number of units produced doubles. A 20 % decline is equivalent to a progress ratio of 0.80.

In the calculation of cost reductions in this report, experience has been related to numbers of units, i.e. turbines and not megawatt capacity. The increase in average unit size is therefore also taken into account.

The progress ratio assumed in this study starts at 0.90 up until 2015, steadily rising again from 2016 onwards. Beyond 2031, when production processes are assumed to have been optimised and the level of global manufacturing output has reached a peak, levels out at 0.98.

The reason for this graduated assumption, particularly in the early years, is that the manufacturing industry has not so far gained the full benefits from series production, especially due to the rapid upscaling of products. Neither has the full potential of the latest design optimisations been realized.

Contrary to this theory, the past few years, particularly since 2006, have seen a marked increase in the price of new wind turbines. This has been triggered by a mixture of rising raw material prices and shortages in the supply chain for turbine components. Examples of raw materials whose price has increased substantially are steel (used in towers, gearboxes and rotors), copper (used in generators) and concrete (used in foundations and towers). Global steel prices have almost doubled in the current year up to August 2008, while copper prices have quadrupled in the last five years. In addition, rising energy prices have also driven up the cost of manufacturing and transporting wind turbines.

Supply chain pressures have included in particular a shortage of gearboxes and the range of bearings used in turbines. These shortages are being addressed by the component manufacturers building new production capacity and by the opening up of new manufacturing bases, for example in China. Some observers predict that component supply may catch up with demand by 2010.

Even so, the cost of wind turbine generators has fallen significantly overall, and the industry is recognised as having entered the "commercialisation phase", as understood in learning curve theory.

Capital costs per kilowatt of installed capacity are taken as an average of €1,300 in 2007, rising to €1,450 in 2009. They are then assumed to fall steadily from 2010 onwards to about €1,150. From 2020 the scenario assumes a leveling out of costs at around €1,050. All figures are given at 2007 prices.

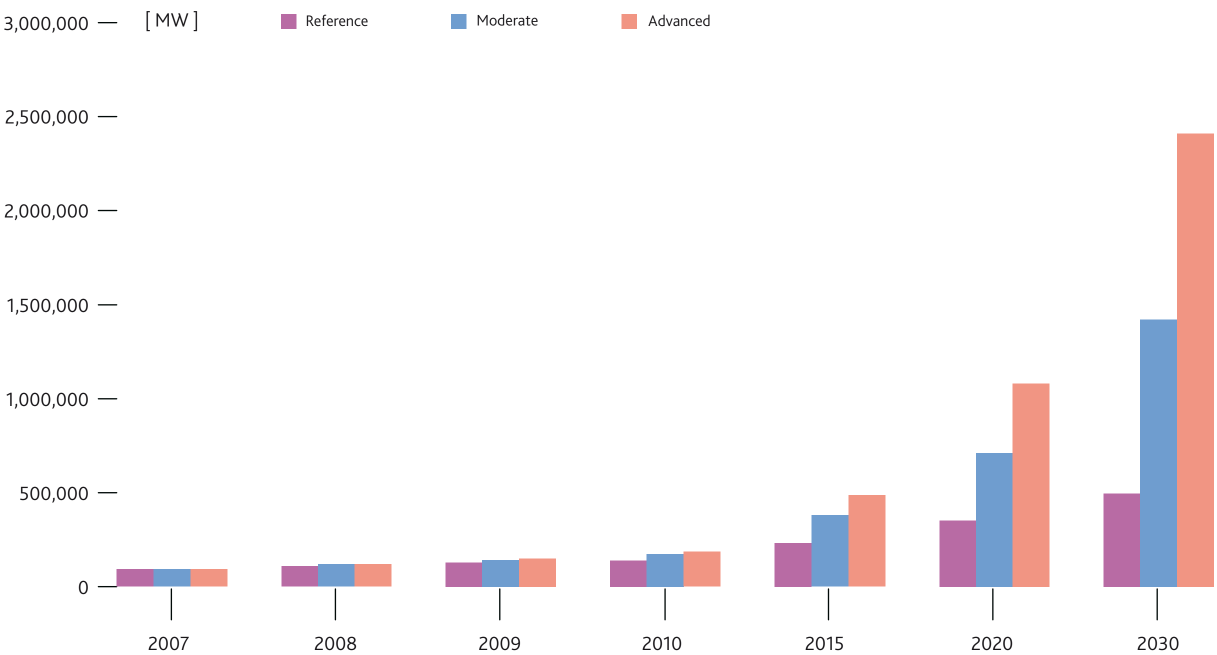
SUMMARY OF GLOBAL WIND ENERGY OUTLOOK SCENARIO FOR 2020

Global Scenario	Cumulative wind power capacity (GW)	Electricity output (TWh)	Percentage of world electricity (Energy Efficiency)	Annual installed capacity [GW]	Annual investment (€ bn)	Jobs [million]	Annual CO_2 saving (million tonnes)
Reference	352	864	4.1%	24	32.14	0.54	518
Moderate	709	1,740	8.2%	82	89.39	1.30	1,044
Advanced	1,081	2,651	12.6%	143	149.35	2.21	1,591

SUMMARY OF GLOBAL WIND ENERGY OUTLOOK SCENARIO FOR 2050

Global Scenario	Cumulative wind power capacity (GW)	Electricity output (TWh)	Percentage of world electricity (Energy Efficiency)	Annual installed capacity [GW]	Annual investment (€ bn)	Jobs [million]	Annual CO_2 saving (million tonnes)
Reference	679	1,783	5.8%	36.6	47.10	0.74	1,070
Moderate	1,834	4,818	15.6%	100	104.36	1.71	2,891
Advanced	3,498	9,088	29.5%	165	168.14	2.98	5,453

GLOBAL CUMMULATIVE NEW WIND CAPACITY



GLOBAL CUMULATIVE CAPACITY [MW] AND ELECTRICITY GENERATION [TWh]

Year		2007	2008	2009	2010	2015	2020	2030
Reference	[MW]	93,864	109,739	128,046	139,000	232,956	352,300	496,730
	[TWh]	206	240	280	304	571	864	1,218
Moderate	[MW]	93,864	117,735	143,376	172,280	378,954	709,332	1,420,436
	[TWh]	206	258	314	377	929	1,740	3,484
Advanced	[MW]	93,864	119,837	149,841	186,309	485,834	1,080,886	2,375,374
	[TWh]	206	262	328	408	1,192	2,651	5,939

Scenario Results

An analysis of the Global Wind Energy Outlook scenarios shows that a range of outcomes is possible for the global wind energy market. This depends on the choice of demand side options and different assumptions for growth rates on the wind power supply side.

REFERENCE SCENARIO

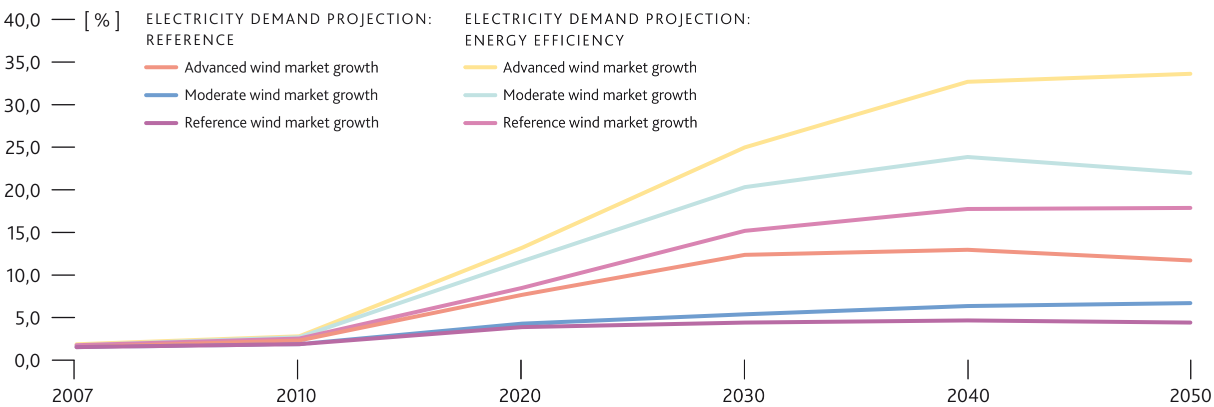
The **Reference scenario**, which is derived from the International Energy Agency's World Energy Outlook 2007, starts off with an assumed growth rate of 27% for 2008, decreases to 10% by 2010, and then falls to 4% by 2030. By 2035, the growth rate stabilises at 1%.

As a result, the scenario foresees that by the end of this decade, cumulative global capacity would have reached 139 Gigawatts (GW), producing 304 TWh per year, and covering 1.7% of the world's electricity demand.

By 2020, global capacity would stand at 352 GW, growing to almost 500 GW by 2030, with an annual capacity increase of around 30 GW. By 2050, close to 680 GW of wind generation capacity would be installed in the world.

The relative penetration of wind energy in the global electricity supply system varies according to which demand projection is applied. Around 864 TWh produced in 2020 would account for 3.6-4.1% of the world's electricity production, depending on the extent of energy efficiency measures introduced. By 2030, production of 1,218 TWh could meet 4.2-5.1% of global demand. Even by 2050, the penetration of wind would be no higher than 4.2-5.8% globally.

WIND POWER PENETRATION OF WORLDS ELECTRICITY SUPPLY



3 DIFFERENT WIND MARKET DEVELOPMENT SCENARIOS - WITH DIFFERENT WORLD ELECTRICITY DEMAND DEVELOPMENTS

		2007	2010	2020	2030	2040	2050
REFERENCE WIND MARKET GROWTH – IEA PROJECTION							
Wind power penetration of world's electricity in % – Reference (IEA Demand Projection)	%	1.4	1.7	3.6	4.2	4.4	4.2
Wind power penetration of world's electricity in % – Energy Efficiency	%	1.4	1.7	4.1	5.1	5.8	5.8
MODERATE WIND MARKET GROWTH							
Wind power penetration of world's electricity in % – Reference	%	1.4	2.1	7.3	11.9	12.5	11.2
Wind power penetration of world's electricity in % – Energy Efficiency	%	1.4	2.1	8.2	14.6	16.4	15.6
ADVANCED WIND MARKET GROWTH							
Wind power penetration of worlds electricity in % – Reference	%	1.4	2.3	11.2	19.7	23.1	21.2
Wind power penetration of world's electricity in % – Energy Efficiency	%	1.4	2.3	12.6	24.0	30.3	29.5

MODERATE SCENARIO

Under the **Moderate** wind energy scenario growth rates are expected to be substantially higher than under the Reference version. The assumed cumulative annual growth rate starts at 27% for 2008, decreases to 19% by 2010, continues to fall gradually to 11% by 2020 until it reaches 3% in 2030 and 1% after 2040.

The result is that by the end of this decade, global wind power capacity is expected to have reached 172 GW, with annual additions of 28.9 GW. By 2020, the annual market would have grown to 81.5 GW, and the cumulative global wind power capacity would have reached a level of over 700 GW. By 2030 a total of over 1,420 GW would be installed, with annual additions in the region of 84 GW. By 2050, the world would have a combined wind power capacity of over 1,800 GW, with the annual market running close to 100 GW.

In terms of generated electricity, this would translate into over 1,700 TWh produced by wind energy in 2020, 3,500 TWh in 2030 and 4,800 TWh in 2050. Depending on demand side development, this would supply 7.3-8.2% of global electricity demand in 2020, 11.9-14.6% in 2030 and 11.2-15.6% in 2050.

ADVANCED SCENARIO

Under the **Advanced** wind energy scenario, an even more rapid expansion of the global wind power market is envisaged. The assumed growth rate starts at 27% in 2008, falls to 22% by 2010, then to 12% by 2020 and 5% by 2030. Thereafter, the growth rate will level out at around a 1% annual increase.

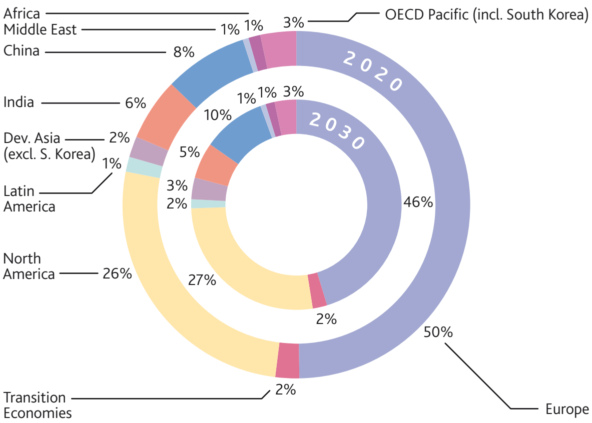
The result is that by the end of this decade, global capacity would have reached 186 GW, with annual additions of around 36.5 GW. By 2020, global capacity would be over 1,000 GW, with annual additions of around 142 GW, and by 2030, total wind generation capacity would reach almost 2,400 GW. The annual market would by then stabilise at around 165 GW. By 2050, the word's total fleet of wind turbines would have a capacity of 3,500 GW.

In terms of generated electricity, this would translate into 2,600 TWh produced by wind energy in 2020, 5,700 TWh in 2030 and over 9,000 TWh by 2050. Again depending on the increase in demand by that time, wind power would cover 11.2 – 12.6% of global electricity demand in 2020, 19.7-24.0% in 2030 and as much as 21.2-29.5% by 2050.

REGIONAL BREAKDOWN

All three scenarios for wind power are broken down by region of the world based on the regions used by the IEA. For the purposes of this analysis, the regions are defined as Europe, the Transition Economies, North America, Latin America, China, India, the Pacific (including Australia, South Korea and Japan), Developing Asia (the rest of Asia), the Middle East and Africa.

REGIONAL BREAK DOWN: REFERENCE SCENARIO [GW]



2020

Europe	176 GW
Transition Economies	7 GW
North America	92 GW
Latin America	5 GW
Dev. Asia (excl. S. Korea)	7 GW
India	20 GW
China	27 GW
Middle East	2 GW
Africa	4 GW
OECD Pacific (incl. South Korea)	12 GW

2030

EUROPE	227 GW
Transition Economies	11 GW
North America	132 GW
Latin America	8 GW
Dev. Asia (excl. S. Korea)	16 GW
India	27 GW
China	49 GW
Middle East	4 GW
Africa	7 GW
OECD Pacific (incl. South Korea)	16 GW

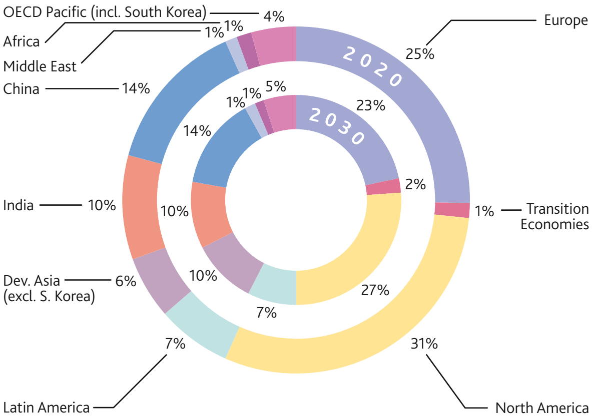
This breakdown of world regions has been used by the IEA in the ongoing series of World Energy Outlook publications. It was chosen here to facilitate a comparison with those projections and because the IEA provides the most comprehensive global energy statistics. A list of countries covered by each of the regions is shown on p. 48.

The level of wind power capacity expected to be installed in each region of the world by 2020 and 2030 is shown on p. 48 and 49. This shows that in the **Reference Scenario**, Europe would continue to dominate the world market. By 2030 Europe would still host 46% of global wind power capacity, followed by North America with 27%. The next largest region would be China with 10%.

The two more ambitious scenarios envisage much stronger growth in regions outside Europe. Under the Moderate scenario, Europe's share will have fallen to 23% by 2030, with North America contributing a dominant 27% and major installations in China (14%), India (10%) and Developing Asia (10%). Latin America (7%) and the Pacific region (5%) will play a smaller role than previously estimated, and the contributions of Africa and the Middle East will be negligible (around 1% each).

The Advanced scenario predicts an even stronger growth for China, which would see its share of the world market increasing to 19% by 2030. The North American market would by then account for 22% of global wind power

REGIONAL BREAK DOWN: MODERATE SCENARIO [GW]



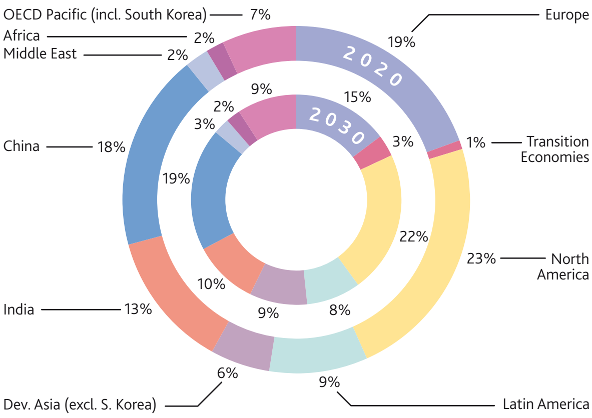
2020

Europe	182 GW
Transition Economies	9 GW
North America	214 GW
Latin America	50 GW
Dev. Asia (excl. S. Korea)	40 GW
India	69 GW
China	101 GW
Middle East	8 GW
Africa	10 GW
OECD Pacific (incl. South Korea)	30 GW

2030

EUROPE	306 GW
Transition Economies	34 GW
North America	366 GW
Latin America	103 GW
Dev. Asia (excl. S. Korea)	140 GW
India	142 GW
China	201 GW
Middle East	20 GW
Africa	21 GW
OECD Pacific (incl. South Korea)	70 GW

REGIONAL BREAK DOWN: ADVANCED SCENARIO [GW]



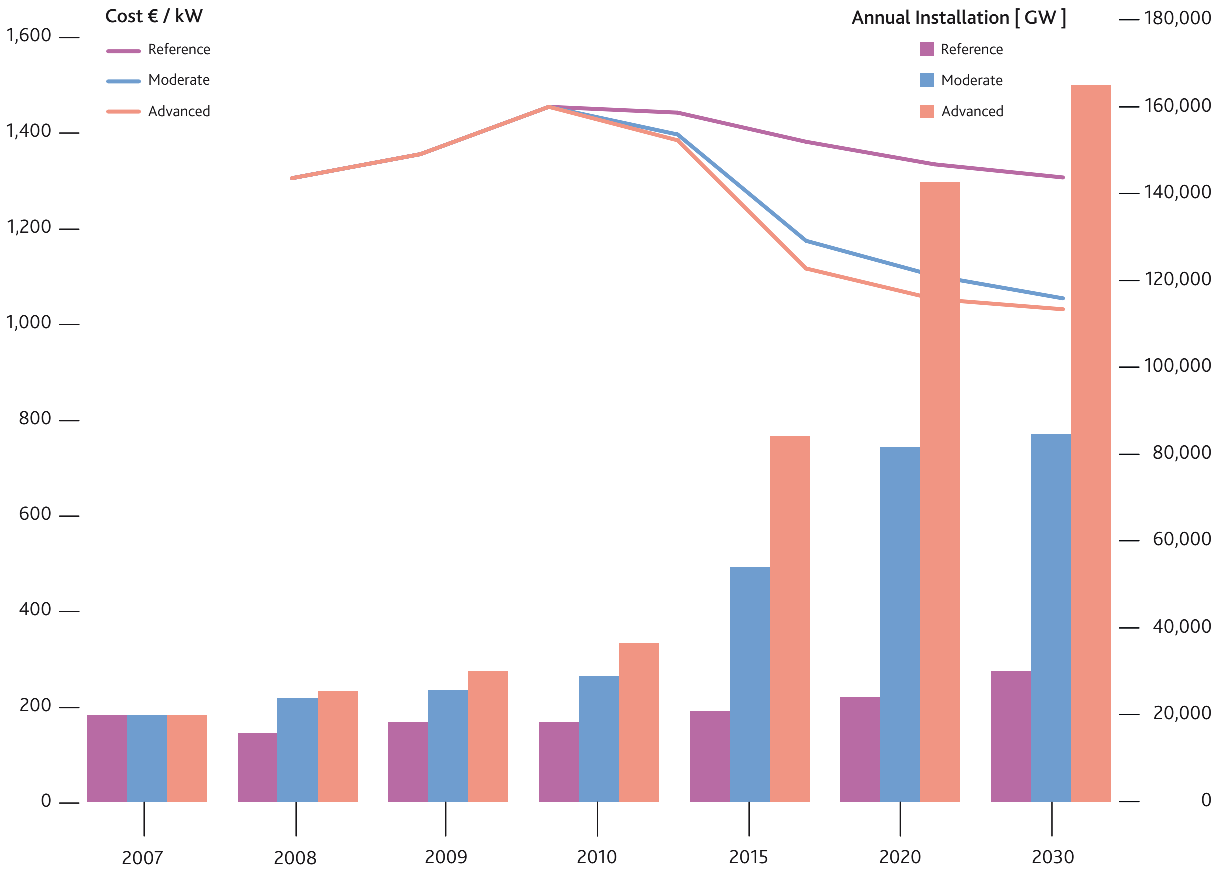
2020

Europe	213 GW
Transition Economies	10 GW
North America	243 GW
Latin America	100 GW
Dev. Asia (excl. S. Korea)	61 GW
India	138 GW
China	201 GW
Middle East	25 GW
Africa	17 GW
OECD Pacific (incl. South Korea)	75 GW

2030

EUROPE	353 GW
Transition Economies	75 GW
North America	520 GW
Latin America	201 GW
Dev. Asia (excl. S. Korea)	211 GW
India	235 GW
China	451 GW
Middle East	63 GW
Africa	52 GW
OECD Pacific (incl. South Korea)	215 GW

COSTS AND CAPACITIES



INVESTMENT AND EMPLOYMENT

	2007	2008	2009	2010	2015	2020	2030
REFERENCE							
Annual Installation [MW]	19,865	18,016	18,034	18,307	20,887	24,180	30,013
Cost € / kW	1,300	1,350	1,450	1,438	1,376	1,329	1,301
Investment € billion /year	25,824,500	25,873,673	25,910,012	26,545,447	28,736,673	32,135,267	39,058,575
Employment Job-year	329,232	387,368	418,625	424,648	479,888	535,074	634,114
MODERATE							
Annual Installation [MW]	19,865	23,871	25,641	28,904	54,023	81,546	84,465
Cost € / kW	1,300	1,350	1,450	1,392	1,170	1,096	1,050
Investment € billion /year	25,824,500	32,225,716	37,179,828	40,220,810	63,182,874	89,390,391	88,658,740
Employment Job-year	329,232	397,269	432,363	462,023	882,520	1,296,306	1,486,589
ADVANCED							
Annual Installation [MW]	19,865	25,509	30,005	36,468	84,160	142,674	165,000
Cost € / kW	1,300	1,350	1,450	1,379	1,112	1,047	1,026
Investment € billion /year	25,824,500	34,437,535	43,506,723	50,304,975	93,546,253	149,352,592	169,297,423
Employment Job-year	329,232	422,545	499,967	572,596	1,340,016	2,214,699	2,810,395

capacity, while Europe's share would have fallen to 15%, followed by India (10%), Developing Asia (9%), the Pacific region (9%) and Latin America (8%). Africa and the Middle East would again play only a minor role in the timeframe discussed (2% each).

In all three scenarios it is assumed that an increasing share of new capacity is accounted for by the replacement of old plant. This is based on a 20 year average lifetime for a wind turbine. Turbines replaced within the timescale of the scenarios are assumed to be of the same cumulative installed capacity as the original smaller models. The result is that an increasing proportion of the annual level of installed capacity will come from repowered turbines. These new machines will contribute to the overall level of investment, manufacturing output and employment. As replacement turbines their introduction will not however increase the total figure for global cumulative capacity.

Costs and Benefits

Generating increased volumes of wind powered electricity will require a considerable level of investment over the next 40 years. At the same time raising the contribution from the wind will have benefits both for the global climate and in terms of increased job creation.

INVESTMENT

The relative attraction to investors of the wind energy market is dependent on a number of factors. These include the capital cost of installation, the availability of finance, the pricing regime for the power output generated and the expected rate of return.

The investment value of the generation equipment in the future wind energy market envisaged in this scenario has been assessed on an annual basis. This is based on the assumption of a gradually decreasing capital cost per kilowatt of installed capacity, as explained above.

In the Reference scenario the annual value of global investment in wind power equipment increases from €25.8 billion in 2007 to €26.5 billion in 2010, then to €39 bn by 2030 and peaks at €47 bn in 2050 [all figures at €2007 values].

In the Moderate scenario the annual value of global investment in the wind power industry reaches €40.2 billion in 2010, increases to €89.4 bn by 2030 and peaks at €104.4 bn in 2050.

In the Advanced scenario the annual value of global investment reaches € 50.3 billion in 2010, increases to €149.4 bn by 2020 and peaks at €169.3 bn in 2030. All these figures take into account the value of repowering older turbines.

Although these figures may appear large, they should be seen in the context of the total level of investment in the global power industry. During the 1990s, for example, annual investment in the power sector was running at some €158-186 billion each year.

GENERATION COSTS

Various parameters need to be taken into account when calculating the generation costs of wind power. The most important of these are the capital cost of wind turbines (see above), the cost of capital (interest rates), the wind conditions at the site, and the price received for the electricity generated. Other important factors include operation and maintenance (O&M) costs and the lifetime of the turbine.

The total cost per generated kWh of electricity is traditionally calculated by discounting and levelising investment and O&M costs over the lifetime of a wind turbine, then dividing this by the annual electricity production. The unit cost of generation is thus calculated as an average cost over the lifetime of a turbine, which is normally estimated at 20 years. In reality capital costs will be higher in the early years of a turbine's operations while the loan is being paid off, where as O&M costs will probably be lower at the beginning of a turbine's operation and increase over the lifespan of the machine.

Taking all these factors into account, the cost of generating electricity from wind energy currently ranges from approximately 4-6 €cents/kWh at high wind speed sites up to approximately 6-9 €cents/kWh at sites with low average wind speeds [1)].

However, over the past 15 years the efficiency of wind turbines has been improving thanks to better equipment design, better siting and taller turbines. Furthermore, it can

be assumed that optimised production processes will reduce investment costs for wind turbines, as described above.

These calculations do not take into account the so-called 'external costs' of electricity production. It is generally agreed that renewable energy sources such as wind have environmental and social benefits compared to conventional energy sources such as coal, gas, oil and nuclear. These benefits can be translated into costs for society, which should be reflected in the cost calculations for electricity output. Only then can a fair comparison of different means of power production be established. The European Commission's ExternE project[2] estimated the external cost of gas fired power generation at around 1.1-3.0 €cents/kWh and that for coal at as much as 3.5-7.7 €cents/kWh, compared to just 0.05-0.25 €cents/kWh for wind.

On top of this, of course, needs to be added the 'price' of carbon within the global climate regime and its regional/national incarnations such as the European Emissions Trading Scheme (ETS).

Furthermore, these calculations do not take into account the fuel cost risk related to conventional technologies. Since wind energy does not require any fuel, it eliminates the risk of fuel price volatility which characterises other generating technologies such as gas, coal and oil. A generating portfolio containing substantial amounts of wind energy will reduce the risks of future higher energy costs by reducing society's exposure to price increases for fossil fuels. In an age of limited fuel resources and high fuel price volatility, the benefits of this are immediately obvious.

In addition, the avoided costs for the installation of conventional power production plant and avoided fossil fuel costs are not taken into consideration. This further improves the cost analysis for wind energy. In 2007, for example, €3.9 bn worth of fuel costs were avoided in Europe through the use of wind energy, and this figure is predicted to increase to €24 bn by 2030[3].

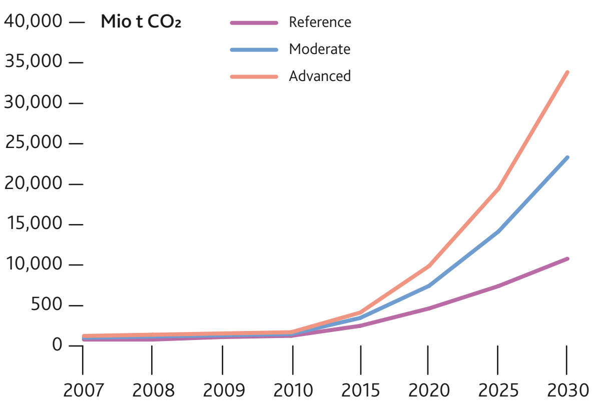
EMPLOYMENT

The employment effect of this scenario is a crucial factor to weigh alongside its other costs and benefits. High unemployment rates continue to be a drain on the social systems of many countries in the world. Any technology which demands a substantial level of both skilled and unskilled labour is therefore of considerable economic importance, and likely to feature strongly in any political decision-making over different energy options.

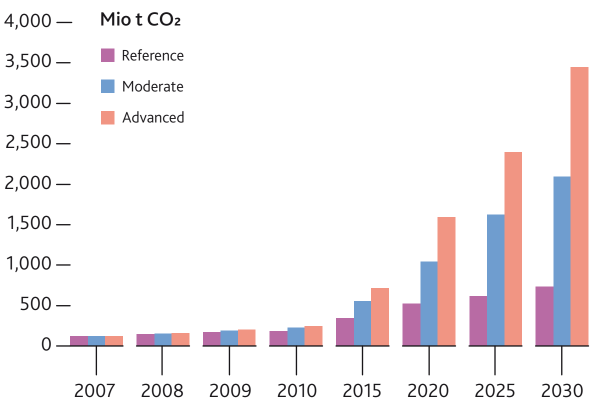
A number of assessments of the employment effects of wind power have been carried out in Germany, Denmark, Spain and the Netherlands. The assumption made in this scenario is that for every megawatt of new capacity, the annual market for wind energy will create employment at the rate of 15 jobs

1 *For Europe, see European Wind Energy Association (2009 - forthcoming): Wind Energy – The Facts; for China, see GWEC/CREIA/CWEA (2006): A study on the Pricing Policy of Wind Power in China*
2 *http://www.externe.info/externpr.pdf*
3 *EWEA (2008): Pure Power – Wind Energy Scenarios up to 2030*

CUMULATIVE CO_2 REDUCTION



ANNUAL CO_2 REDUCTION



CO_2 EMISSIONS

REFERENCE

Year	Annual CO_2 reduction [Mio tCO_2]	Cumulative CO_2 reduction [Mio. tCO_2]
2007	123	406
2008	144	550
2009	168	718
2010	183	901
2015	343	2,245
2020	518	4,459
2025	615	7,333
2030	731	10,776
2035	799	14,632
2040	945	19,118
2045	1,006	24,021
2050	1,070	29,247

MODERATE

Year	Annual CO_2 reduction [Mio tCO_2]	Cumulative CO_2 reduction [Mio. tCO_2]
2007	123	406
2008	155	561
2009	188	749
2010	226	975
2015	558	3,048
2020	1,044	7,216
2025	1,624	14,168
2030	2,090	23,752
2035	2,353	35,068
2040	2,674	48,163
2045	2,789	61,886
2050	2,891	76,141

ADVANCED

Year	Annual CO_2 reduction [Mio tCO_2]	Cumulative CO_2 reduction [Mio. tCO_2]
2007	123	406
2008	157	563
2009	197	760
2010	245	1,005
2015	715	3,513
2020	1,591	9,494
2025	2,397	19,616
2030	3,236	31,294
2035	4,263	54,709
2040	4,942	78,789
2045	5,178	104,197
2050	5,453	130,887

(man years) through manufacture, component supply, wind farm development, installation and indirect employment. As production processes are optimised, this level will decrease, falling to 11 jobs by 2030. In addition, employment in regular operations and maintenance work at wind farms will contribute a further 0.33 jobs for every megawatt of cumulative capacity.

Under these assumptions, more than 329,000 people would have been employed in the wind energy sector in 2007. Under the Reference scenario, this figure would increase to 408,500 jobs by the end of this decade and 535,000 by 2020. In the Moderate scenario, more than 462,000 people would be employed by the sector by 2010, and almost 1.3 million by 2020. The Advanced scenario would see the employment level rise to 572,500 by 2010 and to over 2.2 million jobs in wind energy by 2020.

CARBON DIOXIDE SAVINGS

A reduction in the levels of carbon dioxide being emitted into the global atmosphere is the most important environmental benefit from wind power generation. Carbon dioxide is the gas largely responsible for exacerbating the greenhouse effect, leading to the disastrous consequences of global climate change.

At the same time, modern wind technology has an extremely good energy balance. The CO_2 emissions related to the manufacture, installation and servicing over the average 20 year lifecycle of a wind turbine are "paid back" after the first three to six months of operation.

The benefit to be obtained from carbon dioxide reductions is dependent on which other fuel, or combination of fuels, any increased generation from wind power will displace. Calculations by the World Energy Council show a range of carbon dioxide emission levels for different fossil fuels. On the assumption that coal and gas will still account for the majority of electricity generation in 20 years' time – with a continued trend for gas to take over from coal – it makes sense to use a figure of 600 tonnes per GWh as an average value for the carbon dioxide reduction to be obtained from wind generation.

This assumption is further justified by the fact that around 50% of the cumulative wind generation capacity expected by 2020 will be installed in the OECD regions (North America, Europe and the Pacific). The trend in these countries is for a significant shift from coal to gas. In other regions the CO_2 reduction will be higher due to the widespread use of coal burning power stations.

Taking account of these assumptions, the expected annual saving in CO_2 by wind energy under the Reference scenario would be 183 million tons annually in 2010, rising to 518 million tones by 2020 and 731 million tons in 2030. Under this scenario, CO_2 savings from wind would be negligible, compared with the 18,708 million tons of CO_2 that the IEA expects the global power sector will emit every year by 2030.

Under the Moderate scenario, wind energy would save 226 million tons of CO_2 annually in 2010, 1,044 million tonnes of CO_2 in 2020, rising to 2,090 million tonnes per year in 2030. The cumulative saving until 2020 would account for 7,216 million tonnes of CO_2 since 2003, and over the whole scenario period up to 2050, this would come to just over 76,000 million tonnes of CO_2.

Under the Advanced scenario, the annual CO_2 saving by wind power would increase to 245 million tonnes by 2010, 1,591 million tonnes by 2020, and 3,236 million tonnes by 2030. Between 2003 and 2020, over 9,494 million tones of CO_2 would be saved by wind energy alone. This would increase to over 130,000 million tonnes over the whole scenario period.

Research Background

THE GERMAN AEROSPACE CENTRE

The German Aerospace Centre (DLR) is the largest engineering research organisation in Germany. Among its specialities is development of solar thermal power station technologies, the utilisation of low and high temperature fuel cells, particularly for electricity generation, and research into the development of high efficiency gas and steam turbine power plants.

The Institute of Technical Thermodynamics at DLR (DLR-ITT) is active in the field of renewable energy research and technology development for efficient and low emission energy conversion and utilisation. Working in co-operation with other DLR institutes, industry and universities, research is focused on solving key problems in electrochemical energy technology and solar energy conversion. This encompasses application oriented research, development of laboratory and prototype models as well as design and operation of demonstration plants. System analysis and technology assessment supports the preparation of strategic decisions in the field of research and energy policy.

Within DLR-ITT, the System Analysis and Technology Assessment Division has long term experience in the assessment of renewable energy technologies. Its main research activities are in the field of techno-economic utilisation and system analysis, leading to the development of strategies for the market introduction and dissemination of new technologies, mainly in the energy and transport sectors.

SCENARIO BACKGROUND

DLR was commissioned by the European Renewable Energy Council and Greenpeace International to conduct a study on **global sustainable energy pathways** up to 2050 [4]. This study, published in 2007 and currently being updated, lays out energy scenarios with emissions that are significantly lower than current levels. Part of the study examined the future potential for renewable energy sources; together with input from the wind energy industry and analysis of regional projections for wind power around the world, this forms the basis of the Global Wind Energy Outlook scenario.

The **energy supply scenarios** adopted in this report, which both extend beyond and enhance projections by the International Energy Agency, have been calculated using the MESAP/PlaNet simulation model used for a similar study by DLR covering all 10 world regions ("Energy [R]evolution: A sustainable global energy outlook"), October 2008 for Greenpeace International and the European Renewable Energy Council (EREC). This model has then been developed in cooperation with Ecofys consultancy to take into account the future potential for energy efficiency measures.

ENERGY EFFICIENCY STUDY [5]

The aim of the Ecofys study was to develop low energy demand scenarios for the period 2003 to 2050 on a sectoral level for the IEA regions as defined in the World Energy Outlook report series. Energy demand was split up into electricity and fuels. The sectors which were taken into account were industry, transport and other consumers, including households and services.

The Ecofys study envisages an ambitious overall development path for the exploitation of energy efficiency potential, focused on current best practice as well as technologies available in the future, and assuming continuous innovation in the field. The result is that worldwide final energy demand is reduced by 35% in 2050 in comparison to the reference scenario. Energy savings are fairly equally distributed over the three sectors. The most important energy saving options are the implementation of more efficient passenger and freight transport and improved heat insulation and building design.

While the Ecofys study develops two energy efficiency scenarios, only the more moderate of these has been used in this report.

4 Krewitt W, Simon S, Graus W, Teske S, Zervos A, Schaefer O, "The 2 degrees C scenario - A sustainable world energy perspective"; Energy Policy, Vol.35, No.10, 4969-4980, 2007
5 www.energyblueprint.info

NORTH AMERICA

TOTAL CAPACITY IN MW	2007	2010	2020	2030
Reference scenario	18,664	28,000	92,000	132,000
Moderate scenario	18,664	41,195	214,371	366,136
Advanced scenario	18,664	41,195	252,861	519,747

EUROPE

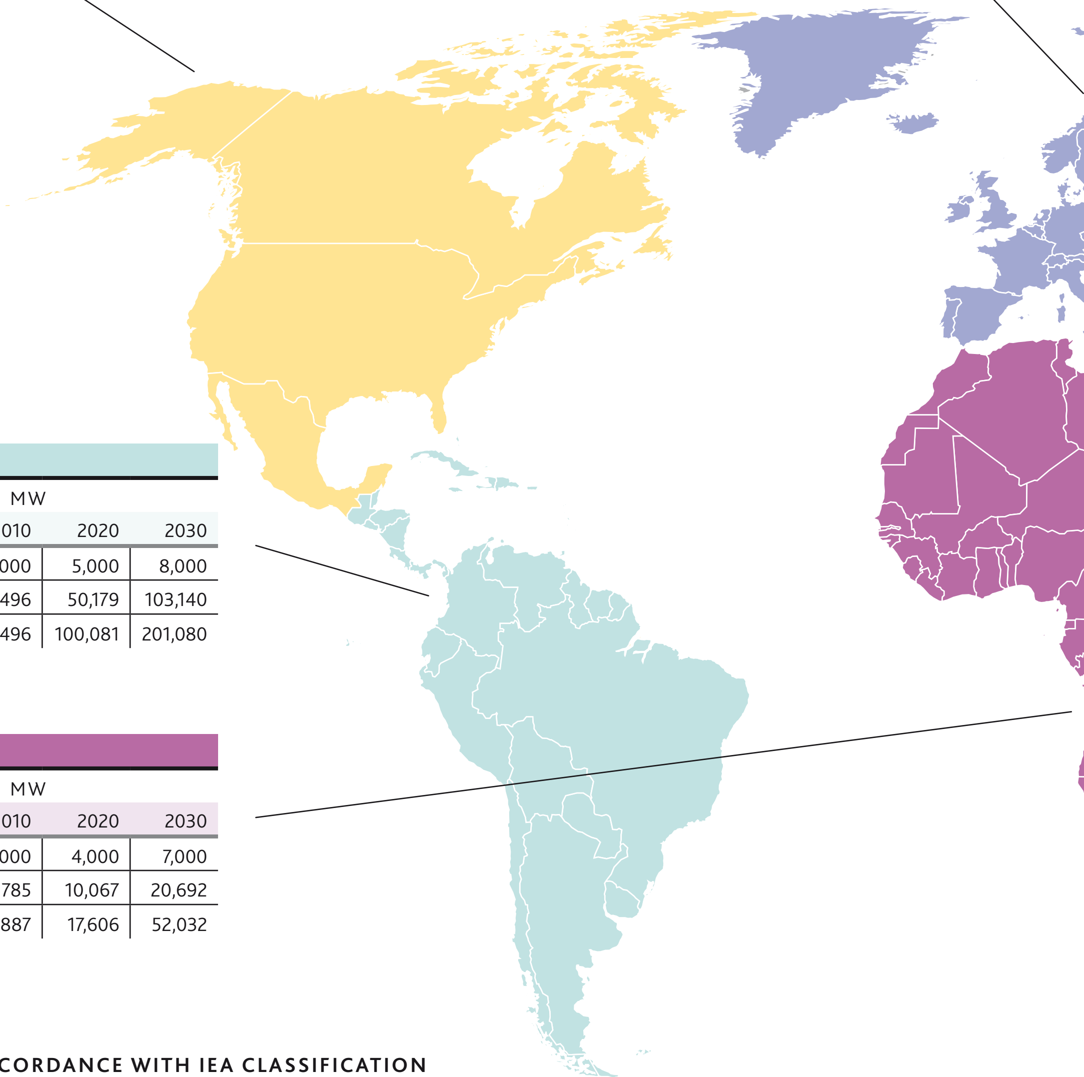
TOTAL CAPACITY IN MW	2007	2010	2020	2030
Reference scenario	57,136	77,000	176,300	226,730
Moderate scenario	57,136	89,227	182,464	306,491
Advanced scenario	57,136	89,132	212,632	353,015

LATIN AMERICA

TOTAL CAPACITY IN MW	2007	2010	2020	2030
Reference scenario	537	2,000	5,000	8,000
Moderate scenario	537	2,496	50,179	103,140
Advanced scenario	537	2,496	100,081	201,080

AFRICA

TOTAL CAPACITY IN MW	2007	2010	2020	2030
Reference scenario	454	1,000	4,000	7,000
Moderate scenario	454	785	10,067	20,692
Advanced scenario	454	887	17,606	52,032



DEFINITIONS OF REGIONS IN ACCORDANCE WITH IEA CLASSIFICATION

OECD Europe: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

OECD North America: Canada, Mexico, United States

OECD Pacific: Australia, Japan, Korea (South), New Zealand

Transition Economies: Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, the former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus [1], Malta [1]

India

Other developing Asia: Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vietnam, Vanuatu

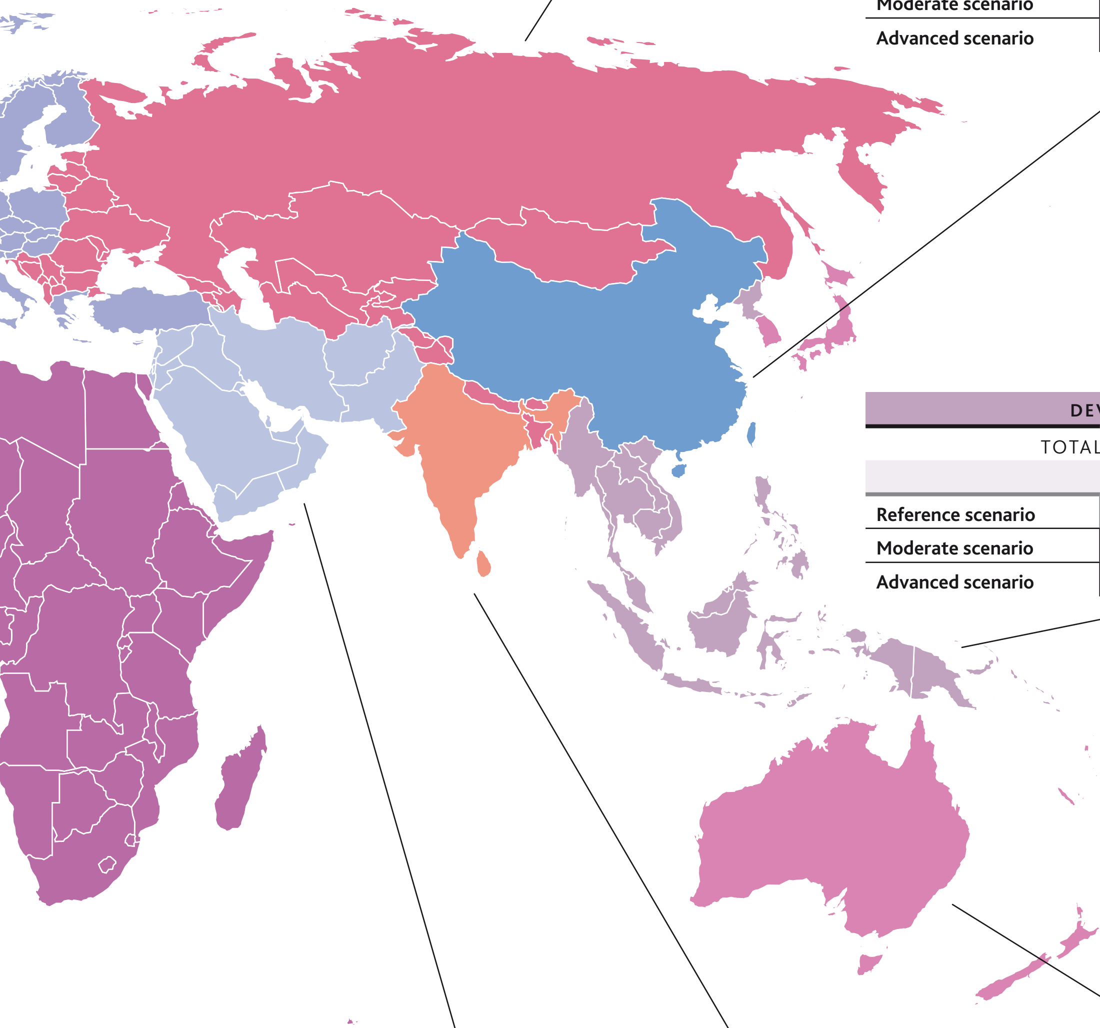
Latin America: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

Middle East: Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

China: People's Republic of China including Hong Kong

1 Cyprus and Malta are allocated to the Transition Economies for statistical reasons



TRANSITION ECONOMIES

TOTAL CAPACITY IN MW

	2007	2010	2020	2030
Reference scenario	204	2,000	7,000	11,000
Moderate scenario	204	449	9,183	33,548
Advanced scenario	204	449	10,411	75,231

CHINA

TOTAL CAPACITY IN MW

	2007	2010	2020	2030
Reference scenario	5,906	9,000	27,000	49,000
Moderate scenario	5,906	17,507	100,724	200,531
Advanced scenario	5,906	19,613	200,880	450,582

DEVELOPING ASIA

TOTAL CAPACITY IN MW

	2007	2010	2020	2030
Reference scenario	312	2,000	7,000	16,000
Moderate scenario	312	1,670	40,274	140,897
Advanced scenario	312	1,817	60,735	210,808

OECD PACIFIC

TOTAL CAPACITY IN MW

	2007	2010	2020	2030
Reference scenario	2,887	5,000	12,000	16,000
Moderate scenario	2,887	3,688	30,018	70,698
Advanced scenario	2,887	3,739	75,380	215,362

MIDDLE EAST

TOTAL CAPACITY IN MW

	2007	2010	2020	2030
Reference scenario	84	1,000	2,000	4,000
Moderate scenario	84	577	8,150	20,136
Advanced scenario	84	413	25,398	62,777

INDIA

TOTAL CAPACITY IN MW

	2007	2010	2020	2030
Reference scenario	7,845	12,000	20,000	27,000
Moderate scenario	7,845	19,683	69,203	142,245
Advanced scenario	7,845	20,571	137,636	235,075

8. INTERNATIONAL ACTION ON CLIMATE CHANGE

The Kyoto Protocol

The Kyoto Protocol was agreed in December of 1997 as a Protocol to the United Nations Framework Convention on Climate Change of 1992(UNFCCC). The Kyoto Protocol sets legally binding targets for industrialised countries (Annex 1 countries) to reduce their emissions of greenhouse gases by an initial aggregate of 5.2% against 1990 levels over the period 2008-2012. This spread of years is known as the "first commitment period". The Protocol finally entered into force in 2005, after sufficient countries had ratified.

In recognition of the fact that industrialized countries are largely responsible for the historic build up of greenhouse gases in the atmosphere, and of developing countries need to expand their economies in order to meet social and development objectives, China, India and other developing countries do not have quantified, binding emission reduction commitments. However, it was agreed that they still share a common responsibility to reduce emissions.

The overall objective of the international climate regime is to achieve "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". National emissions reduction obligations under the Kyoto Protocol range from 8% for the European Union to 7% for the United States, 6% for Japan, 0% for Russia and permitted increases of 8% for Australia and 10% for Iceland. These figures exclude international aviation and shipping.

As of May 2008, 182 'parties' had ratified the protocol. Of these, 38 industrialized countries (plus the EU as a party in its own right) are required to reduce their emissions to the levels specified for each of them in the treaty. 145 developing countries have ratified the protocol, including Brazil, China and India, but have no reduction obligation. The United States is the only industrialized country not to have ratified the Protocol, and Kazakhstan is the only other signatory not to have ratified the agreement so far, although the Kazak government has recently signaled its intention to ratify.

FLEXIBLE MECHANISMS

Since greenhouse gases are 'well-mixed' throughout the atmosphere, in physical terms, it does not matter *where* emissions are reduced, it is the overall global reduction that counts. As a result the Kyoto Protocol has taken a strong market approach, recognising that it may be more cost-effective for Annex I parties to reduce emissions in other countries, for example in the developing world or other countries where there is a large potential for cost-effective reductions. Industrialised countries therefore have the ability to apply three different mechanisms with which they can collaborate with other parties. These are Joint Implementation (JI), the Clean Development Mechanism (CDM) and Emissions Trading.

Emissions Trading

Under the International Emissions Trading provisions, Annex I countries can trade so called "Assigned Amount Units" (AAUs) among themselves. These are allocated to them on the basis of their overall emissions reduction targets. The emissions trading scheme also sees this activity as "supplemental to domestic actions".

Those parties that reduce their emissions below the allowed level can then trade some part of their surplus allowances to other Annex I parties. It is unlikely that there will be very many Annex I Parties who will be sellers of AAUs, and an equally small number of buyers, at least in the first commitment period.

Joint Implementation

Under Joint Implementation, an Annex I country can invest in emissions reduction projects in any other Annex I country as an alternative to reducing emissions domestically. This allows countries to reduce emissions in the most cost-effective way, and apply the credits for those reductions towards their own emissions reduction target. Most JI projects are expected to take place in the so-called "economies in transition to a market economy", mainly Russia and Ukraine. Most of the rest of the "transition economies" have since joined the EU or are in the process of doing so, and therefore covered under the EU Emissions Trading Scheme.

The credits for JI emission reductions are accounted for in the form of Emission Reduction Units (ERUs), with one ERU representing a reduction of one ton of CO_2 equivalent. These ERUs come out of the host country's pool of assigned emissions credits, which ensures that the total amount of emissions credits among Annex I parties remains stable.

ERUs will only be awarded for Joint Implementation projects that produce emissions reductions that are "...additional to any that would otherwise occur" (the so-called "additionality" requirement), which means that a project must prove that it would only be financially viable with the extra revenue of ERU credits. Moreover, Annex I parties may only rely on joint implementation credits to meet their targets to the extent that they are "supplemental to domestic actions". However, since it is very hard to define which actions are "supplemental", this clause is largely meaningless in practice.

Clean Development Mechanism

The Clean Development Mechanism allows Annex I parties to generate or purchase emissions reduction credits from projects undertaken in developing (non-Annex I) countries. In exchange, developing countries will have access to resources and technology to assist in development of their economies in a sustainable manner. The credits earned from CDM projects are known as "certified emissions reductions" (CERs). These projects must also meet the requirement of "additionality".

A wide variety of projects have been launched under the CDM, including those involving renewable energy, energy efficiency, fuel switching, capping landfill gases, better management of methane from animal waste, the control of coal mine methane and controlling emissions of certain industrial gases, including HFCs and N2O.

China has traditionally dominated the CDM market. In 2007 it expanded its market share of transactions to 62%. However, CDM projects have been registered in 45 countries and the UNFCCC points out that investment is now starting to flow into other parts of the world, not only to India and Brazil, but also to Africa, Eastern Europe and Central Asia.

In 2007, the CDM accounted for transactions worth €12 billion [1)] , mainly from private sector businesses in the EU, European governments and Japan .

The average time for CDM projects to be agreed is currently about 1-2 years from the moment that they enter the "CDM pipeline" which contains nearly 4,000 projects as of October 2008. More than 400 projects have received CERs to date, over two thirds of those CERs have come from industrial gas projects. Renewable energy projects have been slower to reach fruition, and the rigorous CDM application procedure has been criticized for being too slow and cumbersome. The "additionality" requirement in particular has been a stumbling block since it is difficult to prove that a project would not be viable without the existence of CERs.

1 Carbon 2008 – Post-Kyoto is now', Point Carbon Annual Report, March 2008

CARBON AS A COMMODITY

The Kyoto Protocol's efforts to mitigate climate change have resulted in an international carbon market that has grown tremendously since the entry into force of the Protocol in 2005. While previously, the relatively small market consisted mostly of pilot programmes either operated by the private sector or by international financial institutions such as the World Bank, the market has experienced strong growth in the past two years, reaching a value of €40 billion in 2007. The total traded volume of emissions increased from 1.6 $MtCO_2$ in 2006 to 2.7 Mt in 2007 [2)].

While the international carbon market has expanded to include a wide variety of project types and market participants, it has to date been dominated by the EU Emissions Trading System (ETS) and the CDM.

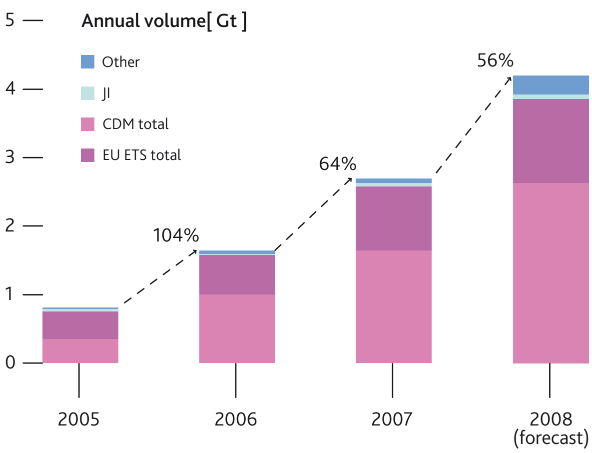
The EU emissions trading scheme continues to be the largest carbon market, with a traded volume of 1.6 $MtCO_2$ and a value of €28 billion in 2007 [3)] . This was a near doubling of both volume and value compared to the previous year. The EU ETS now contains more than 60% of the physical global carbon market and 70% of the financial market. The CDM market increased dramatically to 947 Mt worth €12bn in 2007, making up 35% of the physical market and 29% of the financial market. The JI market, while still small, also finally started to take off in 2007, nearly doubling in volume to 38 $MtCO_2$ and more than tripling in value to €326 million.

However, experts predict that the potential for future market growth is much larger. Market analysts Point Carbon forecast 56% market growth in 2008 (see *Figure 1*), increasing volumes to over 4 million tonnes of carbon, with a value of more than €60 billion. Current prices in the ETS hover around €25/ton, and CDM prices range between €9 and 17/ton, depending on the type of project and its stage of development.

Providing that the price for carbon is high enough, the carbon market is a powerful tool for attracting investment, fostering cooperation between countries, companies and individuals and stimulating innovation and carbon abatement worldwide. In theory, at least, the price of carbon should more or less directly reflect the rigorousness of the economy-wide caps of the Annex B countries. The reality is, however, more complicated, since there is only one real 'compliance market' at present, which is the EU ETS, while the CDM and JI markets are just getting started. It is also not clear what role Canada, Japan and Australia will play in the carbon market during the first commitment period; and of course, the original conception and design of the carbon market was predicated on the fact that the United States would be a large buyer, which has not turned out to be the case, at least not for the first commitment period. Governments negotiating the post-2012 climate agreement seem committed to 'building carbon markets' and 'keeping the CDM', but there is very little detail to go on at present.

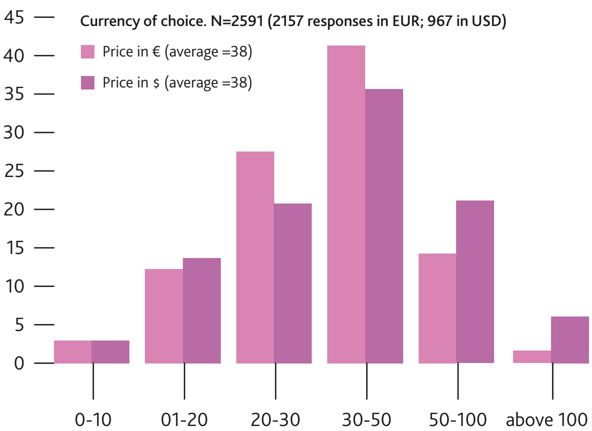
Figure 2 shows a survey of carbon market practitioners as to the expected price of carbon in 2020, conducted by Point Carbon at the end of 2007.

FIGURE 1: ANNUAL CONTRACT VOLUMES 2005-2008



Source: Point Carbon

FIGURE 2: WHAT WILL BE THE COST OF CARBON IN 2020?



Source: Point Carbon

2,3 Carbon 2008 – Post-Kyoto is now'

Wind energy CDM projects

The Clean Development Mechanism has contributed to the deployment of wind energy globally. As of October 2008, a total of 538 wind energy projects were in the "CDM pipeline", totaling an installed capacity of 20,434 MW. This represents 14% of the total number of projects introduced into the pipeline. Almost 7 million CERs have already been issued to these wind projects, a number that will go up to a total of 213 million by the end of the first commitment period in 2012 for the projects currently in the pipeline.

The majority of these projects are located in China and India. In China, 90% of wind energy projects have applied for CDM registration, and there are now 254 projects in the CDM pipeline, making up more than 13 GW of capacity. India has 231 projects in the pipeline, totalling more than 4 GW.

The limited number of countries with CDM-supported wind projects reflects the fact that carbon finance is a useful, and in some cases necessary condition for the development of wind power in the developing world, but it is by no means sufficient. In the case of both India and China carbon finance functions alongside a wide range of other measures necessary for countries to diversify and decarbonise their power supply sectors.

There are signs that some other countries may join the list of major host countries for wind power projects assisted by CDM carbon finance. However, it is clear that the ultimate responsibility for this lies with active government implementation of policies and measures to create the enabling environment within which carbon finance can play its role - as an important source to defray the marginal costs of wind power versus conventional fossil fuel plants. This is particularly the case in the absence of an economy-wide cap on carbon emissions.

WIND CDM PROJECTS (AS OF 1 OCTOBER 2008)

Country	Projects	MW
India	231	4,319
China	254	13,072
Mexico	11	1,222
South Korea	11	320
Brazil	7	436
Dominican Republic	3	173
Phillipines	2	73
Morocco	2	70
Cyprus	3	188
Egypt	2	200
Panama	1	81
Mongolia	1	50
Jamaica	1	21
Costa Rica	2	69
Colombia	1	20
Israel	0	0
Argentina	1	11
Chile	1	19
Nicaragua	2	60
Vietnam	1	30
Ecuador	1	2
Total	**538**	**20,434**

Source: http://www.cdmpipeline.org/cdm-projects-type.htm

Wind energy JI projects

There are currently 12 wind energy projects in the JI pipeline, totaling an installed capacity of 684 MW. The biggest of these (300 MW) is located in the Ukraine. Other projects are based in Bulgaria, Poland, Lithuania and Estonia. While the JI market is very small today, the mechanism could serve to incentivise large countries such as Russia and the Ukraine to tap into their very large wind energy potential.

The path to a post-2012 regime

Negotiations are now taking place with the aim of negotiating a second commitment period for the Kyoto Protocol after 2012. This has been encouraged by the conclusions of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, which showed that climate change is developing faster than previously thought.

In addition, a number of independent studies, such as the report for the British government by former World Bank Chief Economist Sir Nicholas Stern, have highlighted concerns that the economic and social costs associated with the increasing impacts of climate change far outweigh the costs of effective mitigation of greenhouse gas emissions.

Despite political difficulties related to a task which effectively involves reshaping the global economy, the 11th Conference of the Parties (COP 11) in December 2005 managed to agree to move forward towards a second commitment period, while agreeing a parallel process to discuss enhancement of the climate regime under the Convention for those countries without binding emissions reduction obligations. The US delegation at first refused to participate in the talks, but at the end of the day came back to the table. This major climbdown marked the beginning of a new phase in the international climate negotiations.

In December 2007, at COP 13 in Bali, the participating countries agreed that the negotiations should be formally launched and successfully concluded by COP 15, to be held in December 2009 in Copenhagen. For the wind sector, the outcome of these negotiations is critical on a number of key points: the rigour of the emissions reduction targets, the resulting ongoing price of carbon, technology transfer agreements that actually work and an expanded carbon market.

- **The need for strong commitments**
  Rigorous, legally-binding emission reduction targets for industrialised countries will send the most important political and market signal that governments are serious about creating a framework for moving towards a sustainable energy future. The indicative range of targets for industrialised countries agreed by the Kyoto Protocol countries - reductions of 25-40% below 1990 levels by 2020 - is a good starting point. They would need to be closer to the upper end of that range, however, to stay in line with the European Union's stated policy objective of keeping global mean temperature rise to less than 2°C above pre-industrial levels.

- **Carbon prices**
  In addition to achieving climate protection goals, strong emission reduction targets are necessary to bolster the price of carbon in emerging carbon markets. The regime also needs to be broadened so that we move towards a single global carbon market, with the maximum amount of liquidity to achieve the maximum emission reductions at the least cost. While the EU ETS and the Clean Development Mechanism are the two major segments of the market, and are growing enormously, they need to be broadened and deepened until they are truly global and the market is able to 'find' the right price for carbon. Achieving that objective may take significant experimentation and time, but it must be clear that that is the final objective, and that governments are agreed in sending the market a signal that the global economy needs to be largely decarbonised by 2050, and completely decarbonised by the end of the century.

- **Technology transfer**
  One of the fundamental building blocks of the UNFCCC when it was first agreed in 1992 was the commitment by industrialised countries to provide for the development and transfer of climate-friendly technologies to developing countries. For various political and economic reasons this has been difficult to achieve in practice.
  Although the dissemination of climate-friendly technology has direct relevance to the wind industry, a fair balance of commitment between governments and the private sector in pursuing this objective still has to be agreed. If these parameters were clear, it is possible that a useful role for the UN system on this subject might be devised.

- **Expanded carbon markets**
  In pursuit of the final objective of a global, seamless carbon market, a number of steps should be taken. First and foremost, it is essential that the United States join the global carbon market, which was in fact designed largely at the instigation of the US and with the expectation that it would be the major 'buyer' on the global market.
  Secondly, the membership of Annex B needs to be expanded to include those countries which have recently joined the OECD and those whose economies have grown to reach or even exceed OECD or EU average income per capita. Thirdly, there are many proposals under discussion for improving the scope and effectiveness of the CDM in the period after 2012,

- **A sectoral approach for the power sector**
  To ensure the maximum uptake of emissions-reducing technology for the power generation sector, GWEC and others are exploring options for a voluntary Electricity Sector Emissions Reduction Mechanism. The main characteristics of this proposal involve establishing a hypothetical baseline of future emissions in the electricity sector of an industrialising country, quantifying the effect of national policies and measures and on that basis establishing a 'no lose' target for the entire electricity sector. Reductions in emissions below that baseline would then be eligible to be traded as credits on international carbon markets, although there would be no penalty associated with not meeting the target.

The advantages of this system over the current project-based CDM would be in terms its relative simplicity and much greater scope. As well as providing potentially very large sources of investment in the decarbonisation of the energy sector of a rapidly industrialising country, it would incentivize energy efficiency as well as any other emission reducing technology without having to go through the application process on a project-by-project basis. It would also be a good stepping stone between the current situation of non-Annex I countries and their eventual assumption of an economy wide cap as the regime develops and their development warrants.

ANNEX

REFERENCE

Year	Cumulative [GW]	Global Annual Growth Rate [%] - excluding repowering	Annual Installation incl. Repowering	Capacity factor [%]	Production [TWh]	Wind power penetration of world's electricity in % - Reference	Wind power penetration of world's electricity in % - Efficiency	CO_2 reduction (with 600g CO_2/kWh) [annual Mio tCO_2]
2007	94	28	19,865	25	205.6	1.4	1.4	123
2008	110	27	15,857	25	240.3			144
2009	128	15	18,307	25	280.4			168
2010	129	10	17,998	25	304.4	1.7	1.7	183
2015	233	9	20,887	28	571.4			343
2020	352	9	24,180	28	864.1	3.6	4.1	518
2025	418	3	24,301	28	1,025.2			615
2030	497	4	30,013	28	1,218.4	4.2	5.1	731
2035	543	1	30,164	28	1,331.8			799
2040	599	1	36,196	30	1,574.7	4.4	5.8	945
2045	638	1	36,378	30	1,676.0			1,006
2050	679	1	36,560	30	1,783.8	4.2	5.8	1,070

MODERATE

Year	Cumulative [GW]	Global Annual Growth Rate [%] - excluding repowering	Annual Installation incl,. Repowering	Capacity factor [%]	Production [TWh]	Wind power penetration of world's electricity in % - Reference	Wind power penetration of world's electricity in % - Efficiency	CO_2 reduction (with 600gCO_2/kWh) [annual Mio tCO_2]
2007	94	28	19,865	25	205.6	1.4	1.4	123
2008	118	27	23,871	25	257.8			155
2009	143	20	25,641	25	314.0			188
2010	172	19	28,904	25	377.3	2.1	2.1	226
2015	379	15	54,023	28	929.5			558
2020	709	11	81,546	28	1,739.8	7.3	8.2	1,044
2025	1,104	7	81,610	28	2,707.2			1,624
2030	1,420	3	80,536	28	3,484.0	11.9	14.6	2,090
2035	1,599	1	84,465	28	3,922.1			2,353
2040	1,696	1	97,548	30	4,457.3	12.5	16	2,674
2045	1,769	1	100,380	30	4,648.5			2,789
2050	1,834	1	100,302	30	4,818.6	11.2	16	2,891

ADVANCED

Year	Cumulative [GW]	Global Annual Growth Rate [%] - excluding repowering	Annual Installation incl,. Repowering	Capacity factor [%]	Production [TWh]	Wind power penetration of world's electricity in % - Reference	Wind power penetration of world's electricity in % - Efficiency	CO_2 reduction (with 600gCO_2/kWh) [annual Mio tCO_2]
2007	94	28%	19,865	25%	205.6	1.4	1.4	123
2008	120	25%	25,509	25%	262.4			157
2009	150	24%	30,005	25%	328.2			197
2010	186	22%	36,468	25%	408.0	2.3	2.3	245
2015	486	19%	84,160	28%	1191.7			715
2020	1,081	12%	142,674	28%	2,651.2	11.2	12.6	1,591
2025	1,770	8%	153,213	28%	3,994.2			2,397
2030	2,375	5%	165,000	28%	5,393.0	19.7	24.0	3,236
2035	2,961	2%	165,000	28%	7,105.2			4,263
2040	3,163	1%	165,000	30%	8,236.6	23.1	30.3	4,942
2045	3,316	1%	165,000	30%	8,629.4			5,178
2050	3,498	1%	165,000	30%	9,088.1	21.2	24.5	5,453

REFERENCE

Year	CO_2 reduction [cumulative Mio tCO_2]	Jobs	Progress ratio [%]	Capacity [€/MW]	Investment [€]	Worlds electricity in TWh - Reference	World's electricity in TWh - Efficiency
2007	406	329,232	90	1,300	25,824,500		
2008	550	397,269	90	1,350	25,873,673		
2009	718	431,290	90	1,450	25,910,012		
2010	901	417,923	90	1,438	26,545,447	17,890	17,686
2015	2,245	479,887	92	1,376	28,736,673		
2020	4,459	535,074	92	1,329	32,135,267	23,697	21,095
2025	7,333	522,711	94	1,315	31,960,752		
2030	10,776	634,114	94	1,301	39,058,575	29,254	23,937
2035	14,632	611,062	96	1,297	39,113,402		
2040	19,118	713,769	96	1,292	46,748,706	35,698	27,166
2045	24,021	728,531	98	1,290	46,924,011		
2050	29,247	744,123	98	1,288	47,099,974	42,938	30,814

MODERATE

Year	CO_2 reduction [cumulative Mio tCO_2]	Jobs	Progress ratio [%]	Capacity [€/MW]	Investment [T€]	Worlds electricity in TWh - Reference	World's electricity in TWh - Efficiency
2007	406	329,232	90	1,300	25,824,500		
2008	561	397,269	90	1,350	32,225,716		
2009	749	432,363	90	1,450	37,179,828		
2010	975	462,023	90	1,392	40,220,810	17,890	17,686
2015	3,048	882,520	90	1,170	63,182,874		
2020	7,216	1,296,306	92	1,096	89,390,391	23,697	21,095
2025	14,168	1,466,869	94	1,066	97,666,627		
2030	23,752	1,486,589	94	1,050	88,658,740	29,254	23,937
2035	35,068	1,418,326	96	1,045	84,125,291		
2040	48,163	1,637,816	96	1,042	101,659,168	35,698	27,166
2045	61,886	1,693,206	98	1,041	104,522,858		
2050	76,141	1,713,391	98	1,041	104,365,717	42,938	30,814

ADVANCED

Year	CO_2 reduction [cumulative Mio tCO_2]	Jobs	Progress ratio [%]	Capacity [€/MW]	Investment [T€]	Worlds electricity in TWh - Reference	World's electricity in TWh - Efficiency
2007	406	329,232	90%	1,300	25,824,500		
2008	563	422,545	90%	1,350	34,437,535		
2009	760	499,967	90%	1,450	43,506,723		
2010	1,005	572,596	90%	1,379	50,304,975	17,890	17,686
2015	3,513	1,340,016	90%	1,112	93,546,253		
2020	9,494	2,214,699	94%	1,047	149,352,592	23,697	21,095
2025	19,616	2,428,006	94%	1,036	158,727,421		
2030	31,294	2,771,000	98%	1,026	169,297,423	29,254	23,937
2035	54,709	2,800,931	98%	1,022	168,705,910		
2040	78,789	2,868,319	98%	1,021	168,481,382	35,698	27,166
2045	104,197	2,919,146	98%	1,020	168,321,894		
2050	130,887	2,979,981	98%	1,019	168,140,446	42,938	30,814

ABOUT GWEC
GLOBAL REPRESENTATION FOR THE WIND ENERGY SECTOR

GWEC is the voice of the global wind energy sector. GWEC brings together the major national, regional and continental associations representing the wind power sector, and the leading international wind energy companies and institutions. With a combined membership of over 1,500 organisations involved in hardware manufacture, project development, power generation, finance and consultancy, as well as researchers, academics and associations, GWEC's member associations represent the entire wind energy community.

THE MEMBERS OF GWEC REPRESENT:

- Over 1,500 companies, organisations and institutions in more than 70 countries
- All the world's major wind turbine manufacturers
- 99 % of the world's more than 100,000 MW of installed wind power capacity

GLOBAL WIND ENERGY COUNCIL (GWEC)
Renewable Energy House
63-65 Rue d'Arlon
1040 Brussels
Belgium

T: 32 2 100 4029
F: 32 2 546 1944
www.gwec.net
info@gwec.net

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area north of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

GREENPEACE INTERNATIONAL

Ottho Heldringstraat 5
1066 AZ Amsterdam
The Netherlands
T: 31 20 7182000
F: 31 20 5148151
www.greenpeace.org
sven.teske@int.greenpeace.org

Scenario by GWEC, Greenpeace International, DLR and Ecofys
Text edited by Angelika Pullen, Steve Sawyer, Sven Teske, Crispin Aubrey
Design by bitter Grafik & Illustration, Hamburg
Photos courtesy of BWE; Elsam; Enercon; EWEA; Gamesa; Greenpeace; IVPC; JWEA; Lucky Wind; Npower Renewables Ltd; Petitjean; Shell Wind Energy;Vestas Central Europe; Vicson Chua; Vision Quest Windelectric; Winter.

Printed on recycled paper