GLOBAL WIND ENERGY OUTLOOK 2006

GREENPEACE

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GLOBAL WIND ENERGY COUNCIL

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Contents

Foreword

IN MANY PARTS OF THE WORLD, wind energy has already grown to be a mainstream energy source. This growth has long been driven by concerns about global climate change, mainly in the developed world and especially in Europe.

Climate change is a complicated and alarming predicament. As devastating as Hurricanes Katrina and Rita may have been, their wrath is nothing compared to the devastation that climate change will wreak on our planet if governments fail to address the world's fossil fuel addiction. Cutting greenhouse gas emissions makes both environmental and economic sense. The goal of climate policy should be to keep global mean temperature rise to less than 2 ºC above pre-industrial levels in order to avoid dramatic damage to ecosystems and disruption to the climate system. To meet these targets, the world needs to fundamentally change the way it generates and uses energy in the coming decade.

However, other challenges such as energy supply security and the volatility of fossil fuel prices have become just as pressing, both in the OECD and in emerging market. Global energy needs are growing at a staggering rate world wide. Over-reliance on energy imports from few, mostly politically unstable countries and volatile oil and gas prices make for a shaky supply situation that is already inflicting massive drains on the global economy.

Wind energy is the most attractive solution to the world's energy challenges. It is clean and fuel-free. Moreover, wind is indigenous and enough wind blows across the globe to cope with the ever increasing electricity demand. This report demonstrates that wind technology is not a dream for the future – it is real, it is mature and it can be deployed on a large scale. Thanks to twenty years of technological progress, wind turbines have come a long way and a wind farm today acts much more like a conventional power station. Moreover, wind power generation is increasingly competitive with conventional fossil fuel sources and already today is on a par with new coal or gas fired power stations.

Already now, wind energy is rapidly developing into a mainstream power source in many countries of the world, with over 60,000 MW of installed capacity world wide and an average annual market growth rate of 28%. Wind energy could provide as much as 29% of the world's electricity needs by 2030, given the political will to promote its large scale deployment paired with far-reaching energy efficiency measures.

The political choices of the coming years will determine the world's environmental and economic situation for many decades to come. While the industrialised world urgently needs to rethink its energy strategy, the developing world should learn from past mistakes and build their economies on the strong foundation of sustainable energy supply. For the sake of a sound environment, political stability and thriving economies, now is the time to commit to a truly secure and sustainable energy future, built on clean technologies and promoting regional development and the creation of millions of new jobs. The world cannot afford to stick to the 'conventional' energy development path, relying on fossil fuels, nuclear and other outdated technologies from past centuries. Wind can and has to play a leading role in the world's energy future.

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EXECUTIVE SUMMARY

The Global Status of Wind Power

The global market for wind power has been expanding faster than any other source of renewable energy. From just 4,800 MW in 1995 the world total has multiplied more than twelve-fold to reach over 59,000 MW at the end of 2005.

The international market is expected to have an annual turnover in 2006 of more than € 13 billion, with an estimated 150,000 people employed around the world. The success of the industry has attracted investors from the mainstream finance and traditional energy sectors.

In a number of countries the proportion of electricity generated by wind power is now challenging conventional fuels. In Denmark, 20% of the country's electricity is currently supplied by the wind. In Spain, the contribution has reached 8%, and is set to rise to 15% by the end of the decade. These figures show that wind power is already able to provide a significant input of carbon-free electricity. In 2005, the global wind energy sector registered another record year, with a total of 11,531 MW of new capacity installed. This represented a 40.5% increase on an annual basis and a 24% cumulative growth.

Wind power is now established as an energy source in over 50 countries around the world. Those with the highest totals in 2005 were Germany (18,428 MW), Spain (10,027 MW), the USA (9,149 MW), India (4,430 MW) and Denmark (3,122 MW). A number of other countries, including Italy, the UK, the Netherlands, China, Japan and Portugal, have reached the 1,000 MW mark.

Although the wind power industry has up to now been most dynamic in the countries of the European Union, this is changing. The United States and Canada are both experiencing a surge of activity, whilst new markets are opening up in Asia and South America. A new frontier for wind power development has also been established in the sea, with offshore wind parks beginning to make a contribution.

Drivers for Wind Energy

The growth of the market for wind energy is being driven by a number of factors. These have combined in a number of regions of the world to encourage political support for the industry's development.

Security of supply: In the absence of committed energy efficiency measures, the International Energy Agency (IEA) predicts that by 2030, the world's energy needs will be almost 60% higher than now. At the same time, supplies of fossil fuels are dwindling. Some of the major economies of the world are having to rely increasingly on imported fuel, sometimes from regions of the world where conflict and political instability threaten the security of that supply. By contrast, wind energy is a massive indigenous power source which is permanently available, with no fuel costs, in virtually every country in the world.

Environmental concerns: The impetus behind wind power expansion has come increasingly from the urgent need to combat global climate change. This is now accepted to be the greatest environmental threat facing the world. Under the 1997 Kyoto Protocol, OECD member states are committed to cut their CO_2 emissions by an average of 5.2%. In the developing world, more immediate concern comes from the direct environmental effects of burning fossil fuels, particularly air pollution.

Other environmental effects resulting from the range of fuels currently used to generate electricity include the dangers of fossil fuel exploration and mining, pollution caused by accidental oil spills and the health risks associated with radiation. Exploiting renewable sources of energy such as wind power avoids these risks and hazards.

Economics: As the global market has grown, wind power has seen a dramatic fall in cost. A modern wind turbine annually produces 180 times more electricity at less than half the cost per unit (kWh) than its equivalent twenty years ago. At good locations wind can compete with the cost of both coal and gas-fired power. The competitiveness of wind power has been further enhanced by the recent rise in the price of fossil fuels. If the "external costs" associated with the pollution and health effects resulting from fossil fuel and nuclear generation were fully taken into account, wind power would work out even cheaper.

Wind energy also provides economic benefit through the employment which the industry generates. In the developing world, off-grid wind power opens up economic opportunities to dispersed communities.

Technology and industry: Since the 1980s, when the first commercial wind turbines were deployed, their capacity, efficiency and visual design have all improved dramatically. A modern wind turbine annually produces 180 times more electricity at less than half the cost per unit (kWh) than its equivalent twenty years ago. The largest turbines being manufactured now are of more than 5 MW capacity, with rotor diameters of over 100 metres. Modern turbines are modular and quick to install, whilst wind farms vary in size from a few megawatts up to several hundred.

Wind energy has become big business. The major wind turbine manufacturers are commissioning multi-million dollar factories around the world in order to satisfy demand.

The World's Wind Resources and Grid Integration

Studies of the world's wind resources have confirmed that these are extremely large and well distributed across almost all regions and countries. Lack of wind is unlikely to be a limiting factor on global wind power development.

As the industry expands, large quantities of wind powered electricity will need to be integrated into the global grid network. The variability of the wind is not an issue which will hinder this development, however.

The already established control methods and backup capacity available for dealing with variable demand and supply are more than adequate to handle the additional variable supply of wind power at penetration levels up to around 20%. Above that, some changes may be needed in power systems and their method of operation. Improved forecasting techniques and increased geographical dispersion of wind farms - ensuring that the wind is always blowing somewhere - will both help integration.

The potential for incorporating large amounts of wind power generation can be seen from the example of Denmark, where 20% of total electricity consumption can already be met by the wind. The DENA study in Germany concluded that wind power could triple its power production by 2015, providing 14% of net electricity consumption, without any additional need for reserve or balancing power stations.

The Environmental Impacts of Wind Power

The construction and operation of wind power, often in areas of open countryside, raises issues of visual impact, noise and the effect on local wildlife. These issues are usually addressed through an environmental impact assessment.

Visual impact: Wind turbines are tall structures likely to be visible over a relatively wide area. While some people express concern about the effect wind turbines have on the landscape, others see them as elegant and graceful, symbols of a less polluted future.

Birds: Can be affected by wind energy development through loss of habitat, disturbance to their breeding areas and by death or injury caused by the rotating turbine blades. Studies from Europe and the United States have shown, however, that the average rate of collision has been no more than two birds per turbine per year. These figures should be set against the millions of birds killed each year by power lines, pesticides and road vehicles.

Noise: Compared to road traffic, trains, construction activities and other sources of industrial noise, the sound generated by wind turbines in operation is comparatively low. Better design and better insulation have made more recent wind turbine models much quieter. The approach of regulatory authorities has been to ensure that the turbines are positioned far enough away from nearby homes to avoid unacceptable disturbance.

Global Wind Energy Outlook Scenario

The Global Wind Energy Outlook Scenario examines the future potential for wind power up to the year 2050. Three different scenarios for wind power are assumed – a Reference scenario based on figures from the International Energy Agency, a Moderate version assuming that current targets for renewable energy are successful, and an Advanced version assuming that all policy options in favour of renewables have been adopted. These are then set against two scenarios for global energy demand. Under the Reference scenario, growth in demand is again based on IEA projections; under the High Energy Efficiency version, a range of energy efficiency measures result in a substantial reduction in demand.

The results show that wind energy can make a major contribution towards satisfying the global need for clean, renewable electricity within the next 30 years and that its penetration in the supply system can be substantially increased if serious energy efficiency measures are implemented at the same time. Under the Reference wind power scenario, wind energy would supply 5 % of the world's electricity by 2030 and 6.6 % by 2050. Under the Moderate scenario, wind energy's contribution would range from 15.6 % in 2030 to 17.7 % by 2050. Under the Advanced scenario, wind energy's contribution to world electricity demand would range from 29.1 % in 2030 up to 34.2 % by 2050.

All three scenarios assume that an increasing proportion of new wind power capacity is installed in growing markets such as South America, China, the Pacific and South Asia.

THE COSTS AND BENEFITS OF THESE SCENARIOS INCLUDE:

Investment: The annual investment value of the wind energy market in 2030 will range from €21.2 billion under the Reference scenario to €45 bn under the Moderate scenario and up to €84.8 bn under the Advanced scenario.

Generation costs: The cost of producing electricity from wind energy is expected to fall to 3-3.8 €cents/kWh at a good site and 4-6 €cents/kWh at a site with low average wind speeds by 2020.

Employment: The number of jobs created by the wind energy market will range from 480,000 in 2030 under the Reference scenario to 1.1 million under the Moderate scenario and to 2.1 million under the Advanced scenario.

Carbon dioxide savings: Savings will range from an annual 535 million tonnes CO_2 in 2030 under the Reference scenario to 1,661 million tonnes under the Moderate scenario to 3,100 million tonnes under the Advanced scenario.

Energy Policy Issues and Recommendations

Renewable technologies are disadvantaged by the failure to penalise conventional fuels for the economic cost of their pollution and other hazards - and by distortions in the world's electricity markets created by massive financial and structural support to conventional technologies. Without political support, wind power cannot establish its positive contribution towards environmental goals and security of supply.

ACTION IS NEEDED IN THE FOLLOWING AREAS:

Targets for renewable energy: Setting targets will encourage governments to develop the necessary regulatory frameworks to expand renewables, including financial frameworks, grid access regulation, planning and administrative procedures.

Specific policy mechanisms: The market for generated power needs to be clearly defined in national laws, including stable, long term fiscal measures that minimise investor risk and ensure an adequate return on investment.

Electricity market reform: Reforms needed in the electricity sector to encourage renewable energy include the removal of barriers to market entry, removing subsidies to fossil fuels and nuclear and internalising the social and environmental costs of polluting energy.

International action on climate change: Targets for a continuing reduction in greenhouse gas emissions must be established beyond the present Kyoto period of 2008-12.

Reform of international financing: Multi-lateral financing mechanisms should include a defined and increasing percentage of lending directed to renewable energy projects, coupled with a rapid phase out of support for conventional, polluting energy projects.

Action by international bodies: The G8 bloc of countries and the UN Commission on Sustainable Development should support global renewables development.

THE GLOBAL STATUS OF WIND POWER

Over the past decade the global market for wind power has been expanding faster than any other source of renewable energy. Since the year 2000 the average annual increase in cumulative installed capacity has been 28%. From just 4,800 MW in 1995 the world total has multiplied more than twelve-fold in ten years to reach over 59,000 MW by the end of 2005.

The result is an international industry which is expected to have an annual turnover in 2006 of more than 13 billion Euros. A substantial manufacturing industry has been created, with an estimated 150,000 people employed around the world. Such has been the success of the industry that it has attracted an increasing number of investors from the mainstream finance and traditional energy sectors.

In a number of countries the proportion of electricity generated by wind power is now challenging conventional fuels. In Denmark, 20% of the country's electricity is currently supplied by the wind. In northern Germany, wind can contribute 35% of the supply. In Spain, Europe's fifth largest country, the contribution has reached 8%, and is set to rise to 15% by the end of the decade.

These figures show that wind power is already able to provide a significant input of carbon-free electricity.

Record Year in 2005

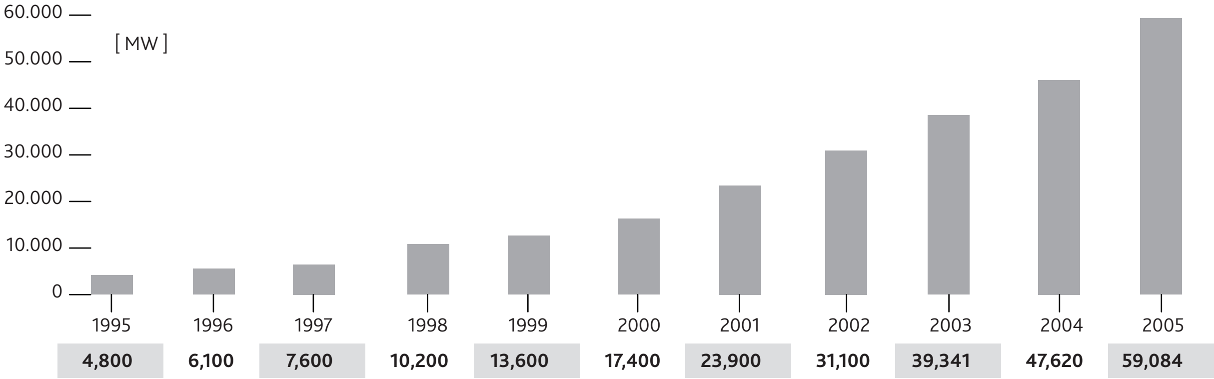
Last year, the global wind energy sector registered another record year. During 2005, a total of 11,531 MW of new capacity was installed in more than 30 countries. This represented a 40.5% increase on an annual basis and a 24% cumulative growth. At the end of 2005, the world's total installed wind power capacity stood at 59,084 MW.

Wind power is now established as an energy source in over 50 countries around the world. Those countries with the highest total installed capacity are Germany (18,428 MW), Spain (10,027 MW), the USA (9,149 MW), India (4,430 MW) and Denmark (3,122 MW). A number of other countries, including Italy, the UK, the Netherlands, China, Japan and Portugal, have reached the 1,000 MW mark.

Although the wind power industry has up to now been most dynamic in the countries of the European Union, this is beginning to change. The United States and Canada are both experiencing a surge of activity, whilst new markets are opening up in Asia and South America. In Asia, both China and India registered a record level of expansion during 2005.

Whilst most wind power development has so far been on land, pressures of space and the attraction of greater productivity from a better wind regime have taken developers offshore. Establishing wind energy projects in the sea has opened up new demands, including the need for stronger foundations, long underwater cables and larger individual turbines, but offshore wind parks are expected to contribute an increasing proportion of global capacity, especially in northern Europe.

GLOBAL CUMULATIVE WIND POWER CAPACITY



Another way to manage the growth in demand for wind energy in areas with limited available land has been through "repowering". This involves replacing older, less efficient wind turbines with a smaller number of more powerful recent models. Repowering is already gaining pace in a number of countries in which the wind industry has been established for ten years or more. These include Denmark, the UK, Germany and the US.

Europe

The European Union still leads the world, with over 40,500 MW of installed wind capacity at the end of 2005, representing 69% of the global total. This has already achieved, five years ahead of time, the target set by the European Commission for 40,000 MW by 2010.

Wind energy expansion in the EU has been driven by individual member states' policies to encourage renewable energy. These incorporate a range of financial incentives, including investment grants and premium tariffs, with the aim of making a contribution towards the reduction of greenhouse gas emissions. In 2001 an EU directive on renewable energy set each member state a target for the proportion of renewable energy it should achieve by 2010. The overall European target is for 21% of electricity supply.

The European Wind Energy Association (EWEA) predicts that by 2010, wind energy alone will save enough greenhouse gas emissions to meet one third of the European Union's Kyoto obligation. EWEA's current targets are for 75,000 MW of wind capacity in Europe by 2010, 180,000 MW by 2020 and 300,000 MW by 2030.

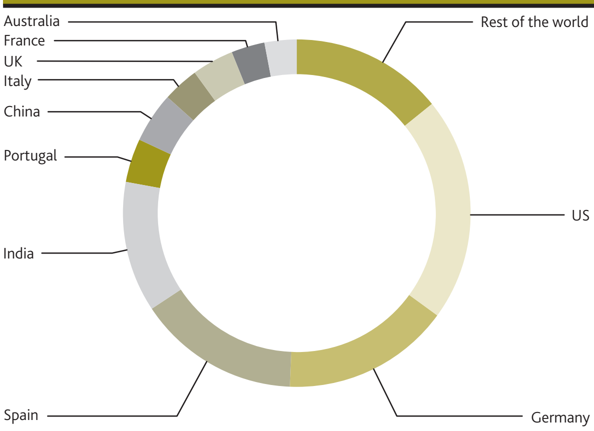
The leading country for wind energy in Europe is **Germany**. Encouraged by successive laws, most recently the 2000 Renewable Energy Sources Act (updated in 2004), generators of wind power have been paid a premium tariff for their output, gradually reducing over a 20 year contract period. This policy mechanism has proved extremely successful, attracting a large number of small business investors, and resulting in double digit annual growth rates since the 1990s.

Wind projects also receive preferential treatment under German land planning law, with each local authority expected to designate zones where wind parks will be encouraged. Wind power currently provides about 5.5% of German electricity, with an installed capacity at the end of 2005 of 18,428 MW.

Although the rate of development on land in Germany has already started to slow down, mainly due to a shortage of available sites, this will be compensated for by the repowering of older turbines and by a new offshore market in the North and Baltic Seas. A study by the German Environment Ministry (BMU) estimates that offshore wind power could reach a level of 12,000-15,000 MW by 2020.

Spain has rapidly increased its wind power capacity since the mid-1990s, encouraged by a national premium tariff and policy based on regional industrial regeneration. In many provinces prospective developers have only been able to access project sites if they first commit to establishing a manufacturing base in the region. This has resulted in the

TOP 10 NEW INSTALLED CAPACITY (JAN.-DEC. 2005)



New capacity	MW	%
US	2,431	21,1
Germany	1,808	15,7
Spain	1,764	15,3
India	1,430	12,4
Portugal	500	4,3
China	498	4,3
Italy	452	3,9
UK	446	3,9
France	367	3,2
Australia	328	2,8
Top 10 – Total	**10,024**	**86,9**
Rest of the world	**1,507**	**13,1**
World total	**11,531**	**100,0**

relatively poor but windy province of Navarra, for example, achieving major economic development and a contribution from wind power now approaching 60% of its electricity supply. In both the more densely populated provinces of Castilla la Mancha and Galicia, the level has reached more than 20%.

Most of the wind turbines deployed in Spain are manufactured domestically. Last year a near record 1,764 MW of wind turbines were commissioned, a 20% increase on 2004, and saving the emission of an additional 19 million tonnes of carbon dioxide. This took the Spanish total to just over 10,000 MW, enough to satisfy 8.25% of the country's electricity demand. The Spanish government's target is to reach more than 20,000 MW by 2010.

Denmark has been the pioneer of the European wind turbine manufacturing industry and continues to have the highest penetration of wind power in its supply system. More than 3,000 MW of capacity was operating by the end of 2005. When the wind blows strongly, wind energy supplies more than half the electricity in the western half of the country. Projections by the national Transmission System Operator Energinet show that by 2010, electricity consumption in western Denmark could be regularly satisfied by a mixture of wind and small combined heat and power stations, without the need for centralised generation. In the 1990s, Denmark also pioneered the development of offshore wind farms, and still has the largest sea-based wind park in the world.

These market leaders are now being joined by a second wave of countries, including **Portugal, France, the UK, Italy, the Netherlands** and **Austria**. In Portugal, strong government policy supported by a fixed tariff payment system has seen wind capacity grow from 100 MW in 2000 to over 1,000 MW by the end of 2005. In Italy, which introduced a national target for renewable energy linked to a green certificate trading system in 2001, wind capacity grew by 452 MW in 2005 to reach more than 1,700 MW.

The potential of the ten new states which joined the European Union in 2004 has still to be realised, but a number of them, including **Poland, Hungary** and the **Baltic States**, are expected to take off in the next few years.

North America

In 2005, nearly a quarter of new global capacity was installed in North America, where the total increased by 37%. Wind energy gained momentum in both the United States and Canada.

The birthplace of large scale wind power deployment in California during the 1980s and early 1990s, the **United States** is experiencing a revival which could soon see it match the success of the European market leaders. With large open spaces available for development, many US states have an excellent wind regime and a growing demand for energy that avoids the volatility of fossil fuel prices.

The US industry shattered all previous annual records in 2005 to install nearly 2,500 MW of new capacity. This brought the country's total wind generating capacity up to more than 9,100 MW. The industry is expected to turn in an even better performance in 2006, with new installations likely to top 3,000 MW.

Spreading out from its Californian base, there are now utility-scale developments across 31 US states. New wind farms completed in 2005 include twelve projects of 100 MW or more, ranging geographically from the 140 MW Maple Ridge project in New York to the 150 MW Hopkins Ridge project in Washington state, in the Pacific Northwest. The largest single project completed last year was the 210 MW Horse Hollow wind energy center in Texas. Texas added some 700 MW of wind in 2005 – the largest amount of any state – bringing it close to long-time national leader California.

Growth in the US market is largely due to the current three year window of stability provided by the federal incentive for wind energy, the Production Tax Credit (PTC). For the first time in the credit's history, the US Congress extended the PTC before it expired, taking it through to the end of 2007. As a result, the wind industry is looking forward to several record-breaking years in a row.

Failure to renew the PTC on time has previously seen a "roller-coaster" US market, with fallow years of falling investor confidence followed by brief boom periods. The American Wind Energy Association (AWEA) is currently lobbying for a longer term extension of the incentive. With stable, supportive policies, wind energy could provide at least 6% of US electricity by 2020, according to the AWEA, a share similar to that of hydropower today. However a share of more than 20% wind power is possible in the longer term.

Thanks to a mixture of federal incentives and initiatives by individual provinces to increase the contribution from renewable energy, wind capacity in **Canada** increased by an impressive 54% in 2005 and now stands at 683 MW. This is enough to power more than 200,000 Canadian homes.

An important contributor to Canada's vibrant market has been the federal government's Wind Power Production Incentive (WPPI). In 2005, the WPPI was extended to 2010, and with the funds available increased to support up to 4,000 MW of capacity. Several provinces have also implemented policies to encourage wind projects, including utility mandates for up to 2,000 MW of new wind farms.

As a result of these policy measures, 2006 is expected to see at least 500 MW of wind projects commissioned. The Canadian Wind Energy Association estimates that more than 8,000 MW could be in place by 2015.

Asia

The Asian continent is developing into one of the main powerhouses of wind energy development, accounting for 19% of new installations in 2005. With a growth rate of over 46%, total capacity in the region reached nearly 7,000 MW.

The strongest Asian market remains **India**, with the installation of over 1,430 MW of new capacity last year taking its total to 4,430 MW. This pushed it into fourth position in the international wind power league table. The Indian Wind Turbine Manufacturers Association (IWTMA) expects between 1,500 and 1,800 MW to be commissioned every year for the next three years.

Incentives are provided to the wind energy sector by the Indian government in the form of tax breaks and tax reductions. The 2003 Electricity Act also established State Electricity Regulatory Commissions in most states with a mandate to promote renewable energy through preferential tariffs and a minimum obligation on distribution companies to source a certain share of their electricity supply from renewables. Tariffs for grid connected wind farms vary from state to state.

Over the past few years, both the government and the wind power industry have succeeded in injecting greater stability into the Indian market. This has encouraged larger private and public sector enterprises to invest. It has also stimulated a stronger domestic manufacturing sector; some companies now source more than 80% of the components for their turbines in India. This has resulted in both more cost effective production and additional local employment.

The geographical spread 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 Andhra Pradesh, starting to catch up. With the potential for up to 65,000 MW of wind capacity across the country (IWTMA estimate), progress in India should be further accelerated over the next decade.

With its large land mass and long coastline, **China** is rich in wind energy potential. The Chinese Meteorology Research Institute estimates the land-based exploitable wind resource to have the potential for 253 GW of capacity. A further 750 GW could be provided by offshore projects.

The first Chinese wind farm went on line in 1986 as a demonstration project. By the end of 2005, total installations in mainland China had reached 1,260 MW, representing an annual growth of 60%.

Chinese government policy has been to encourage the localisation of wind turbine manufacture, thus reducing costs so that wind power can compete with fossil fuel generation. China's power generation industry is currently dominated by coal-fired power stations, which cause air pollution and other environmental problems. To establish a domestic turbine manufacturing industry, the National Development and Reform Commission (NDRC) therefore promoted the idea of Wind Power Concessions for large scale commercial development. Under the concession process local authorities invite investors, both international and domestic, to develop 100 MW size wind farms at potential sites, with a tendering procedure aimed at bringing down the generating cost and increasing the proportion of locally made components. One rule is that 70% of components must be made in China.

Most recently, the wind power market in China has been significantly boosted by a new Renewable Energy Law, which came into force at the beginning of 2006. The aim of this law is to establish a national target for renewable development and to adopt a national supportive tariff system. As a result, a large number of international companies have launched joint ventures with Chinese companies and are setting up manufacturing and assembly outlets.

The current goal for wind power in China is to reach 5,000 MW by the end of 2010. Looking further ahead, 30 GW of wind power has been proposed by the Chinese government in its long term planning up to 2020. By the end of that year it is estimated that, in order to satisfy growing demand, total power capacity in China will have reached 1,000 GW. Wind generated electricity would by then represent 1.5% of total power production.

The wind energy industry in **Japan** has also been expanding, partly spurred by a government requirement for electricity companies to source an increasing percentage of their supply from renewables (Renewable Portfolio Standard-type law), partly by the introduction of market incentives. These include both a premium price for the output from renewable plants and capital grants towards clean energy projects. The result has been an increase in Japan's installed capacity from 461 MW at the end of fiscal year 2002 to more than 1,000 MW by March 2006.

The official government target for wind power in Japan is 3,000 MW by 2010. The main factors which could delay this being achieved are the relatively low level of the RPS percentage target and the difficulties encountered by some wind projects because of turbulent and unstable weather conditions, especially in mountainous regions.

South Korea and **Taiwan** have also experienced strong growth in 2005, with close to 100 MW of installed capacity each by the end of the year. The **Philippines** are estimated to have the highest wind energy potential in the Southeast Asian region, although only one wind farm of 25 MW had been installed by December 2005. The Philippines government has set a target of 417 MW within ten years, while the US-based National Renewable energy Laboratory has concluded that the country could support over 70,000 MW of installed capacity, delivering more than 195 billion kWh per year.

Latin America

Although there has been little activity in Latin America to date, a number of governments are in the process of implementing renewable energy laws or programmes, and wind energy is expected to develop at a strong rate in the coming years.

High oil prices, electricity shortages and air pollution problems have put pressure on the government in **Brazil** to look for sustainable solutions through ethanol, biomass, hydroelectricity, wind and solar power. Wind power matches well the profile of the country's existing hydroelectric plants, especially in the north-east, where high winds coincide with low rainfall and provide a high load factor. According to a wind atlas published by the Brazilian Ministry for Mines and Energy (MME) in 2001,,the country's total wind potential is estimated at 143 GW, even when only sites with wind speeds above 7 m/s (metres per second) are considered.

In 2002 the Brazilian government introduced the PROINFA programme to stimulate the development of biomass, wind and small hydro generation. Its initial target was to implement 3,300 MW of projects by the end of 2006. Power from renewable generators is bought by the Brazilian state-controlled electricity utility Eletrobrás under 20 year power purchase agreements, with a guaranteed purchase price and project financing available through the Brazilian National Development Bank (BNDES). Domestic suppliers must account for 60% of the equipment and construction costs. Due to its limited market perspective, with a short timescale for the programme and no follow-up in sight, PROINFA did not, however, trigger the desired investment in additional manufacturing plants. With an effective monopoly in electricity supply, considerable bureaucracy and lack of infrastructure, the cost of installing wind power has been relatively high (about US$2,000/kW). Progress has therefore been slow, and the first PROINFA wind farms are only now beginning to be built. Total wind power capacity in Brazil is expected to increase from 28 MW in 2005 to about 200 MW in 2006.

Despite having only two small wind farms in operation, the Mexican Wind Energy Association projects that **Mexico** could see at least 3,000 MW of capacity installed over the period 2006-2014. One reason is the passage through the Mexican Congress in December 2005 of a Renewable Energy Utilisation Law aimed at establishing a programme with a target for renewables to supply 8% of national power production by 2012 (excluding large hydro). The law also provides for the creation of a trust to support renewable energy projects, rural electrification, biofuels and technological R&D.

Other countries with potential for wind energy in Latin America and the Caribbean are Argentina, Chile, Costa Rica, Nicaragua, Uruguay, Colombia, the Dominican Republic and Jamaica.

Australasia

Australia enjoys one of the best wind resources in the world, resulting in phenomenal capacity factors in many regions with predominantly open farmland. Growth of the country's installed capacity almost doubled in 2005, with the addition of 328 MW, taking the total to 708 MW. At the same time approximately 6,000 MW of projects are in various stages of pre-construction development.

The main national incentive for wind energy is the Mandatory Renewable Energy Target, which has a modest goal for 9,500 GWh of renewables generation by 2010 – a little over 1% of Australia's electricity demand. The Australian Wind Energy Association (Auswind) has called for this to be increased to 10%.

Although some individual states are planning to introduce more ambitious incentive schemes, such as the Victoria state government's target for 10% of renewable energy capacity by 2010, Auswind argues that federal policy needs to recognise that wind energy is a mature technology which requires specific mechanisms to address the price gap between it and that of conventional fossil fuel generation. The industry believes that nationally, at least 600 MW of new annual capacity is required for the renewable energy industry to continue growing and for Australia to maintain a wind energy manufacturing base.

Although only 168 MW of wind capacity was installed by the end of 2005, **New Zealand** is equally poised to become a dynamic market. After a quiet period, almost 1,000 MW of projects have consent to start construction, with the potential for 2,000 MW of future capacity to follow on.

Africa

The potential for large scale wind power development in Africa is concentrated in the north and the south, with relatively low wind speeds experienced in the central belt.

In the north, there has been development in **Morocco**, with 64 MW installed and a national action plan to install 600 MW by 2010, whilst **Tunisia** is waiting for its first 60 MW project to come to fruition. The most successful country has been **Egypt**, where several large wind farms have been constructed within an 80 km² designated zone at Zafarana on the Gulf of Suez. Most of these have been completed with the support of European government aid agencies. A further area of 700 km² at Gabal El-Zayt on the Gulf has now been earmarked to host a 3,000 MW wind farm. This site enjoys an excellent average wind speed of 10.5 metres/sec.

From a current level of 145 MW, the Egyptian government's New and Renewable Energy Authority is looking for the country to install 850 MW by 2010. By 2020-25 the total could have reached 2,750 MW.

In the south, **South Africa** saw its first small installation in 2002, but larger projects have yet to be encouraged by the right market incentives.

Offshore

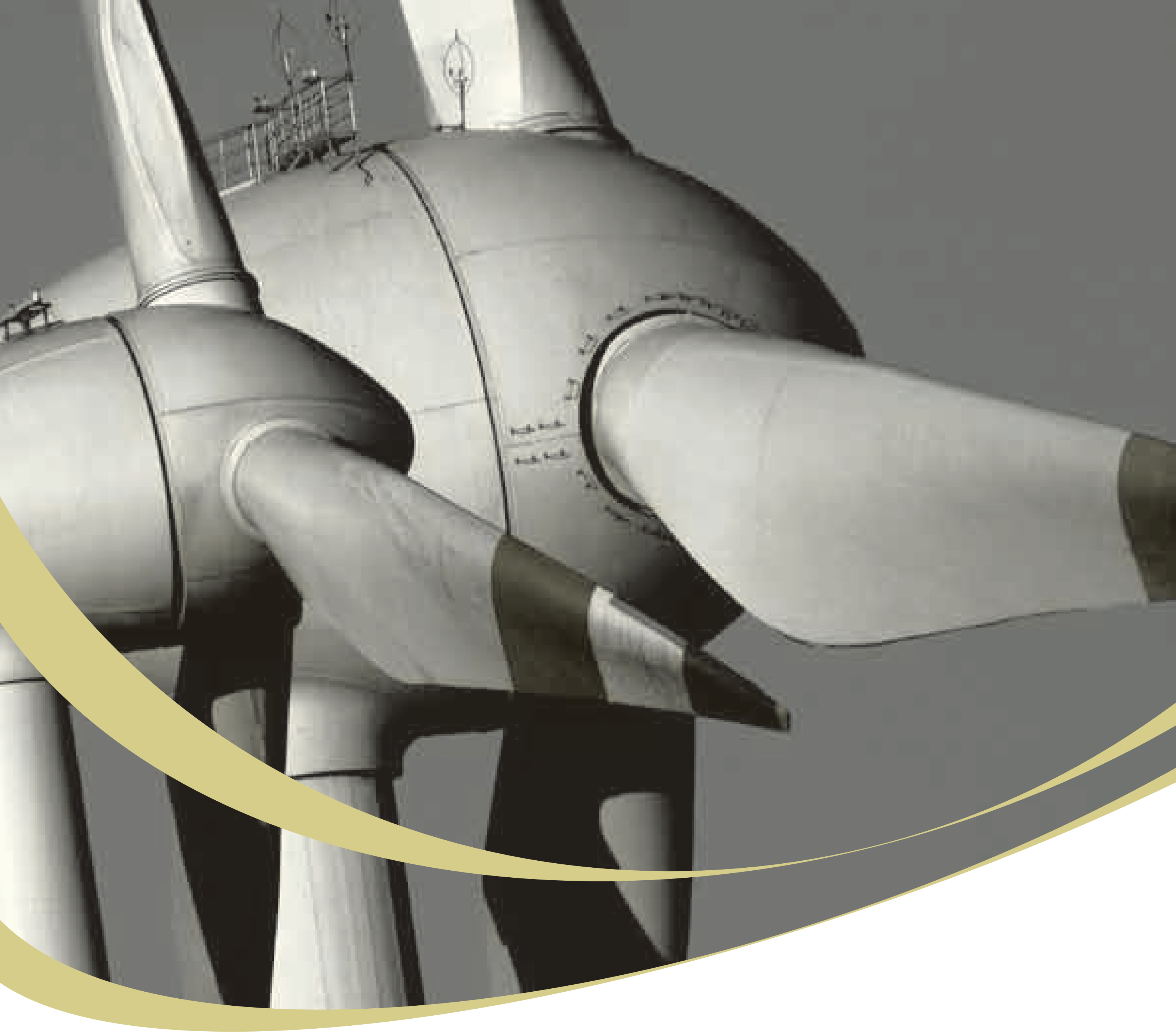
The possibility of locating wind turbines in the sea bed has opened up a new frontier for wind power, especially in the countries of northern Europe, where the availability of relatively shallow coastal waters has combined with the need to find space for much larger projects than are possible on land.

The pioneer in offshore wind farming has been **Denmark**, which has installed the two largest wind parks in the sea – 160 MW at Horns Rev in the North Sea and 158 MW at Nysted in the Baltic. Two further large developments at the same sites are now progressing.

The **UK** has also taken on a leading role, with 214 MW already built in four locations, a further 1,000 MW+ with agreement to proceed across eight sites, and even larger individual projects (of up to 1,000 MW each) planned within three strategic offshore areas identified by the UK government.

Other offshore wind farms have been built around the coasts of **Sweden** and **Ireland**, with the total installed capacity in Europe reaching 680 MW at the end of 2005. Further developments are planned or under construction off the coasts of the **Netherlands, Belgium, France** and **Spain**. In the **United States**, offshore sites are progressing through the planning stages off the east coast and off Texas in the Gulf of Mexico.

Installing wind turbines in the sea has proved more expensive than anticipated, however, and a number of projects are currently on hold whilst their economics are re-assessed. One factor which is expected to improve the viability of offshore wind farms is the commercial deployment of the new generation of larger capacity turbines (over 5 MW). Another issue to be resolved is how the costs of building new grid connection cables out to sea will be shared between the developers and the electricity supply industry.



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 and the impressive improvements in the technology itself. These factors have combined in a number of 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. The International Energy Agency (IEA) predicts that by 2030, the world's energy needs will be almost 60% higher than now. Two-thirds of this increase will occur in China, India and other rapidly developing economies; these countries will account for almost half of global energy consumption by 2030.

If this sharp increase in world energy demand actually takes place, it would require significant investment in new generating capacity and grid infrastructure, especially in the developing world. The IEA estimates that the global power sector will need to build some 4,800 GW of new capacity between now and 2030. This will require investment of approximately US$2 trillion (€1.7 trillion) in power generation and US$1.8 trillion in transmission and distribution networks.

Industrialised countries face a different but parallel situation. Whilst 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.

Without energy efficiency measures, electricity demand in the European Union is expected to increase by 51% between 2000 and 2030, requiring investments in power generation of around €625 billion (US$ 760 billion). About half of this is needed for the replacement of existing power plants.

The potential effect of energy saving on global demand could be considerable, however. According to the study by Ecofys and DLR used in this report, electricity demand could increase by only 30% by 2030, if a wide range of technologies and initiatives were introduced. Although this 'High energy efficiency' scenario recognises the limitations set by cost and other obstacles, global electricity demand would be 39% lower in 2030 than currently estimated by the IEA's Reference scenario.

Just as energy demand continues to increase, in the absence of such efficiency measures, supplies of the main fossil fuels used in power generation, especially gas, are dwindling. One result is that some of the major economies of the world are having to rely increasingly on imported fuel, sometimes from regions of the world where conflict and political instability threaten the security of that supply.

In Europe, sources of indigenous oil and gas, mainly from the North Sea, are in rapid decline. At present, 50% of Europe's energy supplies are imported. Within two decades this is expected to increase to 70%. Even uranium, which currently supplies the fuel for over 30% of European electricity, has a global lifetime estimated at no more than 40 years, whilst the EU countries contain less than 2% of the world's uranium reserves.

Driven by these pressures, the last two years have seen unprecedented increases in the prices of both oil and gas. Oil has risen from a range of $25 - $35 a barrel in 2004 to a peak of more than $70, with the expectation that the price will remain high for some years to come. Rising gas wholesale costs have seen domestic electricity prices increase across Europe; in the UK average domestic energy bills have risen since 2003 by 63% for gas and 44% for electricity.

Analysts point out that the cumulative increase in real crude oil prices since 2002 is close to that of the oil shocks of the 1970s, which produced two global recessions and an unprecedented surge in inflation. Increasingly, governments around the world are waking up to the threat that the current shaky supply situation is posing to their economic growth.

By 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.

Environmental Concerns

The impetus behind wind power expansion has come increasingly from the urgent need to combat global climate change. This is now accepted to be the greatest environmental threat facing the world. 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 of the polar ice caps, flooding of low-lying land, storms, droughts and violent changes in weather patterns. Responsibility for climate change lies with the excessive build-up of greenhouse gases in the atmosphere, a trend encouraged by the world's growing industrialisation. Within energy use, the main culprit is fossil fuels, whose combustion produces carbon dioxide, one of the main greenhouse gases.

A shift in the way the world produces and consumes energy is therefore essential. Alongside more efficient use of energy, renewable sources of energy offer the potential for deep cuts in carbon dioxide emissions.

The main international driver for combating climate change has been the 1997 Kyoto Protocol. This set national targets for OECD member states to cut their CO_2 emissions by an average of 5.2% from their 1990 levels by 2012. Combating climate change is only a secondary driver for wind energy in the developing world, however. More immediate concern comes from the direct environmental effects of burning fossil fuels, particularly air pollution. This is a major issue in countries like India and China, which use large quantities of coal for power generation.

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.

Economics

As the global market has grown, wind power has seen a dramatic fall in cost. A modern wind turbine annually produces 180 times more electricity and at less than half the cost per unit (kWh) than its equivalent twenty years ago. At good locations wind can compete with the cost of both coal and gas-fired power.

The cost of wind power generation falls as the average wind speed rises. Analysis by industry magazine Windpower Monthly (Jan 2006) shows that at a site with an average wind speed of more than 7 metres per second, and a capital cost per installed kilowatt of approximately € 1,000, wind is already cheaper than gas, coal and nuclear.

The competitiveness of wind power has been further enhanced by the recent rise in the price of fossil fuels, in particular the gas used to fuel power stations. In the United States, this has made wind generated electricity an increasingly attractive option for power utilities faced with rising costs. Against the volatility of conventional electricity costs, wind offers an energy source which has no fuel element and is unaffected by world trade issues.

Direct cost comparisons between wind power and other generation technologies are misleading, however, because they do not account for the “external costs” to society and the environment derived from burning fossil fuels or from nuclear generation. These external costs, including the effects of air pollution and radiation emissions, are not included in electricity prices.

The pan-European study, known as the “ExternE” project, conducted across all 15 original EU member states, has assessed these costs for a range of fuels. Its latest results, published in 2002, showed wind power as having the lowest range of these hidden costs - 0.15 to 0.25 € cents/kWh – compared to 2 to 15 € cents/kWh for coal. The study concluded that the cost of electricity from coal or oil would double, and that from gas increase by 30%, if their external costs associated with the environment and health were taken into account.

The polluting effect of fossil fuels has now been reflected through carbon reduction measures such as the European Union’s emissions trading scheme, which sets a limit on the amount of carbon dioxide which can be emitted by all major industrial enterprises.

Employment and Local Development

Wind energy also provides economic benefit through the employment which the industry generates. Manufacturing wind turbines and their components offers major job opportunities, often building on existing engineering skills and raw materials. In rural areas, wind energy can bring investment and jobs to isolated communities; hosting wind farms provides farmers with a steady income whilst they continue to graze or crop their land.

Employment levels vary from country to country, but the German Wind Energy Association (BWE) estimates the number of jobs created in Germany by the end of 2005 at 64,000. The Global Wind Energy Council estimates total worldwide employment at more than 150,000.

A recent study in the US by the government’s National Renewable Energy Laboratory concluded that investment in

wind power had a greater economic impact on the rural regions where it was developed - through new jobs, income and taxes - than a fossil fuel power station.

In the developing world, wind power is attractive as a means of providing a cheap and flexible electricity supply to dispersed communities, often through off-grid stand-alone systems. Its effect on economic development can be dramatic. Supplying enough power for just basic lighting and a television or computer can make a substantial difference to domestic life, educational opportunities and the viability of small businesses.

Technology and Industrial Development

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

The most dramatic improvement has been in the increasing size and performance of wind turbines. From machines of just 25 kW twenty-five years ago, the commercial size range sold today is typically from 750 up to 2,500 kW (2.5 MW). Each 2 MW turbine produces more energy than 200 of the 1980s vintage machines.

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

Complete wind turbines and their support components are manufactured in factories now spread throughout Europe and the world. The leading turbine manufacturers are based in Denmark, Germany, Spain, the United States, India and Japan.

The largest turbines being manufactured today are of more than 5 MW capacity, with rotor diameters of over 100 metres. One result is that many fewer turbines are required to achieve the same power output, saving land use. Depending on its siting, a 1 MW turbine can produce enough electricity for up to 650 households. Overall, wind turbines have a design lifetime of 20-25 years.

Modern turbines are modular and quick to install; the 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 300 MW Stateline development which links the two states of Oregon and Washington in the north-western United States.

The variability of the wind has produced far fewer problems for electricity grid management than sceptics had anticipated. On windy winter nights, for example, wind turbines can account for the majority of power generation in the western part of Denmark, and the grid operators are able to manage this successfully.

As its economic attraction 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.

Most 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. On the electricity supply side, several large conventional power companies have now become major owners of wind farms. These include Florida Power and Light in the United States and the Spanish utility Iberdrola, both with more than 3,500 MW of capacity.

Just as significant is the decision by a number of oil companies to take a stake in wind power. Shell's renewables division, for example, has already invested in 740 MW of wind power capacity, mainly in the US. These acquisitions are evidence that wind is becoming established in the mainstream of the energy market.

THE ADVANTAGES OF WIND POWER

- Low cost – can be competitive with nuclear, coal and gas on a level playing field
- The fuel is free, abundant and inexhaustible
- Clean energy - no resulting carbon dioxide emissions
- Provides a hedge against fuel price volatility
- Security of supply - avoids reliance on imported fuels
- Modular and rapid to install
- Provides bulk power equivalent to conventional sources
- Land friendly - agricultural/industrial activity can continue around it

THE WORLD'S WIND RESOURCES AND GRID INTEGRATION

Wind Resource Assessments

Few studies have been made of the world's wind resources, with the most detailed research confined to the continent of Europe and the US. However, those assessments which have been carried out confirm that the world's wind resources are extremely large and well distributed across almost all regions and countries. Lack of wind is unlikely to be a limiting factor on global wind power development. When specific analysis has been produced on individual countries or regions, this has often shown an even greater resource than the global picture suggests.

According to Michael Grubb and Neils Meyer in "Renewable Energy Sources for Fuels and Electricity" (1994), the world's wind resources have the capacity to generate 53,000 TWh of electricity per year. This is almost three times the International Energy Agency's (IEA) figure for global electricity consumption in 2003 (13,663 TWh).

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 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 per year as the contribution from wind energy in the long term. This represented 35% of the 1998 figure for total world primary energy demand (112,000 TWh) used by the study.

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.

More recently, researchers from the Global Climate and Energy Project at Stanford University, California 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), more than adequate for power generation.

North America was found to have the greatest wind power potential, although some of the strongest winds were observed in Northern Europe, whilst the southern tip of South America and the Australian island of Tasmania also recorded significant and sustained strong winds.

The study did not take into account uncertainties such as long-term variations and climatic effects, or practical considerations such as site availability, access and transmission. Translated into electricity output, however, and using as little as 20% of the potential resource for power generation, the report concluded that wind energy could satisfy the world's electricity demand seven times over.

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, among other examples, 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.

Variability and Grid Integration

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

Electricity flows – both supply and demand – are influenced by a large number of planned and unplanned factors. Changing weather makes people switch their heating and lighting on and off, millions of consumers expect instant power for TVs and computers. On the supply side, when a large power station 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. There is little overall impact if the wind stops blowing in one particular place, because it is always blowing somewhere else.

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 and ameliorate this variability, and what tools can be used to improve efficiency.

The challenge in many parts of the world is that there is no regulatory or physical grid structure in place to allow the full exploitation of the vast global wind reserves. These will have to be developed at significant cost, although large investment would be involved whichever generation option was chosen.

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 whilst 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 major companies.

Grid Integration

One of the biggest mistakes often made during 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.

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 more than 40 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.

For small penetration levels, grid operation will not be affected to any significant extent. Wind power supplies less than 3% of overall EU electricity demand at present, although there are large regional and national variations. The already established control methods and backup capacity available for dealing with variable demand and supply are more than adequate to handle the additional variable supply of wind power at penetration levels up to around 20%. Above that, some changes may be needed in power systems and their method of operation.

The integration of large amounts of wind power is often dismissed as impossible, and many grid operators are reluctant to make changes to their long established procedures. In Denmark, however, 21% of total electricity consumption was met by wind power in 2004. In the western half of the country, up to 25% of demand is met by wind power and, on some occasions, it has been able to cover 100% of instantaneous demand.

"Seven or eight years ago, we said that the electricity system could not function if wind power increased above 500 MW. Now we are handling almost five times as much. And I would like to tell the government and the parliament that we are ready to handle even more, but it requires that we are allowed to use the right tools to manage the system."

[HANS SCHIOETT, CHAIRMAN OF ELTRA,
THE TSO (TRANSMISSION SYSTEM OPERATOR)
FOR WEST DENMARK, IN 2003

Issues for Integrating Wind Power

Despite these successful experiences, a number of issues still have to be addressed if large quantities of wind power are to be successfully integrated into the grid network. These issues relate to system operation, grid connection, system stability and infrastructure improvements.

SYSTEM OPERATION

At first sight wind energy appears to present a difficult challenge for the power system, often resulting in high estimates for ancillary service costs or assumptions that wind capacity must be "backed up" with large amounts of conventional generation. However, such assessments often overlook key factors. These include:

- Grid systems are designed to routinely cope with varying and uncertain demand, and unexpected transmission and generation outages.
- Wind power output can be aggregated at a system level, resulting in significant smoothing effects, which increase with large scale geographic distribution of wind farms.
- Forecasting of wind power output in both hourly and day ahead timeframes.

Wind power will still have an impact on power system reserves, the magnitude of which will depend on the power system size, generation mix, load variations, demand size management and degree of grid interconnection. 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.

The need for additional reserve capacity with growing wind penetration is in practice very modest, and up to significant wind power penetrations, 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 Germany, the level of reserve capacity being kept available has decreased at the same time as wind power has increased. Between 2002 and 2004, the level of "control power" kept available fell from 8.3 GW to 7.3 GW. Over the same period an additional 6 GW of wind capacity was installed.

SOURCE: "OFFSHORE WIND ENERGY: IMPLEMENTING A NEW POWERHOUSE FOR EUROPE", GREENPEACE INTERNATIONAL 2005

Steady improvements are being made in forecasting techniques. 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[1] in predicted wind power for a single wind farm is between 10 and 20 % 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 5% for 1-4 hours in advance.

The effects of geographical distribution can also be significant. Whereas a single turbine 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%.

1 RMSE normalised to installed wind power capacity

GRID CONNECTION AND SYSTEM STABILITY

Connecting wind farms to the transmission and distribution grids causes changes in the local grid voltage levels, and careful voltage management is essential for the proper operation of the network. All network system operators therefore lay down "grid codes" which define the ways in which generating stations connecting to the system must operate in order to maintain stability. These vary from country to country, but cover such issues as voltage quality and frequency control.

In response to increasing demands from TSOs, for example to stay connected to the system during a fault event, the most recent wind turbine designs have been substantially improved. Most of the 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 large faults occur. Modern wind farms are moving towards becoming wind energy power plants that can be actively controlled.

INFRASTRUCTURE IMPROVEMENTS

Transmission and distribution grid infrastructure will need to be upgraded in order to accommodate large amounts of wind power effectively. Expansion of wind power is not the only driver, however. Extensions and reinforcements are needed to accommodate other power sources required to meet a rapidly growing electricity demand.

On costs, a number of country-specific studies have indicated that the grid extension/reinforcement costs caused by additional wind generation are in the range of 0.1 to 4.7€/ MWh, the higher value corresponding to a wind penetration of 30% in the UK system. If these costs were properly "socialised" (paid for by the whole of society), the share for each consumer would be small. Added to this, increasing the share of wind power in electricity supply is likely to have a beneficial effect on the cost of power to end users, especially when the benefits of carbon dioxide reductions, health effects and environmental degradation are taken into account.

Recent Studies

A number of recent studies have concluded that a large contribution from wind energy to power generation needs is technically and economically feasible, and in the same order of magnitude as the contributions from conventional technologies developed over the past century. The barriers to increasing wind power penetration are not inherently technical, they conclude, but mainly a matter of regulatory, institutional and market modifications.

A study by the German Energy Agency (DENA) - "Planning for grid integration of wind energy in Germany onshore and offshore up to the year 2020" (2005) - concluded that:

- Wind energy in Germany could triple its power production to 77 TWh in 2015, providing 14% of net electricity consumption, without any need to build additional reserve or balancing power stations. By 2015 there would be 26 GW of wind capacity installed on land and 10 GW offshore.
- Only minor expansion of the grid would be required. An additional 850 km of extra high voltage lines would need to be built by 2015, and a further 400 km upgraded. This represents only about 5% of the existing network, and takes into account the expected expansion in offshore wind farms. The estimated investment cost of €1.1 billion would increase the price of electricity for consumers by less than €1 per household per annum.

A detailed technical report by the European Wind Energy Association (EWEA) - "Large scale integration of wind energy in the European power supply" (2005) - concluded that:

- It is technically feasible for wind power to cover a significant share (up to 20%) of electricity demand in the large interconnected power systems of Europe whilst maintaining a high degree of system security, and at modest additional cost.
- The efficiency and economics of integrating wind power strongly depend on the ability to apply short term forecasts and on market rules.

- For large scale penetration of wind power, upgrades to the transmission grid infrastructure, including interconnections, are needed. However, the benefits of these upgrades will apply to the entire power system. Additional grid reinforcement costs, as determined in several national wind integration studies, are modest even at high wind penetrations (0.1 – 4.5€/MWh).
- Modern wind energy technology can comply with grid requirements for maintaining supply security. Grid codes in the European member states need to be developed with the specific technology in mind and must be implemented with care in order to avoid unnecessary costs.
- Adding wind power to the existing system is contributing favourably to security of supply by virtue of reduced fuel dependence, technology diversification, indigenous production and wind power's capacity credit – the proportion of its output which can provide firm supply.

A report by the International Energy Agency – "Variability of Wind Power and Other Renewables: Management Options and Strategies" (2005) – confirmed that the barriers to greater penetration of renewables into the existing grid were economic and regulatory rather than technical. Electricity markets in the OECD countries alone will need investments of $1.8 trillion in transmission and distribution networks in the period up to 2030, the report concluded. "A forward-looking policy should aim to integrate these investment needs with renewable energy related investments and thus create an integrated strategy to face future challenges in the transmission, distribution and interconnection field."

THE ENVIRONMENTAL IMPACTS OF WIND POWER

The construction and operation of wind power installations, often in areas of open countryside, raises issues of visual impact, noise and the potential effects on local ecology and wildlife. Many of these issues are addressed during consultation with the local planning authority, from whom consent must be obtained to proceed with a development, and in most cases through a detailed environmental impact assessment.

Visual Impact

Wind turbines are tall structures which ideally need to operate in an exposed site where they can make best use of the prevailing wind. This means they are likely to be visible over a relatively wide area. Whether this has a detrimental effect is a highly subjective issue. Being visible is not the same as being intrusive. While some people express concern about the effect wind turbines have on the beauty of our landscape, others see them as elegant and graceful, or symbols of a better, less polluted future.

The landscape is largely human-made and has evolved over time. Changes to the visual appearance of the countryside, such as lines of electricity pylons, which were once considered intrusions, are now largely accepted as part of the view. In comparison to other energy developments, 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, such as national parks or nature reserves, from development. Others have identified priority areas where wind power is specifically encouraged.

Some wind turbines are located in industrial areas or close to other infrastructure developments, such as motorways, where they may be considered less intrusive. Large wind farms of 100 or more turbines can also be located in the sea. It is also worth emphasising that wind turbines are not permanent structures. Once removed, the landscape can quickly return to its previous condition.

Noise

Generally speaking, the sound output of wind turbines can be subdivided into mechanical and aerodynamic noise. The components emitting the highest sound level are the generator, the yaw drive which turns the nacelle of the turbine to face the wind, the gearbox and the blades. Some of the sound generated by these components is regular and some of it irregular, but all of it (except, that generated by the yaw mechanism) is present only while the turbine is actually operating. Even then, compared to road traffic, trains, construction activities and many other sources of industrial noise, the sound generated by wind turbines in operation is comparatively low (see table).

Better design and better insulation have made more recent wind turbine models much quieter than their predecessors. The approach of regulatory authorities to the issue of noise and wind farms has generally been to firstly calculate the ambient (existing) sound level at any nearby houses and then to ensure that the turbines are positioned far enough away to avoid unacceptable disturbance.

COMPARATIVE NOISE LEVELS FROM DIFFERENT SOURCES

Source/activity	Indicative noise level dB(A)
Threshold of pain	140
Jet aircraft at 250m	105
Pneumatic drill at 7m	95
Truck at 48 kph at 100m	65
Busy general office	60
Car at 64 kph at 100m	55
Wind development at 350m	35-45
Quiet bedroom	35
Rural night-time background	20-40

Source: "Wind Power in the UK", Sustainable Development Commission, 2005

Wildlife – Birds

Birds can be affected by wind energy development through loss of habitat, disturbance to their breeding and foraging areas and by death or injury caused by the rotating turbine blades. Compared to other causes of mortality among birds, however (see table), the effect of wind power is relatively minor. One estimate from the United States is that commercial wind turbines cause the direct deaths of only 0.01 - 0.02% of all of the birds killed annually by collisions with man-made structures and activities.

OECD NORTH AMERICA

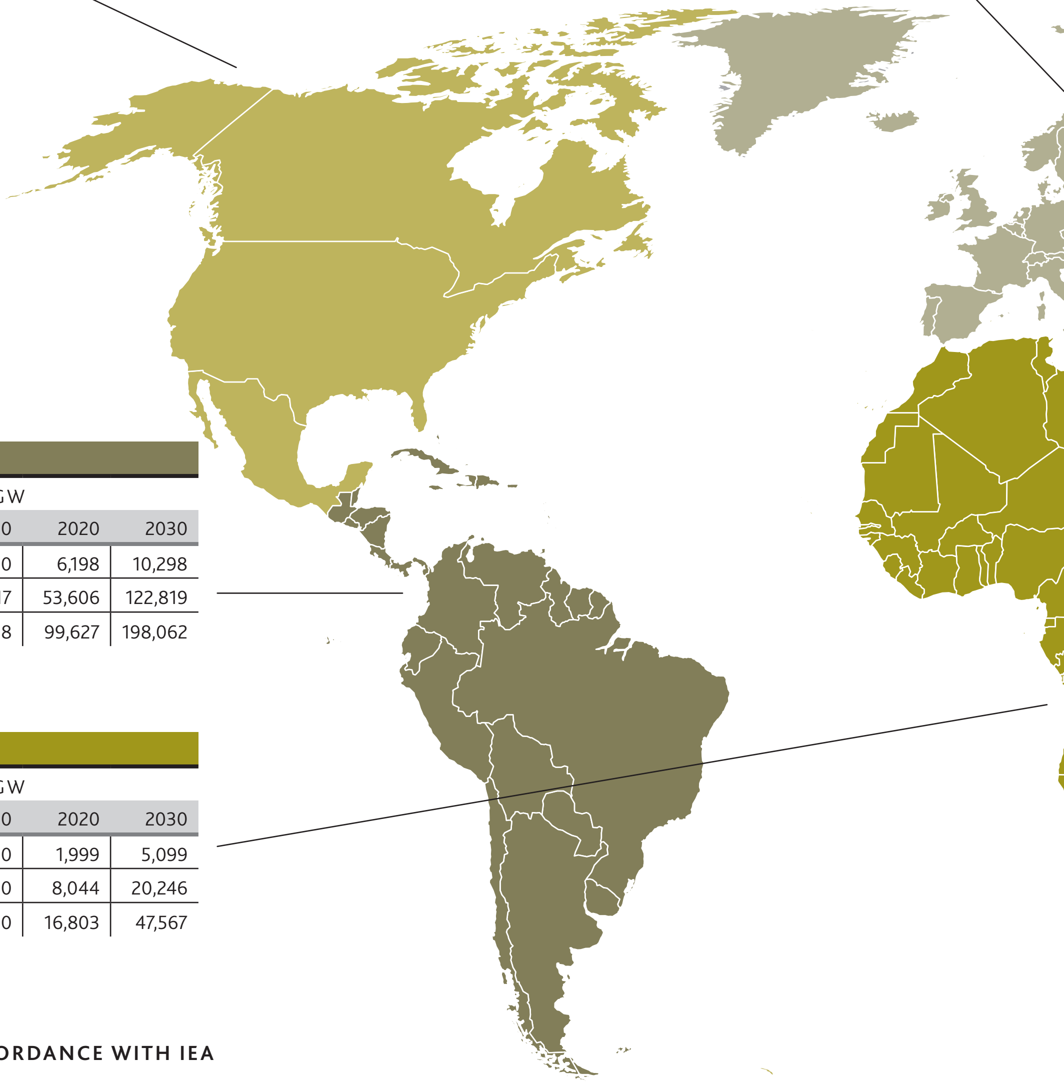
TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	9,839	16.804	43.304	94,204
Moderate-Market growth	9.839	29,100	166,855	333,717
Advanced Market growth	9,839	35,639	283,875	570,178

EUROPE

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	40,783	77,000	142,000	186,000
Moderate-Market growth	40,783	77,159	175,400	294,000
Advanced Market growth	40,783	77,159	241,279	385,663



LATIN AMERICA

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	213	3,200	6,198	10,298
Moderate-Market growth	213	3,217	53,606	122,819
Advanced Market growth	213	3,238	99,627	198,062

AFRICA

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	229	700	1,999	5,099
Moderate-Market growth	229	700	8,044	20,246
Advanced Market growth	229	700	16,803	47,567

DEFINITIONS OF REGIONS IN ACCORDANCE WITH IEA CLASSIFICATION

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

OECD N. America: Canada, Mexico, United States

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

Transition Economies: Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Federal Republic of Yugoslavia, Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latria, Lithunia, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus, Gibraltar, Malta

South Asia: Bangladesh, India, Nepal, Pakistan, Sri Lanka

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

East Asia: Afghanistan, Bhutan, Brunei, Cambodia, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Malaysia, Maldives, Myanmar, New Caledonia, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Thailand, Vietnam, Vanuatu

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, 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, Malati, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, 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

TRANSITION ECONOMIES

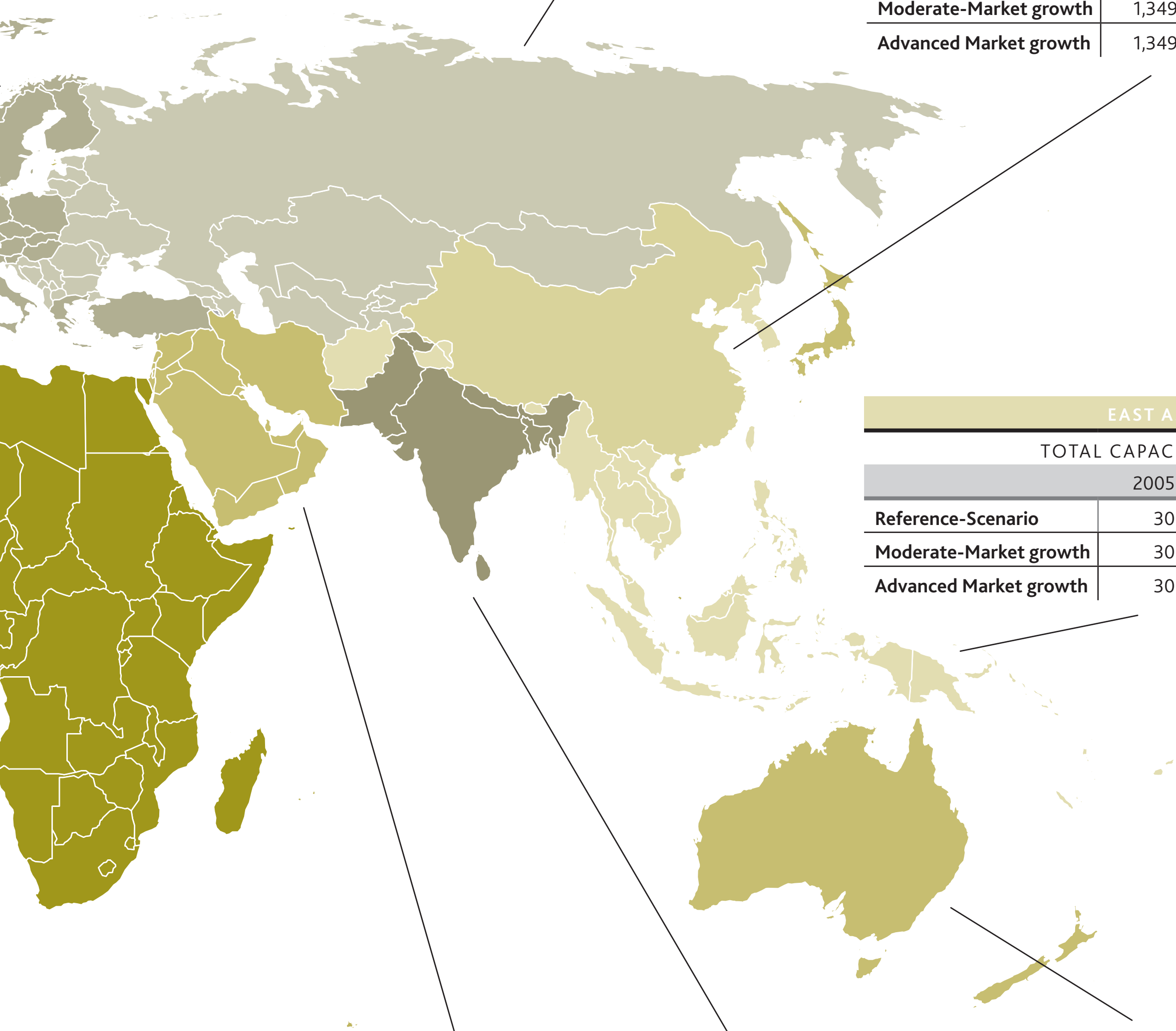
TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	110	300	7,000	12,000
Moderate-Market growth	110	363	7,462	27,712
Advanced Market growth	110	308	13,217	115,539

CHINA

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	1,349	4,502	11,402	24,602
Moderate-Market growth	1,349	7,217	40,738	5,655
Advanced Market growth	1,349	7,217	168,731	328,087



EAST ASIA

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	30	1,000	4,895	6,595
Moderate-Market growth	30	1,117	27,274	59,047
Advanced Market growth	30	1,117	70,577	142,243

OECD PACIFIC

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	2,065	2,500	5,300	12,100
Moderate-Market growth	2,065	3,065	33,859	90,267
Advanced Market growth	2,065	4,960	91,667	143,881

MIDDLE EAST

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	35	500	2,400	3,700
Moderate-Market growth	35	500	8,587	17,749
Advanced Market growth	35	500	24,221	47,437

SOUTH ASIA

TOTAL CAPACITY IN GW

	2005	2010	2020	2030
Reference-Scenario	4,430	6,013	6,300	9,300
Moderate-Market growth	4,430	14,033	38,557	74,989
Advanced Market growth	4,430	17,200	60,918	125,568

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 procedures. Modern wind turbines, with their slower turning blades, have also proved less problematic than earlier models.

A 2001 study by ecological consultants WEST for the National Wind Coordinating Committee estimated that 33,000 birds were killed that year in the United States by the 15,000 turbines then in operation – just over two birds per turbine. The majority of the fatalities had occurred in California, where older, faster rotating machines were still in operation; these are steadily being replaced by more modern, slower rotating turbines.

In Europe, a 2003 study in the Spanish province of Navarra - where 692 turbines were then operating in 18 wind farms - found that the annual mortality rate of medium and large birds was just 0.13 per turbine.

In Germany, records of bird deaths from the National Environmental office Brandenburg showed a total of 278 casualties at wind farms over the period 1989 to 2004. Only ten of the birds were species protected by European Union legislation. By the end of the period Germany had over 16,500 wind turbines in operation[1].

The UK's leading bird protection body, the Royal Society for the Protection of Birds, says that the most significant long-term threat to birds comes from climate change. Changes in the climate will in turn change the pattern of indigenous plant species and their attendant insect life, making once attractive areas uninhabitable by birds. According to the RSPB, "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.

Collaborative work between the wind power industry and wildlife groups has also been aimed at limiting bird casualties. In the Altamont Pass, for example, operators have agreed to turn off their turbines during busy migratory periods.

1 German Federal Government „Kleine Anfrage der Abgeordneten Dr. Christel Happach-Kasan et. all; Drucksache 15/5064 - Gefährdung heimischer Greifvogel- und Fledermausarten durch Windkraftanlagen

In the UK, the solution adopted at the Beinn an Tuirc wind farm in Scotland was to create a completely new habitat for the Golden Eagles which hunted there, providing a fresh source of their favourite prey, the grouse.

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 1,000 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

MAIN CAUSES OF BIRD DEATHS IN THE UNITED STATES

Cause	Estimated deaths per year
Utility transmission and distribution lines	130-174 million
Collision with road vehicles	60-80 million
Collision with buildings	100-1,000 million
Telecommunications towers	40-50 million
Agricultural pesticides	67 million
Cats	39 million

Source: American Wind Energy Association

Wildlife – Bats

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 in the US."

The overall average fatality rate for US wind projects is 3.4 bats per turbine per year, according to a 2004 report by WEST. No nationally endangered or threatened bat species have been found.

Monitoring of wind farms in the US indicates that most deaths involve bats that are migrating in late summer and autumn. One theory is that migrant bats, which are not searching for insects or feeding, turn off their "echolocation" navigation system in order to conserve energy. The American Wind Energy Association (AWEA) 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.

A number of national wind energy industry associations have adopted guidelines for how prospective developers should approach the issue of both birds and bats. The Australian Wind Energy Association (Auswind), for example, "strongly recommends… scientifically rigorous study of the activities over all seasons of birds and bats…" This should include targeted investigations that are "necessary to obtain general data on bird and bat use of sites and their surrounding region" to enable the developer and their regulators to assess the risk of collisions.

In general, wind farming is popular with farmers, because their land can continue to be used for growing crops or grazing livestock. Sheep, cows and horses are not disturbed by wind turbines. The first wind farm built in the UK, Delabole in Cornwall, is home to a stud farm and riding school, and the farmer, Peter Edwards, often rides around the turbines on his horse.

Offshore Wind Farms

In most European coastal states national regulations have been established covering the procedures required to obtain building permits for offshore wind farms. The project developer has to assess in qualitative and quantitative terms the expected environmental impacts on the marine environment. These procedures ensure that projects comply with international and EU law, conventions and regulations covering habitat and wildlife conservation.

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

POTENTIAL IMPACTS OF OFFSHORE WIND FARMS INCLUDE[2]:

Electromagnetic fields: Magnetic fields emanating from power transmission cables can affect marine animals. Connections for offshore wind farms are therefore based on multi-conductor cable systems to avoid this phenomenon.

Noise: Construction operations, especially the ramming of turbine foundations into the sea bed, can disturb marine wildlife. However at the Horns Rev site in the North Sea off Denmark, for example, monitoring has shown that neither seals nor harbour porpoises, both active in the area, have been forced to make any substantial changes to their behaviour. Both fish and benthic communities have in fact been attracted to the foundations of the wind turbines after their construction, the latter using them as hatchery or nursery grounds.

On the noise produced by operating offshore wind turbines, information currently available indicates that this lies in the same range of frequencies as that generated by sources such as shipping, fishing vessels, the wind and waves.

Birds: As on land, sea birds have generally learned to live with the presence of offshore wind turbines. At the Utgrunden and Yttre Stengrund wind farms off Sweden, for example, research shows that very few waterfowl, including Eider ducks, fly close enough to the turbines to risk collision. One estimate is that one waterfowl is killed per wind turbine per year.

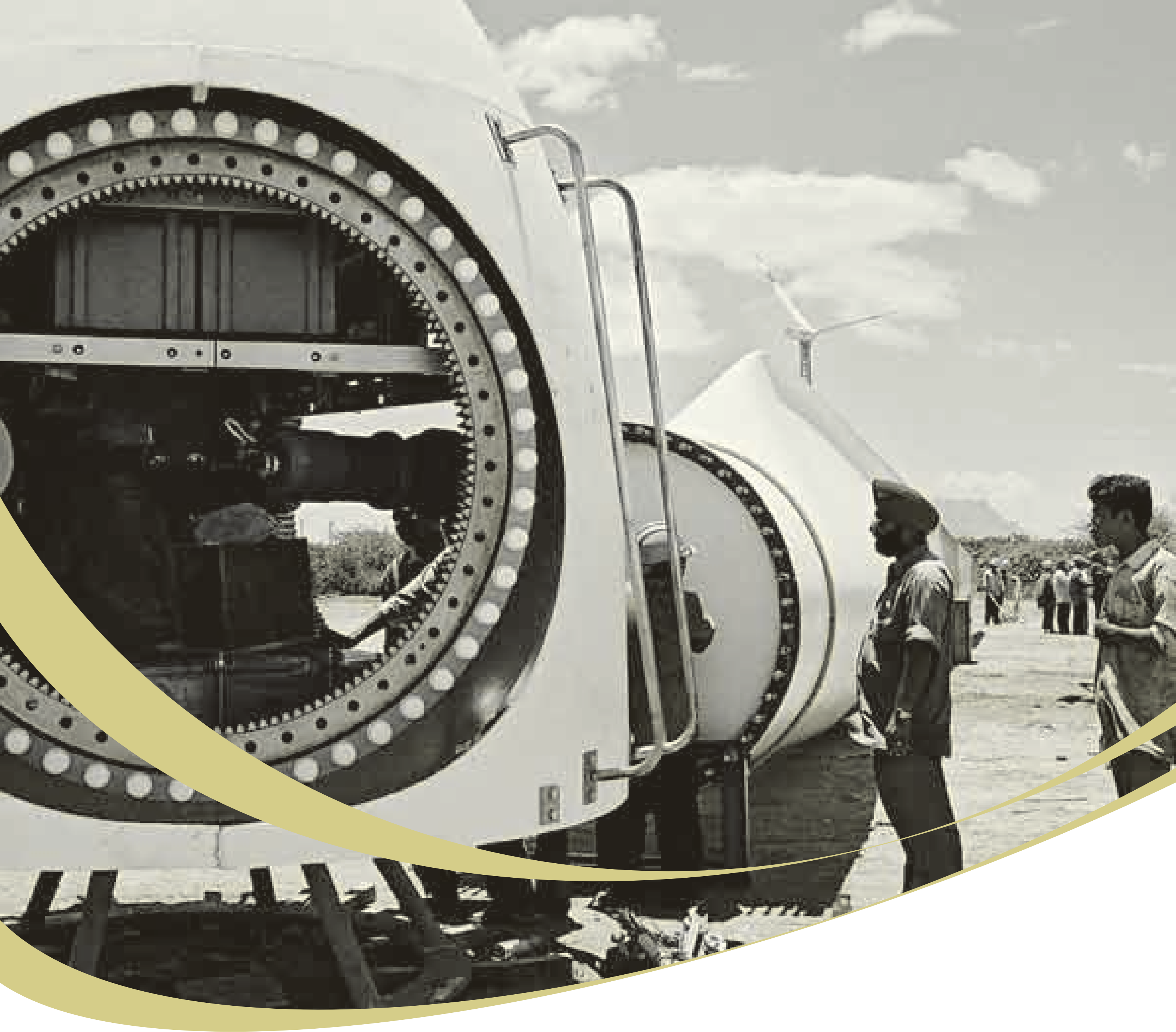
At the much larger Nysted wind farm off the coast of Denmark, radar plotting research found that flocks of migrating sea birds mostly flew round the outside of the block of 72 turbines.

At a nine turbine development along the sea wall at Blyth in Northumbria, UK, 1-2 collisions have been recorded per turbine per year.

ENVIRONMENTAL BENEFITS

Against the potential negative effects of wind power development must be set the benefits resulting from switching to a renewable source of energy. Wind energy is one of the most environmentally benign ways of producing the electricity we need to power our daily lives. If we don't switch to cleaner forms of energy, climate change will severely and irrevocably alter much of our landscape as well as the animal and plant life it contains.

2 Offshore Wind - Implementing a new Power House for Europe is a strategic blueprint that outlines how offshore wind farms will be able to supply about 10% of Europe's electricity sector by 2020. The report represents a crucial tool in the race to cut greenhouse emissions. It also highlights the urgency for political, technical and environmental actions to build up an environmental friendly powerhouse. The full report is available under: http://www.greenpeace.org/international/press/reports/offshore-wind-implementing-a#



THE "GLOBAL WIND ENERGY OUTLOOK" SCENARIO

The initial sections of this report have described the current status of wind energy development around the world, the range of drivers behind its expansion, and the environmental and grid supply issues which need to be resolved in order for this expansion to continue. Although the progress of wind power has been driven most strongly by the urgent need to combat the dangers of global climate change, this is now being supported by increasing concerns over security of energy supply, in particular the rising cost of fossil fuels. In the developing world, a further attraction of wind energy is that it can help satisfy the pressing requirement for new electricity supply with speed and flexibility.

Against that background this second part of the report now examines the future potential of wind power. Through the Global Wind Energy Outlook scenario the horizon is opened up to the year 2050 against a range of projections for both the wind energy industry's expected development and the anticipated global growth in demand for electricity.

This exercise has been carried out as a collaboration between the Global Wind Energy Council (GWEC), Greenpeace International and the German Aerospace Centre (DLR), the largest engineering research organisation in Germany (see "Global Wind Energy Outlook – Research Background"). Projections on the future pattern of wind energy development have been extrapolated from a larger study of global sustainable energy pathways up to 2050 conducted by DLR for Greenpeace and the European Renewable Energy Council (EREC).

The Scenarios

Three different scenarios are outlined for the future growth of wind energy around the world. The most conservative **"Reference"** scenario is based on the projection in the latest (2005) World Energy Outlook report from the International Energy Agency (IEA). This projects the growth of all renewables, including wind power, up to 2030. The IEA assessment has then been extended up to 2050 using input from the DLR study.

The **"Moderate"** scenario takes into account all policy measures to support renewable energy either under way or planned around the world. It also assumes that the targets set by many countries for either renewables or wind energy are successfully implemented. The assumption here is that the success achieved in Europe in meeting the goals for wind energy implementation set by the European Union will be repeated globally.

The most ambitious scenario, the **"Advanced"** version, follows a similar development path to that outlined in the series of Wind Force 10 and 12 reports produced since 1999 by the European Wind Energy Association (EWEA), the Global Wind Energy Council (GWEC) and Greenpeace. These examined how feasible it would be for 10%, and later 12%, of the world's electricity to come from wind power by 2020. The assumption here is that all policy options in favour of renewable energy, along the lines of this report's recommendations, have been selected, and the political will is there to carry them out.

Up to 2010 the figures for installed capacity are closer to being predictions 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. After 2010 the pattern of development is clearly much more difficult to anticipate. Nonetheless, the scenarios still show what could be achieved if the wind energy market is given the encouragement it deserves.

Energy Efficiency Projections

These three scenarios for the global wind energy market are then set against two trajectories for the future growth of electricity demand. Most importantly, these projections do not just assume that growing demand by consumers will inevitably need to be matched by supply options. On the basis that demand will have to be reduced if the threat of climate change is to be seriously tackled, they take into account an increasing element of energy efficiency.

The more conservative of the two global electricity demand projections is again based on data from the IEA's 2005 World Energy Outlook, extrapolated forwards to 2050. This is the **"Reference"** projection. It does not take into account any possible or likely future policy initiatives, and assumes, for instance, that there will be no change in national policies on nuclear power. The IEA's assumption 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 13,423 TWh in 2003 to reach 25,667 TWh by 2030 and continue to grow to 37,935 TWh by 2050.

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. This describes an ambitious development path for the exploitation of energy efficiency measures. It focuses on current best practice and available technologies in the future, and assumes that continuous innovation takes place.

Under the **"High energy efficiency"** projection, input from the DLR/Ecofys models shows the effect of energy efficiency savings on the global electricity demand profile. Although this assumes that a wide range of technologies and initiatives have been introduced, their extent is limited by the potential barriers of cost and other likely roadblocks. This still results in global demand increasing by less than 30 % to reach 17,786 TWh in 2030. By the end of the scenario period in 2050, demand is 39 % lower than under the Reference scenario.

Core Results

The results of the Global Wind Energy Outlook scenarios show that even under the conservative IEA view of the potential for the global market, wind energy could be supplying 5 % of the world's electricity by 2030 and 6.6 % by 2050. This assumes that the "High Energy Efficiency" projection has been introduced.

Under the Moderate wind energy growth projection, coupled with ambitious energy saving, wind power could be supplying 15.6 % of the world's electricity by 2030 and 17.7 % by 2050.

Under the Advanced wind energy growth projection, coupled with ambitious energy saving, wind power could be supplying 29.1 % of the world's electricity by 2030 and 34.2 % by 2050.

At the levels of penetration envisaged under the Advanced scenario any wind energy output which could not be used for electricity generation would be freed up either for storage or to supply new sectors such as transport. Considerable research and development effort is currently being devoted to advancing and improving both these technologies.

These results show not only that wind energy can make a major contribution towards satisfying the global need for clean, renewable electricity within the next 30 years but that its penetration in the supply system can be substantially increased if serious energy efficiency measures are implemented at the same time.

SUMMARY OF GLOBAL WIND ENERGY OUTLOOK SCENARIO FOR 2030

Global Scenario	Cumulative wind power capacity (GW)	Electricity output (TWh)	Percentage of world electricity (High Energy Efficiency)	Annual installed capacity [GW]	Annual investment (€ bn)	Jobs [million]	Annual CO_2 saving (million tonnes)
Reference	364	892	5 %	24.8	21.2	0.48	535
Moderate	1,129	2,769	15.6 %	58.3	45.0	1.14	1,661
Advanced	2,107	5,176	29.1 %	129.2	84.8	1.44	3,100

SUMMARY OF GLOBAL WIND ENERGY OUTLOOK SCENARIO FOR 2050

Global Scenario	Cumulative wind power capacity (GW)	Electricity output (TWh)	Percentage of world electricity (High Energy Efficiency)	Annual installed capacity [MW]	Annual investment (€ bn)	Jobs [million]	Annual CO_2 saving (million tonnes)
Reference	577	1,517	6.6 %	34.3	28.8	0.65	910
Moderate	1,557	4,092	17.7 %	71.0	54.2	1.39	2,455
Advanced	3,010	7,911	34.3 %	168.6	112.0	2.80	4,747

Detailed Results

A more detailed analysis of the Global Wind Energy Outlook scenario shows that a range of outcomes is possible for the global wind energy market, depending on the choice of demand side options and different assumptions for growth rates on the wind power supply side.

Under the basic **Reference wind energy scenario**, a 15 % annual growth rate of wind power capacity is assumed until 2010, followed by 10 % until 2014. After that it declines rapidly, falling to 3 % per annum by 2031.

The result is that by the end of this decade, cumulative global capacity would have reached almost 113 Gigawatts (GW). By 2020, global capacity would be over 230 GW and by 2030 almost 364 GW. By the end of the scenario period in 2050 the capacity of worldwide wind power would be more than 577 GW. The annual rate of installation of new capacity would by then be running at 34 GW.

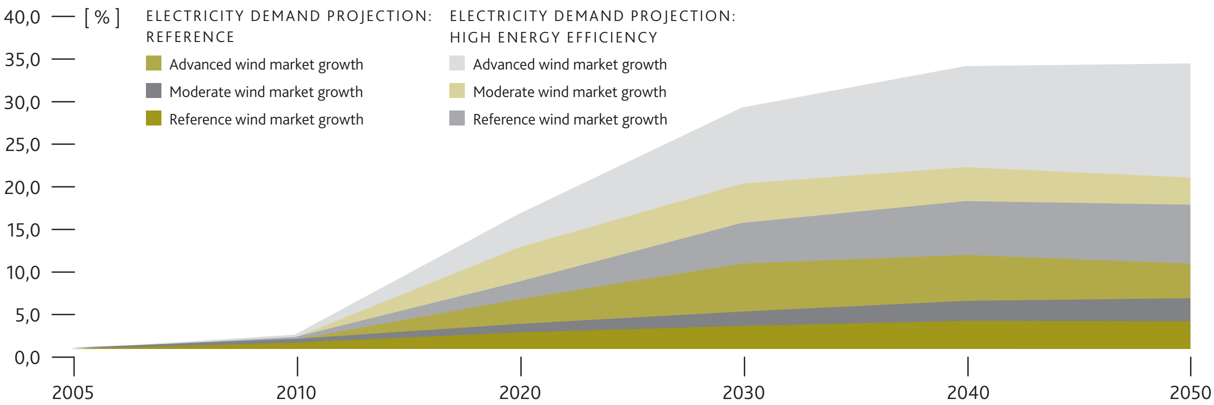
The relative penetration of wind energy in the global electricity supply system varies according to which demand projection is applied. Under the Reference projection, wind's contribution would increase from 1.5 % in 2010 up to 4 % in 2050. Under the "High Energy Efficiency" projection it would increase from 1.8 % in 2010 to 6.6 % in 2050.

Under the **Moderate wind energy scenario** growth rates are expected to be substantially higher than under the Reference version. Up to 2010, the annual growth rate is 19 %, from 2011 to 2014 it is 16 %, and from 2015 to 2020 it is 15 %. It then declines to 10 % until 2025 before falling to 5 %.

The result is that by 2020, global wind power capacity would have reached a level of 560 GW and by 2030 almost 1,129 GW. By the end of the scenario period in 2050 the capacity of worldwide wind power would have reached almost 1,557 GW. The annual rate of installation of new capacity would by then be running at almost 71 GW.

In terms of penetration in the global electricity supply system, wind energy's contribution would increase under the Reference demand projection scenario from 1.8 % in 2010 to 10.8 % in 2050. Under the High Energy Efficiency projection it would increase from 2.2 % in 2010 to 17.7 % in 2050.

WIND POWER PENETRATION OF WORLDS ELECTRICITY SUPPLY



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

		2005	2010	2020	2030	2040	2050
WIND MARKET GROWTH - IEA PROJECTION ("REFERENCE")							
Wind power penetration of Worlds electricity in % - Reference (IEA Demand Projection)	%	0.8	1.5	2.7	3.5	4.1	4.0
Wind power penetration of Worlds electricity in % - High Energy Efficiency	%	0.8	1.8	3.6	5.0	6.3	6.6
MODERATE WIND MARKET GROWTH							
Wind power penetration of Worlds electricity in % - Reference	%	0.8	1.8	6.6	10.8	11.8	10.8
Wind power penetration of Worlds electricity in % - High Energy Efficiency	%	0.8	2.2	8.6	15.6	18.1	17.7
ADVANCED WIND MARKET GROWTH							
Wind power penetration of Worlds electricity in % - Reference	%	0.8	2.1	12.1	20.1	22.1	20.9
Wind power penetration of Worlds electricity in % - High Energy Efficiency	%	0.8	2.4	16.5	29.1	34.0	34.2

Under the **Advanced wind energy scenario**, an even more rapid expansion of the global wind power market is envisaged. Growth rates are faster in the first two decades. Up to 2015, a growth rate in annual wind power capacity of 20 % is assumed, falling to 17 %. It then reduces to approx 10 % for the five years to 2025, before falling below 5 %. The result is that by the end of this decade, global capacity would have reached almost 154 GW. By 2020, global capacity would be almost 1,073 GW and by 2030 almost 2,110 GW. By the end of the scenario period in 2050 the capacity of worldwide wind power would be more than 3,010 GW. The size of the annual market for new wind power capacity would by then be 150 GW.

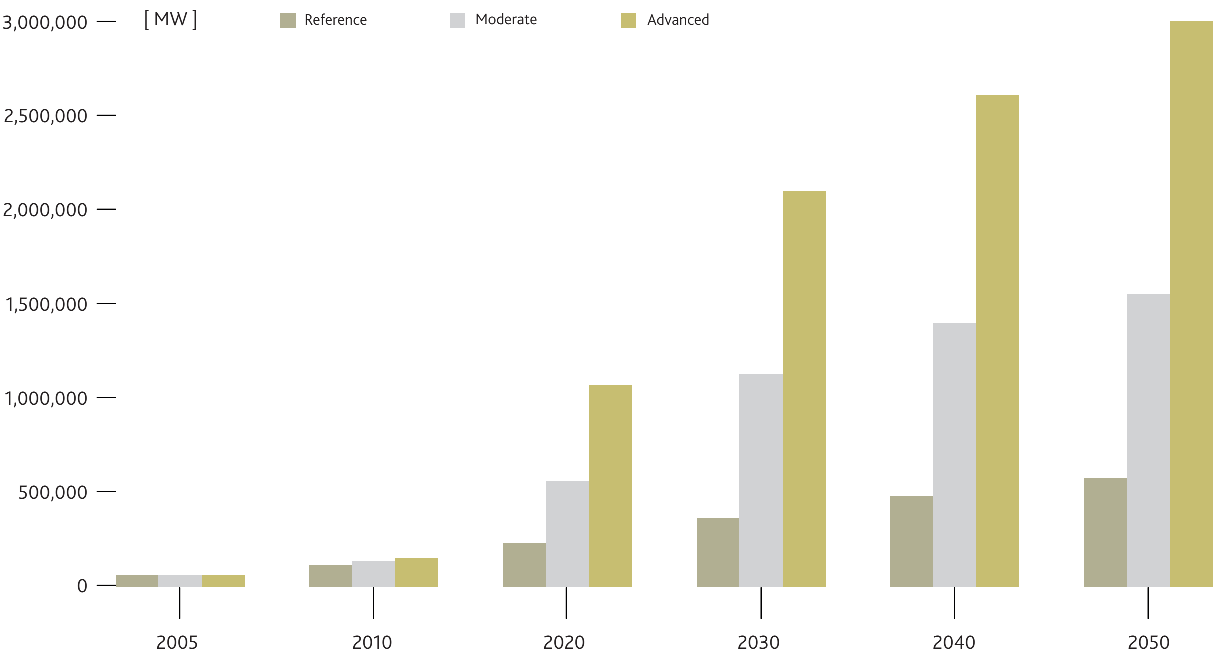
In terms of penetration in the global electricity supply system, under the Reference demand projection, wind's contribution would increase from 2.1 % in 2010 up to 20.9 % in 2050. Under the "High Energy Efficiency" projection it would increase from 2.4 % in 2010 to 34.3 % in 2050.

Regional Breakdown

All three scenarios for wind power are broken down by region of the world based on the methodology used by the IEA, with a further differentiation in Europe. For the purpose of this report, the regions are defined as European Union (current EU member states, plus Romania and Bulgaria), the rest of Europe (non-EU countries), the Transition Economies (former Soviet Union states, apart from those now part of the EU), North America, Central and South America, East Asia, South Asia, China, the Middle East, Africa and the Pacific (including Australia, South Korea and Japan).

A regional break-down of the wind power capacity and output (TWh) expected in each region of the world by 2010, 2020 and 2030 is shown on page 41. This shows that Europe would continue to dominate the world market under the least ambitious **Reference scenario.** By 2030 Europe would still have

GLOBAL CUMULATIVE WIND POWER CAPACITY



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

Year		2005	2010	2020	2030	2040	2050
Reference	[MW]	59,078	112,818	230,658	363,758	482,758	577,257
	[TWh]	124	247	566	892	1,269	1,517
Moderate	[MW]	59,078	136,543	560,445	1.128,707	1.399,133	1.556,901
	[TWh]	124	299	1,375	2,768	3,677	4,092
Advanced	[MW]	59,078	153,759	1.072,928	2.106,656	2.616,210	3.010,302
	[TWh]	124	337	2,632	5,167	6,875	7,911

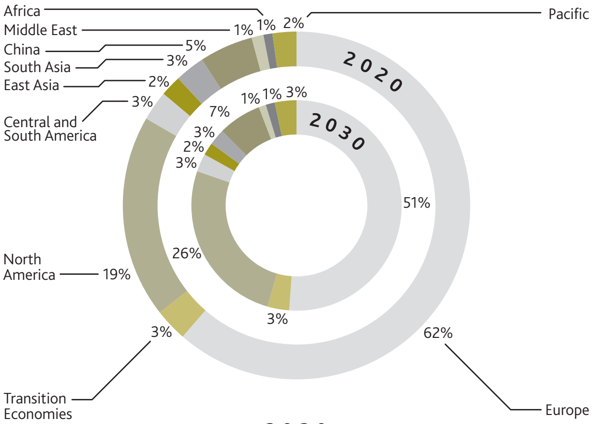
51 % of the global wind power marker, followed by North America with 26 %. The next largest region would be China with 7 %.

The two more ambitious scenarios envisage much stronger growth in regions outside the currently dominant European Union. Under the **Moderate scenario**, Europe's share will have fallen to 26 % by 2030, with North America contributing a dominant 30 % and major contributions coming from Central and South America (11 %), China (8 %), the Pacific region (8 %) and South Asia, which includes India (7 %).

Under the **Advanced scenario**, an even stronger input would come from Asia and South America, with China's share of the world market increasing to 16% by 2030, South America's share rising to 9% and the Pacific region's to 7%. Europe's share would make up only 19% of the world's total wind capacity. Given the slow pace of progress so far, and continuing market barriers, a less important contribution is expected from the Transition Economies than had previously been envisaged.

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 installed capacity as the original 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.

REGIONAL BREAK DOWN: REFERENCE SCENARIO [GW]



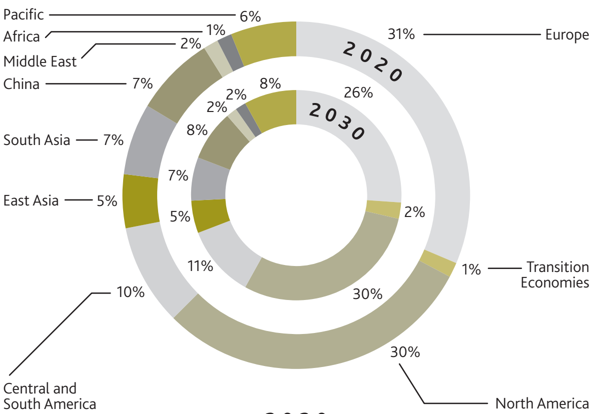
2020

Europe	142 GW
Transition Economies	7 GW
North America	43 GW
Central and South America	6 GW
East Asia	5 GW
South Asia	6 GW
China	11 GW
Middle East	2 GW
Africa	2 GW
Pacific	5 GW

2030

Europe	186 GW
Transition Economies	12 GW
North America	94 GW
Central and South America	10 GW
East Asia	7 GW
South Asia	9 GW
China	25 GW
Middle East	4 GW
Africa	5 GW
Pacific	12 GW

REGIONAL BREAK DOWN: MODERATE SCENARIO [GW]



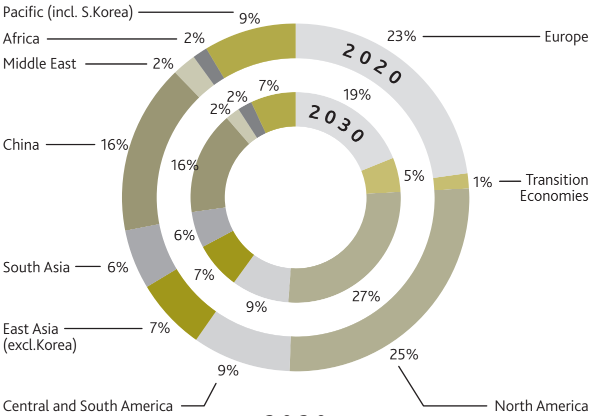
2020

Europe	174 GW
Transition Economies	7 GW
North America	167 GW
Central and South America	54 GW
East Asia	27 GW
South Asia	39 GW
China	41 GW
Middle East	9 GW
Africa	8 GW
Pacific	34 GW

2030

Europe	295 GW
Transition Economies	28 GW
North America	334 GW
Central and South America	123 GW
East Asia (excl.Korea)	59 GW
South Asia	75 GW
China	87 GW
Middle East	18 GW
Africa	20 GW
Pacific	90 GW

REGIONAL BREAK DOWN: ADVANCED SCENARIO [GW]



2020

Europe	245 GW
Transition Economies	13 GW
North America	284 GW
Central and South America	100 GW
East Asia	71 GW
South Asia	61 GW
China	169 GW
Middle East	24 GW
Africa	17 GW
Pacific	90 GW

2030

Europe	392 GW
Transition Economies	116 GW
North America	570 GW
Central and South America	198 GW
East Asia (excl.Korea)	142 GW
South Asia	126 GW
China	328 GW
Middle East	47 GW
Africa	48 GW
Pacific	140 GW

Main Assumptions and Parameters

1. GROWTH RATES

Market growth rates in this scenario are based on a mixture of historical figures and information obtained from analysts of the wind turbine market. Growth rates of up to 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. Since the year 2000 the average annual increase in global cumulative installed capacity has been 28 %.

It should also be borne in mind that whilst growth rates eventually decline to single figures across the range of scenarios, the level of wind power capacity envisaged in 30 years' time means that even small percentage growth rates will by then translate into large figures in terms of annually installed megawatts.

2. TURBINE CAPACITY

Individual wind turbines have been steadily growing in terms of their installed capacity – the maximum electricity output they could achieve when operating at full power. The average capacity of wind turbines installed globally in 2005 was 1.2 MW. At the same time the largest turbines being prepared for the market are now reaching more than 5 MW in capacity. This scenario makes 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 however that this figure will turn out to be greater in practice. As the average capacity of turbines increases, fewer will be needed in total to satisfy a given penetration of global electricity demand.

3. CAPACITY FACTOR

The capacity factor of a wind turbine is an indication of how efficiently it is operating. The percentage refers to the average proportion of the year during which they will be generating electricity at the equivalent of full capacity. From an average capacity factor today of 24 %, 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 out to sea, where winds are stronger and more predictable. 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.

4. CAPITAL COSTS AND PROGRESS RATIOS

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

Studies of the past development of the wind power industry show that progress through R&D efforts and by learning have already resulted in a 15-20 % price reduction – equivalent to a progress ratio of 0.85 to 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 2010. After that it is reduced to 0.92. Beyond 2025, when production processes are assumed to have been optimised and the level of global manufacturing output has reached a peak, it goes down to 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 future design optimisations been utilised. Even so, the cost of wind turbine generators has still fallen significantly, and the industry is recognised as having entered the "commercialisation phase", as understood in learning curve theories.

Capital costs per kilowatt of installed capacity are taken as an average of € 1,000 in 2005. They are then assumed to fall steadily to € 912 in 2010 and to € 784 by 2025. From then onwards the scenario assumes a leveling out of costs. All figures are given at 2005 prices.

Costs and Benefits

1. 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 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 already explained.

In the **Reference scenario** the annual value of global investment in the wind power industry reaches € 10.7 billion in 2010, increases to € 21.2 bn by 2030, with a peak at € 28.8 bn in 2050.

In the **Moderate scenario** the annual value of global investment in the wind power industry reaches € 18.2 billion in 2010, increases to € 62.4 bn by 2020 with a peak at € 74.9 bn in 2040.

In the **Advanced scenario** the annual value of global investment reaches € 23.2 billion in 2010, peaks at € 141 bn by 2020 and decreases slowly to € 112.1 bn until 2050. 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.

2. 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) and the expected electricity production. The second is highly dependent on the wind conditions at a given site, making selection of a good location essential to achieving economic viability. Other important factors include operation and maintenance (O&M) costs, the lifetime of the turbine and the discount rate (the cost of capital).

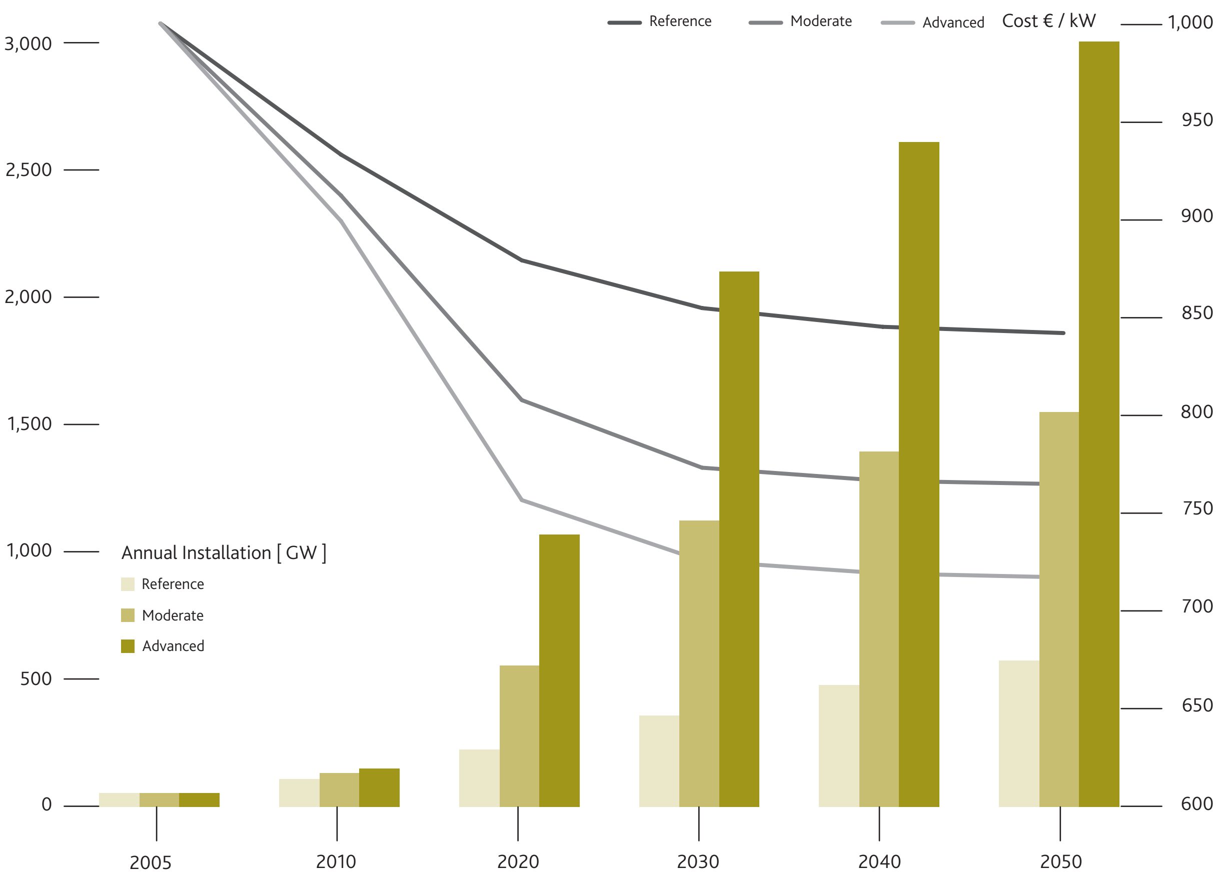
The total cost per generated kWh of electricity is traditionally calculated by discounting and levelising investment and O&M costs over the lifetime of a wind turbine, then dividing this by the annual electricity production. The unit cost of generation is thus calculated as an average cost over the lifetime of a turbine, which is normally estimated at 20 years. In reality, however, the actual costs will be lower at the beginning of a turbine's operation, due to lower O&M costs, and increase over the lifespan of the machine.

Taking into account all these factors, the cost of generating electricity from wind energy currently ranges from approximately 4-5 €cents/kWh at high wind speed sites up to approximately 6-8 €cents/kWh at sites with low average wind speeds.

However, over the past 15 years the efficiency of wind turbines has improved considerably thanks to better equipment design, better siting and taller turbines. As a result, efficiency has been increasing by 2% to 3% annually. Furthermore, it can be assumed that as a result of optimised production processes, the investment costs for wind turbines will decrease as described above.

As a result, it is expected that by 2020, the costs of producing electricity will have fallen to 3-3.8 €cents/kWh at a good site and 4-6 €cents/kWh at a site with low average wind speeds. By 2050, these costs could be as low as 2.8-3.5 €cents/kWh and 4.2-5.6 €cents/kWh respectively.

COSTS AND CAPACITIES



INVESTMENT AND EMPLOYMENT

	2005	2010	2020	2030	2040	2050
REFERENCE						
Annual Installation [MW]	11,524	11,506	15,547	24,816	27,447	34,266
Cost € / kW	1,000	933	879	854	845	842
Investment € billion /year	11.524	10.732	13.662	21.205	23.185	28.841
Employment Job-year	150,120	241,484	322,729	481,624	531,723	653,691
MODERATE						
Annual Installation [MW]	11,524	19,906	77,365	58,260	97,737	70,957
Cost € / kW	1,000	912	807	773	766	764
Investment € billion /year	11.524	18.154	62.449	45.009	74.854	54.227
Employment Job-year	150,120	390,408	1.310,711	1.141,016	1.663,578	1.386,085
ADVANCED						
Annual Installation [MW]	11,524	25,831	186,825	117,014	142,260	156,423
Cost € / kW	1,000	899	756	725	719	717
Investment € billion /year	11.524	23.220	141.249	84.827	102.229	112.090
Employment Job-year	150,120	492,384	2.899,776	2.143,587	2.506,871	2.795,873

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 ExternE project, funded by the European Commission, has estimated the external cost of gas at around 1.1-3.0 €cents/kWh and that for coal at as much as 3.5-7.7 €cents/kWh.

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. As a result, 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 would further improve the cost analysis for wind energy.

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 economies 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 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 16 jobs through manufacture and component supply. A further 5 jobs will be contributed by wind farm development, installation and indirect employment. As production processes are optimised, this level will decrease, falling to 11 manufacturing jobs and 5 in development and installation 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 the **Reference scenario** this means that more than 241,000 jobs would be created by 2010, over 481,000 jobs by 2030 and almost 653,000 jobs by 2050. In the **Moderate scenario** these numbers would increase to more than 390,000 jobs by 2010, almost 1.1 million by 2030 and then leveling out at about 1.4 million by 2050. Under the **Advanced scenario**, the results show increases in the employment level to 2.9 million jobs by 2020, leveling out to 2.8 million by 2050.

4. CARBON DIOXIDE SAVINGS

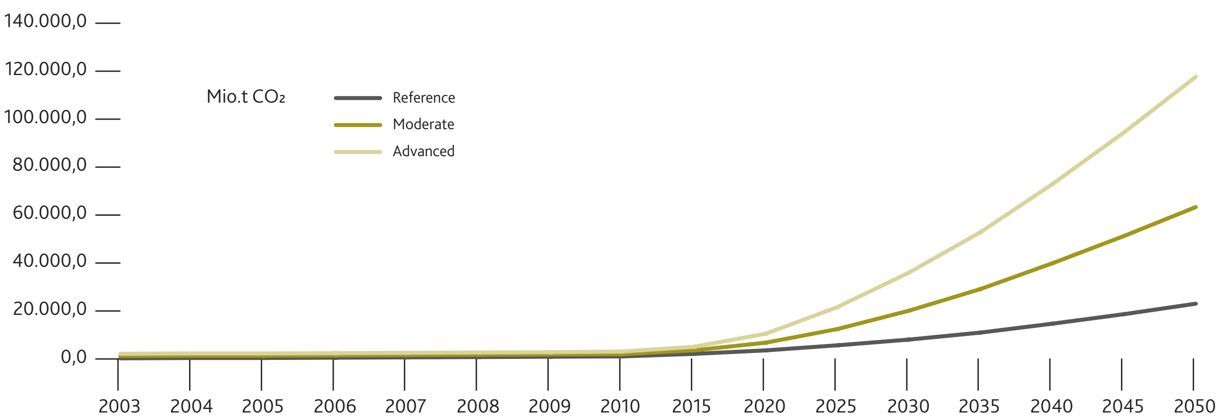
A reduction in the levels of carbon dioxide being emitted into the global atmosphere is the most important environmental benefit from wind power generation. Carbon dioxide is the gas largely responsible for exacerbating the greenhouse effect, leading to the disastrous consequences of global climate change.

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 more than 50 % of the cumulative wind generation capacity expected by 2020 will be installed in the OECD regions (North

CUMULATIVE CO_2 REDUCTION [MIO TCO_2]



CO_2 EMISSIONS

REFERENCE

Year	Annual CO_2 reduction [Mio tCO_2]	Cumulative CO_2 reduction [Mio. tCO_2]
2003	50.8	50.8
2004	60.0	110.8
2005	74.5	185
2006	90.8	276
2007	104	381
2008	119	499
2009	133	632
2010	148	781
2015	253	1,851
2020	339	3,375
2025	437	5,366
2030	535	7,847
2035	623	10,786
2040	761	14,405
2045	836	18,434
2050	910	22,836

MODERATE

Year	Annual CO_2 reduction [Mio tCO_2]	Cumulative CO_2 reduction [Mio. tCO_2]
2003	50.8	50.8
2004	60.0	110.8
2005	74.5	185
2006	93.7	279
2007	111	391
2008	131	522
2009	153	675
2010	179	854
2015	412	2,413
2020	825	5,593
2025	1,320	11,229
2030	1,661	18,918
2035	1,891	27,948
2040	2,206	38,639
2045	2,345	50,100
2050	2,455	62,165

ADVANCED

Year	Annual CO_2 reduction [Mio tCO_2]	Cumulative CO_2 reduction [Mio. tCO_2]
2003	50.8	50.8
2004	60.0	110.8
2005	74.5	185
2006	95.2	281
2007	116	396
2008	140	536
2009	168	704
2010	202	906
2015	576	2,916
2020	1,579	8,363
2025	2,340	18,540
2030	3,100	32,521
2035	3,475	49,147
2040	4,125	68,970
2045	4,436	90,528
2050	4,747	113,640

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 inefficient coal burning power stations.

Taking account of these assumptions, the expected annual saving in CO_2 from the **Reference scenario** will be 339 million tonnes in 2020, rising to 910 million tonnes in 2050. The cumulative saving over the whole scenario period would be 22,800 million tonnes.

Under the **Moderate scenario** the saving would be 825 million tonnes of CO_2 annually in 2020, rising to 2,455 million tonnes in 2050. The cumulative saving over the scenario period would be just over 62,150 million tonnes.

Under the **Advanced scenario**, the annual saving in 2020 would increase to 1,582 million tonnes and by 2050 to 4,700 million tonnes. The cumulative saving over the whole scenario period would be 113,600 million tonnes.

Global Wind Energy Outlook – 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 Greenpeace International and EREC to conduct a study on global sustainable energy pathways up to 2050. This study, due to be published in early 2007, will result in energy scenarios with emissions that are significantly lower than current levels. Part of this study examines 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 the EU-25 countries ("Energy revolution: A sustainable pathway to a clean energy future for Europe", September 2005 for Greenpeace International). This model has then been further developed by the Ecofys consultancy to take into account the future potential for energy efficiency measures.

ENERGY EFFICIENCY STUDY

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 47% 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. These together account for 46 % of the worldwide energy savings.

In this report, the "Reference" energy demand projection is based on the IEA's World Energy Outlook 2004, including its assumptions on population and GDP growth, extrapolated forward to 2050. It takes account of policies and measures that were enacted or adopted by mid-2004, but does not include possible or likely future policy initiatives. It is assumed that there will be no changes in national policies on nuclear power.

Two low energy demand projections are then developed based on the IEA reference scenario - an "Ambitious" energy efficiency scenario (which is not used in this report) and a more economic "Constraint" version (descripted as the "High Energy Efficiency" projection for the purposes of this report). The first takes into account the technical potential whilst the second introduces an economic element. In the Ambitious version the assumption is made that the best available technologies are introduced and there is continuous innovation in the field of energy efficiency. In the Constraint version the potential for advanced energy saving measures is tempered by the constraints of cost and other barriers to implementation.

ECOFYS ENERGY EFFICIENCY MODEL

STEP 1: REFERENCE SCENARIO

Development of a reference energy demand scenario for the period 2003-2050 per region and per sector.

STEP 2: LIST OF MEASURES

Establishment of possible energy savings options per sector.

STEP 3: ENERGY SAVINGS POTENTIAL

Determination of the energy savings potential per year (2010, 2020, 2030, 2040 and 2050) and per sector. A distinction is made between the economic and the technical energy savings potential, leading to two low energy demand scenarios:

Ambitious: *This is an ambitious energy efficiency scenario focused on current best practice and technologies available in the future. It assumes continuous innovation in the field of energy efficiency.*

Constraint (="High Energy Efficiency" Scenario): *This scenario assumes more moderate energy savings, taking into account the implementation constraints of energy efficient technologies in terms of costs and other barriers.*

ENERGY POLICY ISSUES AND RECOMMENDATIONS

At a time when governments around the world are in the process of liberalising their electricity markets, wind power's increasing competitiveness should lead to a higher demand for wind turbines. Distortions in the world's electricity markets, however, created by decades of massive financial, political and structural support to conventional technologies, have placed wind power at a competitive disadvantage. New wind projects have to compete with old nuclear and fossil fuel power stations producing electricity at marginal cost, because the interest and depreciation on the investment has already been paid for by consumers and taxpayers. Renewable technologies are also disadvantaged by the failure to penalise conventional fuels for the economic cost of their pollution and other hazards. Without political support, therefore, wind power cannot establish its positive contribution towards environmental goals and security of supply.

This chapter presents a summary of the current political frameworks which support wind power and the barriers that need to be overcome in order to unlock the technology's potential to become a major contributor to future global energy supply. Over 48 countries have already introduced some kind of policy or law to promote renewables, including 14 developing countries.

More than 25 years of wind power experience around the world has shown that successful frameworks for the development and deployment of wind energy must include appropriate measures in each of these five vital areas:

- Legally binding targets for renewable energy
- Well designed payment mechanisms
- Grid access and strategic development of grids
- Appropriate administrative procedures
- Public acceptance and support

Legally binding Targets for Renewable Energy

Setting targets serves as an important catalyst for governments to develop the necessary regulatory frameworks to expand renewables, including financial frameworks, grid access regulation, planning and administrative procedures. However, targets have little value if they are not accompanied by policies which compensate for distortions in electricity markets, eliminate market barriers and create an environment which attracts investment capital.

An increasing number of countries have established targets for renewable energy as part of their greenhouse gas reduction policies. To date, 49 countries have set targets, including eleven developing countries. These are either expressed as specific quantities of installed capacity or as a percentage of energy consumption.

The most ambitious target has been set by the European Union. In 1997, a White Paper on Renewable Sources of Energy set the goal of doubling the share of renewable energy in the EU from 6% to 12% by 2010. This was followed by the 2001 Renewable Electricity Directive, which detailed the aim (within the White Paper goal) of increasing the amount of renewable electricity from 14% in 1997 to 21% by 2010. Each European Union member state was allocated its own individual target. Although these targets are indicative (not binding), they have served as an important incentive for political initiatives throughout Europe to increase renewable energy's share of electricity supply. Wind power is expected to contribute a substantial part of this increase.

The next step would be for these targets to be made mandatory, and for their horizon to be extended beyond 2010. But although the European Parliament has proposed a mandatory target for 20% of EU energy by 2020, with a linked target for 33% of electricity supply, this has not yet been accepted by the European Commission or the 25 member state governments. A first step in this direction was taken in March 2006 with reference by the EU Heads of State and Government to a 15% target for renewable energy by the year 2015.

Specific Policy Mechanisms

A clear market for wind generated power must be defined in order for a project developer to get involved. As with any other investment, the lower the risk to the investor, the lower the costs of supplying the product. The most important measures for establishing new wind power markets are therefore those where the market for generated power is clearly defined in national laws, including stable, long term fiscal measures that minimise investor risk and ensure an adequate return on investment.

The main purpose of the wide range of available economic measures to encourage renewable energy is to provide incentives for improvements and cost reductions in environ-

mental technologies. Markets need to be strong, stable and reliable, with a clear commitment to long-term expansion. A number of mechanisms have been introduced in different countries to further these aims.

Overall, there are two main types of incentives to promote deployment of renewable energy:
Fixed Price Systems where the government sets the electricity price (or premium) paid to the developer/producer and lets the market determine the amount of capacity which will be built. Examples of countries which have adopted this system in Europe are Germany, Spain, France and Portugal.

Payments can be made to developers or producers in the form of:
1. Investment subsidies
2. Fixed feed-in tariffs
3. Fixed premium payments
4. Tax credits

Renewable Quota Systems where the government or other authority sets the quantity of renewable electricity it would like to see produced, and leaves it to the market to determine the price. This system operates in some states in the USA, where it is referred to as a Renewable Portfolio Standard, and in a number of EU countries, including the UK, Sweden, Belgium and Italy.

Two types of renewable quota systems have been employed in national wind power markets: tendering systems and green certificate systems. Under the former, developers compete on price to construct projects within an allocated quota of capacity. Under the latter, operating projects are issued with green certificates according to their power output, the price of which varies according to supply and demand.

Any policy measure adopted by a government, however, needs to be acceptable to the requirements of the investment community in order to be effective. There are two key issues here:

- The price for renewable power must allow for risk return profiles that are competitive with other investment options.
- The duration of a project must allow investors to recoup their investment.

Electricity Market Reform

Essential reforms in the electricity sector are necessary if new renewable energy technologies are to be accepted on a larger scale. These reforms include:

REMOVAL OF ELECTRICITY SECTOR BARRIERS

Current energy legislation on planning, certification and grid access has been built around the existence of large centralised power plants, including extensive licensing requirements and specifications for access to the grid. This favours existing large scale electricity production and represents a significant market barrier to renewables. It also fails to recognise the value of not having to transport decentralised power generation over long distances.

Distortions in the conventional power market include:

1. Institutional and legal barriers
2. Regional and national dominant players
3. Barriers to third party grid access
4. Limited interconnection between regional and national markets
5. Discriminatory grid connection tariffs
6. Lack of effective "unbundling" by companies of their production and transmission interests.

One major challenge is to implement the necessary redesigns of the grid infrastructure, system management, grid regulation and grid codes so that they reflect the characteristics of renewable energy technologies. Cross-border electricity interconnectors are also vital for those markets that are not geographically isolated.

The reforms needed to address market barriers to renewables include:

- Streamlined and uniform planning procedures and permitting systems and integrated least cost network planning;
- Access to the grid at fair, transparent prices and removal of discriminatory access and transmission tariffs;
- Fair and transparent pricing for power throughout a network, with recognition and remuneration for the benefits of embedded generation;
- Unbundling of utilities into separate generation and distribution companies;
- The costs of grid infrastructure development and reinforcement must be carried by the grid management authority rather than individual renewable energy projects;
- Disclosure of fuel mix and environmental impact to end users to enable consumers to make an informed choice of power source.

REMOVAL OF MARKET DISTORTIONS

In addition to market barriers there are also market distortions which block the expansion of renewable energy. These come in the form of direct and indirect subsidies, and the fact that the social and environmental effects of different generation technologies are currently excluded from the costs of electricity production.

A major barrier preventing wind power from reaching its full potential is the lack of pricing structures in the energy markets that reflect the full costs to society of producing energy.

Furthermore, the overall electricity market framework is very different today from the one that existed when coal, gas, and nuclear technologies were introduced. For almost a century, power generation has been characterised by national monopolies with mandates to finance investments in new production capacity through state subsidies and/or levies on electricity bills. As many countries move in the direction of more liberalised electricity markets, those options are no longer available. This places new generating technologies such as wind power at a competitive disadvantage.

Two developments could ease this situation:

Removal of subsidies to fossil fuel and nuclear power sources
Subsidies to fully competitive and polluting technologies are highly unproductive, seriously distort markets and increase the need to support renewables. Removing subsidies to conventional electricity would not only save taxpayers' money and reduce current market distortions in the electricity market. It would also dramatically reduce the need for renewables support. Wind power would not need special provisions if markets were not distorted by the fact that it is still virtually free for electricity producers to pollute.

Subsidies artificially reduce the price of power, keep renewables out of the market place, and prop up increasingly uncompetitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move towards a level playing field across the energy sector.

Conventional energy sources currently receive an estimated $250 billion in subsidies per year worldwide, according to the United Nations Development Programme. This heavily distorts markets. The UNDP World Energy Assessment gives the annual cost of global subsidies for fossil fuels and nuclear energy between 1995 and 1998 as $215 billion, compared with $9 billion for renewables and energy efficiency.

Research and development funding can make a crucial difference as to whether a technology becomes commercially viable, particularly at the early stage of development. It also accounts for about 40% of continued cost reductions in the technology.

According to the International Energy Agency report "Renewable Energy: Market and Policy Trends in IEA Countries" (2004), between 1974 and 2002, 92% of all R&D funding ($267 billion) was spent on non-renewables, largely fossil fuel and nuclear technologies, compared to 8% ($23 billion) for all renewable technologies.

Internalising the social and environmental costs of polluting energy
The real cost of energy production by conventional energy includes expenses absorbed by society, such as health impacts and local and regional environmental degradation – from mercury pollution to acid rain – as well as the global impact of climate change.

Hidden costs also include the waiving of nuclear accident insurance, which is either unavailable or too expensive to be covered by the nuclear operators. The costs of decommissioning nuclear plants, storage of high level nuclear waste and the health costs associated with mining, drilling and transportation are equally not added to the real economics of fossil and nuclear power.

Environmental damage should be avoided at source. Translated into energy generation that would mean that, ideally, production of energy should not pollute and it is the energy producers' responsibility to prevent it. If they do pollute they should pay an amount equal to the damage their production causes to society as a whole.

The European Commission – through the ExternE project – has attempted to quantify the true costs, including environmental costs, of electricity generation. ExternE estimates that the cost of producing electricity from coal or oil would double, and from gas increase by 30%, if their external costs, in the form of damage to the environment and health, were taken into account. The study further estimates that these costs amount to 1-2% of EU GDP, or between €85 billion and €170 billion/ annum, not including the additional costs of the impacts of human-induced climate change on human health, agriculture and ecosystems. If those environmental costs were levied on electricity generation, many renewables, including wind power, would not need any support to successfully compete in the marketplace.

As with other subsidies, such external costs must be factored into energy pricing if competition in the market is to be truly fair. This requires that governments apply a "polluter pays" system that charges the emitters accordingly, or applies suitable compensation to non-emitters. Adoption of polluter pays taxation to polluting electricity sources, or equivalent compensation to renewable energy sources, and exclusion of renewables from environment-related energy taxation, is essential to help achieve fairer competition in the world's electricity markets.

International Action on Climate Change

Final ratification of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCC) in February 2005 was a vital first step towards protecting the climate from dangerous anthropogenic climate change. As a legally binding international instrument, the Protocol heralds the beginning of carbon constrained economies. In time, this will mean an increased demand for low and carbon-free power production. Protecting the climate will demand more and deeper cuts in greenhouse gas emissions, which will further increase the market for renewable energy technologies such as wind power.

The international issue now is what objectives for reduction in greenhouse gases will follow on from the present 2008-12 Kyoto target period. Meeting in March 2005, EU heads of state recommended that "reduction pathways… in the order of 15-30% by 2020, compared to the baseline envisaged in the Kyoto Protocol… should be considered." At the Montreal UNFCC conference (COP-11) in December 2005 delegates agreed to start "a process to consider further commitments". It is critical that the next round of emissions reductions be agreed soon, so that the market is clear that the strong signal sent by the entry into force of the Kyoto Protocol will continue beyond 2012.

Emissions trading in the form it currently operates, both at a European level and through the international mechanisms (Clean Development and Joint Implementation) established under Kyoto, is unlikely to provide a major boost for wind energy in the short term. The first steps in emissions trading within the European Union have sent a good signal to markets about the costs of carbon-intensive energy production, but they do not go far enough and need to be strengthened in the next round. In particular, free allocation of allowances should be replaced by 100% auctioning - to avoid market distortions and apply the polluter pays principle. Emissions trading should not be seen as a substitute for environmental taxes or policies to support renewable energy.

Reform of International Financing

Demand for energy, particularly electricity, is increasing worldwide. This is especially the case in developing countries, which also rely heavily on export credit agencies (ECAs) and multi-lateral development banks to provide financing for energy and other industrial projects.

To be consistent with the emerging international regime for limiting greenhouse gas emissions, ECAs and other international financial institutions which support or underwrite projects around the world must have policies consistent with the need for limiting greenhouse gas emissions and climate change protection. At the same time there needs to be a transition plan and flexible timeframes to avoid undue hardships on developing country economies overly reliant on conventional energy sources and exports, whilst also recognising that meeting the development goals for the world's poorest nations will require subsidies for the foreseeable future.

Policies to address these issues must include:

- A defined and increasing percentage of overall energy sector lending directed to renewable energy projects.
- A rapid phase out of support for conventional, polluting energy projects.

Action by International Bodies

Against the backdrop of ever rising oil prices, political leaders have slowly started to acknowledge that the global energy challenge requires urgent action in three areas: securing global energy supply, meeting rising energy demand and tackling the threat of climate change. These issues are now higher on the political agenda than ever before. Moreover, a better understanding of energy issues and dramatic advances in modern technologies provide the opportunity for tackling the energy challenge in an efficient and sustainable way.

An opportunity for action is provided by international government meetings such as the G8 Summits, bringing together the leaders of the United States, Russia, Italy, Japan, Germany, France, Canada and the UK, and the UN's Commission on Sustainable Development (CSD).

In July 2005, the G8 members, plus Brazil, China, India, Mexico and South Africa, agreed a dialogue on climate change, clean energy and sustainable development. These Partners, along with the World Bank and IEA, agreed to work together on a number of issues, including the deployment of renewable energy technology. The IEA has outlined a G8 Gleneagles Programme, which focuses on the following areas: Alternative energy scenarios and strategies; Energy efficiency in buildings, appliances, transport and industry; Cleaner fossil fuels; Carbon capture and storage; Renewable energy; and Enhanced international co-operation.

The IEA is to publish a report on Alternative Energy Technologies, and a report on progress on the work programme is to be provided at the G8 Summit in St Petersburg in July 2006 and at the Gleneagles Dialogue Ministerial in Mexico in the autumn.

An earlier report by the G8 countries' International Climate Change Task Force, "Meeting the climate challenge", published in January 2005, made several recommendations in relation to both climate change and renewable energy. These included that:

- A long-term objective be established to prevent global average temperature from rising more than 2°C (3.6°F) above the pre-industrial level, to limit the extent and magnitude of climate-change impacts.
- G8 Governments establish national renewable portfolio standards to generate at least 25% of electricity from renewable energy sources by 2025, with higher targets needed for some G8 Governments.
- Governments remove barriers to and increase investment in renewable energy and energy efficient technologies and practice such measures as the phase-out of fossil fuel subsidies.

Implementation of these recommendations would support the achievement of the targets outlined in this report.

Energy for Sustainable Development and Climate Change are two of the thematic priorities of the 2006 and 2007 sessions of the UN Commission on Sustainable Development, which will review progress made by the world's governments in implementing the agreements of the World Summit on Sustainable Development in 2002. These sessions provide a key opportunity for ministers from around the world to focus on the promotion of renewable energy.

Policy Summary

NATIONAL POLICIES

1. Establish legally binding targets for renewable energy
2. Create legally based market deployment instruments
3. Provide defined and stable returns for investors by ensuring that
- The price for renewable power should allow for risk return profiles that are competitive with other investment options
- The duration of a project should allow investors to recoup their investment
4. Reform electricity markets by ensuring that
- Electricity sector barriers to renewables are removed
- Market distortions are removed
- Subsidies to fossil fuel and nuclear power sources are halted
- The social and environmental costs of polluting energy are internalised

INTERNATIONAL POLICIES

1. Implement the Kyoto Protocol and post-2012 emission reduction targets
2. Reform the operation of Export Credit Agencies, Multi-lateral Development Banks and International Finance Institutions by ensuring
- A defined and increasing percentage of overall energy sector lending is directed to renewable energy projects
- A rapid phase out of support for conventional, polluting energy projects
3. Implement key G8 task force recommendations

REFERENCE

Year	Cumulative [MW]	Growth rates	Annual [MW] incl. Repowering	Annual avg. WTG [MW]	Capacity factor [%]	Production [TWh]	Wind power penetration of Worlds electricity in % - Reference	Wind power penetration of Worlds electricity in % - Efficiency
2005	59,078	17%	11,524	1,4	24%	124		
2006	69,139	15%	10,061	1,4	25%	151		
2007	79,510	13%	10,371	1,5	25%	174		
2008	90,222	12%	10,713	1,5	25%	198		
2009	101,311	11%	11,089	1,5	25%	222		
2010	112,818	10%	11,506	1,5	25%	247	1.5	1.8
2015	171,738	7%	13,074	2,0	28%	421		
2020	230,658	6%	15,547	2,0	28%	566	2.7	3.6
2025	297,208	4%	24,774	2,0	28%	729		
2030	363,758	3%	24,816	2,0	28%	892	3.5	5.0
2035	423,258	3%	24,974	2,0	28%	1,038		
2040	482,758	2%	27,447	2,0	30%	1,269	4.1	6.3
2045	530,007	2%	34,224	2,0	30%	1,393		
2050	577,257	0%	34,266	2,0	30%	1,517	4.0	6.6

MODERATE

Year	Cumulative [MW]	Growth rate	Annual [MW] incl. Repowering	Annual avg. WTG [MW]	Capacity factor [%]	Production [TWh]	Wind power penetration of Worlds electricity in % - Reference	Wind power penetration of Worlds electricity in % - Efficiency
2005	59,078	21%	11,524	1,4	24%	124	0.8	0.8
2006	71,344	19%	12,266	1,4	25%	156		
2007	84,837	18%	13,493	1,5	25%	186		
2008	99,862	17%	15,025	1,5	25%	219		
2009	116,637	17%	16,774	1,5	25%	255		
2010	136,543	16%	19,906	1,5	25%	299	1.8	2.2
2015	279,682	15%	37,972	2,0	28%	686		
2020	560,445	13%	77,365	2,0	28%	1,375	6.6	8.6
2025	897,014	6%	75,507	2,0	28%	2,200		
2030	1.128,707	3%	58,260	2,0	28%	2,768	10.8	15.6
2035	1.285,087	2%	65,057	2,0	28%	3,152		
2040	1.399,133	1%	97,737	2,0	30%	3,677	11.8	18.1
2045	1.487,253	1%	91,476	2,0	30%	3,909		
2050	1.556,901	0%	70,957	2,0	30%	4,092	10.8	17.7

ADVANCED

Year	Cumulative [MW]	Growth rate	Annual [MW] incl. Repowering	Annual avg. WTG [MW]	Capacity factor [%]	Production [TWh]	Wind power penetration of Worlds electricity in % - Reference	Wind power penetration of Worlds electricity in % - Efficiency
2005	59,078	23%	11,524	1,4	24%	124	0.8	0.8
2006	72,449	20%	13,371	1,4	25%	159		
2007	88,080		15,631	1,5	25%	193		
2008	106,560		18,481	1,5	25%	233		
2009	127,928		21,368	1,5	25%	280		
2010	153,759		25,831	1,5	25%	337	2.1	2.4
2015	391,077		70,478	2,0	28%	959		
2020	1.072,928	17%	186,825	2,0	28%	2,632	12.6	16.5
2025	1.589,792	8%	117,014	2,0	28%	3,899		
2030	2.106,656	4%	117,014	2,0	28%	5,167	20.1	29.1
2035	2.361,433	2%	142,260	2,0	28%	5,792		
2040	2.616,210	2%	142,260	2,0	30%	6,875	22.1	33.9
2045	2.813,256	1%	156,423	2,0	30%	7,393		
2050	3.010,302	1%	156,423	2,0	30%	7,911	20.9	34.2

REFERENCE

Year	CO_2 reduction [annual Mio tCO_2]	CO_2 reduction [cumulative Mio tCO_2]	Progress ratio	Costs [€/MW]	Investment [T€]	Jobs Total
2005	74.5	185	90%	1,000	11.524,000	150,120
2006	90.8	276	90%	983	9.889,197	163,200
2007	104	381	90%	968	10.041,461	197,208
2008	119	499	90%	955	10.232,704	234,698
2009	133	632	90%	943	10.461,858	242,974
2010	148	781	90%	933	10.732,388	241,484
2015	253	1,851	92%	900	11.772,485	280,866
2020	339	3,375	92%	879	13.662,230	322,729
2025	437	5,366	94%	865	21.433,038	463,332
2030	535	7,847	94%	854	21.205,467	481,624
2035	623	10,786	96%	849	21.209,089	480,290
2040	761	14,405	96%	845	23.185,273	531,723
2045	836	18,434	98%	843	28.855,459	638,180
2050	910	22,836	98%	842	28.841,545	653,691

MODERATE

Year	CO_2 reduction [annual Mio tCO_2]	CO_2 reduction [cumulative Mio tCO_2]	Progress ratio	Costs [€/MW]	Investment [T€]	Jobs Total
2005	74.5	185	90%	1,000	11.524,000	150,120
2006	93.7	279	90%	979	12.011,158	194,809
2007	111	391	90%	961	12.963,314	252,185
2008	131	522	90%	944	14.179,355	316,841
2009	153	675	90%	928	15.564,006	350,120
2010	179	854	90%	912	18.154,695	390,408
2015	412	2,413	92%	857	32.546,652	711,520
2020	825	5,593	92%	807	62.449,022	1.310,711
2025	1,320	11,229	94%	784	59.164,707	1,304,506
2030	1,661	18,918	94%	773	45.009,206	1.141,016
2035	1,891	27,948	96%	769	49.996,767	1.227,882
2040	2,206	38,639	96%	766	74.854,172	1.663,578
2045	2,345	50,100	98%	765	69.973,078	1.614,825
2050	2,455	62,165	98%	764	54.227,304	1.386,085

ADVANCED

Year	CO_2 reduction [annual Mio tCO_2]	CO_2 reduction [cumulative Mio tCO_2]	Progress ratio	Costs [€/MW]	Investment [T€]	Jobs Total
2005	74.5	185	90%	1,000	11.524,000	150,120
2006	95.2	281	90%	977	13.068,143	199,300
2007	116	396	90%	956	14.947,434	261,405
2008	140	536	90%	936	17.301,934	381,523
2009	168	704	90%	917	19.603,796	434,676
2010	202	906	90%	899	23.220,095	492,384
2015	576	2,916	92%	827	58.320,108	1.238,311
2020	1,579	8,363	92%	756	141.249,518	2.899,776
2025	2,340	18,540	94%	738	86.317,305	1.996,795
2030	3,100	32,521	94%	725	84.827,690	2.143,587
2035	3,475	49,147	96%	722	102.653,895	2.428,819
2040	4,125	68,970	96%	719	102.229,545	2.506,871
2045	4,436	90,528	98%	718	112.243,052	2.732,703
2050	4,747	113,640	98%	717	112.090,129	2.795,873

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 50 countries
- All the world's major wind turbine manufacturers
- 99 % of the world's nearly 60,000 MW of installed wind power capacity

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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.

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