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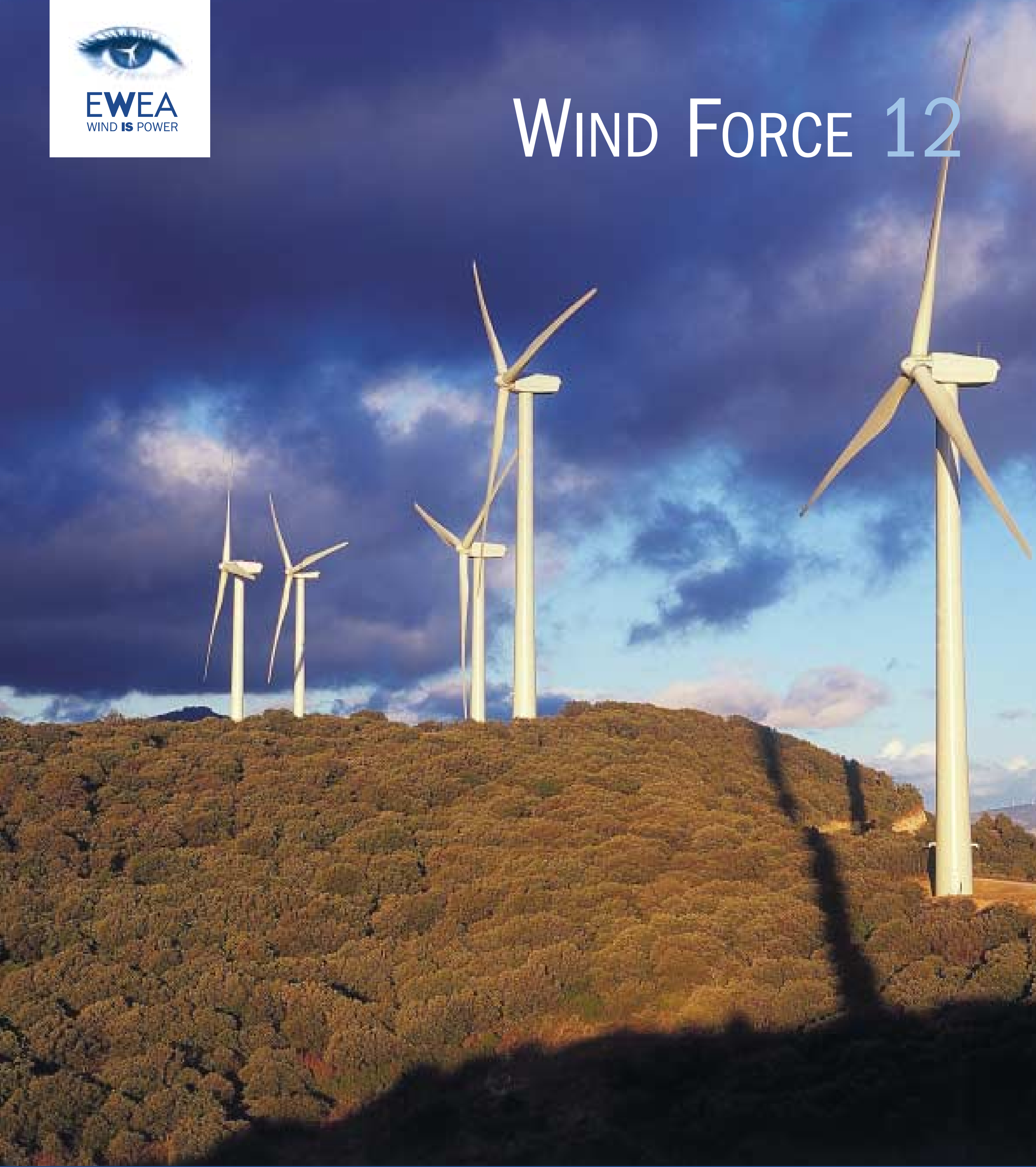
WIND IS POWER

WIND FORCE 12



A BLUEPRINT TO ACHIEVE 12% OF THE WORLD'S ELECTRICITY FROM WIND POWER BY 2020

GREENPEACE

May 2004

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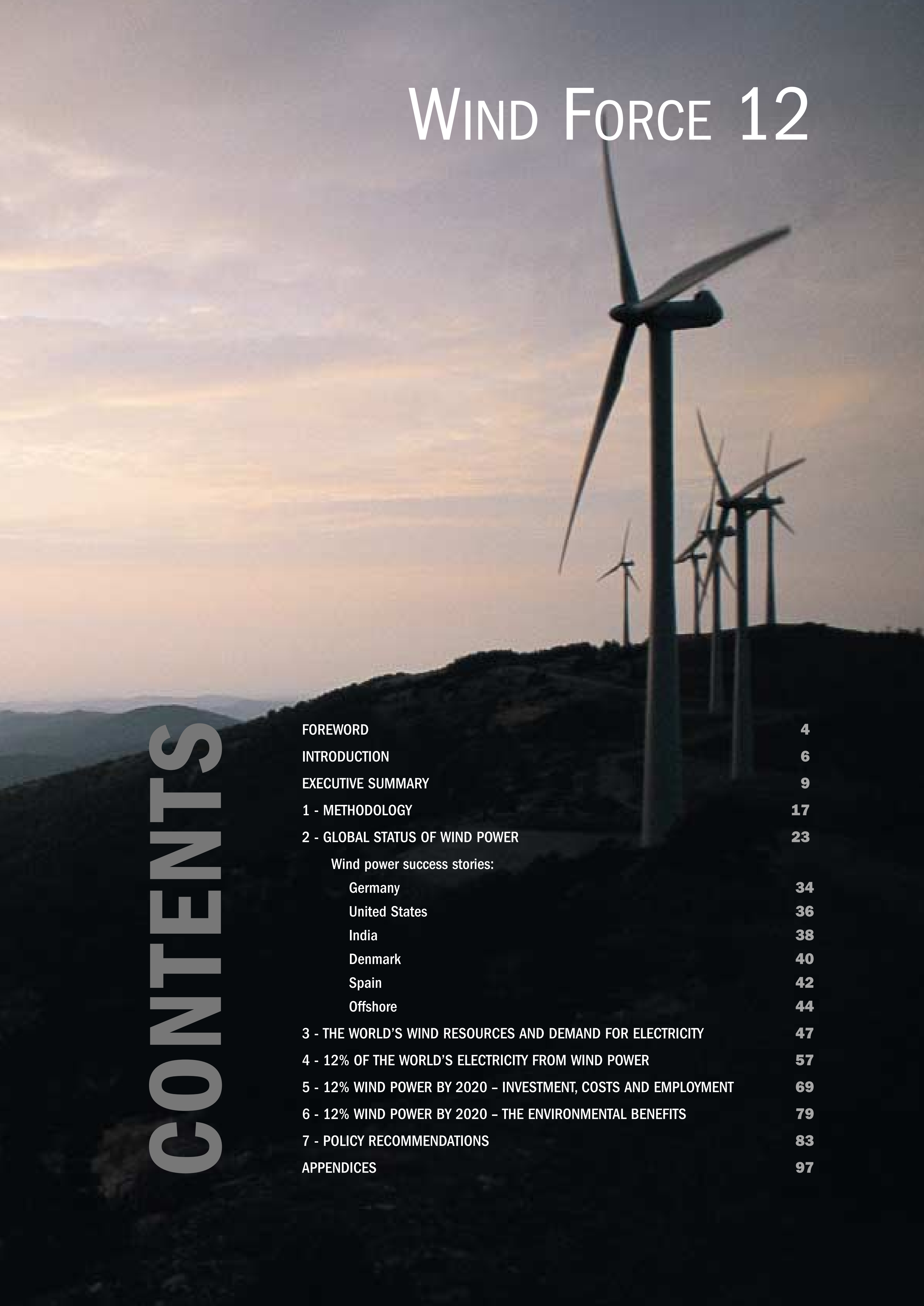

Wind Force 12

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Foreword

SECRETARIA DE ESTADO DO MEIO AMBIENTE

GABINETE DO SECRETÀRIO

Energy is fundamental to economic and social development, both North and South. Yet, at the dawn of the 21st century, we are confronted with the unacceptable fact that there are nearly 2 billion people without access to basic energy services. At the same time, we are facing the greatest threat to our collective survival *because* of our unsustainable use of energy: global climate change.

Wind Force 12 gives us a glimpse of the solution – how we can begin to meet our present needs without compromising the needs of future generations. Wind energy is the first of the 'new renewable' technologies to have penetrated the energy markets in some parts of the developed world in a serious way with the right kind of policy support. The wind industry can lead the way for other renewable energy technologies: as it matures and penetrates markets world wide it drives costs down which will make this technology competitive worldwide including developing countries.

The energy choices the world makes in the next few years will determine our collective development path for many decades to come. Shall we choose to continue to go down the 'conventional' energy development path, using fossil fuels, nuclear and other 19th and 20th century technologies? Or shall we choose now to pursue a truly sustainable development path both North and South based on efficient use of sustainable, clean renewable energy, building new industries and creating millions of new jobs?

How to meet the challenge of climate change, and how to provide clean, affordable energy to the world's poorest are issues which are debated in many fora, but none this year will be more important than ***Renewables 2004*** to be held in Bonn, Germany from June 1-4. Seeking to galvanize the support for action to fight climate change and poverty at the Johannesburg Earth Summit into concrete action, many nations are expected to heed German Chancellor Schroeder's call to bring their concrete plans and commitments to Bonn this spring. See you there!

Professor Jose Goldemberg
Secretary for the Environment of the State of São Paulo, Brazil

Introduction

This latest edition of Wind Force 12 demonstrates that there are no technical, economic or resource barriers to supplying 12% of the world's electricity needs with wind power alone by 2020 - and this against the challenging backdrop of a projected two thirds increase of electricity demand by that date.

The wind industry we have today is capable of becoming a dynamic, innovative € 80 billion annual business by 2020, able to satisfy global energy demands and unlock a new era of economic growth, technological progress and environmental protection. Wind energy is a significant and powerful resource. It is safe, clean, abundant and limitless and provides an endless, secure energy supply. The wind industry is the world's best opportunity to begin the transition to a global economy based on sustainable energy.

Wind power has come a long way since the prototypes of just 20 years ago. Two decades of technological progress have resulted in today's wind turbines being state-of-the-art modern technology - modular and rapid to install. A single wind turbine is 100 times more powerful than its equivalent two decades ago.

Unlike some other ‘solutions’ to clean energy and climate protection, wind power does not need to be invented, nor is there need to wait for any magical 'breakthrough'; it is ready for global implementation now. Modern wind farms provide bulk power equivalent to conventional power stations. In the future, this blueprint will see the boundaries of technological progress pushed further to bring far greater benefits.

In 2003 more than 8,000 Megawatts of wind power was installed worldwide, valued at € 8 billion and generating enough electricity to power the equivalent of 19 million average European homes. But as outlined in the opening chapters of this report, the success of the industry to date has been largely created by the efforts of a handful of countries, led by Germany, Spain, and Denmark. It is obvious that if other countries matched these efforts, the impact would be far greater.

The fact that just three countries have created the bulk of the progress to date underlines the fact that today's technology is merely the tip of the iceberg, and a huge potential remains untapped. Wind power is capable of continuing its successful history over the next two decades if a positive political and regulatory framework is

implemented, one that removes the obstacles and market distortions that currently constrain the industry's real potential.

This year's international conference "Renewables 2004" in Bonn, Germany charts the way towards an expansion of renewable energy worldwide, responding to the call from the 2002 Johannesburg summit and maintaining the momentum generated by the Johannesburg Renewable Energy Coalition. The European Union is playing an important role in this process, with the European regional renewables conference, held in Berlin in January 2004, agreeing that *"A target value of at least 20% of gross inland energy consumption by 2020 for the EU is achievable."* This target could be even higher if coupled with stronger energy efficiency policies.

Targets for renewables act as a catalyst for governments to develop the necessary framework conditions for investment in renewable energy technologies. A powerful example is the EU Directive on the Promotion of Electricity from Renewable Energy Sources, which sets national indicative targets for all EU Member States. These targets have initiated action throughout the entire European Union to put in place framework conditions for renewables. But although targets are an important first step in developing the clean energy sources of tomorrow that will contribute substantially to climate protection, they must be followed by concrete political action. Wind Force 12 is a political blueprint for action that governments can implement, and shows what is possible with just one renewable technology.

The message from this report is clear. Wind power is world scale; it has the capacity to satisfy the energy and development needs of the world without destroying it; and it will play a key role in our future sustainable energy supply.

Corin Millais

Corin Millais
Chief Executive European Wind Energy Association

Sven Teske

Sven Teske
Renewables Director Greenpeace

"THIS STUDY CLEARLY DEMONSTRATES THAT THERE ARE NO TECHNOLOGICAL, COMMERCIAL OR RESOURCE LIMITS CONSTRAINING THE WORLD FROM MEETING 12% OF FUTURE GLOBAL ELECTRICITY DEMAND FROM WIND POWER IN LESS THAN TWO DECADES"

EXECUTIVE SUMMARY

Wind Force 12 is a feasibility study into the potential for wind energy to supply 12% of the world's electricity by 2020. It concludes that there are no practical constraints to this level of expansion, but that a series of national and international policy shifts are required for its achievement. In the process, a capacity level of 1,200 GW of wind power would be installed, over 2 million jobs created and more than 10,700 million tonnes of carbon dioxide saved from contributing to climate change.

Methodology

The aim of this study is to assess whether it is feasible for wind power to achieve a penetration equal to 12% of global electricity demand by 2020. In the process, a number of technical, economic and resource implications have had to be examined.

The main inputs to this study have been:

- An assessment of the world's wind resources and their geographical distribution.
- The level of electricity output required and whether this can be accommodated in the grid system.
- The current status of the wind energy market and its potential growth rate.
- Analysis of wind energy technology and its cost profile.
- A comparison with other emerging technologies using "learning curve theory".

This is the fifth version of a study originally published in 1999 as Wind Force 10. This was subsequently transformed into Wind Force 12, first published in 2002. Like its predecessors it is not a forecast but a feasibility study whose implementation will depend on decisions taken by governments around the world.

The global status of wind power

Since the original report was published, wind power has maintained its status as the world's fastest growing energy source. Installed capacity has continued to grow at an annual rate in excess of 30%. During 2003 alone, more than 8,300 MW of new capacity was added to the electricity grid. This investment was worth more than € 8 billion.

By the beginning of 2004, global wind power installations had reached a level of 40,300 MW. This provides enough power to satisfy the needs of around 19 million average European households, close to 47 million people. Although Europe accounts for 73% of this capacity, other regions are beginning to emerge as substantial markets. Over 50 countries around the world now contribute to the global total, whilst the number of people employed by the industry is estimated to be around 90-100,000.

The impetus behind wind power expansion has come increasingly from the urgent need to combat global climate change. Wind energy offers both a power source which completely avoids the emission of carbon dioxide, the main greenhouse gas, but also produces none of the other pollutants associated with either fossil fuel or nuclear generation.

Starting from the 1997 Kyoto Protocol, a series of greenhouse gas reduction targets has cascaded down to a regional and national level. These in turn have been translated into targets for increasing the proportion of renewable energy, including wind.

In order to achieve these targets, countries in both Europe and elsewhere have adopted a variety of market support mechanisms. These range from premium payments per unit of output to more complex mechanisms based on an obligation on power suppliers to source a rising percentage of their supply from renewables.

As the market has grown, wind power has shown a dramatic fall in cost. Production costs have fallen by up to 50% over 15 years.

At optimum sites, wind can be competitive with new coal-fired plants and in some locations can challenge gas. Individual wind turbines have also increased in capacity, with the largest commercial machines now reaching 3,600 kW and prototypes being built of up to 5,000 kW. The average capacity of wind turbines installed worldwide during 2003 increased to 1,200 kW.

The booming wind energy business has attracted the serious attention of the banking and investment market, with new players such as oil and power companies entering the market.

Important "success stories" for wind energy can be seen in the experiences of Germany, Spain and Denmark in Europe, the United States in the Americas and India among the countries of the developing world. A new market sector is about to emerge offshore, with many thousands of megawatts of wind farms proposed in the seas around Northern Europe.

The world's wind resources and demand for electricity

A number of assessments confirm that the world's wind resources are extremely large and well distributed across almost all regions and countries. The total available resource that is technically recoverable is estimated to be 53,000 Terawatt hours (TWh)/year. This is over twice as large as the projection for the world's entire electricity demand in 2020. Lack of resource is therefore unlikely ever to be a limiting factor in the utilisation of wind power for electricity generation.

When more detailed assessments are carried out for a specific country, they also tend to reveal a much higher potential for wind power than a general study suggests. In Germany, for example, the Ministry of Economic Affairs has shown that the potential is five times higher than indicated in a 1993 study of OECD countries. Across Europe there is ample scope to meet at least 20% of electricity demand by 2020, especially if the new offshore market is taken into account.

Future electricity demand is assessed regularly by the International Energy Agency. The IEA's 2002 World Energy Outlook assessment shows that by 2020, total world demand will reach 25,578 TWh. For wind power to meet 12% of global consumption it will therefore need to generate an output in the range of 3,000 TWh/year by 2020.

There are no substantial obstacles to the integration of these increased quantities of wind power into the electricity grid. In Denmark, peak levels often account for more than 50% of consumption in the western part of the country during very windy periods. The cautious assumption adopted here is that a 20% penetration limit is easily attainable.

12% of the world's electricity from wind power

On the basis of recent trends, it is feasible that wind power can be expected to grow at an average rate for new annual installations of 25% per annum over the next seven years. This is the highest growth rate during the timescale of the study, ending up with a total of 197,500 MW of capacity on line by the end of 2010.

From 2011 to 2014, the growth rate falls to 20% per annum, resulting in 453,800 MW of installed capacity by the end of 2014. After that the annual growth rate falls to 15%, and then to 10% in 2019, although by this time the expansion of wind power will be taking place at a much higher level of annual installation.

By the end of 2020, the scenario shows that wind power will have achieved a global installed capacity of over 1.2 million MW. This represents an output of 3,000 TWh, a penetration level equivalent to 12% of the world's electricity demand.

From 2020 onwards the annual installation rate will level out at 158,700 MW per annum. This means that by 2040, wind energy's global total will have reached over 3,200 GW, which by then will represent about 23% of the world's consumption.

The 12% scenario has also been broken down by regions of the world. The OECD countries are expected to take the lead in implementation, especially Europe and North America, but other regions such as China will also make a major contribution.

The choice of parameters and assumptions underlying this scenario has been based on historical experience from both the wind power industry and from other energy technologies.

The main assumptions are:

- **Annual growth rates:** Growth rates of 20-25% are high for an industry manufacturing heavy equipment, but the wind industry has experienced far higher rates during its initial phase of industrialisation. Over the last five years the average annual growth rate of cumulative turbines installed has been almost 32%. After 2015, the scenario growth rate falls to 15% and then to 10% in 2019. In Europe, an important factor will be the opening up of the offshore wind market. As far as developing countries are concerned, a clear message from the industry is that it would like to see a stable political framework established in emerging markets if this expansion is to be achieved.
- **Progress ratios:** Industrial learning curve theory suggests that costs decrease by some 20% each time the number of units produced doubles. The progress ratios assumed in this study start at 0.85 up until 2010. After that the ratio is reduced to 0.90 and then to 1.0 in 2026.
- **Growth of wind turbine size:** The average size of new turbines being installed is expected to grow over the next decade from today's figure of 1,200 kW (1.2 MW) to 1.5 MW in 2007 and 2.0 MW in 2013. Larger turbine sizes reduce the number of machines required.
- **Comparisons with other technologies:** Both nuclear power and large scale hydro are energy technologies which have achieved substantial levels of penetration in a relatively short timescale. Nuclear has now

reached a level of 17.1% globally and large hydro 16.6%. Wind energy is today a commercial industry which is capable of becoming a mainstream power producer. The time horizon of the 12% scenario is therefore consistent with the historical development of these two technologies.

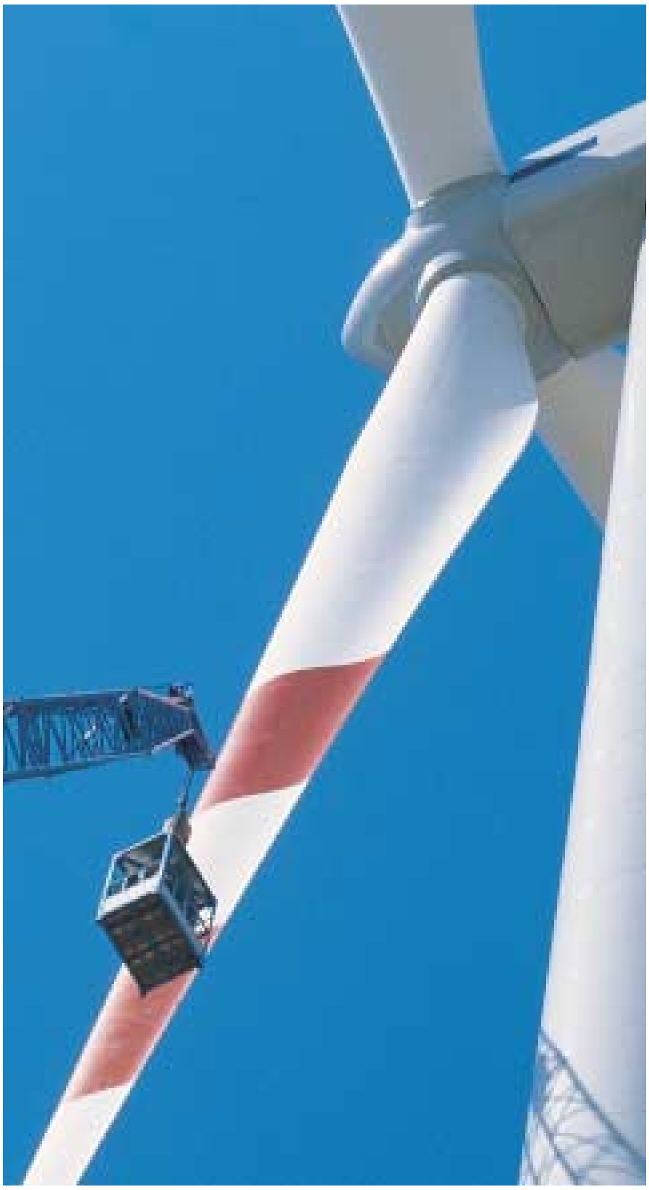
12% wind power by 2020 investment, costs and employment

The annual investment required to achieve the deployment of wind energy outlined above starts at € 8.2 billion in 2004 and increases to a peak of € 82.7 billion by 2019.

The total investment needed to reach a level of almost 1,200 GW of capacity by 2020 is estimated at € 692 billion over the whole period. This is a very large figure, but it can be compared with the annual investment in the power sector during the 1990s of some € 158-186 billion. The future investment required globally has also been broken down on a regional basis.

The cost per unit of wind-powered electricity has already reduced dramatically as manufacturing and other costs have fallen. This study starts from the basis that a "state of the art" wind turbine in 2003 in the most optimal conditions had an investment cost of € 804 per installed kW and a unit cost for its output of 3.79 € cents/kWh.

Using the progress assumptions already discussed, and taking into account improvements both in the average size of turbines and in their capacity factor, the cost per kilowatt hour of installed wind capacity is expected to have fallen to 3.03 € cents/kWh by 2010, assuming a cost per installed kilowatt of € 644. By 2020 it is expected to have reduced to 2.45 € cents/kWh, with an installation cost of € 512/kW - a substantial reduction of 36% compared with 2003.



Wind energy costs are also expected to look increasingly attractive when compared with other power technologies. The employment effect of the 12% wind energy scenario is a crucial factor to weigh alongside its other costs and benefits. A total of 2.3 million jobs will have been created around the world by 2020 in manufacture, installation and other work associated with the industry. This total is also broken down by region of the world.

12% wind power by 2020 the environmental benefits

A reduction in the levels of carbon dioxide being emitted into the world's 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.

On the assumption that the average value for carbon dioxide saved by switching to wind power is 600 tonnes per GWh, the annual saving under this scenario will be 1,832 million tonnes of CO_2 by 2020 and 5,106 million tonnes by 2040.

The cumulative savings would be 10,771 million tonnes of CO_2 by 2020 and 88,857 million tonnes by 2040.

If the external costs, including environmental damage, caused by different fuels used for electricity generation were given a monetary value, then wind power would either benefit from a reduction in price or the cost of other fuels would increase substantially.

Policy recommendations

This study clearly demonstrates that there are no technological, commercial or resource limits constraining the world from meeting 12% of future global electricity demand from wind power in less than two decades. Without political support, however, wind power remains at a competitive disadvantage. Distortions in the world's electricity markets - created by decades of massive financial, political and structural support to conventional technologies - are coupled with the fact that new wind power plants have to compete with existing nuclear and fossil fuel power stations producing electricity at marginal costs - because their interest and depreciation have already been paid for by consumers and taxpayers. In order to fully enjoy the economic and environmental benefits of wind energy, action is needed to overcome those distortions and create a level playing field.

Recognising that renewable energy sources, including wind power, can contribute to sustainable economic growth, reduce fuel imports, provide high quality jobs and help achieve the Kyoto Protocol commitments to reduce greenhouse gas emissions, a number of initiatives have already been taken. Within the European Union, indicative targets have been set for each member state in contributing to a doubling of the overall contribution from renewables to 22% of electricity supply by 2010. These targets need to be made legally binding.

Encouraged by such targets, economic measures have been introduced in some countries to encourage investment in renewable energy technology.

The two main types of incentive have been:

- **Fixed Price Systems**, where the government sets the electricity price or premiums paid to the producer and lets the market determine the quantity.
- **Renewable Quota Systems** (in the USA referred to as Renewable Portfolio Standards), where the government sets the quantity of renewable electricity and leaves it to the market to determine the price.

In addition to these financial measures, a successful policy for promoting wind power should include regulation on grid access and streamlining of administrative procedures.

Other factors which need to be considered when encouraging further development of renewable energy include a stable environment for the investment community, the removal of barriers to the development of renewables (such as planning and grid connection issues), the ending of subsidies to both fossil fuels and nuclear power and the internalising of the social and environmental costs associated with polluting energy sources.

A number of specific recommendations are made in pursuit of these objectives:

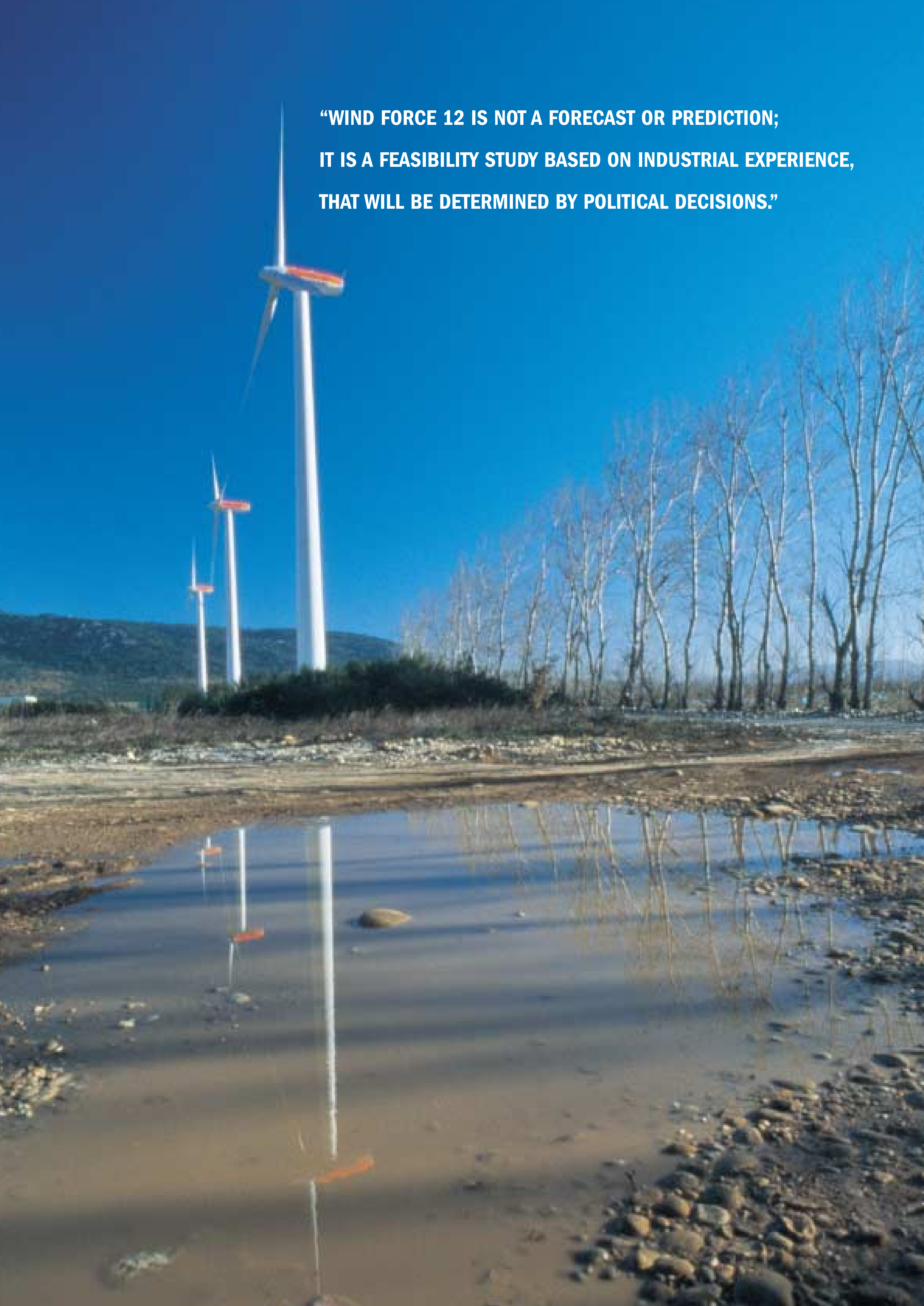
National Policies

- Establish legally binding targets for renewable energy;
- Provide defined and stable returns for investors;
- Introduce electricity market reforms, including the removal of electricity sector barriers to renewables and market distortions;
- Halt subsidies to fossil fuel and nuclear power sources;
- Internalise the social and environmental costs of polluting energy.

International Policies

- Ratification of the Kyoto Protocol;
- Reform of Export Credit Agencies, Multilateral Development Banks and International Finance Institutions;
- 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.

"WIND FORCE 12 IS NOT A FORECAST OR PREDICTION;
IT IS A FEASIBILITY STUDY BASED ON INDUSTRIAL EXPERIENCE,
THAT WILL BE DETERMINED BY POLITICAL DECISIONS."



1 - METHODOLOGY

The aim of this study is to assess whether it is feasible for wind power to achieve a penetration equal to 12% of global electricity demand by 2020. The main inputs have been an assessment of the world's wind resources, the level of electricity output required, the current status of the wind energy market, an analysis of current technology and its cost profile and a comparison with other emerging technologies.

1 - METHODOLOGY

The central analysis in this report has been carried out by BTM Consult, an independent Danish consultancy specialising in wind energy.

The aim of the study has been to assess the technical, economic and resource implications for a penetration of wind power into the global electricity system equal to 12% of total future demand within two decades, and whether a 12% penetration is possible within that timescale.

The methodology used in this study explores the following sequence of questions:

- ☐ Are the world's wind resources large enough and appropriately distributed geographically to achieve a level of 12% penetration?
- ☐ What level of electricity output will be required and can this be accommodated in the existing grid system?
- ☐ Is wind power technology sufficiently developed to meet this challenge? What is its technical and cost profile?
- ☐ With the current status of the wind power industry, is it feasible to satisfy a substantially enlarged demand, and what growth rates will be required?

For wind power to achieve 12% penetration by 2020, a manufacturing capacity of more than 158,000 MW/year must be established – nineteen times that of 2003.

This is the fifth edition of this report. An initial study was carried out by BTM Consult for the Danish Forum for Energy & Development (FED) in 1998. This was the model for a more detailed analysis released in 1999 by FED, Greenpeace and the European Wind Energy Association, entitled "Wind Force 10". An updated report, "Wind Force 12", was first published in 2002 by EWEA and Greenpeace.

The original 1998 study approached the potential for 10% wind penetration by working with two different scenarios for world electricity demand. In the more detailed Wind Force10 report (1999) only one parameter of future electricity demand was used – the International Energy Agency's 1998 "World Energy Outlook", a conservative projection which assumes "business as usual" and in which electricity consumption is predicted to double by 2020. For consistency, the market data are those produced by BTM Consult, which sometimes differ slightly in the totals for individual countries from the industry statistics published annually by EWEA.

Since 1999 a number of factors have prompted changes in successive editions. Firstly, the IEA's 2000 World Energy Outlook produced a forecast for future global electricity demand that was slightly lower than in 1998/9, enabling the percentage of wind power's contribution to world electricity to rise. Secondly, wind industry growth rates have turned out in practice well above those in the original Wind Force 10 report. This in turn made it possible for the annual growth rates projected for the period 2004 to 2015 to be substantially reduced, making the scenario more conservative. All these factors made it possible to project a 12% contribution from wind power to global electricity demand by 2020.

This present version of Wind Force 12 has involved a limited number of fresh adjustments. Firstly, the initial annual market growth rate of 25% has been extended by two years to 2010. The subsequent period of 15% growth then shifts forward one year to end in 2018. The chosen growth rates in this report are still more moderate than those actually recorded in the market over the last five years - an average growth of about 26% per annum.

Secondly, the average size of individual wind turbines projected to be installed has been increased to 1.3 MW in 2004, 1.4 MW in 2005, 1.5 MW in 2007 and 2.0 MW in 2013. This reflects the rapid recent upscaling in the actual market, partly but not only driven by the expected developments offshore.

Finally, the reference projection for global electricity demand - the latest IEA World Energy Outlook report (2002) – is the same as that used for the 2003 edition. This shows projected demand by 2020 at a similar level to WEO 2000 (25,579 TWh compared to 25,818 TWh)

In the assessment of the distribution of new wind power capacity by world region, the take-off for large scale development has been delayed by a few years in some continents. Even with a favourable market framework in place, areas such as East Asia, China and the Transition Economies will not be able to achieve a high level of annual installation before 2006 and 2008.

This report also compares the development of wind power technology to that of other emerging technologies by using so-called “learning curve theory”. Because of its modular nature, wind power can benefit significantly from such learning curve effects. This means that a high initial penetration level can contribute to technological and economic progress, in turn justifying an expectation of further progress and enabling a very high level of development. For this reason the penetration curve has been extended to 2040 and beyond, by which time a saturation level will have been achieved.

For wind power to achieve 12% penetration by 2020, a manufacturing capacity of more than 158,000 MW/year must be established – nineteen times that of 2003. If this level of output were maintained beyond 2020 it would open up the potential for an even higher penetration by 2040. By that time 3,000 GW of wind turbines would be in operation.

Penetration of wind power beyond 2020 has not been assessed in detail in terms of implementation constraints. However, if wind power can fulfil the requirements of this scenario up to 2020, it is likely that development will continue.

Finally, it has to be emphasised that the BTM Consult analysis is not a long-term forecast. Nor is it a prediction, as the study is rooted in the real world experience and development of the wind industry today. It is a feasibility study taking into account the essential physical limitations facing large-scale development of wind power.

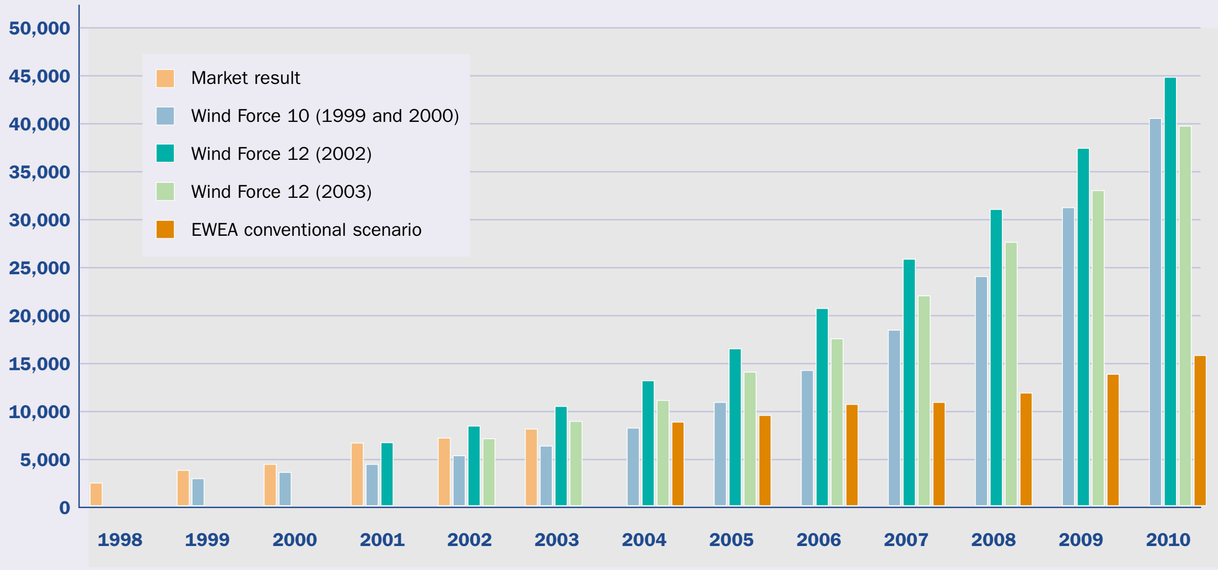
This study also assesses and compares actual industrial growth patterns seen in the sector so far with those in other energy technology areas. Over the past half century, generation technologies such as large scale hydro and nuclear power have achieved a high penetration in a relatively short timescale. There is no evidence to suggest that the same cannot be achieved by wind power. The actual pattern of wind power development, however, will be determined by political initiatives taken at a regional, national and global level.

Market results and scenario predictions

As this is the fifth version of the scenario, it is useful to make a comparison between their predictions and actual market results over the period 1999-2003, as well as seeing how the scenarios have varied in their expectation for the coming decade.

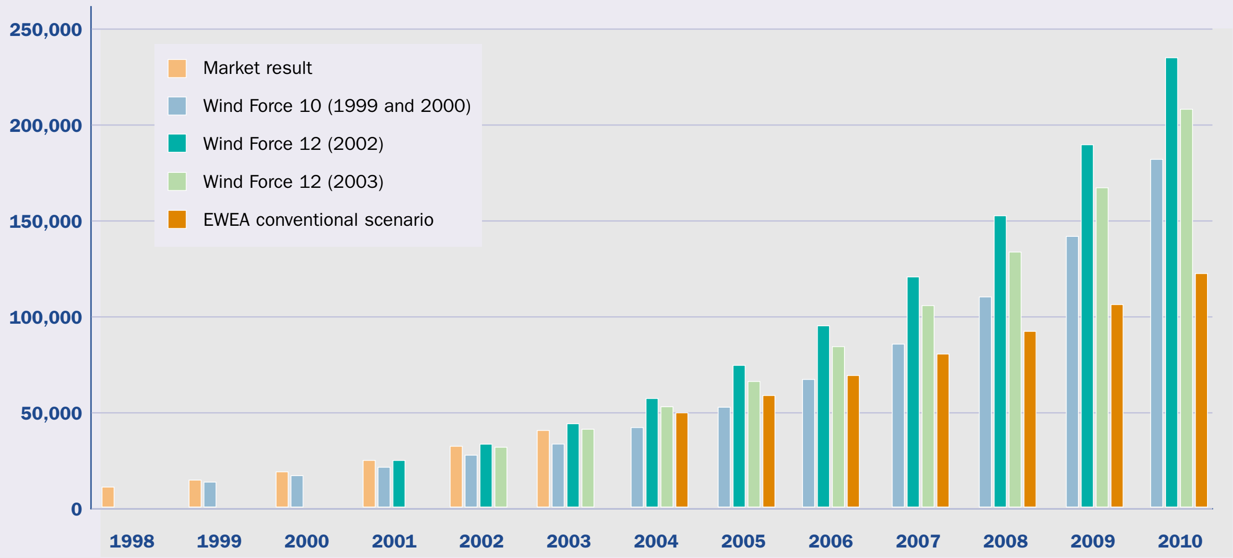
The two figures illustrate the changing scenario results over time compared to market reality. In the first four years, the market results outstripped the scenario forecasts. In 2003, for the first time, market results were lower than the scenario figures, a trend that is set to continue in the absence of stronger policy intervention. The comparison of the EWEA conventional scenario versus Wind Force 12 for the years 2004-2010 indicates the size of that gap.

Figure 1.1 - Annual MW installation capacity: market results versus scenario predictions



Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Market result	2,597	3,922	4,495	6,824	7,227	8,344							
Wind Force 10 (1999 and 2000)		3,120	3,744	4,493	5,391	6,470	8,411	10,934	14,214	18,478	24,021	31,228	40,596
Wind Force 12 (2002)				6,800	8,500	10,625	13,281	16,602	20,752	25,940	31,128	37,354	44,824
Wind Force 12 (2003)					7,227	9,034	11,292	14,115	17,644	22,055	27,569	33,083	39,699
EWEA conventional scenario							8,800	9,600	10,650	11,000	11,950	13,800	15,870

Figure 1.2 - Cumulative MW installation capacity: market results versus scenario predictions



Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Market result	10,153	13,932	18,449	24,927	32,037	40,301							
Wind Force 10 (1999 and 2000)		13,273	17,017	21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
Wind Force 12 (2002)				24,900	33,400	44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905
Wind Force 12 (2003)					32,037	41,071	52,363	66,478	84,122	106,177	133,746	166,829	206,528
EWEA conventional scenario							48,800	58,400	69,050	80,050	92,000	105,800	121,670

“WIND POWER ALREADY BUILT IN THE WORLD TODAY MEETS THE ELECTRICITY NEEDS EQUIVALENT TO 19 MILLION AVERAGE EUROPEAN HOMES.”

2 - THE GLOBAL STATUS OF WIND POWER

Wind power capacity has expanded around the world over the past five years at an average cumulative rate of 32%. By the end of 2003 the worldwide total had reached over 40,300 MW, enough to supply the electricity needs of 19 million average European households. Global employment in the industry has reached a level of an estimated 90-100,000 people.

2 - THE GLOBAL STATUS OF WIND POWER

Over the past five years, global wind power capacity has continued to grow at an average cumulative rate of almost 32% (Figure 2.1). The increase in year-on-year installations has been an average of 26%. During 2003 alone, over 8,300 MW of new capacity was added to the electricity grid worldwide. The value of this investment was € 8 billion.

By the end of 2003, the capacity of wind turbines installed globally had reached a level of over 40,300 MW. This is enough power to satisfy the needs of more than 19 million average European households, close to 47 million people. Europe accounts for 73% of this capacity, and for 66% of the growth during 2003. But other regions are beginning to emerge as substantial markets for the wind industry. Over 50 countries around the world now contribute to the global total, and the number of people employed by the industry worldwide is estimated to be 90-100,000, with 70-80,000 of these in Europe.

Worldwide markets

Within Europe, Germany is the clear market leader. During 2003, German wind capacity grew by 2,674 MW, taking the country's total up to more than 14,600 MW. In a normal wind year, this would provide enough power to meet 5.9% of national electricity demand.

Denmark and Spain have also continued to expand, the latter by almost 1,400 MW during 2003. On current form, the Spanish wind industry will continue to pursue Germany for the European crown. Denmark has meanwhile succeeded in being able to satisfy 20% of its electricity demand from the wind, the highest contribution of any country in the world.

By the end of 2003, the capacity of wind turbines installed globally had reached a level of over 40,300 MW. This is enough power to satisfy the needs of more than 19 million average European households.

Eight other members of the European Union – Austria, France, Greece, Italy, the Netherlands, Portugal, Sweden and the UK – now each have more than 200 MW installed, and have all effectively reached the take-off stage. Italy and the Netherlands have both pushed through the 900 MW barrier.

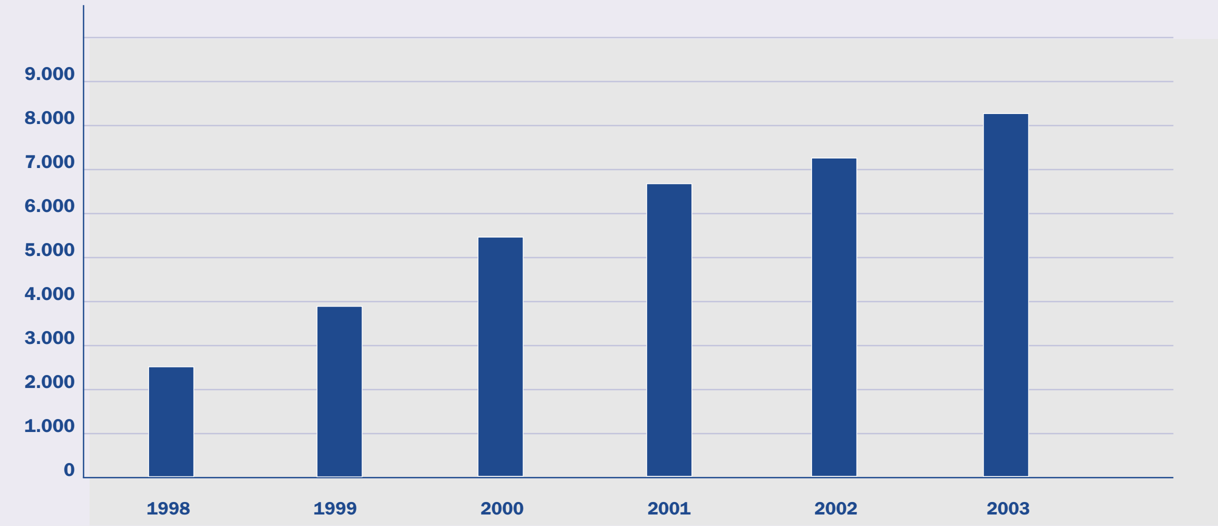
In the Americas, the United States market has experienced a major revival, although still handicapped by lack of continuity in federal policies. In a volatile power market, large utilities are increasingly looking to wind power as a source of low-priced, stable electricity. Total US capacity has now reached 6,361 MW.

Canada, with one of the largest wind resources in the world, is ready to expand well beyond its present level of 317 MW after the introduction of a production tax credit similar to that operating in the US. In South America, an urgent need for new power capacity has prompted the Brazilian government to launch a programme with a target for 1,000 MW of wind capacity. Argentina's vast potential is waiting for similar stimulation. Spanish companies lead those providing the development expertise.

New markets are also opening up in other continents. Australia almost doubled its capacity in 2003 to reach 239 MW, and with a further 1,700 MW in the pipeline. In Asia, the Indian market has revived after a quiet period in the late 1990s, pushing beyond 2,000 MW by the end of 2003. China is looking to increase its capacity to 1,200 MW by 2005, whilst Japan continues to steadily expand. In Africa, both Egypt and Morocco have shown what is possible with national planning and the backing of European developers. Morocco already gets 2% of its electricity from a 50 MW wind farm and has plans for a further 460 MW.

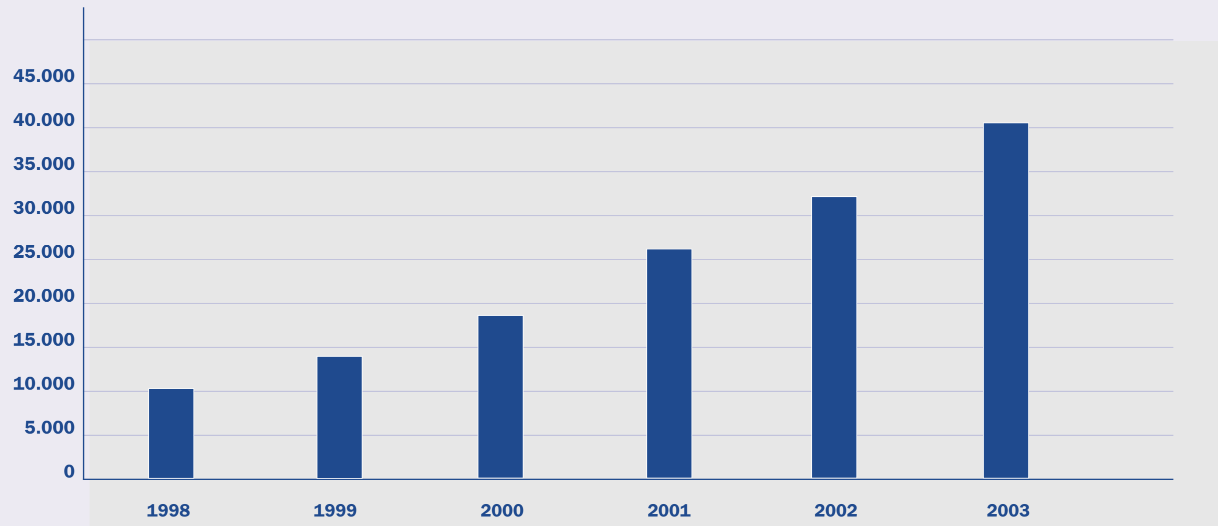
Figure 2.1 - Growth in world wind power market 1998-2003

Annual installed capacity (MW)



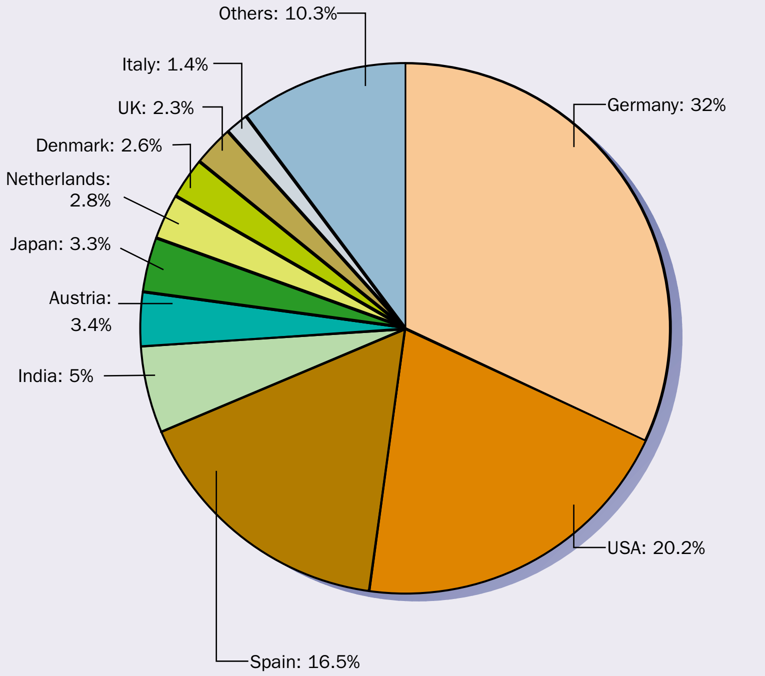
Year	1998	1999	2000	2001	2002	2003	Average growth over 5 years
Annual installed capacity (MW)	2,597	3,922	4,495	6,824	7,227	8,344	
Increase		51%	15%	52%	6%	15%	26.3%

Cumulative installed capacity (MW)



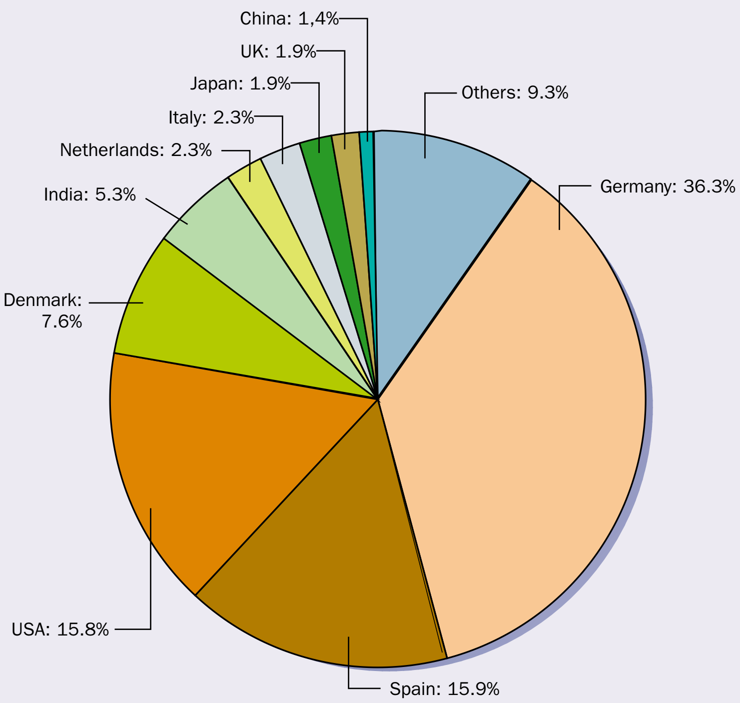
Year	1998	1999	2000	2001	2002	2003	Average growth over 5 years
Cumulative installed capacity (MW)	10,153	13,932	18,449	24,927	32,037	40,301	
Increase		37%	32%	35%	29%	26%	31.7%

Figure 2.2 - Top ten wind power markets 2003: Annual MW capacity installed



Countries	New capacity in 2003 (MW)
Germany	2,674
USA	1,687
Spain	1,377
India	423
Austria	285
Japan	275
Netherlands	233
Denmark	218
UK	195
Italy	116
Others	861
World total	**8,344**

Figure 2.3 - Top ten wind power markets 2003: Total MW capacity installed



Countries	Total capacity end 2003 (MW)
Germany	14,612
Spain	6,420
USA	6,361
Denmark	3,076
India	2,125
Netherlands	938
Italy	922
Japan	761
UK	759
China	571
Others	3,756
World total	**40,301**

Climate change imperative

The impetus behind wind power expansion has come increasingly from the urgent need to combat global climate change. The UN-Intergovernmental Panel on Climate Change projects that average temperatures around the world will increase by up to 5.8ºC over the next century, bringing flooding, droughts and violent climate swings in its wake.

Wind power and other renewable energy technologies generate electricity without producing the pollutants associated with fossil fuels and nuclear power generation, and emit no carbon dioxide, the most significant greenhouse gas. Starting from the 1997 Kyoto Protocol, which called for a global cut of 5.2% from 1990 levels by the period 2008-2012, a series of greenhouse gas reduction targets has cascaded down to regional and national levels. These in turn have been translated into targets for introducing an increasing proportion of renewables into the supply mix.

The EU 15 have an overall target for 22% of their electricity to come from renewables by 2010, an increase from a baseline of 14% in 1997. The 10 Accession countries have a target of 11% by 2010 compared to 5.6% in 2000.

In order to achieve these targets, countries in Europe and elsewhere have adopted a variety of market support mechanisms. These range from simple premium payments per unit of electricity produced by renewable power plants to more complex mechanisms which place an obligation on power suppliers to source a rising percentage of their supply from renewables.

The argument behind these mechanisms is two-fold. Firstly, there is the need to stimulate a market to the point where a substantial industry can been established. Secondly, there is the historic distortion of the market in favour of both fossil fuels and nuclear.

Nuclear power continues to take a significant share of energy research funding in both the US and Europe. At the same time, the generation costs of “conventional” fuels take no account of their external environmental, health and social costs. Alongside the competitive liberalisation of energy markets around the world, these distortions make it difficult for new technologies to gain a foothold.

Conventional energy sources receive an estimated € 230-280 billion in subsidies per year world-wide.

In the developing world, by contrast, wind power is attractive as a means of providing a cheap and flexible electricity supply to often isolated communities, whether or not it is supported by an environmental premium. Over the coming decades, the majority of demand for new power will come from the developing world; wind power offers an opportunity to provide large quantities of grid-connected electricity, leap-frogging dirty technology to aid clean industrial development.

Falling costs

As the market has grown, wind power has shown a dramatic fall in cost. The average cost of production from a coastal turbine has decreased from approximately 8.8 € cents/kWh for a turbine installed in the mid-1980s to 4.1 € cents/kWh for a recently built 1,000 kW turbine, an improvement of more than 50% over 15 years. Wind is already competitive with some new coal-fired plants and in some locations can challenge gas, currently the cheapest option.

The cost of wind power generation falls as the average wind speed rises.

Analysis by industry magazine Windpower Monthly shows that at a site with an average wind speed of 8.5 metres per second, and a capital cost per installed kilowatt of approximately € 800, wind is already competitive with gas.

Figure 2.4 - Growth rates in top ten wind energy markets

Country	MW end 2001	MW end 2002	MW end 2003	Growth rate 2002-3 (%)	3 years average growth
Germany	8,734	11,968	14,612	22.1%	33.8%
USA	4,245	4,674	6,361	36.1%	34.6%
Spain	3,550	5,043	6,420	27.3%	31.3%
Denmark	2,456	2,880	3,076	6.8%	9.5%
India	1,456	1,702	2,125	24.9%	20.3%
Italy	700	806	922	14.4%	29.5%
UK	525	570	759	33.1%	21.3%
Netherlands	523	727	938	29.0%	25.6%
China	406	473	571	20,7%	17,5%
Japan	357	486	761	56,6%	75,1%
Total 'top 10'	**22,952**	**29,329**	**36,545**	**24.6%**	**29.2%**
World total	**24,927**	**32,037**	**40,301**	**25.6%**	**29.2%**

As its economic attraction has increased, wind power has become big business. Most importantly, the wind power business is attracting serious interest from new players such as General Electric and Shell.

Wind power technology

Wind power is a deceptively simple technology. Behind the tall, slender towers and steadily turning blades lies a complex interplay of lightweight materials, aerodynamic design and computerised electronic control.

Although a number of variations continue to be explored, the most common configuration has become the horizontal axis three bladed turbine with its rotor positioned upwind – on the windy side of the tower. Power is transferred from the rotor through a gearbox, sometimes operating at variable speed, and then to a generator. Some turbines avoid a gearbox by use of direct drive.

Within this broad envelope, continuing improvements are being made in the ability of the machines to capture as much energy as possible from the wind. These include more powerful rotors, larger blades, improved power electronics, better use of composite materials and taller towers.

The most dramatic improvement has been in the increasing size and performance of wind turbines. From machines of just 25 kW twenty years ago, the commercial size range sold today is typically from 750 up to 2,500 kW. In 2003 the average capacity of new turbines installed in Germany rose to almost 1,600 kW. A 2,000 kW turbine is 100 times more powerful than the old 1980s vintage machines.

The largest machines commercially available today are of 3,600 kW capacity, with a rotor diameter of 104 metres. Towers at inland sites can now stretch up more than 100 metres to catch the wind. One result is that many fewer turbines are required to achieve the same power output, saving land use in the process. Depending on its siting, a 1 MW turbine can produce enough electricity for up to 650 households.

The average cost of production from a coastal turbine has decreased more than 50% over 15 years. Wind is already competitive with some new coal-fired plants and in some locations can challenge gas.

In the future, even larger turbines will be produced to service the new offshore market. Machines in a range up to 5,000 kW are currently under development. In 2003 the German company Enercon erected the first prototype of its 4,500 kW turbine with a rotor diameter of 112 metres.

For offshore developments, there are new technical demands. The wind turbines must be firmly positioned on the sea bed by using one of several foundation designs – steel monopiles driven deep into the sub-soil, gravity-based concrete caissons or tripod supports. Cables have to be laid both between the turbines in an array and back to

shore to feed the electricity output into the grid. Maintenance requires the ready availability of service vessels, making turbine reliability of paramount importance. Overall, wind turbines have a design lifetime of 20-25 years.

> **With penetration levels of up to 20% in Denmark and around 5% in both Germany and Spain, wind power is already making a significant contribution.**

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.

Developing a specific wind farm involves advance monitoring of wind speeds at the site, using a mast-mounted anemometer, careful planning of the layout to make best use of the resource, and avoidance of such obstacles as archaeological remains or bird migration routes. Construction can be completed within a matter of weeks, with large cranes installing the turbine towers, nacelles and blades on top of reinforced concrete foundations. The wind turbines themselves represent about 75% of the capital cost of an onshore project, with the remainder coming mainly from grid connection, land costs, foundations and road construction.

Once operating, wind farms can be controlled remotely by computer link-up, with constant monitoring of their output and performance. They can vary in size from a

Achievements and issues

- **Reliability**
  In larger projects using proven medium sized turbines an availability of 98% is consistently achieved.

- **Noise**
  Some early turbine designs were noisy, but improved engineering has resulted in mechanical noise being virtually eliminated and aerodynamic noise levels vastly improved.

- **Efficiency**
  Wind turbines are now highly efficient, with less than 10% thermal losses in system transmission.

- **Visual impact**
  How and where to position wind farms requires sensitive treatment, but surveys of European public reaction to operational wind farms have shown a largely positive response.

- **Contribution to power supply**
  With penetration levels of up to 20% in Denmark and around 5% in both Germany and Spain, wind power is already making a significant contribution. Growth of the offshore market, a resource large enough to supply all of Europe's electricity, will further reinforce this significance.

few megawatts up to the largest so far - 300 MW in the 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, wind turbines account for up to 50% of power generation in the western part of Denmark, for example, but the grid operators have managed it successfully. It would improve the effectiveness and reliability of the European wind input, however, if a new super-grid was installed to link up the many large offshore plants expected to start generating power over the next decade.

WIND POWER SUCCESS STORIES

More than 50 countries around the world now have some wind power capacity, but a handful of countries have so far proved themselves to be the market leaders. Whilst Europe has been most successful, other continents are following suit, whilst a new frontier for wind power development is offshore.

Germany	World Leader
United States	Waking Giant
India	Wind Leader in Asia
Denmark	Commercial Success
Spain	Southern Europe's Powerhouse
Offshore	The New Frontier

GERMANY

Germany – World leader

Germany is the undisputed world leader in wind energy. Since the early 1990s, encouraged by supportive national and regional policies, a rapidly expanding industry has shown the way forward for other European nations.

The current figure for installed wind power capacity in Germany (by end 2003) stands at more than 14,600 MW. These turbines can produce enough electricity in a normal wind year to meet 5.9% of demand in a country of 82 million people. If present trends continue, the proportion is expected to reach 10% by 2010.

Wind power in Germany can produce enough electricity in a normal wind year to meet 5.9% of demand in a country of 82 million people.

During 2003 alone more than 1,700 new wind turbines were connected to the grid, representing a capacity of 2,645 MW. This continued the impressive growth seen in Germany since the mid-1990s. The average annual increase in cumulative capacity over the past three years has been 34%.

A major new industry has been established in a country already recognised for its engineering skills. Sales in the sector were expected to have reached € 4.8 billion during 2003.

No other development in the history of the country's electricity industry can compare with this. The German Wind Energy Association contrasts the output from nuclear power after its first ten years of commercial expansion – 6.5 TWh in 1970 – with the output from wind after ten years of government support – more than 11 TWh in 2000.

In the process, a major new industry has been established in a country already recognised for its engineering skills. Most of the wind turbines operating in Germany are now home produced, with companies like Enercon, Vestas Deutschland, Nordex, GE Wind Energy and REpower having built up major manufacturing bases. More than 45,000 people are currently employed by the industry. Sales in the sector were expected to have reached € 4.8 billion during 2003.

Landmark legislation

Following government-sponsored research programmes during the 1980s, the big breakthrough for the German market came in 1991, when the Stromein-speisungsgesetz – Electricity Feed Law (EFL) - was passed by parliament. This landmark legislation guaranteed to all renewable energy producers up to 90% of the domestic sale price of electricity for every kilowatt hour they generated. Based on the argument that clean energy sources need encouragement both to establish a market and to compete with historically subsidised fuels like coal and nuclear, the law has proved both administratively simple and effective in practice.

In 2000 the principle of the EFL was further established through a new Renewable Energy Law. This recognised wind's increasing competitiveness by introducing a decreasing output payment after five years of a turbine's operation. Despite further adaptations in the payments, making inland turbines less attractive to install, the German market continues to expand National policies have also been shadowed by strong regional development plans. In the northern state of Schleswig-Holstein, for example, 34% of electricity demand is now satisfied by wind power. One factor has been the low interest loans available to wind farm developers through the non-profit making Investitionsbank. In the neighbouring, more populated state of Lower Saxony, which has equally strong support policies, wind turbines now satisfy 15.6% of the supply. To progress developments faster, many states have designated certain areas as prime sites for new wind schemes.

Broad ownership

The powerful financial incentives provided both nationally and regionally in Germany have had two other important effects. Firstly, they have enabled wind power to spread far beyond the most obviously windy sites along the North Sea coastline. The result is that even land-locked inland states like Saxony-Anhalt (1,632 MW, 24% of demand) and Brandenburg (1,807 MW, 22% of demand), where wind speeds are much lower, have benefited from the boom. The industry has responded by producing turbines specially adapted to work efficiently at lower wind speed sites.

The second effect has been to open up the ownership and investment potential of wind energy to a wide range of people. Many wind parks have been developed through investment funds in which shares are bought by small businessmen and companies, who in turn benefit from an investment tax rebate. One estimate is that more than 150,000 Germans now hold a stake in a wind energy project, another reason why developments are well supported by local people. In many regions wind power has become an important source of income for farmers and local government.

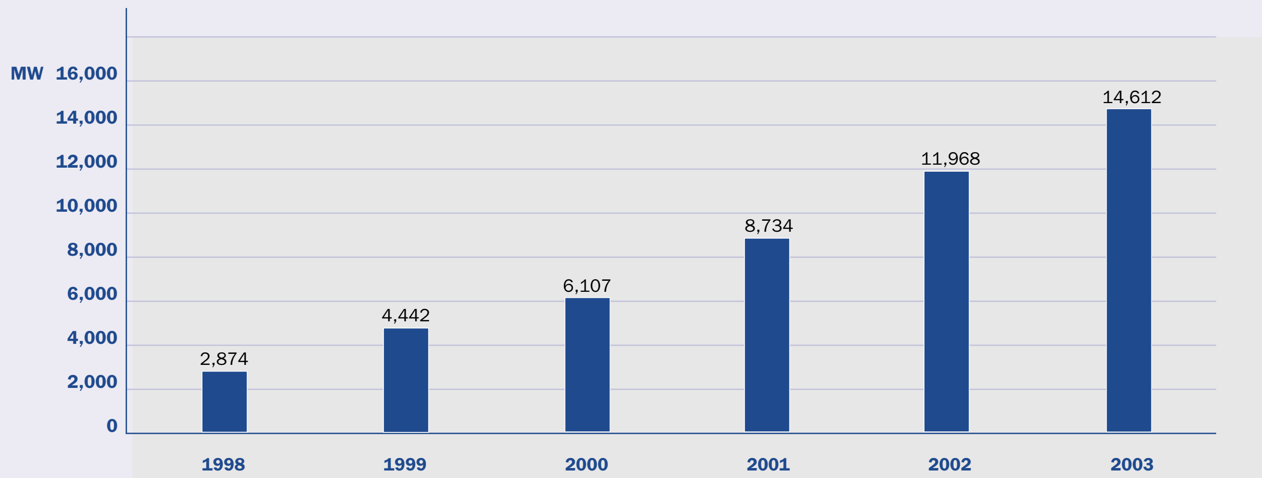
Green policies

Political support for wind power comes from the strong influence wielded by environmentalists, including the Greens, who currently share government with the Social Democrats. Green-Social Democrat coalitions also control a number of individual states. Another important policy decision has been the announced intention to shut down the country's 19 nuclear power stations, presently providing 30% of electricity, within 30 years, at the end of their technical lifetime.

By 2030 according to DEWI wind power could be providing 30% of German electricity demand over half of that total out to sea.

At the same time, the German government has taken up Greenpeace proposals and established a new long term target for wind power to produce at least 25% of the country's electricity by 2025. Much of this will be supplied by offshore wind parks in the North and Baltic Seas and by "re-powering" older machines on existing sites with newer turbines. By 2030 according to DEWI wind power could be providing 30% of German electricity demand from approximately 54,000 MW of capacity, over half of that total out to sea.

Figure 2.5 - Windpower in Germany: Cumulative MW installed



United States – Waking giant

The United States is fast becoming one of the world's leading wind energy markets, following a long lull during the 1990s. There are now utility-scale wind power installations in 30 states, totaling 6,361 MW at the end of 2002. These generate enough electricity to serve more than 1.6 million average US households.

While the US wind industry's long-term prospects remain very bright, owing to the country's enormous wind resource, commercial activity was again staggered at the end of 2003 by expiry of the federal wind energy production tax credit (PTC), a major development incentive. It was the third time in less than five years that the US Congress has allowed the credit to expire, creating serious short-term market instability.

The industry installed a near-record 1,687 MW in 2003, boosting wind energy's five year growth rate to 28%.

With expiry of the credit looming at year's end, the industry installed a near-record 1,687 MW in 2003, boosting wind energy's five year growth rate to 28%. Many analysts and industry executives expect to see double-digit growth for the rest of the decade, although it is likely that 2004 will see a temporary slowdown.

The reliable and affordable cost of wind energy is one of the main factors underpinning wind energy's expansion. This stability allows utilities and merchant power companies to "hedge their bets" against volatility in natural gas prices, and a growing number are including wind in their portfolio. PacifiCorp, for example, a utility serving customers in six western states, plans to develop 1,400 MW of renewable energy as part of 4,000 MW of new power it will seek between 2004 and 2014.

Preliminary economic studies suggested that the optimal scenario was one in which most of the additional power should come from wind. The largest US wind developer is FPL Energy, a subsidiary of Florida Power and Light, a major utility which owns and operates large nuclear and gas plants.

Renewables portfolio standards

Supportive state policies have also helped to create a growing market for wind. In an effort to diversify their energy portfolios, several states have passed legislation to increase the share of renewable sources in their utilities' generation mix. Texas adopted a minimum renewable energy requirement, or renewables portfolio standard (RPS), with great success in 1999. Wind energy installations already exceed 1,200 MW in the Lone Star state.

In New York, it has been estimated that an RPS aiming for 25% renewable generation by 2012 would generate $100 million a year in income, local tax revenue, and jobs to farmers and communities that host wind power generators. Farmers earn income from leasing their "wind rights" and continue to grow crops up to the base of the turbines. The policy will also create thousands of construction jobs. As of February 2004, 14 states had adopted an RPS.

The absence of a stable national policy on wind power is still a major constraint on the American wind energy industry.

The federal production tax credit (PTC) provides a 1.5 cent/kWh credit (adjusted for inflation) for electricity produced from wind technology, and was enacted in 1992 to help "level the playing field" with other energy sources. But although the PTC has been extended twice over the past five years, each time Congress has allowed it to expire before acting, and then has only approved short extensions. This has produced a “boom and bust” cycle, resulting in cancelled projects and laid-off workers, and is a case study in how poorly-applied national policies can slow the growth of an emerging industry.

With the PTC's future duration currently uncertain, a multi-year extension would provide a much-needed stable market signal. Long-term stability in the wind energy market would equally be encouraged by a national renewable energy goal or renewables portfolio standard.

Unlocking transmission barriers

In order to unlock the vast wind energy potential of America's heartland and transport that power to market, it is critical that wind generators be able to gain access to the transmission network on fair terms compared with other generation technologies.

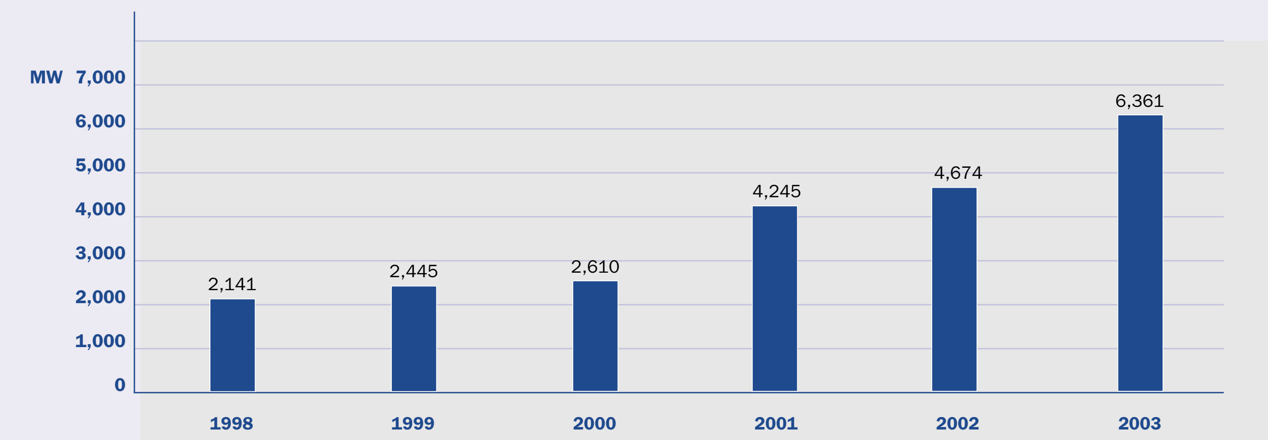
Fortunately, transmission barriers, which have slowed expansion of wind power in many regions of the US, are beginning to recede.

Federal regulators have proposed a dramatic overhaul of the wholesale electricity market structure that includes fair treatment of wind energy in transmission pricing. Among other changes this would eliminate all penalties associated with wind's variable output when that variability does not result in increased costs to the system. However, carrying out these changes will be difficult due to power struggles between federal and state authorities.

Wind development also requires investments in bulk transmission capacity from the rural, sparsely populated but windy regions to markets in major population centres. In Minnesota, for instance, the state has authorised construction of the largest single transmission project in over twenty years specifically to tap the state's powerful winds.

The United States still has far to go before wind power realises its full potential - enough, according to federal studies, to meet more than twice the nation's electricity demand. The state of North Dakota alone has about fifty times the wind resource of Germany. But the pace of wind power development in the US will depend to a large extent on the adoption of steady, supportive policies.

Figure 2.6 - Windpower in the US: Cumulative MW installed



India – Wind leader in Asia

Among countries outside Europe and the United States, India has pioneered the use of wind energy as a vital alternative to its dependence on fossil fuels. The wind leader in Asia, a total of over 400 MW of new capacity was commissioned during 2003 – the highest ever installation level achieved in a single year. India is now poised to leap forward again with a new generation of more powerful wind farms.

With a total capacity of 2,125 MW, India is maintaining its position as the fifth largest producer of wind power in the world.. Even so, given the country's vast potential, especially in the windy coastal regions, progress could be much faster than this.

The wind leader in Asia, a total of over 400 MW of new capacity was commissioned during 2003 – the highest ever installation level achieved in a single year.

The original impetus to develop wind energy in India came in the early 1980s from the then Department of Non-Conventional Energy Sources, now known as the Ministry of Non-Conventional Energy Sources (MNES). Its purpose was to encourage a diversification of fuel sources away from the growing demand for coal, oil and gas required by the country's rapid economic growth. The total potential of wind power in India is around 45,000 MW.

Monitoring stations

In order to pinpoint the best resources, MNES established a country-wide network of wind speed measurement stations. A number of financial incentives have also been provided for investors, including depreciation of capital costs and exemptions from excise duties and sales tax. An 80% tax rebate on the income from power generation during the first ten years of operation is available for wind power projects. Individual states have their own incentive schemes, including capital cost subsidies.

One result of these incentives has been to encourage industrial companies and businesses to invest in wind power. An important attraction is that owning a wind turbine assures them of a power supply to their factory or business in a country where power cuts are common. Wind farms in India therefore often consist of clusters of individually owned generators.

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 involved a mixture of encouragement to larger private and public sector enterprises to invest in the sector and the parallel stimulation of an indigenous manufacturing base. Some companies now produce up to 80% of components for their turbines in India, rather than importing them from the major European manufacturers. This has resulted both in more cost effective production and in creating additional local employment.

One result of these incentives has been to encourage industrial companies and businesses to invest in wind power.

Manufacturing base

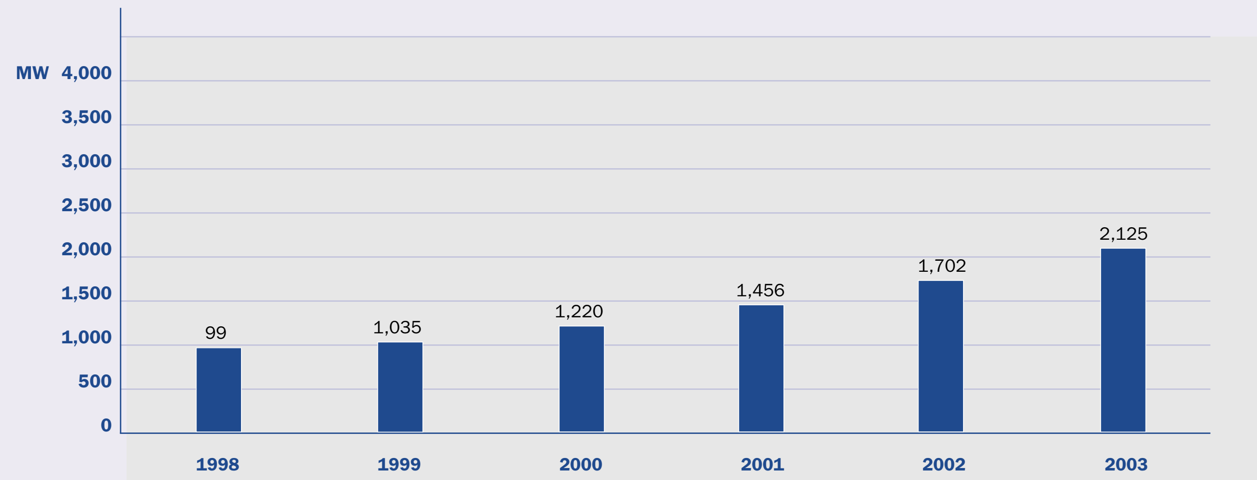
Around ten wind turbine manufacturers are currently offering their products on the Indian market. The major players are Vestas RRB, Suzlon, Enercon, GE Wind Energy and Gamesa.

The geographical spread of wind power in India has so far been concentrated in a few regions, especially the southern state of Tamil Nadu, which accounts for roughly half of all installations.

Over the past few years, both the government and the wind power industry have succeeded in injecting greater stability into the Indian market.

This is beginning to change, with other states like Maharashtra, Gujarat, Rajasthan and Andhra Pradesh catching up. The Indian government envisages a capacity addition of around 5,000 MW by 2012, reflecting a yearly installation of 500-600 MW.

Figure 2.7 - Windpower in India: Cumulative MW installed



Denmark – Commercial success

Denmark's wind power manufacturing industry is a major commercial success story. From a standing start in the 1980s to a turnover of more than € 3 billion, the wind sector has grown faster than any other business sector in Denmark and is bigger than the cement or steel industries Danish wind turbines dominate the global market, and the country has forged itself a position at the head of the fastest growing energy source in the world.

Over the past 15 years the Danish wind turbine industry has grown into one of the heavyweights in machinery manufacturing. Alongside the two major turbine manufacturers - Vestas and Bonus - there are a score of large component companies and dozens of smaller suppliers. From a few hundred workers in 1981 the industry now provides jobs for over 20,000 people in Denmark – more than the whole electricity sector – and further thousands in manufacture and installation around the world.

From a few hundred workers in 1981 the industry now provides jobs for over 20,000 people in Denmark – more than the whole electricity sector.

The past decade in particular has seen a dramatic increase in the production capacity of Danish turbine manufacturers. Annual output, mainly for export around the world, has increased from 368 MW in 1994 to over 3,200MW in 2003. Despite the emergence of competing manufacturing countries, 40% of the wind turbine capacity being installed globally today is of Danish origin.

Government commitments

One reason for the Danish wind industry's success is the commitment from successive governments to a series of national energy plans aimed at reducing dependency on imported fuel, improving the environment and moving towards greater sustainability. Nuclear power has been rejected as an option and there is firm commitment to phase out coal completely as a fuel in power stations. No new coal-fired capacity will be installed. These domestic policies have in turn helped spawn a thriving export industry for wind turbines.

In 1981, the first Danish government energy plan envisaged that 10% of electricity consumption should be met with wind power by 2000. The government then expected that this could be reached by installing 60,000 wind turbines with an average capacity of 15 kW. The 10% target was in fact reached three years early with less than 5,000 turbines with an average size of 230 kW. In 2004, wind power will account for more than 20% of Danish electricity consumption.

Following a new agreement in parliament adding a total of 750 MW to existing installed capacity will, by 2010, increase the proportion to more than 25%. This is a higher proportion than any other country in the world.

By 2030 wind is expected to be supplying up to half of the country's electricity and a third of its total energy. To reach this level, a capacity in excess of 5,500 MW will need to be installed, a good proportion of it offshore.

Engineering innovation

Having already achieved more than 20% penetration, fresh challenges have emerged for wind power in Denmark, especially in the context of a new liberalised EU internal electricity market. The Danish authorities, transmission system operators, power companies and manufacturers are now working closely to find new market based, as well as technical, solutions for introducing even more wind power into the system.

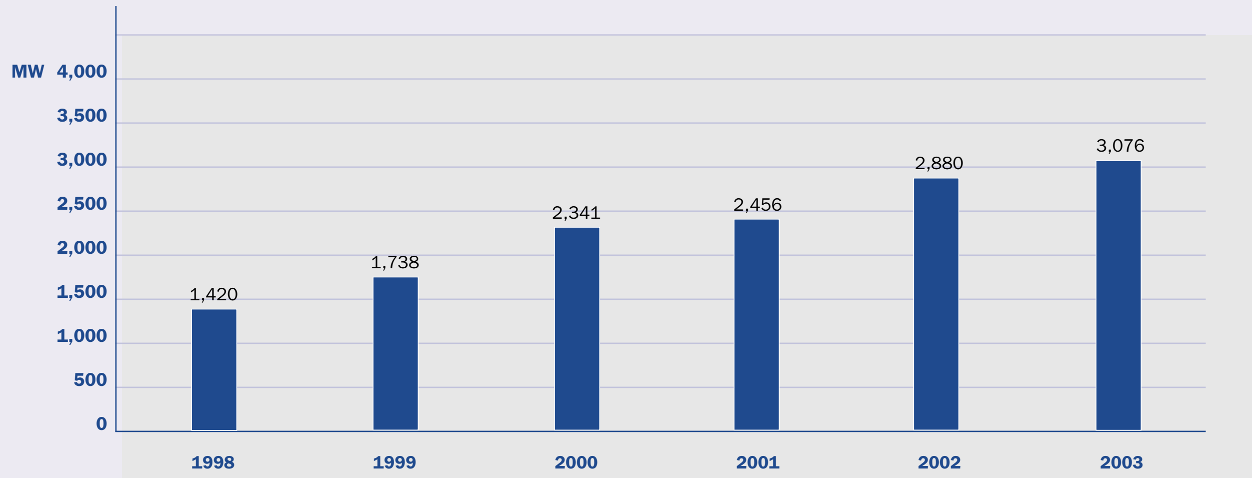
An important element in the Danish success story has always been technological innovation. At a time in the 1980s when wind turbine design was locked in a "biggest is best" approach, the Danes went back to basics, using skills partly from agricultural engineering to construct smaller, more flexible machines. From the outset the focus was customer-oriented and on making machines that produce electricity at the lowest possible cost per unit. The familiar three-bladed design with the rotor and blades set upwind (on the windy side of the tower) is now the classic concept against which all others are judged.

More recently, Denmark has led the world in the development of proposals to build large wind farms of turbines in its coastal waters. The first of these, at Horns Rev in the North Sea (160 MW) was built during 2002; the second, off the coast from Nysted at Roedsand Banke (158 MW), was completed in 2003. In 2007 and 2008 two new offshore wind farms of at least 200 MW will be completed. A succession of further large offshore wind farms is expected to be announced in the coming years.

Another feature of Danish development is that historically most of the turbines erected have been owned by individuals or specially established wind co-operatives. Over 150,000 Danish families now either own themselves, or have shares in, wind energy schemes. Even the large 40 MW Middelgrunden wind farm in the sea just outside Copenhagen is partly owned by a co-operative with 8,500 members.

One reason for the Danish wind industry's success is the commitment from successive governments to a series of national energy plans.

Figure 2.8 - Windpower in Denmark: Cumulative MW installed



SPAIN

Spain – Southern Europe's powerhouse

The Spanish wind energy industry has forged ahead in recent years more successfully than any other in southern Europe.

A sparsely populated countryside combined with strong government policies have together made Spain a powerhouse for both manufacture and development.

In 1993 just 52 MW of wind energy capacity was operating in the Spanish landscape, much of that concentrated in the windy district of Tarifa facing south towards Africa. By the end of 2001 the total had mushroomed to 3,550 MW, almost 30% installed in that one year alone. During 2003, new capacity increased yet again to reach 6,420 MW, maintaining Spain's position as No.2 wind nation in the world.

A crucial impetus for wind development in Spain has come from the bottom up, from regional governments keen to see factories built and local jobs created.

As importantly, this development is now taking place across many regions, from the jagged Atlantic coastline in the northwest to the mountains of Navarre, in the shadow of the Pyrenees, to the sun-drenched plains of Castilla la Mancha. Around 75% of the wind turbines installed so far have come from three Spanish manufacturers – Gamesa, Made and Ecotècnia.

National support

The origins of Spain's success can be found in a mixture of factors – a good wind regime liberally spread across a land mass over ten times as large as Denmark, a national support scheme which is strong and straightforward and a focused regional development policy.

The first piece of legislation to provide substantial backing for renewable energy was introduced in 1994. This obliged all electricity distribution companies to pay a guaranteed premium price for green power, operating in a similar way to the Electricity Feed Law in Germany. Political and legal commitment to renewables was reaffirmed in 1997 by a new Electricity Act designed to bring the whole electricity system into harmony with the steady opening up of European power markets to full competition.

The 1997 law enshrined for the first time an objective for at least 12% of the country's energy to come from renewable sources by 2010, in line with the European Union's target. To help achieve this, the law says that renewable energy producers are entitled to be paid the wholesale electricity market price, plus a premium or incentive, so that the total amount paid per unit of electricity produced ranges between 80% and 90% of the average retail price. During 2003, wind energy producers were paid a final average price of 6.38 € cents/kWh, keeping wind a relatively attractive investment.

Provincial plans

Whilst national laws are important, a crucial impetus for wind development in Spain has come from the bottom up, from regional governments keen to see factories built and local jobs created. The busiest regions have so far been Galicia, Castilla la Mancha, Aragon, Castilla y Leon and Navarre.

The incentive is simple: companies who want to develop the region's wind resource must ensure that the investment they make puts money into the local economy and sources as much of its hardware as possible from local manufacturers.

A pioneer of this approach has been Galicia, the northwestern region whose coastline juts out into the Atlantic Ocean. The new regional government's plan is to install a capacity of 4,000 MW by 2010, enough to satisfy about 55% of the province's power demand. To achieve this, a shortlist of promoting companies, including power utilities, independent developers and turbine manufacturers, have been granted concessions to develop set quotas of capacity within 140 specified "areas of investigation". The total investment value could reach € 3.3 billion.

Galicia's aim is that at least 70% of this investment should be made within its borders, creating thousands of jobs. As a result, factories making blades, components and complete turbines have sprouted up around the province. By the end of 2003, the region had already achieved 1,579 MW, almost 40% of the target. The mountainous province of Navarre is relatively even more ambitious. During 2003 it reached 717 MW, already well on the way to its target for 900 MW by 2010. Together with other green power sources, this would make it completely self-sufficient from renewable energy alone. Most of the wind farms in Navarre have been built by EHN, the leading independent Spanish wind developer.

Other provinces have similar industrial development plans, with at least 13,000 MW of wind capacity planned to be constructed across 14 regions by 2011. One of the last wind energy provincial plans has been adopted by Valencia, with the goal of developing more that 2,000 MW. Environmental concerns have been given a different emphasis in different regions. Navarra included environmental impact assessment as a key aspect in site selection right from the start, thus preventing local conflicts. Other provinces have not fully dealt with these issues, leading to conflicts with organisations and residents. If such conflicts had been prevented beforehand, wind power would have been developed in Spain to an even greater extent and with even more public acceptance.

Financial confidence

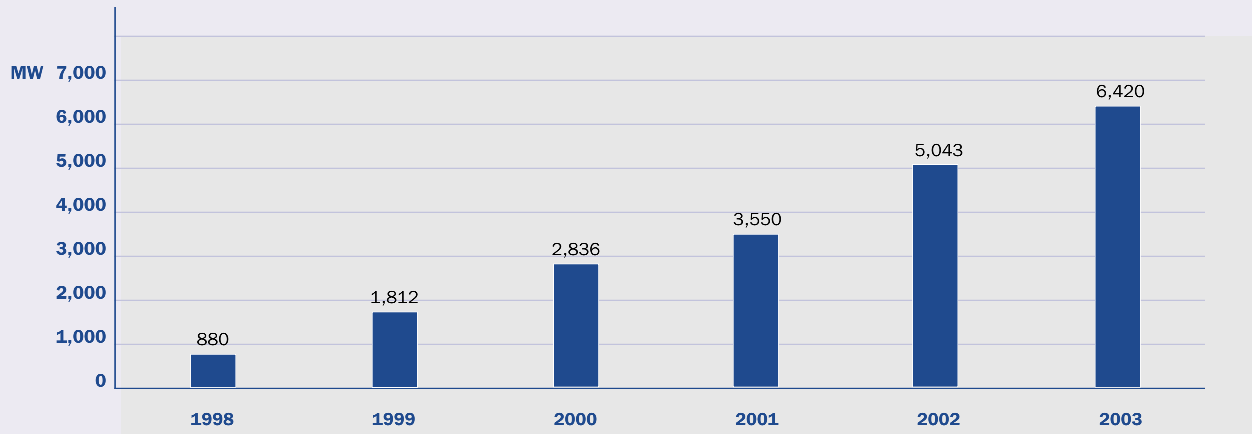
The Spanish model of development has also been different from other European countries. Most wind farms constructed have been large, with investment coming from consortia linking independent developers, power utilities, turbine manufacturers, financial institutions and regional governments.

One important feature of the Spanish market is the confident approach taken by financial institutions.

Although the national law does not specify how long the present system of price support will last, major Spanish banks are relatively happy to lend on wind schemes due to the wide political consensus for renewables and the fact that the Electricity Act links the amount of the premiums to the achievement of the 12% goal by 2010.

The major technical problem has been the poor grid infrastructure in some parts of the country, necessitating the building of many kilometres of new power lines to connect up wind farms. This problem is now being solved partly by agreements to share the cost of grid strengthening between groups of developers who will all ultimately benefit from the improvement. However, many developers have still encountered substantial difficulties in reaching an agreement with the grid operator. Utilities in many cases have been abusing their dominant position to try to avoid or delay access to their networks by wind projects, especially those coming from independent operators. The province of Aragon has introduced a binding system to overcome the difficulty of access to the grid.

Figure 2.9 - Windpower in Spain: Cumulative MW installed



OFFSHORE

Offshore – The new frontier

Offshore sites are the new frontier for the international wind industry. In northern Europe alone many thousands of megawatts of capacity are planned off the coasts of a dozen countries. Eventually, this new offshore business could challenge the oil and gas producers on their home territory.

The main motivation for going offshore is the considerably higher – and more predictable – wind speeds to be found out at sea. With average speeds well above 8 metres per second at a height of 60 metres, most of the marine sites being considered in northern European waters are expected to deliver between 20% and 40% more energy than good shoreline sites. A second advantage is that placing wind farms offshore reduces their impact on the landscape, with many of the developments now being planned virtually invisible from the shore.

Individual turbines with capacities up to 5 MW are being manufactured to meet the offshore demand.

It is currently more expensive to build wind turbines out at sea. Offshore wind farms require strong foundations which must be firmly lodged in the sea bed. Many kilometres of cabling is required to bring their power back to shore, and both construction and maintenance work must be carried out in reasonable weather conditions using specialist boats and equipment. Nonetheless, as demand increases the industry is beginning to substitute cheaper standard components and facilities, driving down electricity costs, as has happened on land.

The goal of the German Government is to see up to 25,000 MW of wind parks in the sea by 2025-30. This would satisfy roughly 15% of the country's (1998) electricity demand.

Larger projects

Part of the wind industry's solution has been to go for increasingly large projects which can benefit from economies of scale and reduce the unit production cost. Some of those being planned off the coasts of the UK envisage total capacities of more than 1,000 MW. At the same time, individual turbines with capacities up to 5 MW - and with special features to withstand the more severe weather out at sea - are being manufactured to meet the offshore demand. A large number of specialist companies have also entered the construction, installation and servicing market.

At the cutting edge in the offshore race has been Denmark, which already accounts for most of the current installed capacity of 529 MW. In 2002, the first large offshore wind farm was constructed at Horns Rev, between 14 and 20 kilometres from the Danish North Sea coast. With eighty 2 MW turbines this has a capacity of 160 MW, enough to satisfy 2% of Denmark's demand. A similarly sized development was installed at Nysted in the Baltic during 2003. Two new offshore wind farms of at least 200 MW each are being commissioned for completion by 2007 and 2008.

Danish plans are likely to be matched soon, however, by those of the UK. Overseen by the Crown Estate, which owns the rights to exploration in the seas round Britain, a first round of bidding resulted in rights being granted to consortia of companies to develop 15 sites with up to 600 turbines. The first outcome of this, the 60 MW North Hoyle wind farm, was opened off the coast of north Wales in 2003, with a second 60 MW development now under construction in the North Sea.

In a second bidding round, the results of which were announced at the end of 2003, a series of far larger projects were proposed. Fifteen wind farms with a total capacity of up to 7,200 MW are now planned in three strategic sea areas identified by the UK government off the country's eastern and western coasts. The largest, in the Greater Wash area off eastern England, would alone have a capacity of 1,200 MW. When completed, these "second round" projects could provide enough power for four million homes, or one in six UK households, according to calculations by the British Wind Energy Association.

Ambitious plans

Germany also has extremely ambitious offshore plans, with more than 20 companies and development consortia proposing over 65,000 MW of offshore capacity. In order to avoid coastal conservation zones, many of these are set at distances of up to 60 kilometres from the shore, and in water depths of up to 35 metres. Construction permits from the national maritime authority have already been granted to six projects in the North and Baltic Seas with a total capacity of up 1,200 MW, depending on the turbine size chosen, although some depend on agreement over the location of undersea cables bringing power back to shore. None has yet started construction, however.

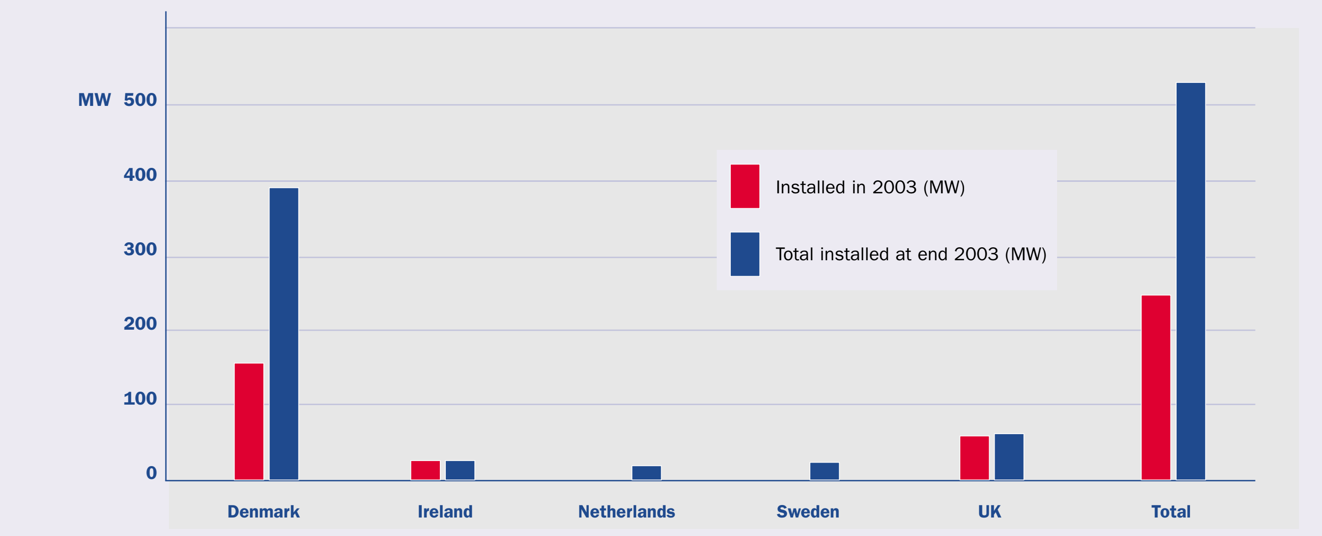
The goal of the German Government is to see up to 25,000 MW of wind parks in the sea by 2025-30. This would satisfy roughly 15% of the country's (1998) electricity demand. Under the Renewable Energy Law, offshore schemes started up before 2008 are also eligible to receive the maximum guaranteed "feed-in" tariff for their output over twelve years, as opposed to the normal five for on shore projects.

Other European countries with advanced offshore plans include the Netherlands, Belgium, Ireland and Sweden. Ireland saw the first 25MW pilot phase of the 500 MW Arklow Bank wind farm built in 2003.

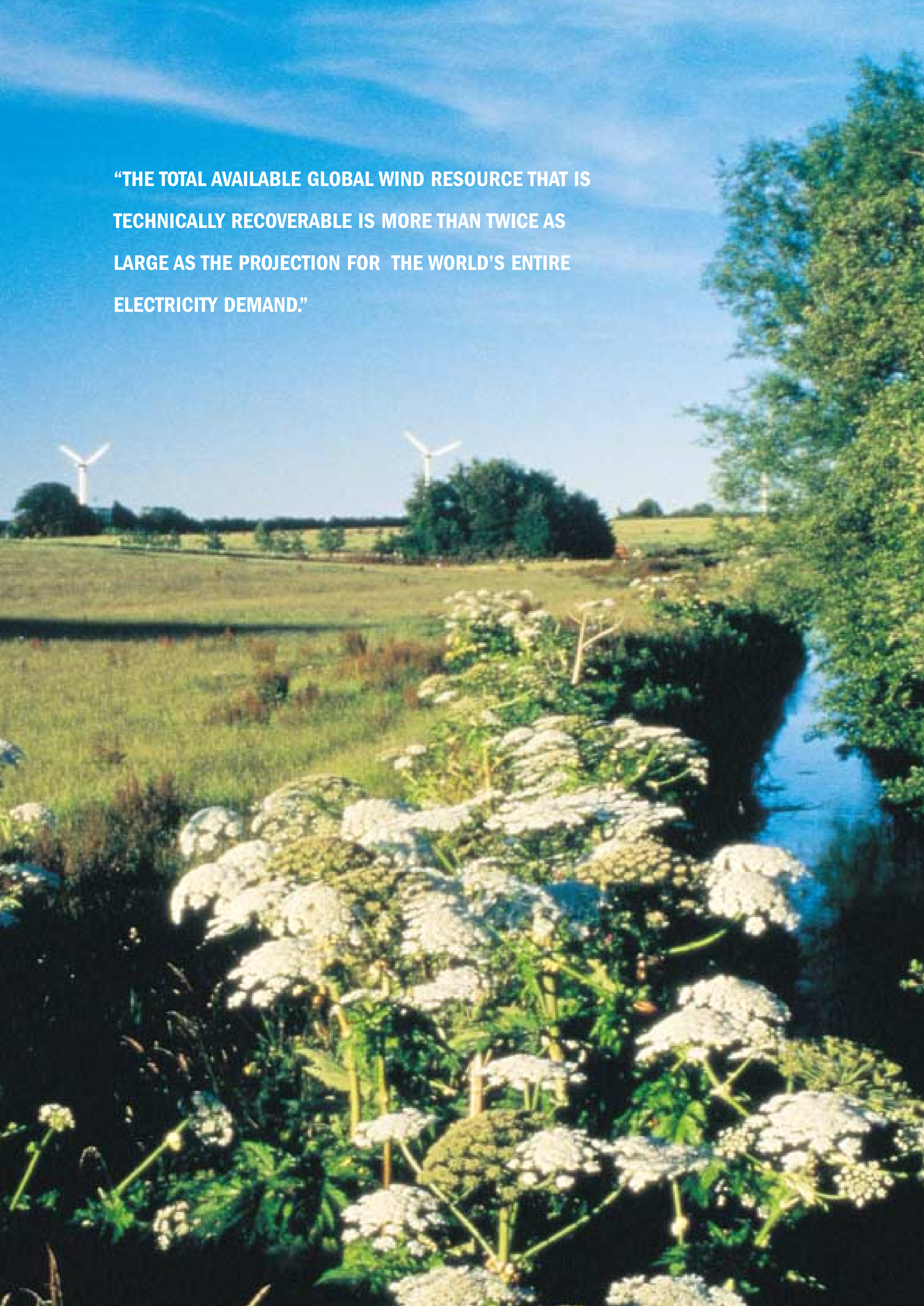
Eventually, it is estimated that a sea area of 150,000 square kilometres with a water depth of less than 35 metres could be available for offshore schemes. This would provide enough power to satisfy all of Europe's current demand.

In the Netherlands, the E-Connection consortium has plans to start construction soon on its 120 MW scheme, whilst the C-Power consortium is also poised to break ground on its 2-300 MW project off the Belgian coast. Sweden has given approval for its largest scheme so far – 48 turbines in the Øresund strait at the entrance to the Baltic Sea. With the longer lead times required for offshore developments, including detailed monitoring of fauna and flora, the period during which these plans are expected to seriously take off is from 2005 onwards. Eventually, it is estimated that a sea area of 150,000 square kilometres with a water depth of less than 35 metres could be available for offshore schemes. This would provide enough power to satisfy all of Europe's current demand.

Figure 2.10 - Europe's offshore wind capacity



	Denmark	Ireland	Netherlands	Sweden	UK	Total
Installed in 2003	165	25	0	0	60	250
Total installed at end 2003	397	25	18.8	23.3	64	528.1



"THE TOTAL AVAILABLE GLOBAL WIND RESOURCE THAT IS TECHNICALLY RECOVERABLE IS MORE THAN TWICE AS LARGE AS THE PROJECTION FOR THE WORLD'S ENTIRE ELECTRICITY DEMAND."

3 - THE WORLD'S WIND RESOURCES AND DEMAND FOR ELECTRICITY

If wind power is to expand substantially beyond its present level around the world, then it is essential to understand clearly whether the natural resources are available to achieve these ambitious targets. In practice, a lack of resource is unlikely to be a limiting factor in the utilisation of wind power for electricity production. The world's wind resources are estimated to be 53,000 TWh/year, whilst the world's electricity consumption is predicted to rise to less than half that by 2020.

3 - THE WORLD'S WIND RESOURCES AND DEMAND FOR ELECTRICITY

Is there enough wind?

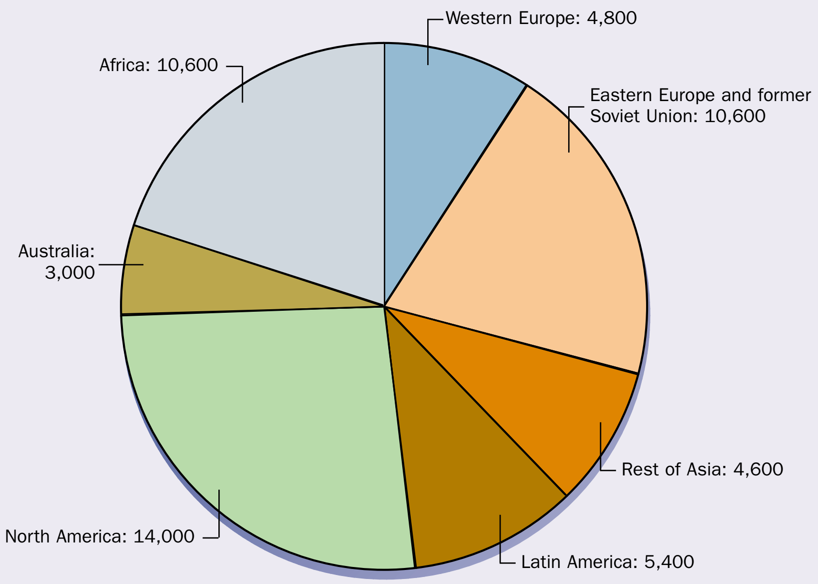
If wind power is to expand substantially beyond its present level around the world, then it is essential to understand clearly whether the natural resources are available to achieve these ambitious targets. Research to date shows that the world's wind resources are huge, and distributed over almost all regions and countries. Several assessments of their magnitude have been carried out.

The methodology used in such studies is to assess the square kilometres of land available with average annual wind speeds of more than 5-5.5 metres per second (m/sec) at a height of ten metres above ground level. This average speed is recognised as feasible for the exploitation of wind power at today's generating costs. The total available resource is then reduced by 90% or more in order to account for constraints on the use of land. This could include other human activities or infrastructure or a high population density. At the end of this process the wind resource is converted into Terawatt hours (TWh) of electricity produced per year, based on the "state of the art" performance of commercial wind turbines available on the market.

Experience from countries where wind power development is already established also shows that when more detailed assessments are carried out, more potential sites have in fact proved to be available than was expected. A good example of this has been the exploitation of less obviously windy inland sites in Germany. In other cases the local topography creates exceptionally good conditions, such as in the mountain passes of California. It is therefore likely that the total global resource will be even higher than indicated by assessments based on regional climatic observations. Finally, it is certain that further improvements in the technology will extend the potential for utilising wind speeds of less than 5 m/sec.

What is clear is that a lack of resource is unlikely ever to be a limiting factor in the utilisation of wind power for electricity production. The world's wind resources are estimated to be 53,000 TWh/year, whilst the world's electricity consumption is predicted to rise to 25,579 TWh/year by 2020. The total available global wind resource that is technically recoverable is therefore more than twice as large as the projection for the world's entire electricity demand.

Figure 3.1 - The world's wind resources, TWh (World total 53,000TWh)



Source: "Renewable Energy sources for Fuels and Electricity", Chapter 4, Wind Energy: Resources, Systems and Regional Strategies, Michael Grubb and Neils Meyer, Island Press, Washington DC, 1994

On land wind resources in Europe

The wind energy potential of OECD countries was examined in a 1993 Utrecht University study by Wijk and Coelingh. This was a conservative scenario that restricted the "exploitable resource" considerably compared with the Grubb & Meyer study used in Figure 3-1. The reason for this was to take into account Europe's high population density and large infrastructure elements such as roads, airports and railways.

Table 3.1 - Technical potential for onshore wind power in EU-15 plus Norway

Country	Total electricity consumption (TWh) in 2001*	Technical wind potential (TWh/year)**
Austria	60.97	3
Belgium	85.04	5
Denmark	35.15	10
Finland	81.38	7
France	450.83	85
Germany	560.42	24
United Kingdom	364.01	114
Greece	51.25	44
Ireland	22.8	44
Italy	308.03	69
Luxembourg	6.72	0
Netherlands	106.83	7
Portugal	42.69	15
Spain	220.72	86
Sweden	142.45	41
Norway	119.57	76
Total	**2,658.86**	**630**

* *IEA (2003): Key World Energy Statistics*
** *BTM (1993): Technical Wind Potential from University of Utrecht Study, Wijk and Coelingh*

In Table 3.1, the total technical wind energy potential is shown for each country alongside the amount that it would have left over after a notional 20% "penetration limit" had been set on the national grid network (see "Electricity Grid Limitations" below). One reason for doing such calculations in Europe is that all the national grids are interconnected, enabling the export of electricity from one country to another.

It is also worth emphasising that the Utrecht University study was carried out when the average size of new wind turbine was 250-300 kW. It is obvious that with upscaling since then to an average size closer to 1,000 kW, and with turbine rotors at a height of up to 100 metres instead of 30, a considerably higher annual yield will result. The study is therefore conservative in the context of today's "state of the art" technology. Another important observation is that when more detailed assessments are carried out for a specific region, they tend to reveal much higher potentials. Detailed studies by the Ministry of Economic Affairs in Germany, for example, have shown that the onshore wind potential is 124 TWh (an installed capacity of 64,000 MW), five times higher than the 24 TWh given in Table 3.1.

Overall, the figures in Table 3.1 indicate that there is an exploitable potential for on land wind power in Europe of more than 600 TWh/year. Some countries can also produce much more electricity from the wind than they could use internally. This presents a challenge to the developing cross-border European power market.

Offshore wind resources in Europe

There is an enormous additional wind resource to be found in the seas around the coastline of Europe. Several European countries, led by Denmark, are already seeing the first large scale offshore wind farms built in their territorial waters. A study led by consultants Garrad Hassan and Germanischer Lloyd, carried out under the European Union's Joule research programme in 1993-5, estimated an offshore wind potential in the EU of 3,028 TWh. Even though Norway and Sweden were not included, this figure far exceeded the total electricity consumption within the Union's 15 members in 1997.

There is an enormous additional wind resource to be found in the seas around the coastline of Europe.

Using a geographical database developed by Garrad Hassan, this study assumed that the wind resource can be used out to a water depth of 40 m and up to 30 km from land. A reference wind turbine of 6 MW capacity and 100 m diameter rotor was used, with the spacing between turbines set at one kilometre.

For the purposes of this report, BTM Consult have taken a very conservative approach to the potential shown in

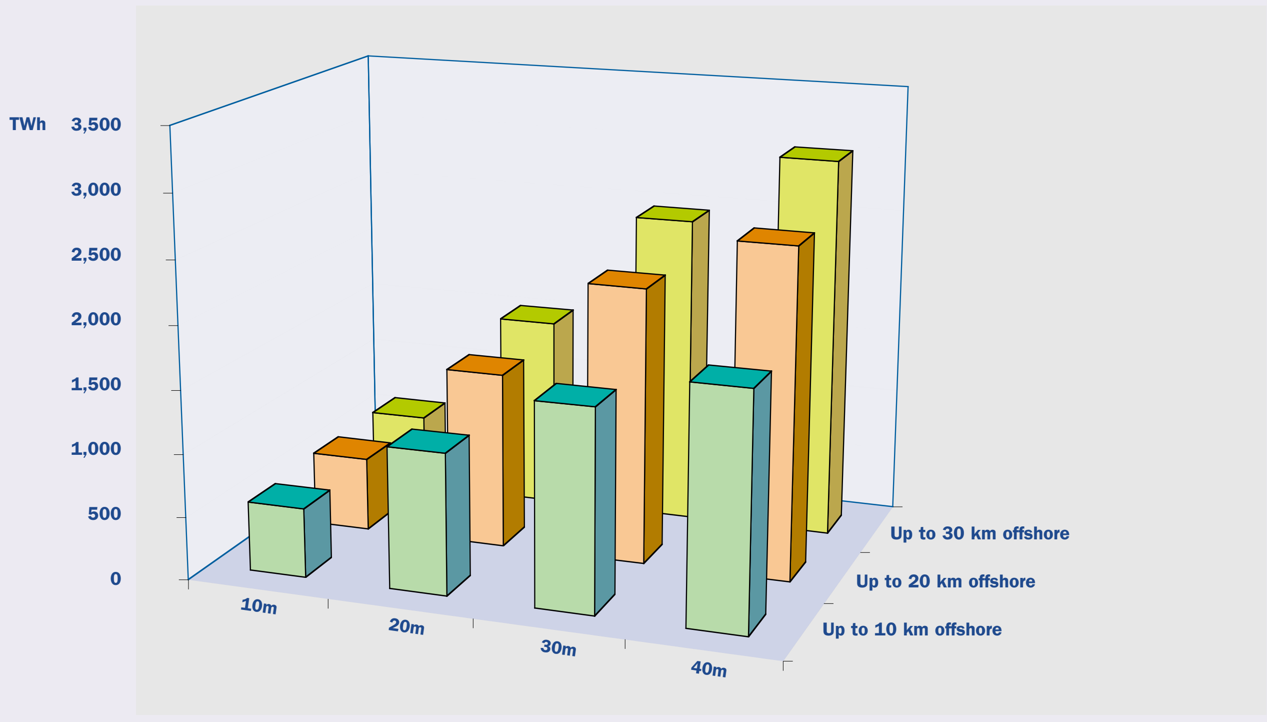
Figure 3.2 in order to come up with a likely "exploitable resource" available for development within the next two to three decades, given anticipated technology advances.

Reductions to the figures in the offshore resources study have been made using the following criteria:

- Because of the current expense involved, particularly in foundation work, all water depths over 20 m have been excluded. This is a conservative assumption given that a number of projects are already planned in greater water depths (see "Offshore – The New Frontier", above). Sites less than 10 km from the shore have been reduced by 90% to be sensitive to visual concerns.
- The resource within the range 10-20 km from the shore has been reduced by half in order to allow for potential visual restrictions and adequate spacing between wind farms, whilst the 20-30 km resource has also been reduced by 50% on the assumption that the expense of lengthy power cable connections will deter smaller developers.

Even taking all these reductions into account, the final figure for European offshore wind potential amounts to 313.6 TWh, about 10% of the gross potential identified in the offshore study. This is still equal to half the potential on land in Europe.

Figure 3.2 - Offshore wind resources in Europe (electricity production in TWh/year)



Water depth	Up to 10 km offshore	Up to 20 km offshore	Up to 30 km offshore
10m	551	587	596
20m	1,121	1,402	1,523
30m	1,597	2,192	2,463
40m	1,852	2,615	3,028

Source: "Study of Offshore Wind Energy in the EC", Garrad Hassan & Germanischer Lloyd, 1995.

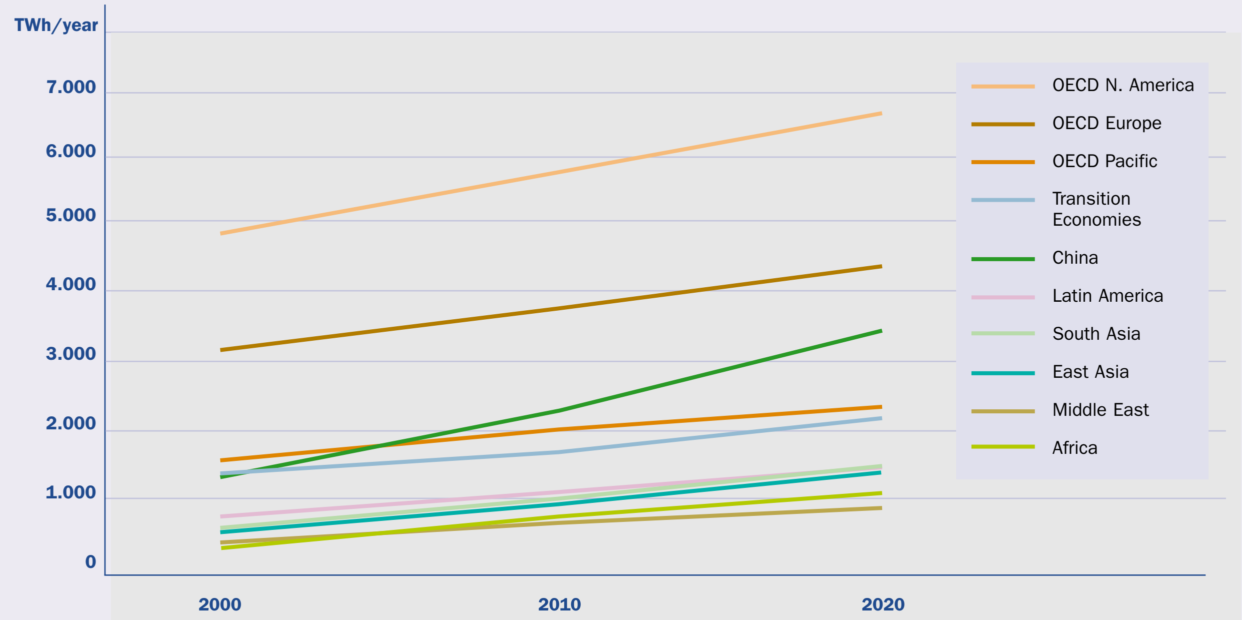
The combined figure for both land and sea, taking into account only the most feasible offshore sites, leaves Europe with a potential resource of some 940 TWh – enough to meet 21% of anticipated electricity demand by 2020. Most importantly, since only 10% of the gross potential has been accounted for, improved technology and cheaper foundation techniques are likely to make it easy to extend the offshore contribution by a significant amount.

Future demand for electricity

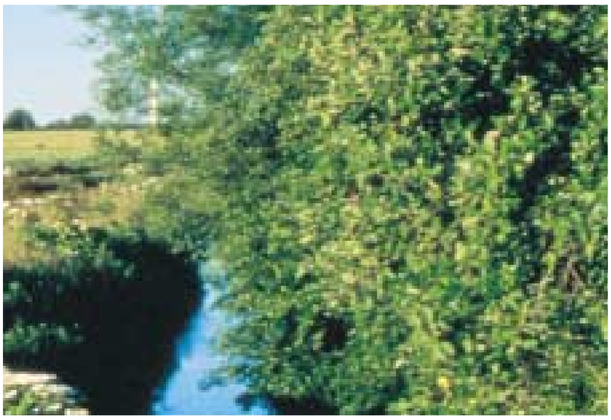
Future demand for electricity is assessed from time to time by international organisations, including the World Energy Council and the International Energy Agency (IEA). This study is based on the latest projections for worldwide electricity demand contained in the IEA report "World Energy Outlook 2002". This shows that by 2020 global power consumption will have reached an annual level of 25,578 TWh, a 63% increase over the 2002 figure. By the early 2030s, world demand will have doubled.

If wind power is enabled to achieve the 12% penetration outlined in this scenario, this would represent almost 20% of current world electricity demand.

Figure 3.3 - Projections of future electricity demand by region (IEA)



Region	2000 (TWh/year)	% of total	2010 (TWh/year)	% of total	2020 (TWh/year)	% of total	Average growth (TWh/year) (% p.a.)
OECD N. America	4,813	31.3	5,758	28.7	6,702	26.2	1.7%
OECD Europe	3,164	20.6	3,763	18.8	4,339	17.0	1.6%
OECD Pacific	1,622	10.5	2,003	10.0	2,317	9.1	1.8%
Transition Economies	1,484	9.6	1,765	8.8	2,238	8.7	1.8%
China	1,387	9.0	2,282	11.4	3,461	13.5	4.7%
Latin America	804	5.2	1,135	5.7	1,566	6.1	3.4%
South Asia	635	4.1	1,001	5.0	1,505	5.9	4.4%
East Asia	585	3.8	970	4.8	1,461	5.7	4.7%
Middle East	462	3.0	675	3.4	899	3.5	3.4%
Africa	435	2.8	684	3.4	1,091	4.3	4.7%
World	**15,391**	**100.0**	**20,036**	**100.0**	**25,579**	**100.0**	**2.6%**



Although the IEA projection for 2020 has been slightly reduced from the organisation's previous (2000) assessment, it is possible that more rational use of electricity will further limit the growth in demand. Whereas earlier IEA assessments in the 1990s employed two scenarios, including an "Energy Savings Case", these were subsequently amalgamated into a single "Business as Usual" scenario - clearly reflecting the cautiousness of the IEA over the world community's future efforts to reduce electricity consumption.

Nonetheless, the lower projected future electricity consumption in World Energy Outlook 2002 enabled us to show that with the same amount of wind electricity, the relative proportion of wind power would increase – one factor behind the increase from 10% of world demand in Wind Force 10 (1999) to the newer projection of 12% in Wind Force 12.

Figure 3.3 hows projected future electricity demand according to the IEA's 2002 assessment broken down by regions of the world. This is important in assessing what contribution wind power needs to make in each region. Table 3.2 shows that in all regions of the world there is an excess of wind resource over what would be needed to achieve a 20% contribution to electricity supply by 2020. Table 3.3 shows how much wind energy generation will be required if the technology is to grow fast enough to satisfy 20% of world power demand within the next 40 years.

It is worth bearing in mind that if wind power is enabled to achieve the 12% penetration outlined in this scenario, it would represent almost 20% of current world electricity demand, highlighting the significant additional benefits of wind power if consumption does not increase as expected.

Table 3.2 - Available wind resource and future world electricity demand

Region	OECD Europe	OECD N. America	OECD Pacific	Latin America	East Asia	South Asia	China	Middle East	Transition Economies	Africa	World
Future estimated electricity use (TWh/year)	4,339	6,702	2,317	1,566	1,461	1,505	3,461	899	2,238	1,091	**25,579**
Available wind resource (TWh/year)	943	14,000	3,600	5,400	4,600	4,600	4,600	n/a	10,600	10,600	**49,743**

Electricity grid limitations

The quantity of wind-powered electricity which can be readily integrated into a country or region's electricity grid depends mainly on the system's ability to respond to fluctuations in supply. Any assessment must therefore include data about the extent of output from other power station suppliers, their ability to regulate their supply, and the consumption pattern in the system, particularly variations in the load over a daily and annual timescale. Various assessments involving modern European grids have shown that no technical problems will occur by running wind capacity together with the grid system up to a penetration level of 20%.

Table 3.3 - Projected electricity consumption and wind electricity output (IEA)

Consumption growth rate	Year	Global TWh	Wind TWh	Wind penetration %
	2003	16,666	84,7	0.51%
	2004	17,110	106,7	0.62%
	2005	17,567	134,1	0.76%
2.67%	2006	18,035	175,3	0.97%
	2007	18,516	220,0	1.19%
	2008	19,010	275,7	1.45%
	2009	19,517	345,4	1.77%
	2010	**20,037**	**432,6**	**2.16%**
	2011	20,532	537,1	2.62%
	2012	21,040	742,1	3.53%
	2013	21,560	910,7	4.22%
	2014	22,093	1,113.1	5.04%
2.47%	2015	22,639	1,345.8	5.94%
	2016	23,198	1,613.5	6.96%
	2017	23,772	1,921.2	8.08%
	2018	24,359	2,275.2	9.34%
	2019	24,961	2,664.5	10.67%
	2020	**25,578**	**3,053.8**	**11.94%**
	2021	26,118	3,443.1	13.18%
	2022	26,670	3,832.5	14.37%
	2023	27,233	4,221.8	15.50%
	2024	27,809	4,611.1	16.58%
2.11%	2025	28,396	5,000.5	17.61%
	2026	28,996	5,349.8	18.45%
	2027	29,608	5,689.2	19.21%
	2028	30,234	6,016.0	19.90%
	2029	30,872	6,327.3	20.50%
	2030	**31,524**	**6,619.0**	**21.00%**
	2031	31,997	6,891.3	21.54%
	2032	32,477	7,140.0	21.98%
	2033	32,964	7,360.7	22.33%
	2034	33,459	7,547.7	22.56%
1.50%	2035	33,961	7,704.3	22.69%
	2036	34,470	8,385.0	24.33%
	2037	34,987	8,472.4	24.22%
	2038	35,512	8,510.3	23.96%
	2039	36,045	8,510.3	23.61%
	2040	**36,585**	**8,510.3**	**23.26%**
1.50%	2041	37,134	8,510.3	22.92%
	2042	37,691	8,510.3	22.58%

In Denmark, peak levels in excess of 50% wind power have been successfully incorporated by grid managers in the western part of the country during very windy periods. The Danish Energy Plan includes a goal to consistently cover 50% of the country's electricity consumption from wind energy by 2030 by balancing imports and exports.

Various assessments involving modern European grids have shown that no technical problems will occur by running wind capacity together with the grid system up to a penetration level of 20%.

This includes the use of interconnectors to neighbouring countries, especially Norway and Sweden, both of which have large capacities of hydro power that complement the wind load profile.

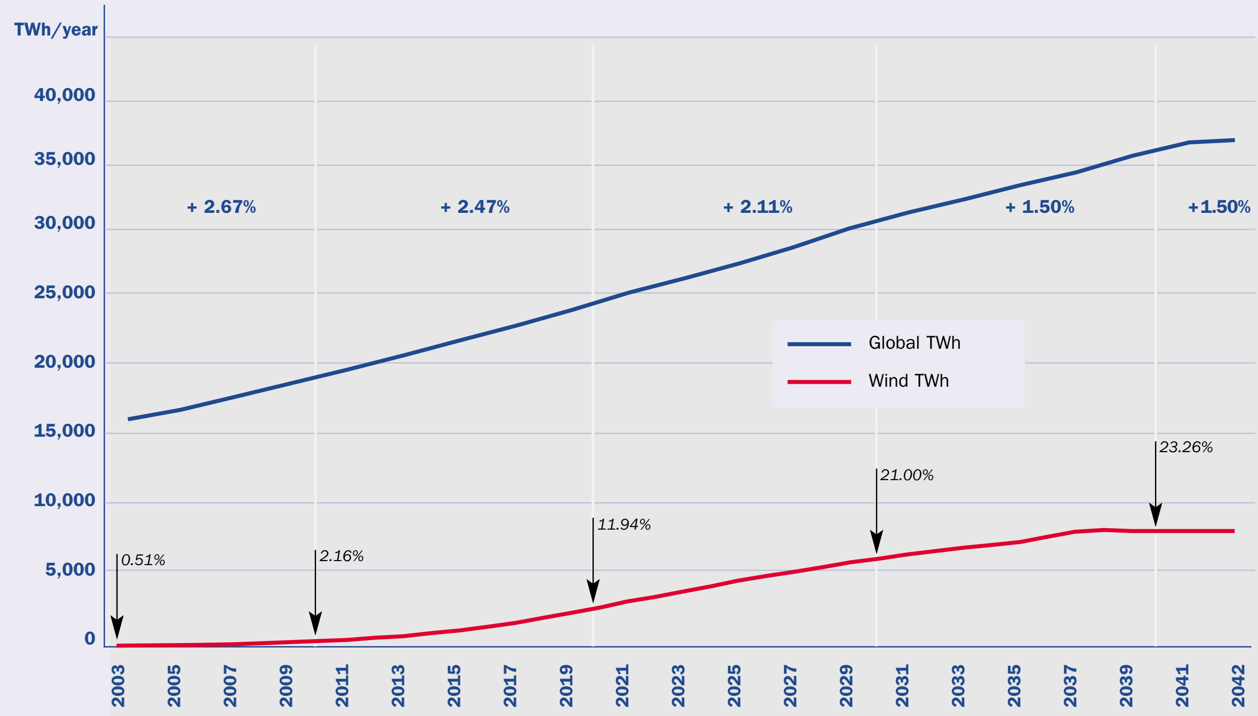
The cautious assumption adopted here is that a 20% limit is an acceptable figure to be taken into account in the potential penetration of wind power into the world's grid networks.

Table 3.2 shows how the world's wind resources are able to easily satisfy the technical issues of attaining a level of 20% of electricity penetration by 2020.

Figure 3.4 - Projected global electricity consumption and wind electricity output

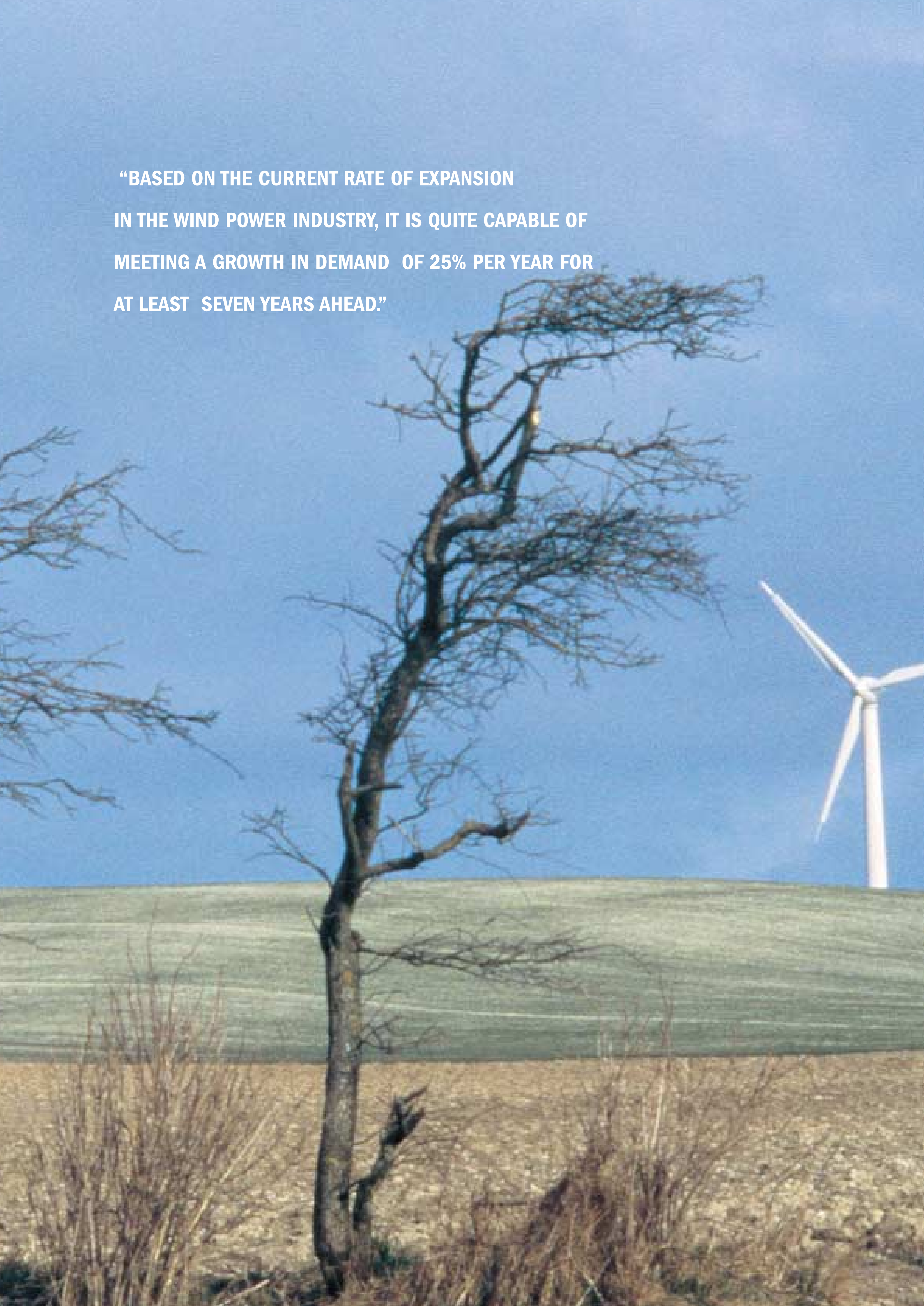
% figure is the increase in global electricity demand

→ : *Percentage wind penetration*



Source: IEA, World Energy Outlook 2002

"BASED ON THE CURRENT RATE OF EXPANSION IN THE WIND POWER INDUSTRY, IT IS QUITE CAPABLE OF MEETING A GROWTH IN DEMAND OF 25% PER YEAR FOR AT LEAST SEVEN YEARS AHEAD."



4 - 12% OF THE WORLD'S ELECTRICITY FROM WIND POWER

Taking off from the figure for installed wind power capacity at the end of 2003, this scenario projects a growth rate of 25% up to 2010, followed by lower rates as the world total expands. Individual turbine size and capacity factors will both steadily increase. By the year 2020, an installed capacity of 1,245 GW will have been achieved, with an annual production capable of matching 12% of the world's demand. This projected growth is comparable with the level of market penetration achieved by other power generation technologies.

4 - 12% OF THE WORLD'S ELECTRICITY FROM WIND POWER

Outline of the 12% scenario

The initial sections of this report have described the current status of wind power development around the world, the environmental impetus behind its expansion, the global wind resource region by region and the expected increase in electricity demand which will have to be satisfied. These elements are now brought together to demonstrate that it is feasible for 12% of that worldwide demand for electricity to be supplied by wind power.

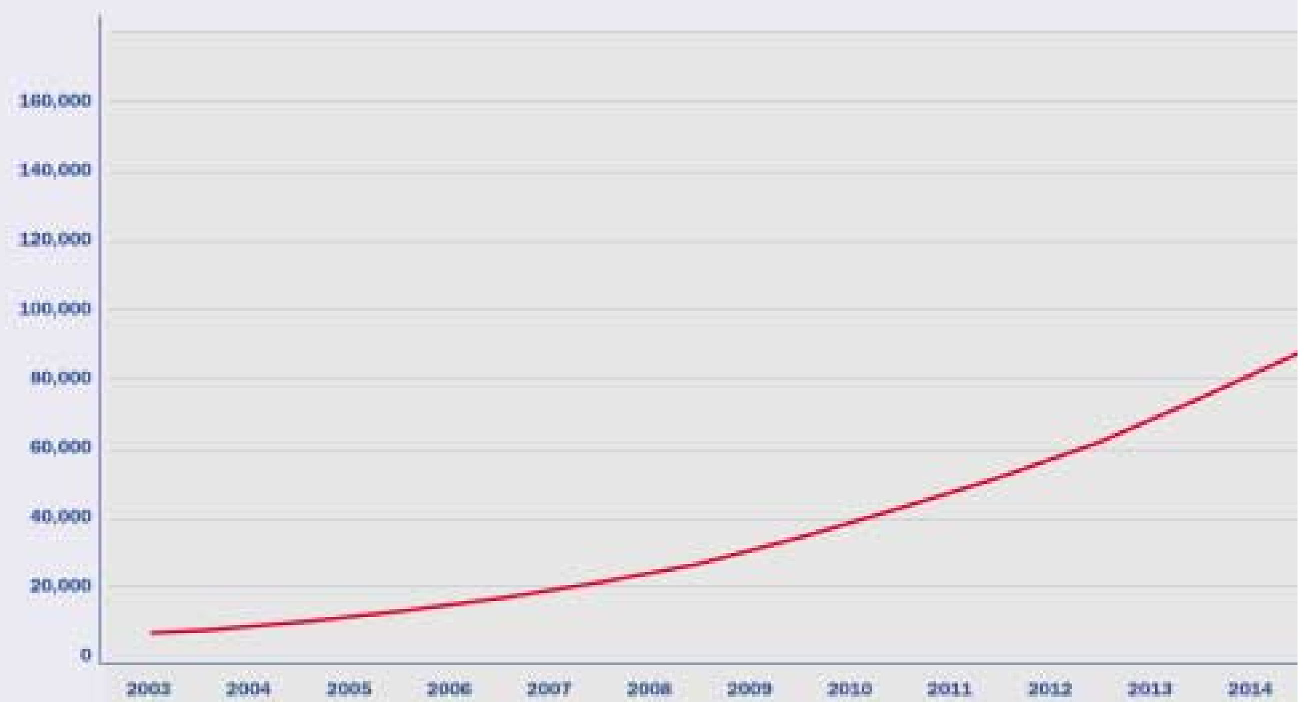
By 2030 wind power will account for 21% of world electricity demand, and by 2040 for 23%.

The summary results of this exercise can be seen in Figure 4.1a and b, and Table 4.1. More detailed figures are given in the Appendices.

This feasibility study takes off from the figures for cumulative wind energy at the end of 2003. The total installed capacity around the world by then was just over 40,000 MW, with new installations during 2003 reaching 8,344 MW. Moving forward, the growth rate of new annual installation during the period 2004 to 2010 is estimated to be 25% per annum, ending up with some 197,517 MW on line by the end of 2010. This is the highest growth rate during the period. From 2011 onwards the rates steadily decline, although the continued growth of wind power will clearly take place at a new high level of annual installation.

By the year 2020, an installed capacity of 1,245 GW will have been achieved, with an annual production capable of matching 12% of the world's demand for electricity, as projected by the IEA.

Figure 4.1a - 12% wind power by 2020 - Annual new capacity MW



Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Annual new capacity (MW)	8,344	10,430	13,038	16,297	20,371	25,464	31,830	39,787	47,745	57,294	68,752	82,503

The scenario also projects the development of wind power forward into 2040 though in far less detail. These projections shows that by 2030 wind power will account for 21% of world electricity demand, and by 2040 for 23%.

Beyond 2019, development continues with an annual installation rate of about 158,700 MW. Market penetration is expected to follow a typical S-curve, with a "saturation" point reached in some 30-40 years, when a global level of roughly 3,200 GW of wind energy will be maintained.

Over time, an increasing share of new capacity will involve the replacement of old wind power plant. This assumes a 20 year average lifetime for a wind turbine, requiring replacement of existing turbines as well as the construction of new developments. Replacement, or "re-powering", of turbines will become increasingly important in the later years of the scenario, picking up considerable speed from 2025 onwards. By 2040 re-powering will account for all new installed capacity.

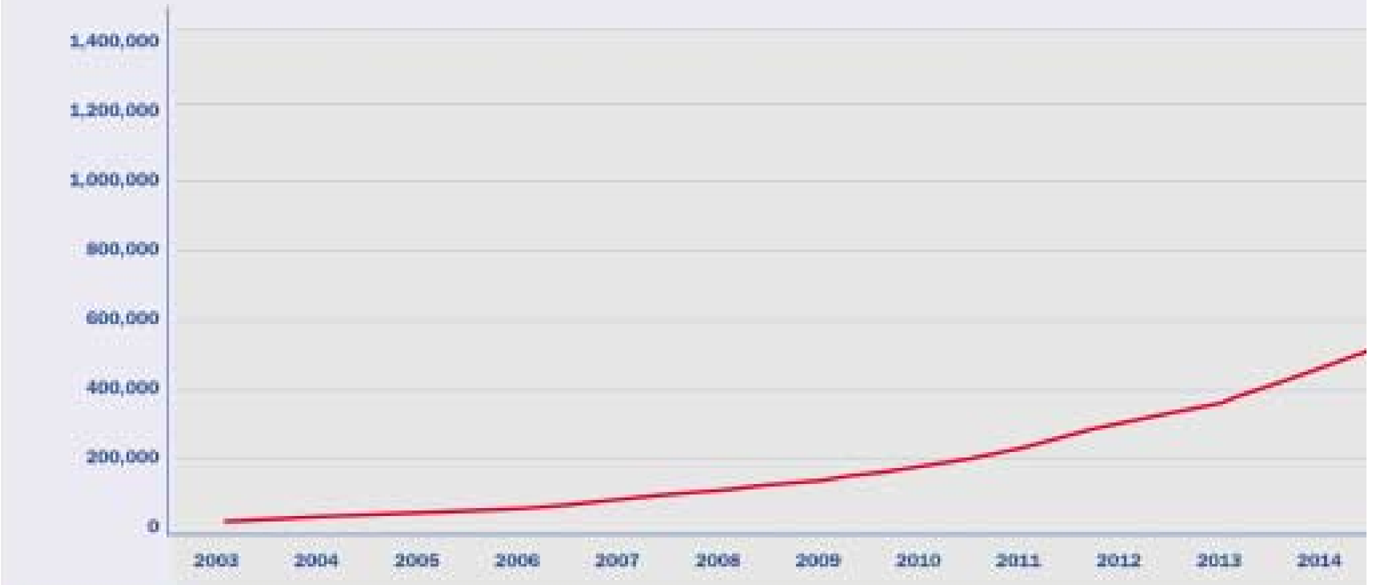
Growth rates for wind power are based on a mixture of historical figures and information obtained from leading companies in the wind turbine market. The exploitable wind potential worldwide and the level of electricity consumption in different regions of the world have also been assessed. Future cost reductions in wind technology are based on expectations of "learning rates" and take off from today's level, which is approximately € 804 per kW of installed capacity, resulting in a price per kWh of 3.79 € cents.

The growth rate beyond 2004 will be supported by new capacity from the emerging offshore wind power market, mainly in Northern Europe. This is expected to make an important contribution. Other regions may well join in during the timescale of this study, including the US and Japan, where the offshore potential is assessed as equivalent to 180% of the national power supply.

2015	2016	2017	2018	2019	2020
94,878	109,110	125,477	144,298	158,728	158,728

4 - 12% OF THE WORLD'S ELECTRICITY FROM WIND POWER

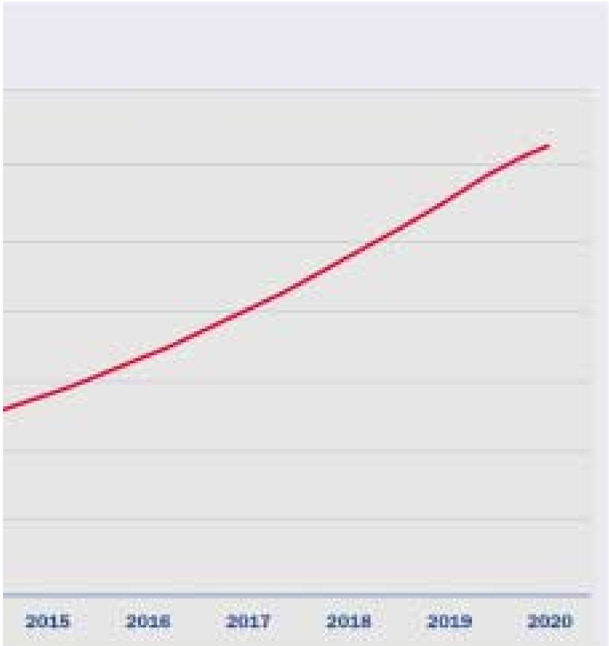
Figure 4.1b - 12% wind powered by 2020 - Cumulative new capacity MW



Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cumulative new capacity (MW)	40,301	50,731	63,769	80,065	100,436	125,900	157,730	197,517	245,262	302,556	371,308	453,811
Average annual growth rate (%)		25%	25%	25%	25%	25%	25%	25%	20%	20%	20%	20%

Table 4.1 - 12% wind power by 2020 – Electricity production

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Annual wind electricity production (TWh)	84.7	106.7	134.1	175.3	220.0	275.7	345.4	432.6	537.1	742.1	910.7	1,113.1
Projected world electricity demand (TWh)	16,666	17,110	17,567	18,035	18,516	19,010	19,517	20,037	20,532	21,040	21,560	22,093
Wind power penetration of world electricity (%)	0.51%	0.62%	0.76%	0.97%	1.19%	1.45%	1.77%	2.16%	2.62%	3.53%	4.22%	5.04%



2015	2016	2017	2018	2019	2020
548,690	657,800	783,276	927,575	1,086,303	1,245,030
15%	15%	15%	15%	10%	0%

2015	2016	2017	2018	2019	2020
1,345.8	1,613.5	1,921.2	2,275.2	2,664.5	3,063.8
22,639	23,198	23,772	24,359	24,961	25,578
5.94%	6.96%	8.08%	9.34%	10.67%	11.94%

Assumptions and parameters

The choice of parameters used in this study has been based on historical experience both from the wind power industry and from other technological developments in the energy field.

The main assumptions were:

- **Annual growth rates**

  Growth rates of 20-25% per annum are high for an industry manufacturing heavy equipment. However, the wind industry has experienced far higher growth rates in the initial phase of its industrialisation. Between 1993 and 1998, when the first Wind Force 10 assessment was made, the average annual growth in new capacity was 40%, whilst from 1998 to 2003 it has continued at an impressive average of 26%.

  Based on the current rate of expansion in the wind energy industry, it is quite capable of meeting a growth in demand of 25% a year for at least seven years ahead. By the end of 2010 manufacturing output is expected to reach a level of 39,787 MW/year. From 2011 onwards the annual growth rate of new capacity slows down in the scenario to 20%, then to 15% in 2015 and finally to 10% in 2019. The growth in manufacturing capacity levels out in 2019 at a figure of 158,728 MW annually.

  An important factor in Europe is the likely opening up of offshore development from 2005 onwards, a market segment which will add further volume to the generally high level of expansion on land. Nonetheless, a clear message from the industry is that it would like to see a stable political framework established for wind power development in emerging markets around the world before it enters local manufacturing through joint ventures.

- **Progress ratios**

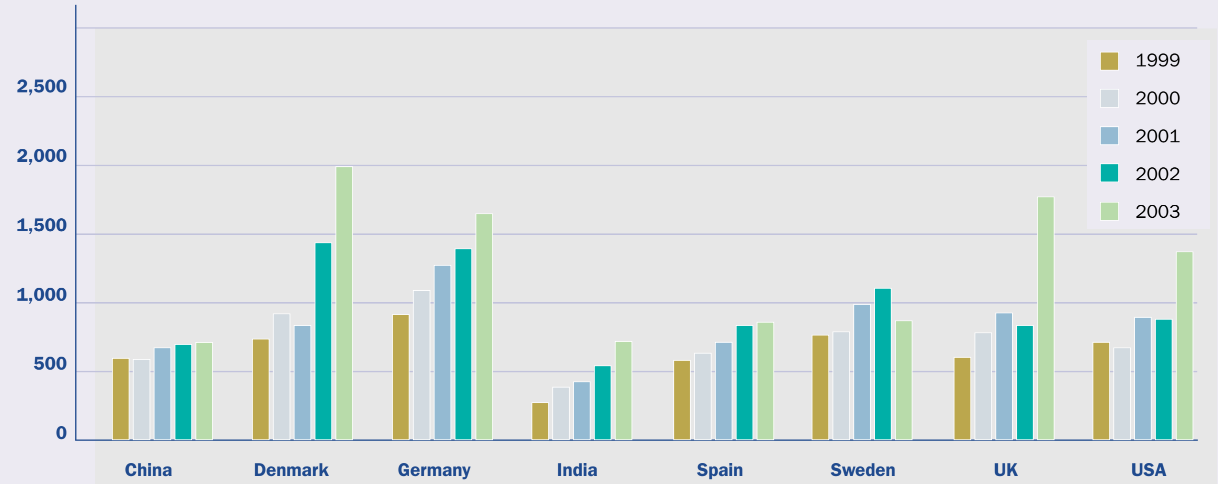
  The general conclusion from industrial learning curve theory is that costs decrease by some 20% each time the number of units produced doubles. A 20% decline is equivalent to a progress ratio of 0.80. Studies of the past development of the wind power industry show that progress through R&D efforts and by learning 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.

Based on the current rate of expansion in the wind energy industry, it is quite capable of meeting a growth in demand of 25% a year for at least seven years ahead.

The progress ratio assumed in this study starts at 0.85 up until 2010. After that it is reduced to 0.90. Beyond 2025, when development is approaching its saturation level, it goes down to 1.0.

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.

Figure 4.2 - Average size of wind turbines installed in selected markets (kW)



Year	China	Denmark	Germany	India	Spain	Sweden	UK	USA
1999	610	750	919	283	589	775	617	720
2000	600	931	1,101	401	648	802	795	686
2001	681	850	1,281	441	721	1,000	941	908
2002	709	1,443	1,397	553	845	1,112	843	893
2003	726	1,988	1,650	729	870	876	1,773	1,374

Note: The average turbine size supplied worldwide in 2003 was 1,211 kW

☐ Future growth of wind turbine size

Figure 4.2 shows the rapid growth of wind turbine size in the commercial market over the past five years. From this it can be seen that in some of the leading markets, notably the UK, Denmark and India, the average size of turbine being installed has more than doubled. In the 12% scenario, the average size of new wind turbines being installed is expected to grow over the next decade from today's figure of 1.2 MW to 2.0 MW. By the middle of the first decade of the scenario this increase will be pushed even harder by the emerging offshore sector. Wind turbines for that market are expected to be in the size range up to 5 MW. Most importantly, the development of larger sizes reduces the number of turbines needed for a given capacity and decreases the progress ratio.

☐ Increases in capacity factor

The capacity factor of wind turbines has already increased to the 24% global average we see today. This is the result of both better initial design and better siting. Most recently, the major contribution to improved capacity factors has been the increased hub height above ground of the larger turbines. The production of wind turbines with relatively large rotors (for inland sites) has also contributed. From the point of view of the electricity network, a high capacity factor is welcomed because it means more power into the grid at a given point. It is also worth noting that improving the capacity factor of wind turbines presents no technical obstacle, it is simply a matter of improved grid integration, modeling and cost. This scenario foresees average capacity factors increasing further to 25% by 2006 and 28% by 2012.

The average size of new wind turbines being installed is expected to grow over the next decade from today's figure of 1.2 MW to 2.0 MW.

☐ Comparisons with other technologies

If wind energy is to achieve the level of market penetration anticipated in this feasibility study, how does that compare with the record of other power sources?

The most commonly used power plants in the world's electricity supply are large scale technologies such as thermal power stations fired with coal, gas or oil, nuclear reactors and large scale hydroelectric plants. Both nuclear power stations and large scale hydro are technologies which have been mainly developed since the middle of the twentieth century. They have now reached a penetration of 17.1% and 16.6% respectively in the world's power supply.

- Starting from 1,000 MW in 1960, nuclear power plants accounted for 343,000 MW by the end of 1997.
- Starting from 45,000 MW in 1950, hydro power plants accounted for 714,602 MW by the end of 1996.

The history of these two technologies highlights that it is possible to achieve such levels of penetration with a new technology over a period of 40-50 years. German Wind

Energy Association analysis shows that more electricity was produced by wind during its first decade of commercial exploitation in Germany than by the nuclear industry in the equivalent period (see "Wind Energy Success Stories"). The time horizon of the 12% target and beyond is therefore consistent with the historical development of nuclear power and large scale hydro.

It is difficult, nonetheless, to directly compare these technologies with the likely penetration pattern for wind energy. The main difference between wind and thermal plant is that wind power is a small scale technology, with a maximum commercial unit size today of 2-3 MW, although the modularity of wind power makes it ideal for all sizes of installations, from a single unit to huge wind farms.

On the supply side this gives a greater potential for cost reduction, with serial production of units. It also makes wind energy suitable for many different types of electricity infrastructure, from isolated loads fed by diesel power to huge national and transnational grids.

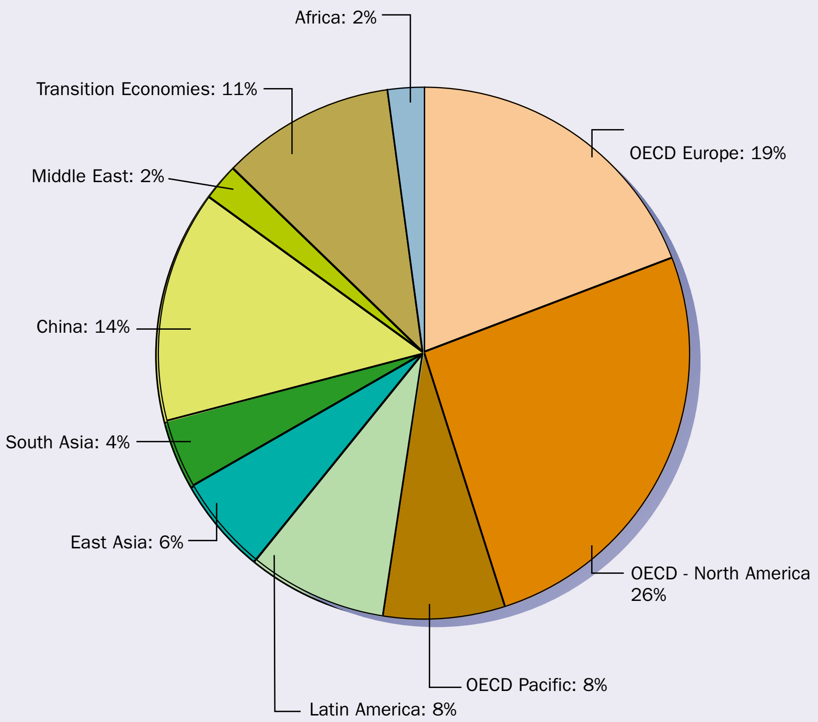
Seen from this viewpoint it is quite feasible that wind energy can penetrate to a level of 12%. The amount of installed capacity would then in fact be equivalent to that of hydro power today – even though on paper it appears some 50% higher. This is because of wind power's lower capacity factor.

Two other factors are important in the development of a new technology. One is the market "push" from publicly funded R&D, the other is the market "pull" achieved by a wide range of incentives directed either towards investors in generation technology or the end user of electricity. The latter stimulation is often politically driven.

The relative progress of new power technologies has been assessed in the study "Global Energy Perspectives", produced by the Austrian institute IIASA and the World Energy Council in 1998. The report gives the following examples, all from the United States:

- Photovoltaics – from 1981 to 1992, achieved a progress ratio rate of 20% (0.80);

Figure 4.3 - 12 % wind power in 2020 - Regional breakdown of GW



Region	Share of 1,200 GW wind power in 2020 (GW)
OECD Europe	230
OECD N. America	310
(USA)	(250)
(Canada)	(60)
OECD Pacific	90
Latin America	100
East Asia	70
South Asia	50
China	170
Middle East	25
Transition Economies	130
Africa	25
World	**1,200**

- Wind turbines – from 1982 to 1987, achieved a progress ratio of 20% (0.80);
- Gas turbines – progress ratio of 20% for the first 1,000 MW installed, then 10% from 1963 to 1980, when 90,000 MW was installed.

Penetration levels based on the above assumptions have been used in Figure 4.1.

Breakdown of the 12% scenario by region

The general guideline followed in the 12% scenario has been to distribute the 1,245 GW to be installed by 2020 in proportion to the consumption of electricity in the different regions of the world. The OECD countries, however, are expected to take the lead in implementation, enabling them to grow faster and ending up with a surplus in relation to their global share of consumption. An adjustment has therefore been made for Europe and for North America, particularly the USA.

Another consideration has been the quality of wind resources in terms of regional share of "high average wind speed regimes". Areas with extremely high annual wind speeds will be more interested in developing wind power than large geographical areas with moderate wind speeds, even if the absolute resources are huge in the latter.

A third issue, which has not been assessed in detail for this report, is how the windy regions of the world are situated in relation to where consumption takes place. If the main areas generating wind electricity in a particular country are concentrated far from populated areas and industrial centres, it might either result in restrictions on the utilisation of wind power or require a major investment in transmission lines.

The expected regional distribution of the 12% target is outlined in Figures 4.3-4.5.

Definitions of regions in accordance with IEA classification

OECD-Europe:
The EU-15 plus Czech Republic, Hungary, Iceland, Norway, Switzerland and Turkey

OECD N. America:
USA and Canada

OECD Pacific:
Japan, Australia and New Zealand

Transition Economies:
Albania, Bulgaria, Romania, Slovak Republic, Former Jugoslavia and Former Soviet Union and Poland

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

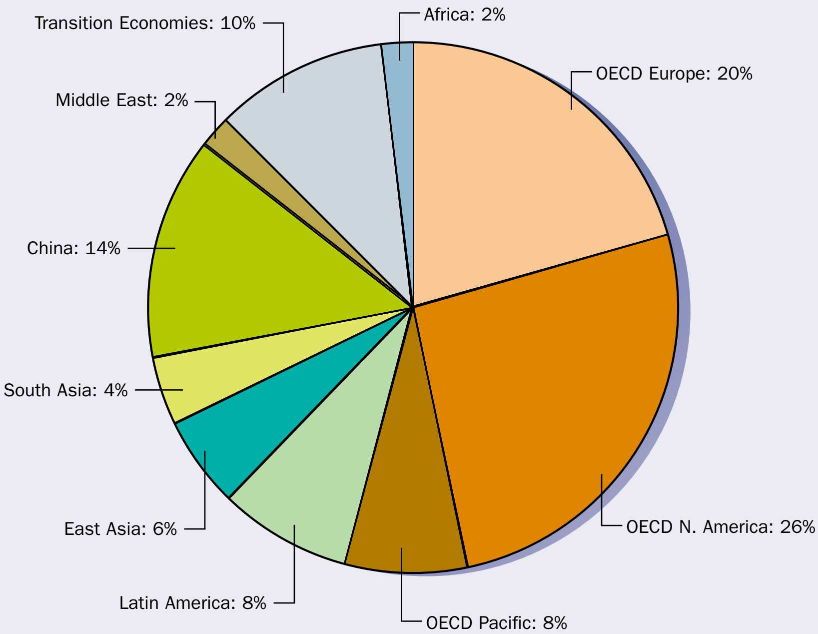
Latin America:
All South American countries and islands in the Caribbean

East Asia:
Brunei, Dem. Republic of Korea, Indonesia, Malaysia, Philippines, Singapore, Rep. of Korea, Chinese Taipei, Thailand, Vietnam and some smaller countries, including the Polynesian Islands

Africa:
Most African countries in the North and the South

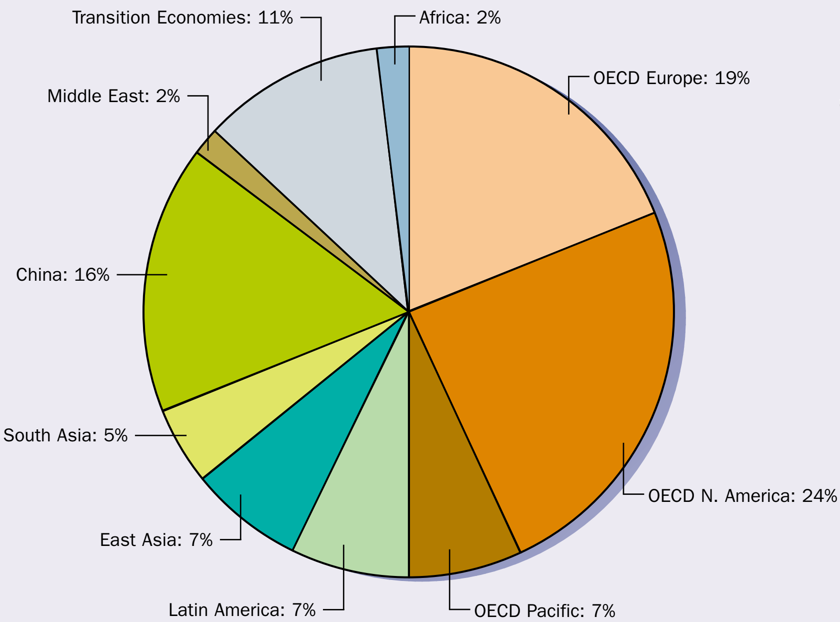
Middle East:
Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen

Figure 4.4 - Distribution of the 12% electricity production from wind power in 2020



Region	Annual electricity production (TWh/year)
OECD Europe	626.0
OECD N. America (USA)	800.0 (656.0)
OECD Pacific	230.1
Latin America	245.2
East Asia	171.5
South Asia	122.6
China	416.9
Middle East	61.3
Transition Economies	318.9
Africa	61.3
World	**3,053.8**

Figure 4.5 - Annual reduction of CO_2 in 2020



Region	Annual reduction of CO_2 (billion tonnes)
OECD Europe	375.6
OECD N. America (USA)	480.0 (374.8)
OECD Pacific	138.1
Latin America	147.1
East Asia	133.9
South Asia	95.6
China	325.2
Middle East	36.8
Transition Economies	221.6
Africa	36.8
World	**1,990.7**

"THE COST PER UNIT (KWH) OF WIND ELECTRICITY HAS ALREADY REDUCED DRAMATICALLY AS MANUFACTURING AND OTHER COSTS HAVE FALLEN."

5 - 12% WIND ENERGY BY 2020 INVESTMENT, COSTS & EMPLOYMENT

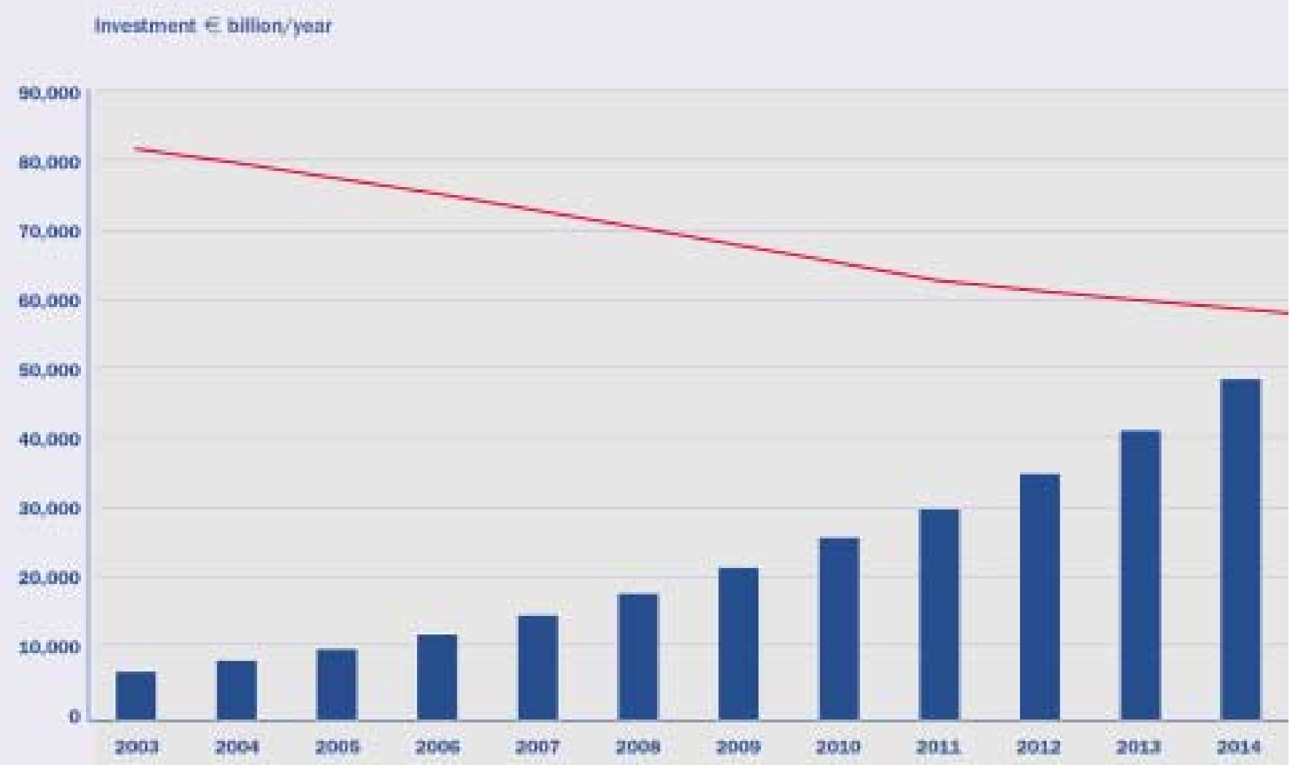
This feasibility study shows that the investment value of wind energy will increase from a level of € 7 billion in 2003 to a peak of € 82.7 billion by 2019. The total investment required to reach a level of 1,245 GW of wind power worldwide in 2020 is estimated at € 692 billion. Over the same period production costs are expected to fall from 3.79 €cents/kWh to 2.45 €cents/ kWh. By 2020, 2.3 million jobs will have been created around the world in manufacture, installation and other work associated with the wind energy industry.

Investment value

This feasibility study shows the investment value of the projected growth in wind power on a yearly basis, starting with about € 7 billion in 2003 and increasing to a peak of € 82.7 billion by 2019. The total investment (at 2003 prices) required to reach a level of 1,245 GW of wind power worldwide in 2020 is estimated at € 692 billion. Although this figure may appear large, it should be borne in mind that it is cumulative over the whole 20 year period, and also represents only a fraction of total global power sector investment. During the 1990s, for example, annual investment in the power sector was running at some € 158-186 billion each year. By 2020 it might represent a more substantial proportion, but by then, it should be remembered, wind power development will be heading towards a coverage of 20% of electricity demand, more than that of hydro power today.

Figure 5.1 shows the cumulative global investment needed to achieve a 12% penetration by the year 2020. Investment costs are based on the progress assumptions already explained and are state of the art figures with the average cost level in 2003 taken as € 804 per kW of installed capacity. By 2020 the investment cost falls to € 512/kW, a substantial reduction of 36% compared to today.

Figure 5.1 - 12% wind power by 2020: investment and employment

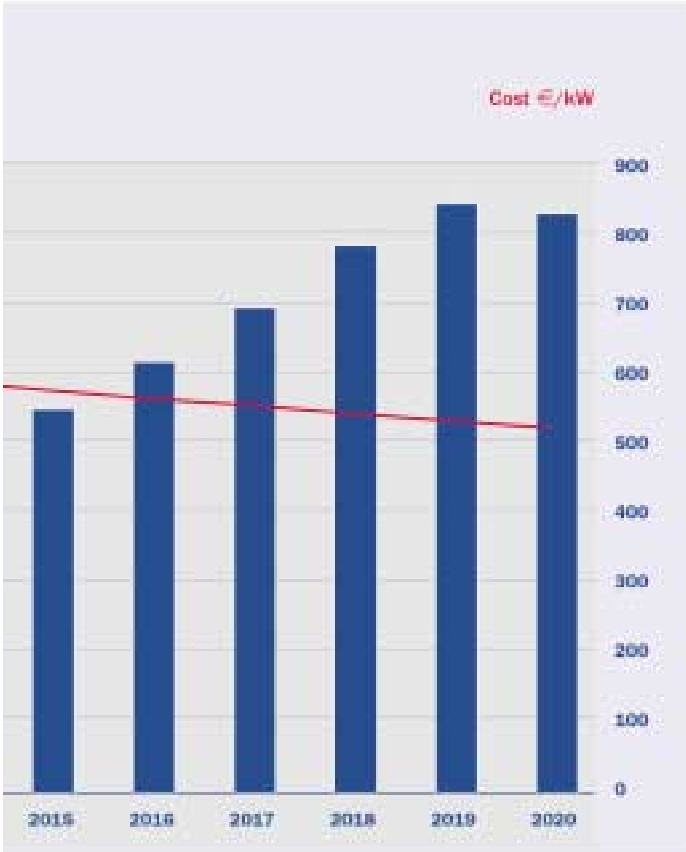


Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Annual installation MW/year	8,344	10,430	13,038	16,297	20,371	25,464	31,830	39,787	47,745	57,294	68,752	82,503
Cost €/kW	804	783	762	740	717	694	669	644	619	603	591	579
Investment € billion/year	6,707	8,167	9,936	12,053	14,610	17,660	21,292	25,610	29,553	34,560	40,650	47,767
Cumul. investment € billion	6,707	14,874	24,810	36,863	51,472	69,132	90,425	116,035	145,588	180,148	220,798	268,565
Employment job-year	194,678	237,061	288,399	349,843	424,061	512,606	618,035	743,372	857,805	1,003,130	1,179,915	1,386,495

Analysing how this investment would be spread around the regions of the world is not just a matter of dividing up the capacity in accordance with the regional distribution in Figure 4.1. This is because development will not start at the same time in all regions.

Experience from the leading wind power nations has shown that even with commercial technology available, it still takes some time for large scale development to take off. The institutional framework facilitating the development must be in place, and it is desirable to get at least some local manufacturing in progress before major investments are made.

Increasing to an annual peak of € 82.7 billion by 2019, the total investment (at 2003 prices) required to reach a level of 1,245 GW of wind power worldwide in 2020 is estimated at € 692 billion.



2015	2016	2017	2018	2019	2020
94,878	109,110	125,477	144,298	158,728	158,728
567	555	544	532	521	512
53,789	60,568	68,199	76,790	82,772	81,304
322,354	382,922	451,121	527,911	610,684	691,988
1,561,292	1,758,061	1,979,565	2,228,914	2,402,565	2,359,934

Table 5.1 shows the average investment cost over different periods of time in the first two decades of the 21st century. This in turn allows us to allocate the regional investment, taking into account when development in individual regions is likely to take off.

Cost reductions

The cost per unit (kWh) of wind electricity has already reduced dramatically as manufacturing and other costs have fallen. Between 1981 and 1995, according to an evaluation of wind turbines installed in Denmark by the RISØ National Research Laboratory, the cost per unit fell from 15.8 € cents/kWh to 5.7 € cents/kWh, a decrease of two thirds.

The reasons included improved design of turbines and better siting.

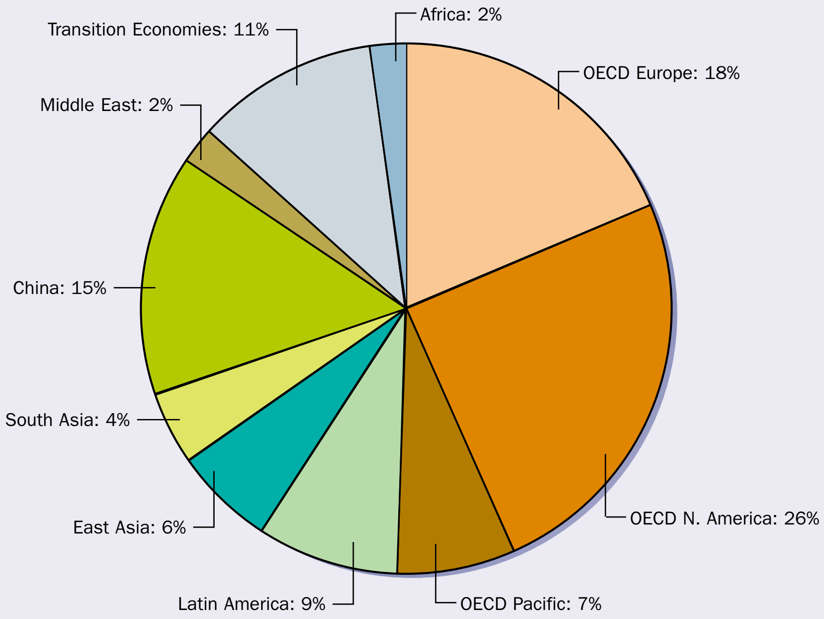
Since that time, the 500 kW size turbines then just being introduced into the commercial market have been overtaken by new generations of optimised and upscaled

Table 5.1 - Average investment per KW of wind power, 2003 to 2020

Period	Average investment €/kW			
2004 to 2008	€ 729			€ 568.00
2009 to 2013	€ 618		€ 556.00	
2014 to 2017	€ 559	€ 539.00		
2018 to 2020	€ 521			

Exchange rate between US$ and €: 1.28 as at Feb 2004

Figure 5.2 - Cumulative investment per region up to 2020



Region	Cumulative investment (€ billion)
OECD Europe	130.6
OECD N. America (USA)	176.1 (140.9)
OECD Pacific	51.1
Latin America	61.4
East Asia	43.0
South Asia	30.8
China	104.7
Middle East	14.0
Transition Economies	79.8
Africa	15.4
World	**706.9**

Region	Take- off year for large scale development
OECD Europe	on track
OECD N. America	on track
OECD Pacific	on track
Latin America	2008
East Asia	2008
South Asia	2006
China	2006
Middle East	2008
Transition Economies	2008
Africa	2008

machines with capacities of up to 2-3 MW. The International Energy Agency estimates that the price of wind turbines has reduced by 16% each time their average size doubles.

Based on market and industry experience, this study has taken the following reference figures for "state of the art" wind turbines in 2003 under optimum conditions:

- Investment cost: € 804 per installed kW
- Unit price for electricity: 3.79 € cents/kWh

The following parameters have been used in the calculation of future costs:

1. The average size of turbine on the commercial market will grow from 1,200 kW (1.2 MW) today to 1.4 MW by 2005, 1.5 MW by 2007 and later to 2.0 MW, depending on the increasing share of offshore developments.
2. Progress ratios will decline from 0.85 to 0.90 from 2011 onwards. This takes into account improved cost effectiveness and improved design gained from R&D

as well as benefits from better logistics and "economies of scale".

3. Improvement in the average capacity factor from today's 24% to 28% after 2012.

This feasibility study therefore envisages a cost reduction in wind electricity from 3.79 € cents/kWh to a level of 3.03 € cents/kWh by 2010, assuming a cost per installed kilowatt of € 644. This is comparable with current cost levels for combined cycle gas generation. By 2020, the figure will have fallen to 2.45 € cents per unit of electricity produced (€ 512 per kW). The year by year cost reductions can be seen in the Appendices.

Comparison with other generation technologies

How do the costs of wind energy compare with other generation technologies already in widespread use? The most recent data (Figure 5-3) is from the annual survey of price comparisons by specialist magazine Windpower Monthly, published in January 2004. At current electricity prices, this shows that the cheapest wind plants – those with the optimum site conditions and economies of scale – are now competitive with gas where the average wind speed is above 8m/s and the investment cost is US$ 1,000/kW.

The cost per unit (kWh) of wind electricity has already reduced dramatically as manufacturing and other costs have fallen.

One other factor should be taken into account in these comparisons. The lower capacity factor of wind power means that to produce a given quantity of electricity it is necessary to install 2-2.5 times more generating capacity than with fossil fuel plants. This tends to make wind energy more expensive in the initial phase of the life cycle. On the other hand there is no fuel cost during the lifetime of wind plant.

Wind energy costs are also expected to drop significantly over the next two decades, as cumulative experience

Figure 5.3 - Power costs analysis: The price of wind power against coal, gas and nuclear

"Courtesy of Windpower Monthly News Magazine, Vol 20, Issue 1, January 2004"

grows. The three thermal generation technologies mentioned here are unlikely to get significantly cheaper than they are today, especially if gas becomes increasingly scarce. A direct cost comparison also does not represent the whole picture, since it does not deal with externalities, as outlined in the next chapter.

This study envisages a cost reduction in wind electricity from 3.79 e cents/kWh to a level of 3.03 e cents/kWh by 2010. By 2020, the figure will have fallen to 2.45 e cents.

Employment potential

The employment effect of the 12% wind energy scenario is a crucial factor to weigh alongside its other costs and benefits. High unemployment rates continue to be a major drain on the economies of nearly every country 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.

The employment effect of the 12% wind power scenario is a crucial factor to weigh alongside its other costs and benefits.

Looking two decades ahead, it may not still be reasonable to assume that employment will continue to be a determining parameter. However, if the opposite situation should occur – an ongoing shortage of labour – then it is important to know how much employment will result from a long term technological development such as this. Several assessments of the employment effects of wind power have been carried out in Germany, Denmark and the Netherlands. The most comprehensive study to date has been by the Danish Wind Turbine Manufacturers Association (DWTMA) in 1996.

The methodology used by the DWTMA is to break down the manufacturing activities involved in the wind turbine industry into its different sectors – metalwork, electronics and so on – and then add together the individual employment contributions. The results cover three areas – the direct and indirect employment from wind turbine manufacture, the direct and indirect employment effects of installing wind turbines, and the global employment effects of the Danish industry's exports business.

One good reason for using the Danish figures is that the country's wind turbine industry has been the most successful on the supply side, with a world market share consistently close to 50%. It is reasonable to assume, however, that the methodology will be valid for the other main turbine manufacturing nations – Germany, Spain and the United States.

For the purposes of this study, the latest available Danish figures (1998) for employment are used. These show that 17 job-years are created for every MW of wind energy manufactured and 5 job-years for the installation of every MW. With the average price per kW of installed wind power at $1,000 in 1998, these employment figures can then be related to monetary value, showing that 22 job-years (17+5) are created by every $1 million in sales.

In order to allow for greater efficiency in design, manufacture and installation – resulting in a reduction in employment – it has been chosen to let the labour consumption follow the total value of wind power installation, a decreasing value over time. These indicative reductions in the level of employment over the period of the 12% study are shown in the Appendices.

The results of the employment assessment for the entire implementation of the 12% scenario are shown in Figures 5.4a and 5.4b. These are directly based on the assumptions above and the actual new installation of wind power expected in the years 2004, 2008, 2012 and 2020.

The years 2008 and 2012 have been chosen as the beginning and end of the period scheduled for achievement of the Kyoto Protocol targets for reduction in global greenhouse gas emissions (see "The Environmental Benefits" and "Policy Recommendations"). As seen in Figure 5.4b, it is assumed that some regions will start their large scale development of wind energy later than OECD countries already on track for major deployment.

The main outcome from the scenario is that a total of 2.3 million jobs will have been created around the world by 2020 in manufacture, installation and other work associated with the wind power industry.

It is also important to emphasise that a prerequisite for the employment figures allocated by region in Figure 5.1 is that the whole manufacturing process, including the upstream production and supply of the technology, is provided within the region itself. Given that this is unlikely to be a totally realistic outcome, given the present world trading situation, the expected local “value added” and derived employment to be obtained from the 12% scenario is assessed separately in the tables listing the key figures by region.

In Figure 5.4a, the total installation quota of wind energy is divided by regions into periods up to 2020. For individual regions, the figures can only represent a rough estimate, however, since a detailed assessment of the penetration pattern has not been possible within the limits of this study. Nonetheless, the sum of each period makes up the total annual figure in accordance with the 12% scenario (see Table 4-1).

The annual installation figures in MW are turned into employment figures in Figure 5.4b. These “core figures” will in due course have to be corrected region by region, taking into account such issues as the actual price of labour, manufacturing efficiency (related to the above), and the rate of import of materials or components for manufacturing the regional share of global installation.

It is also necessary to explain the difference between the 194,000 job years in Figure 5.1 and the estimated 90-100,000 jobs in the global industry today. The 90-100,000 figure is an estimate based on specific individual national data of direct and indirect employment – i.e. for primary industry and major sub-suppliers. However this estimate cannot capture every single job or part-job created by wind power. The 194,000 job years is based on a statistical model comparing jobs, investment and MW which covers all wind-related employment.

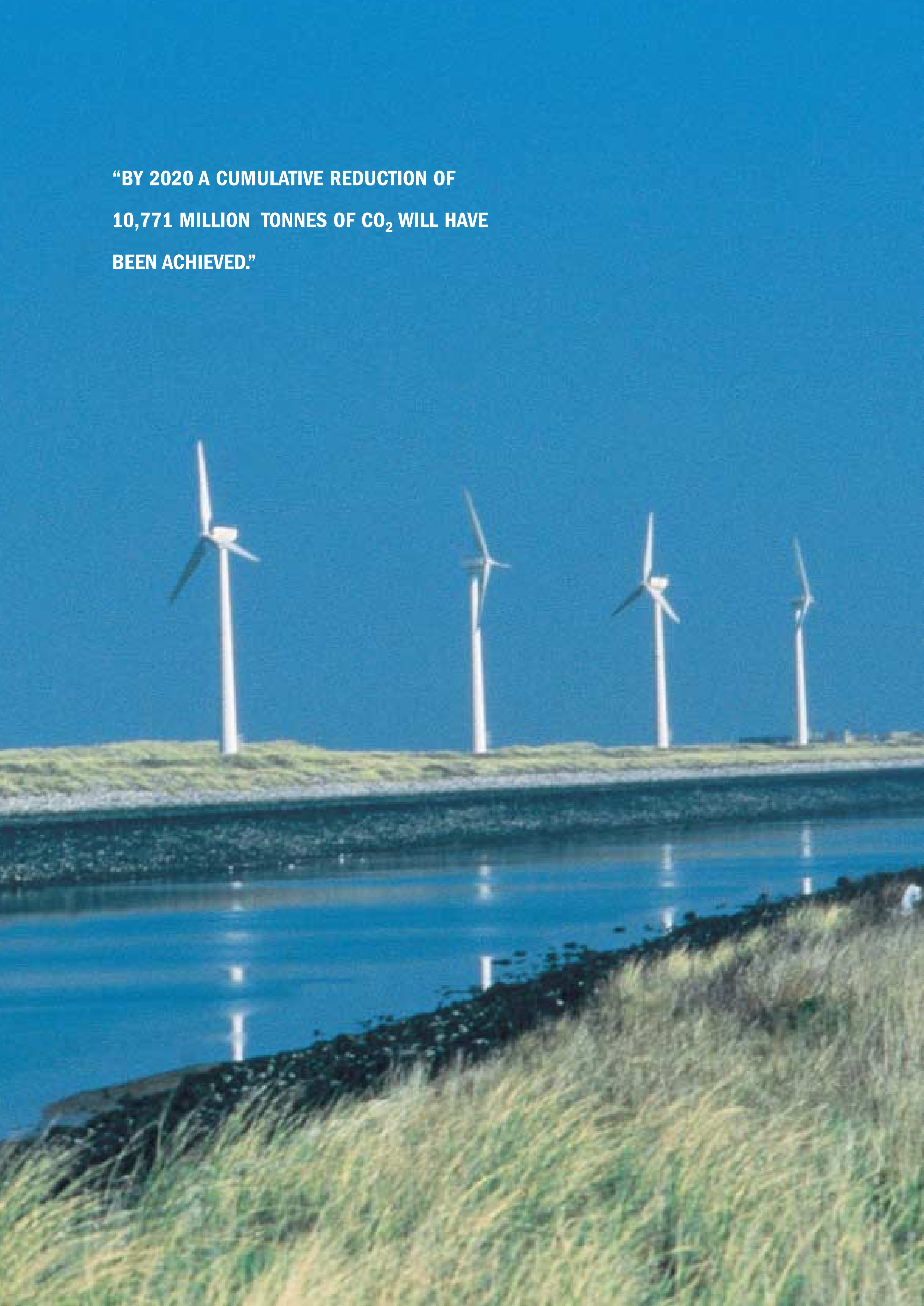
Figure 5.4a - Distribution of annual installed capacity by region

Year	2004 (MW/year)	2008 (MW/year)	2012 (MW/year)	2020 (MW/year)
OECD Europe	5,900	9,300	10,750	15,000
OECD N. America	2,200	6,500	14,000	30,000
OECD Pacific	800	1,700	4,600	10,000
Latin America	350	1,500	4,500	17,000
East Asia	100	500	2,300	10,000
South Asia	500	1,500	4,600	18,000
China	350	2,500	7,800	30,000
Middle East	50	300	1,000	3,000
Transition Economies	100	1,200	6,400	22,000
Africa	50	400	1,300	3,000
Total MW per year	**10,400**	**25,400**	**57,250**	**158,000**

Figure 5.4b - Distribution of employment by region

Year	2004 (1,000 job-year)	2008 (1,000 job-year)	2012 (1,000 job-year)	2020 (1,000 job-year)
OECD Europe	133.9	186.9	188.1	222
OECD N. America	49.9	130.7	245	444
OECD Pacific	18.2	34.2	80.5	148
Latin America	7.9	30.2	78.8	251.8
East Asia	2.2	11	40.3	148
South Asia	11.4	32	80.5	266.4
China	7.9	50.3	136.5	444
Middle East	1.1	6	17.5	44.4
Transition Economies	2.2	24.1	112	325.6
Africa	1.1	8	22.8	44.4
Total employment job-year	235.8	513.4	1,002	2,338.6
Annual installation	10,430	25,464	57,294	158,000
Job-year/MW	22.7	20.1	17.5	14.8

"BY 2020 A CUMULATIVE REDUCTION OF 10,771 MILLION TONNES OF CO_2 WILL HAVE BEEN ACHIEVED."



6 - 12% WIND POWER BY 2020 THE ENVIRONMENTAL BENEFITS

The most important environmental benefit from this scenario is a reduction in the global output of carbon dioxide – the major gas responsible for climate change. The annual level of reductions will rise from 50.8 million tonnes of of CO_2 in 2003 to 1,832 million tonnes in 2020. By then the cumulative saving will have reached a total of 10,771 million tonnes.

Global carbon dioxide reductions

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 generation method wind power is substituting for. Calculations by the World Energy Council show a range of carbon dioxide emission levels for different fossil fuels (Table 6.1). 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.

By 2020 a cumulative reduction of 10,771 million tonnes of CO_2 will have been achieved.

This assumption is further justified by the fact that close to 50% of the cumulative wind generation capacity two decades ahead, according to our scenario, will be installed in the OECD regions (North America, Europe and the OECD-Pacific). The trend in these countries is for a significant shift from coal to gas. Development will start later in other regions, but in some, the specific CO_2 reduction will be much higher due to the widespread use of inefficient coal burning power stations.

Taking account of these assumptions, covering 12% of global demand for electricity with wind power will reduce carbon dioxide emissions by the following amounts:

- Annual reductions rising from 50.8 million tonnes CO_2 in 2003 to 1,832 million tonnes CO_2 in 2020.
- By 2010, a cumulative reduction of 1,065 million tonnes CO_2.
- By 2020, a cumulative reduction of 10,771 million tonnes CO_2.
- By 2040, wind power will contribute an annual reduction of 5,106 million tonnes CO_2 resulting in a cumulative reduction of 88,857 million tonnes CO_2.

The effect of improved efficiency

As already explained, the improving efficiency of wind technology is expected to follow a pattern from today's average capacity factor of 24% and ending up with figures of 28% and 30% in 2012 and 2036 respectively. Expressed in terms of the benefit to an electricity utility, this is a shift from 2,000 "full-load hours" of operation per year to 2,500-2,600 full-load hours/year. Future offshore installations are expected to perform even better – in the range of 3,000-4,000 full-load hours/year. It should also be noted that wind turbines in particularly windy sites on land in Denmark, the US and the UK have already demonstrated capacity factors of 30% and above.

These improvements in the technology and the growth rates seen in the 12% scenario will make an important contribution to the level of CO_2-free electricity. The Appendices show the carbon dioxide reductions from the feasibility study calculated year by year up to 2045.

Value of carbon dioxide reductions

Many studies have been carried out to determine the abatement cost of various methods of CO_2 reductions. The general conclusion is that energy saving is often the cheapest option. When it comes to generating plant, this will depend on the local structure of the electricity system and which fuel is being replaced. Studies in Denmark have shown that wind power replacing coal fired electricity represents one of the lowest CO_2 abatement costs of all options available.

A common misunderstanding in this area is that new wind power is often compared with fossil fuel generation built up to 30 years ago, and with its capital cost depreciated to zero. In an electricity market under the competitive pressure of a deregulated market, such plant may well deliver power at prices only a little over the variable cost. That situation will not last forever. As soon as demand growth calls for new capacity, wind power will be in a far better competitive position.

If the future improvements on cost effectiveness calculated for this study are taken into account, then the abatement cost of substituting wind energy for fossil fuel generated electricity is likely to be near zero.

External costs

Direct cost comparisons of wind power and fossil fuels or nuclear power are misleading as they do not account either for external costs or for the intrinsic benefits resulting from 'embedded' generation. Embedded generation means capacity, such as wind power, which is often located at the periphery of the grid distribution system, close to local demand, and therefore both reinforces a weak distribution network and reduces the cost of using the main transmission network.

The "external costs" to society and the environment derived from burning fossil fuels or from nuclear generation are not included in electricity prices. These costs have both a local and a global component, the former mainly related to the eventual consequences of climate change. There is a lot of uncertainty, however, about the magnitude of such costs in monetary terms, and they are difficult to identify and quantify. A recent European study, known as the "Extern E" project, conducted over the past 10 years across all 15 EU member states, has assessed these costs for a range of fuels.

Its latest results, published in 2002, outlined the external costs as:

nuclear	0.2 - 0.7 € cents/kWh
gas	1 - 3 € cents/kWh
coal	2 - 15 € cents/kWh
wind power	0.15 - 0.25 € cents/kWh

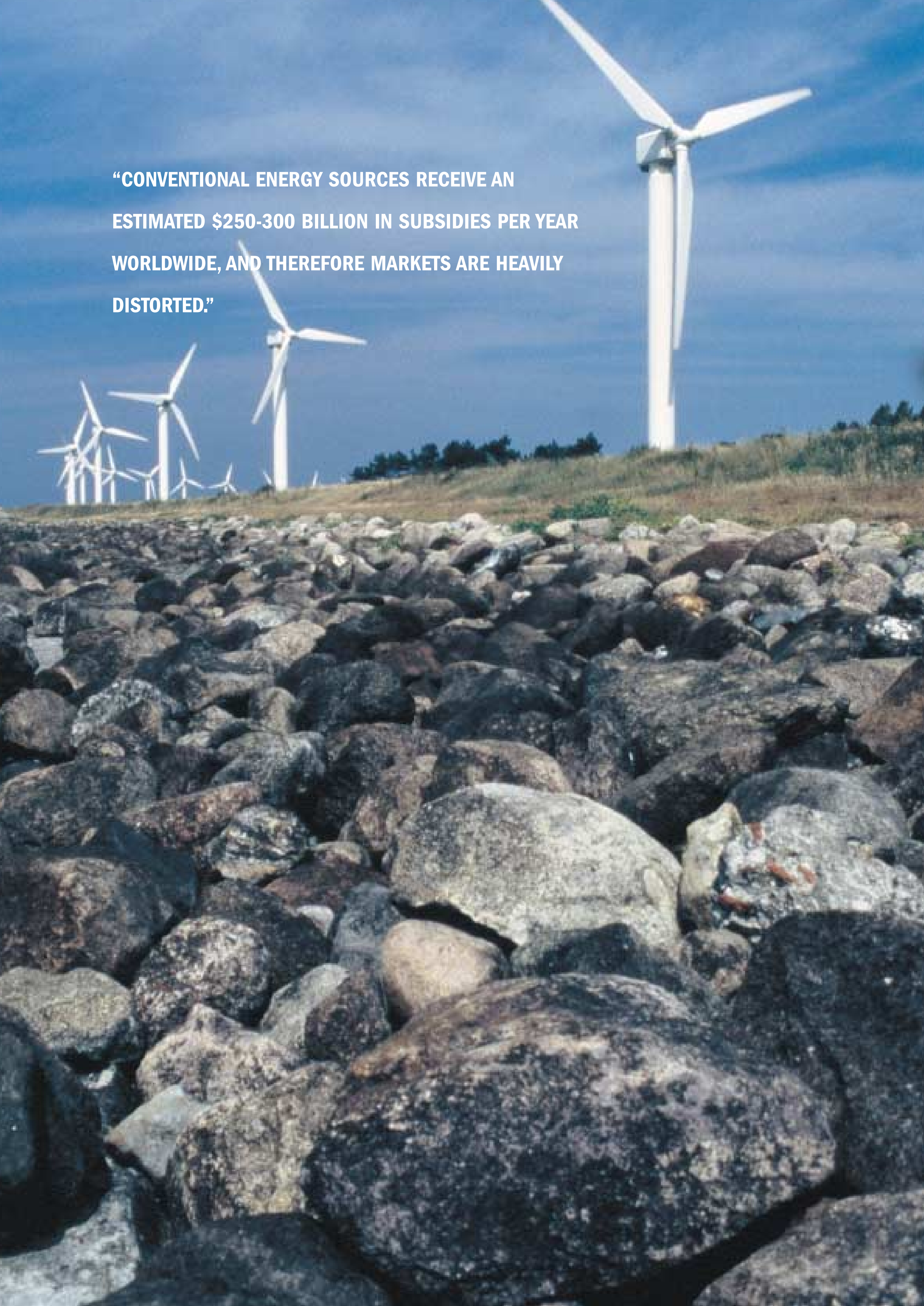
The cost of electricity from coal or oil would double, and that from gas increase by 30%, if their external costs associated with the environment and health were taken into account.

The 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. Nuclear faces greater external costs for major issues such as public liability, waste and decommissioning.

Table 6.1 - CO_2 emissions from fossil fuelled electricity generation

Coal (various technologies)	751-962 tonnes per GWh
Oil	726 tonnes per GWh
Gas	428 tonnes per GWh
Average	600 tonnes per GWh

Source: WEC statistics cited in "Wind Energy – The Facts", Vol.4, 1998, EWEA/European Commission



“CONVENTIONAL ENERGY SOURCES RECEIVE AN ESTIMATED $250-300 BILLION IN SUBSIDIES PER YEAR WORLDWIDE, AND THEREFORE MARKETS ARE HEAVILY DISTORTED.”

7 - POLICY RECOMMENDATIONS

Governments face many challenges in formulating future energy policy over the coming years. They have to respond to the need to address security of energy supply, economic growth, sustainable development, climate change, employment and technological development. Renewable energy technologies have a positive effect on all these issues. This study clearly demonstrates that wind power is in the vanguard of the new renewable energy industries, and furthermore, it shows that there are no technological, commercial or resource limits constraining the world in meeting 12% of future global electricity demands from wind power in less than two decades.

7 - POLICY 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 higher demand for wind turbines. In a report from October 2003[1] the European Wind Energy Association estimates that 28% of new generation capacity installed in the EU during this decade (2001-2010) will be wind power, under the assumption that the clear commitments of the EU and its Member States to wind power continue to strengthen. Without political support, however, wind power remains at a competitive disadvantage, because of distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies.

The European Directive aims to double renewables' share of the energy mix from 6% to 12% by 2010

New wind power stations have to compete with old nuclear and fossil fuel power stations that produce electricity at marginal costs, because interest and depreciation on the investments have already been paid for by consumers and taxpayers. Political action is needed to overcome those distortions, and create a level playing field in order to fully enjoy the economic and environmental benefits of wind energy.

The following is an overview of current political frameworks for wind power and barriers that must be overcome in order to unlock wind power's great potential to become a major contributor to global energy supply in the future.

According to a European Commission Green Paper on Security of Energy Supply, in two decades Europe will be importing 70% of its energy (up from 50% today) unless Europe changes direction. Wind power can plug the gap in the European energy supply, and at the same time contribute greatly to the goals set out in the EU Lisbon Strategy: Sustainable economic growth, high quality jobs, technology development, global competitiveness, and European industrial and research leadership. Furthermore, wind power and other renewable energy technologies will have a large impact in meeting (Kyoto Protocol) commitments and contribute to sustainable development.

1 Wind Power targets for Europe: 75,000 MW by 2010

The Commission's Green Paper on Security of Supply recognises this potential:

"Renewable sources of energy have a considerable potential for increasing security of supply in Europe. Developing their use, however, will depend on extremely substantial political and economic efforts. (...) In the medium term, renewables are the only source of energy in which the European Union has a certain amount of room for manoeuvre aimed at increasing supply in the current circumstances. We can not afford to neglect this form of energy."

"Effectively, the only way of influencing [European energy] supply is to make serious efforts with renewable sources."

National policies

1. Legally binding targets for renewable energy

In recent years an increasing number of countries have established targets for renewable energy, as part of their greenhouse gas reduction policies. These are either expressed as specific amounts of installed capacity or as a percentage of energy consumption.

The most ambitious target has been set by the European Union. In 2001, the European Council and the European Parliament adopted a Renewable Energy Directive establishing national targets for each member country. Although these targets are not legally binding, they have served as a very important catalyst in initiating political initiatives throughout Europe to increase renewable energy's share of electricity supply.

The Directive aims to double renewables' share of the energy mix from 6% to 12% by 2010, equal to 22% of European electricity consumption. The next step forward from the Directive is that the Commission should submit proposals to the European Parliament and Council for mandatory renewables energy targets. Furthermore, targets should be set for 2020. A time-horizon of six years is not long in an electricity sector where the investment horizon is up to 40 years.

The table below shows the national targets for electricity supply from renewable energy in the member countries which are laid down in the EU Directive as a percentage of gross national electricity consumption. With most of the large hydro potential in Europe already exploited, the majority of this increase is expected to come from biomass and wind energy.

Table 7.1 - RES-E targets and progress in EU-25

Country	Share of RES-E (%) in 1997	RES-target for 2010 (%)
Austria	70.0	78.1
Belgium	1.1	6.0
Denmark	8.7	29.0
Finland	24.7	31.5
France	15.0	21.0
Germany	4.5	12.5
Greece	8.6	20.1
Ireland	3.6	13.2
Italy	16.0	25.0
Luxembourg	2.1	5.7
Netherlands	3.5	9.0
Portugal	38.5	39.0
Spain	19.9	29.4
Sweden	49.1	60.0
United Kingdom	1.7	10.0
Total EU-15	**13.9**	**22.0**

Source: Directive 2001/77/EC

Country	Share of RES-E (%) in 2000	RES-target for 2010 (%)
Cyprus	0.1	6.0
Czech Republic	3.8	8.0
Estonia	0.2	5.1
Hungary	0.7	3.6
Latvia	42.4	49.3
Lithuania	3.3	7.0
Malta	0	5.0
Poland	1.6	7.5
Slovakia	17.9	31.0
Slovenia	29.9	33.6
Total EU-10	**5.6**	**11.0**
TOTAL EU-25	–	**21.0**

Source: DG TREN presentation at EWEC 2003, Madrid, June 2003.

Setting targets does not in itself lead to any expansion of wind power and other renewable energy sources. But, as very well demonstrated by the indicative targets in the Renewables Directive mentioned above, they serve as a very important catalyst for governments to take action and develop the necessary regulatory frameworks to expand renewables such as financial frameworks, grid access regulation, planning and administrative procedures.

Europe has been a world leader in the development of wind energy, as has India and some states in the United States. The development of other renewable energy technologies such as biomass, geothermal and solar have also had significant leadership from countries in Latin America and Asia. Because the Johannesburg World Summit on Sustainable Development in 2002 was unable to agree concrete programmes for the development of renewables, the Johannesburg Renewable Energy Coalition (JREC - now 85 countries) was formed, and agreed to work together to pursue the massive take up of renewable energy globally that will be required to meet the challenge of climate change as well as to help ensure access to clean and affordable energy to the world's poorest. Renewables 2004, a conference to be convened by the German government in Bonn from June 1-4 this year, is the first major milestone for the JREC, and there is an expectation of new announcements of new targets, policies and measures for the global dissemination of renewable energy.

Renewable energy targets are most effective if they are based on a percentage of a nation's total electricity consumption. One advantage is that this creates an incentive to optimise turbines. If these targets are set as short term targets and long term mile-stones this acts as a guide to identify where immediate policy changes are required to achieve 5 and 10 year targets.

However, targets have little value if they are not accompanied by policies which achieve a level playing field in electricity markets, eliminate market barriers and create an environment which attracts investment capital.

1.1. Specific policy mechanisms

A clear market for wind generated power must be defined in order for a project developer to enter. 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, as well as providing stable, long term fiscal measures, low investor risk and a sufficient return on investment.

The main purpose of the wide range of available economic measures to encourage renewable energy technology investments is to provide incentives for technological improvements and cost reductions of environmental technologies. That will ensure that we will have competitive, clean technologies available in the future as a competitive alternative to conventional, polluting power sources. It is less important whether markets are controlled through prices or through quantities. What matters is that control is achieved in a rational and effective manner.

In order to attract wind power companies to establish manufacturing facilities, 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 types of incentives to promote deployment of renewable energy:

1. **Fixed Price Systems where the government (or the EU) sets the electricity prices (or premiums) paid to the producer and lets the market determine the quantity.**
2. **Renewable Quota Systems (in the USA referred to as Renewable Portfolio Standards) where the government sets the quantity of renewable electricity and leaves it to the market to determine the price.**

There are many variants of the fixed price system. The term is rather misleading as not all of them actually fix the total price per kWh paid to the producer but for analytical purposes it is valuable to make a distinction between fixed prices and fixed quantities:

1. Investment Subsidies
2. Fixed Feed-in Tariffs
3. Fixed Premium Systems
4. Tax Credits.

Two types of renewable quota systems have been employed in national wind power markets:

1. Tendering Systems
2. Green Certificate Systems.

At a national level, the UK, Ireland and Australia tend to prefer to fix quantities, while a majority of countries on the European Continent lean towards fixing prices. The USA is currently somewhere in between with its dual system of a federal tax credit (fixed prices) and renewable quotas (fixed quantities) at the state level.

In addition to the financial mechanisms described in the following, two other factors are crucial for the development of an overall framework for wind power investments: grid access and planning procedures.

1.2.1. Investment subsidies

Usually, investment subsidies are given on the basis of the rated power (in kW) of the generator. If used in isolation, these systems can be problematic because a subsidy is given whether or not production is efficient. In some countries investment subsidies have in the past resulted in poor siting of wind turbines, and manufacturers followed customer demands to use larger generators than necessary for optimal production of electricity. It improved project profitability but reduced production, because the turbines were not optimally designed.
Systems that base the amount of support on generator

size rather than on electricity output are problematic because they lead to less efficient technology development. Any incentive should be related to efficiency of producing power rather than efficiency in completing the construction phase. For wind energy, the global trend is to reject investment subsidies as the only means of encouraging wind power investments.

However, investment subsidies can be effective if combined with other incentives as in the UK. In order to take account of the current higher cost of offshore wind power compared to the more mature onshore market, the British government offers investment grants to offshore projects to complement the ROC (Renewable Obligation Credits) system (a renewable quota system).

1.2.2. Fixed feed-in tariff systems

Mechanisms based on fixed feed-in tariffs (FIT) have been widely adopted throughout Europe and have proved very successful in expanding wind energy in Germany, Spain and Denmark. Operators of wind farms are paid a fixed price for every kWh of electricity they feed into the grid. In Germany, legislation fixes the price of electricity from renewable energy in relation to the generation costs of renewable technologies. The price will decrease 2% each year. In the Spanish system the wholesale price of electricity from renewable energy follows the market price for electricity, after which an environmental bonus is added per kWh. A key characteristic of the fixed price system is that the government sets a price on the societal value of generating a significant share of renewable energy in the electricity system.

As production costs decline, for instance as a result of improved technology and economies of scale, lower wind

speed sites become profitable, expanding wind power further. Fixed feed-in tariff systems encourage competition among wind turbine manufacturers, pressuring them to produce ever more cost effective turbines and thus lower the cost to society of expanding wind power.

The most important advantage of fixed price systems is that they enable investors to plan ahead for new renewable energy plant. The challenge in a fixed price system is fixing the "right" price.
The main benefit of fixed feed-in tariffs is that they are simple and often encourage better planning.

They are not associated with a formal Power Purchase Agreement (PPA) and have no definite term. In principle, therefore, the level of the tariff can be changed at any time or removed by repealing the Law. The disadvantage is the political uncertainty that may arise over how long the system will continue, which means that investors must calculate a risk premium in case the price falls during the life of the project. Germany has been able to reduce much of the political risk by guaranteeing tariffs for 20 years.

1.2.3. Fixed premium systems

A "Fixed Premium" or "Environmental Bonus" mechanism is another variant of the fixed price system. Rather than fixing the total price paid, the government fixes a premium to be added to the electricity price. In principle, a mechanism that is based on a fixed premium/environmental bonus that reflects the external costs of conventional power generation could establish fair trade, fair competition and level the playing field in the Internal Electricity Market between renewable energy sources and conventional power sources.

Together with taxing all power sources in accordance with their environmental impact, fixed premium systems are theoretically the most effective way of internalising external costs. In reality, however, fixed premiums for renewable energy technologies, such as the Spanish model, are based on estimated renewable electricity production costs and comparison with the electricity price rather than the environmental benefit of the renewable energy source compared to conventional power technologies.

1.2.4. Tax credits

A Tax credit is another variant of the fixed price system. Whether an incentive is given in the form of a tax credit or a cash payment does not make a big difference from a socio-economic or investor perspective. But politically it can make a difference whether an incentive is paid by the electricity consumer or by the taxpayer.

The largest wind power market to make use of a tax credit is the United States. Canada is also considering introducing a tax driven system. The United States market is driven by a federal Production Tax Credit (PTC) of approximately 1.8 cents per kWh. It is adjusted annually to take inflation into account.

1.2.5. Competitive bidding, tendering

Tendering systems or competitive bidding havbeen/are used to promote wind power in Ireland, France (for wind farms larger than 12 MW) and the UK. Also Scotland and Northern Ireland has made use of the mechanism and the Danish government is finalising a tender procedure for the future development of offshore wind power.

Developers of wind farm projects are invited to bid for a limited wind energy capacity in a given period. The companies that bid to supply electricity at the lowest costs win the contracts to do so. Usually 15 to 20-year power purchase agreements are entered into. The difference in price between these contracts and the price of conventional power represents the additional costs of producing green electricity. Allocation of development rights is usually achieved by letting the suppliers of electricity from renewable energy sources (the wind turbine owners) compete for the power purchase agreements.

The system removes much of the political risk for investors as the price is agreed upon for a defined period, and the power purchase agreement is enforced under civil law. However, investors are faced with another risk element under tendering. All developers that enter a bid risk losing the planning costs if the bid is not accepted or if planning permission is not given on the location in question. Therefore, the model may be better suited for large projects than small ones.

Furthermore, the method tends to only encourage development of the most economic (windy) sites. From an electricity systems integration point of view, a reasonable geographical spread of wind power is a clear advantage, as it reduces the balancing costs of the system.

One of the major drawbacks of the tenders made so far, e.g. in the UK, has been that they have encouraged 'gaming' of the system. Renewable energy technologies get cheaper over time. Therefore, a contract holder will wait as long as possible to build a project. Partly because of this inherent flaw, the British NFFO (Non-Fossil Fuel Obligation) tender system did not result in many projects being built. Another flaw of the NFFO model was that it did not penalise developers if they failed to install the capacity for which they had secured a power purchase contract. Therefore, the model should be combined with a performance bond and meaningful penalties for failing to meet the contract.

Tendering systems with high penalty clauses appear to be economically efficient, but they are probably only workable for large investors, and not smaller operators such as co-operatives or individual owners, at least not unless they are part of a larger risk-sharing arrangement through a joint project organisation. Experience has shown that the aggressive competition created for lowest price leaves only small margins that will deter investors and force developers to use only the highest wind resource sites.

1.2.6. Tradable green certificates

A tradable Green Certificate Systems (TGC) is, in principle, the same as the tendering system described above. The main difference is that the price for the power and certificates are settled on a daily basis on the electricity market alongside a separate market for tradable certificates (tendering systems are typically based on 15-20 year power purchase agreements). With daily settling of prices the TGC model is more risky for the investor unless an effective market for long-term certificates contracts (probably financial futures or options) is developed.

Under a TGC system, the government sets a specific and gradually increasing quantity – or minimum limit – for the amount of renewable electricity in the supply portfolio. An obligation is placed on either the electricity suppliers or end users of electricity. The generators (producers), wholesalers, retailers or consumers (depending who is obligated in the electricity supply chain) are obligated to supply / consume a certain percentage of electricity from renewable energy sources. At the settlement date, they have to submit the required number of certificates to demonstrate compliance.

The TGC mechanism is more complex in nature than other payment mechanisms. Wind turbine operators will have to be active in two interrelated financial markets: one for TGCs and one for power. One of the challenges in developing such systems is that there seems to be an asymmetry between the demand and the supply side in the markets. Wind turbine owners would prefer to have as long contracts as possible to minimise risk, while the electricity companies on the demand side seem to prefer short contracts.

Another aspect to consider is whether all renewables technologies should be included in a single »umbrella certificate« or whether a certificate for each technology is the answer. One certificate only ensures development of the cheapest renewable energy technology, while several certificates will result in markets with dangerously low liquidity, at least in the beginning of development.

As with the auction / tender model, it is important to introduce penalties for not purchasing green certificates that are sufficiently high to deter non-compliance.

One drawback of a system with fixed quantities of renewables is that the speed with which they are introduced into the electricity supply system is largely independent of technical progress and the increasing efficiency of using renewables, and hence could become a cap on development.

1.3. Emissions caps

Whereas taxation provides a pre-defined cost, much like the tariff system, an emissions cap can set a standard for the industry, but leave it to the market to decide how best to comply with the standard. This can also allow for the introduction of energy saving measures which are often cheaper than new low emission generating capacity. The Kyoto Protocol is a system based on emissions caps, although it does allow for the use of flexible mechanisms that effectively raise the level of the emissions cap within an individual national territory.

Emission trading is an effective and potentially powerful tool to meet targets for emissions of greenhouse gasses. But its limitations must be recognised. It will not fully internalise external costs – a condition for a level playing field between polluting and clean technologies. The philosophy behind emissions trading is that greenhouse gas reductions should be made at the lowest possible cost to society. However, it is important to acknowledge that the cheapest solution in the short run

is not necessarily the cheapest long-term solution. In fact it is unlikely to be so.

If we take on a short-term approach to combating climate change, and only focus on once-in-a-lifetime solutions such as shifts from coal to natural gas (fuel-switching); or only focus on (very necessary but insufficient) energy efficiency measures such as installing thermostats and insulating buildings, we risk creating a gap in the technological development of those new and renewable energy sources that are a precondition for combating climate change at the lowest possible cost in the long run.

Therefore emissions trading should not be seen as a substitute for environmental taxes or policies to promote renewable energy.

The main goal of policies to promote renewables should not be only to reduce emissions here and now (although it is a pleasant side-effect). The main purpose should be to develop clean technologies and ensure that renewable energy in the future can become a fully competitive source of power, which will secure a clean, cheap and indigenous energy supply in the future.

2. Defined and stable returns for investors

Policy measures adopted by governments need to be acceptable to the requirements of the investment community in order to be effective.

There are two key issues:

- 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.

3. Electricity market reform

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

3.1. Removal of electricity sector barriers to renewables

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. Furthermore it does not recognise the value of not having to transport decentralised power generation over large distances.

Legislation needs to reflect the following recent changes:

- ☐ **In technology:** renewables and gas generation have emerged as the fastest growing electricity generation technologies.
- ☐ **In fuels:** coal and nuclear power are becoming increasingly less competitive.
- ☐ **In size:** small modular renewable and gas generating plants are now producing competitively priced power.
- ☐ **In location:** the new modular technologies can be distributed throughout a network.
- ☐ **In environmental and social impacts:** fossil fuel and nuclear power sources are now widely acknowledged to cause local and regional environmental and social

impacts; fossil fuels also have global impacts on the climate.

Another major barrier is the short to medium term surplus electricity generating capacity in Europe. The costs of producing wind power are falling, but still need special provisions. Due to overcapacity in the electricity market, it is still cheaper to burn more coal or gas in an existing power plant than to build, finance and depreciate a new wind power plant. The effect is that, even in those situations where a new technology, such as wind power, would be fully competitive with new coal or gas fired power plants, the investment will not be made. Until we reach a situation where new capacity is needed and electricity prices start reflecting the cost of investing in new capacity rather than the marginal cost of existing capacity, support to renewable energies has to level the playing field in the absence of internalisation of external costs.

Other barriers include the lack of long term planning at national, regional and local level; lack of integrated resource planning; lack of integrated grid planning and management; lack of predictability and stability in the markets; no legal framework for international bodies of water; grid ownership of vertically integrated companies and a lack of long-term R&D funding.

Furthermore there is a complete absence of grids for offshore wind power; weak or non-existing grids onshore; little recognition of the economic benefits of embedded/distributed generation; effective separation of transmission and distribution grids from vertically integrated utilities has not happened leading to obscure and discriminatory requirements for grid access that do not reflect the nature of the technology.

The reforms needed to address market barriers to renewables include:

- Streamlined and uniform planning procedures and permitting systems and integrated least cost network planning;
- Fair 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.

3.2. Removal of market distortions

In addition to market barriers there are also market distortions which block the expansion of renewable energy. These distortions are in the form of direct and indirect subsidies, and the social cost of externalities currently excluded from costs of traditional, polluting electricity from nuclear and fossil fuels.

A major barrier preventing wind power from reaching its full potential is the fundamental 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 existing when coal, gas, and nuclear technologies were introduced. For most of a century, power generation has been characterized by national monopolies with mandates to finance investments in new production capacity through state subsidies and/or levies on electricity bills. As many countries are moving in the direction of more liberalised electricity markets, those options are no longer available, which put new generating technologies, such as wind power, at a competitive disadvantage relative to existing technologies.

3.2.1. End subsidies to fossil fuel and nuclear power sources

Conventional energy sources receive an estimated $250-300 billion in subsidies per year worldwide, and therefore markets are heavily distorted. The Worldwatch Institute estimates that total world coal subsidies are $63 billion, whilst in Germany alone the total is $21 billion, including direct support of more than $85,000 per miner.

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 us toward a level playing field across the energy sector. As the 1998 OECD study "Improving the Environment through Reducing Subsidies" noted: *"Support is seldom justified and generally deters international trade, and is often given to ailing industries. …support may be justified if it lowers the long-term marginal costs to society as a whole. This may be the case with support to 'infant industries', such as producers of renewable energy."*

The 2001 report of the G8 Renewable Energy Task Force goes further, stating that *"re-addressing them [subsidies] and making even a minor re-direction of these considerable financial flows toward renewables, provides an opportunity to bring consistency to new public goals and to include social and environmental costs in prices."* The Task Force recommends that *"G8 countries should take steps to remove incentives and other supports for environmentally harmful energy technologies, and develop and implement market-based mechanisms that address externalities, enabling renewable energy technologies to compete in the market on a more equal and fairer basis."*

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 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.

3.2.2. Internalise 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 global impacts from climate change. More than 30,000 Americans die prematurely every year due to emissions from electric power plants, for example. Hidden costs also include the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear operators. The Price-Anderson Act, for instance, limits the liability of US nuclear power plants in the case of an accident to a subsidy of up to $3.4 billion annually.

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

The environmental impacts of electricity generation can be difficult to quantify, though. How do we put a price on lost homes on Pacific Islands as a result of melting icecaps, deteriorating health or the visual impact of a wind turbine? An ambitious project, funded by the European Commission - ExternE – has tried to quantify the true costs, including environmental costs of electricity generation. It estimates that the cost of producing electricity from coal or oil would double and the cost of electricity production from gas would increase by 30 %, if 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 Euro 85 billion and Euro 170 billion, not including the cost of global warming and climate change. If those environmental costs were levied on electricity generation according to their impact, many renewables, including wind power, would not need any support. If, at the same time, direct and indirect subsidies to fossil fuels and nuclear power were removed, the need to support renewable electricity generation would seriously diminish or cease to exist.

As with the other subsidies, such external costs must be factored into energy pricing if the market is to be truly competitive. 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 important to achieve fairer competition on the world's electricity markets.

International policies

1. Ratification of the Kyoto Protocol

Ratification of the Kyoto Protocol to the United Nations Framework Convention on Climate Change is a first vital step towards protecting the climate from dangerous anthropogenic climate change – the overall goal of the Climate Convention. The Protocol as a legally binding international instrument heralds the beginning of carbon-constrained economies. This will mean an increased demand for low and no carbon power production. Protecting the climate will demand more and deeper cuts in greenhouse gas emissions which will further increase the demand and market for renewable energy technologies such as wind power.

2. Reform of Export Credit Agencies (ECAs), Multi-lateral Development Banks (MDBs) and International Finance Institutions (IFIs)

Demand for energy, particularly electricity, is increasing worldwide. This is especially the case in developing countries, which rely heavily on export credit agencies 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 upon conventional energy sources and exports, whilst also recognising that meeting the development goals for the world's poorest will require subsidies for the foreseeable future.

The G8 Task Force report, whilst acknowledging the role of international finance institutions and ECAs, makes significant recommendations that would go some way to addressing this issue. It states: *"Modern energy access and environmental considerations should be integrated into the IFIs' energy sector dialogue and investment programmes. Thus current instruments and agency programmes should be adapted to provide increased support for renewable energy projects which, although economically attractive, may be small and have long pay back periods. Guarantee funds, refinancing schemes for local banks, ad hoc loan facilities to local small private operators, should be considered in this respect."*

In addition, the report recommends that *"the G8 should extend so-called 'sector arrangements' for energy lending to renewables and develop and implement common environmental guidelines among the G8 Export Credit Agencies (ECAs). This could include: identifying criteria to assess environmental impacts of ECA-financed projects, and establishing minimum standards of energy-efficiency or carbon-intensity for these projects; developing a common reporting methodology for ECAs to permit assessment of their local and global environmental impacts."*

Finally, note should be made of the recommendations of the World Bank's Extractive Industries Review, which is currently before the Bank for consideration. The Review was set up by the Bank, and the recommendations call for sweeping reform of the Bank's lending policies in the energy sector, including a phase out of support for fossil fuel based energy.

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.

Policy summary

National policies

1. Establish legally binding targets for renewable energy

2. Provide defined and stable returns for investors
   - 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.

3. Electricity market reforms
   - 3.1. Remove electricity sector barriers to renewables
   - 3.2. Remove market distortions
     - Halt subsidies to fossil fuel and nuclear power sources.
     - Internalise social and environmental costs of polluting energy.

International policies

1. Kyoto Protocol Ratification

2. Reform of Export Credit Agencies (ECAs), Multi-lateral Development Banks (MDBs) and International Finance Institutions (IFIs)
   - 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.

APPENDICES

Table 1 - Wind Force 12 - Projected wind power market development, 2003-2045

Growth ratio	Year	Cumulative MW	Annual MW	Annual avg. WTG (MW)	Cumulative no. of units	Capacity factor (%)	Production TWh	Progress ratio	Replacement MW	Replacement Units
25%	2003	40,301	8,344	1,2	67,950	24%	84.7	85%		
	2004	50,731	10,430	1,3	75,973	24%	106.7			
	2005	63,769	13,038	1,4	85,286	24%	134.1			
	2006	80,065	16,297	1,4	96,926	25%	175.3			
	2007	100,436	20,371	1,5	110,507	25%	220.0			
	2008	125,900	25,464	1,5	127,483	25%	275.7			
	2009	157,730	31,830	1,5	148,703	25%	345.4			
	2010	197,517	39,787	1,5	175,228	25%	432.6			
20%	2011	245,262	47,745	1,5	207,057	25%	537.1	90%		
	2012	302,556	57,294	1,5	245,253	28%	742.1			
	2013	371,308	68,752	2	279,629	28%	910.7			
	2014	453,811	82,503	2	320,881	28%	1,113.1			
15%	2015	548,690	94,878	2	368,320	28%	1,345.8			
	2016	657,800	109,110	2	422,875	28%	1,613.5			
	2017	783,276	125,477	2	485,613	28%	1,921.2			
	2018	927,575	144,298	2	557,763	28%	2,275.2			
10%	2019	1,086,303	158,728	2	637,127	28%	2,664.5			
0%	**2020**	**1,245,030**	**158,728**	**2**	**716,491**	**28%**	**3,053.8**			
	2021	1,403,758	158,728	2	795,854	28%	3,443.1			
	2022	1,562,486	158,728	2	875,218	28%	3,832.5			
	2023	1,721,214	158,728	2	954,582	28%	4,221.8			
	2024	1,879,942	158,728	2	1,033,946	28%	4,611.1			
	2025	2,038,670	158,728	2	1,113,310	28%	5,000.5			
	2026	2,181,101	158,728	2	1,192,506	28%	5,349.8	100%	16,297	11,641
	2027	2,319,458	158,728	2	1,271,686	28%	5,689.2		20,371	13,581
	2028	2,452,722	158,728	2	1,350,850	28%	6,016.0		25,464	16,976
	2029	2,579,620	158,728	2	1,430,000	28%	6,327.3		31,830	21,220
	2030	**2,698,561**	**158,728**	**2**	**1,509,137**	**28%**	**6,619.0**		**39,787**	**26,525**
	2031	2,809,544	158,728	2	1,588,270	28%	6,891.3		47,745	31,830
	2032	2,910,978	158,728	2	1,667,401	28%	7,140.0		57,294	38,196
	2033	3,000,954	158,728	2	1,746,519	28%	7,360.7		68,752	34,376
	2034	3,077,179	158,728	2	1,825,626	28%	7,547.7		82,503	41,251
	2035	3,141,029	158,728	2	1,904,732	28%	7,704.3		94,878	47,439
	2036	3,190,646	158,728	2	1,983,838	30%	8,385.0		109,110	54,555
	2037	3,223,898	158,728	2	2,062,944	30%	8,472.4		125,477	62,738
	2038	3,238,328	158,728	2	2,142,049	30%	8,510.3		144,298	72,149
	2039	3,238,328	158,728	2	2,221,164	30%	8,510.3		158,728	79,364
	2040	**3,238,328**	**158,728**	**2**	**2,300,306**	**30%**	**8,510.3**		**158,728**	**79,364**
	2041	3,238,328	158,728	2	2,379,471	30%	8,510.3		158,728	79,364
	2042	3,238,328	158,728	2	2,458,653	30%	8,510.3		158,728	79,364
	2043	3,238,328	158,728	2	2,537,851	30%	8,510.3		158,728	79,364
	2044	3,238,328	158,728	2	2,617,061	30%	8,510.3		158,728	79,364
	2045	3,238,328	158,728	2	2,696,283	30%	8,510.3		158,728	79,364

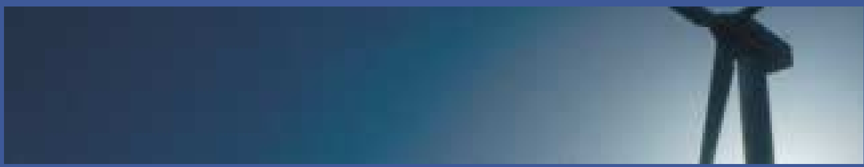
Table 2 - Cost reduction and market development, 2003-2045

Progress ratio	Year	Cumulative MW	Cumulative turbines	Electricity €cent/kWh	Capacity €/kW
	2003	40,301	67,950	3.79	804
	2004	50,731	75,973	3.69	783
	2005	63,769	85,286	3.59	762
85%	2006	80,065	96,926	3.48	740
	2007	100,436	110,507	3.38	717
	2008	125,900	127,483	3.27	694
	2009	157,730	148,703	3.15	669
	2010	197,517	175,228	3.03	644
	2011	245,262	207,057	2.96	619
90%	2012	302,556	245,253	2.88	603
	2013	371,308	279,629	2.82	591
	2014	453,811	320,881	2.76	579
	2015	548,690	368,320	2.71	567
	2016	657,800	422,875	2.65	555
	2017	783,276	485,613	2.60	544
	2018	927,575	557,763	2.54	532
	2019	1,086,303	637,127	2.49	521
	2020	**1,245,030**	**716,491**	**2.45**	**512**
	2021	1,403,758	795,854	2.41	504
	2022	1,562,486	875,218	2.37	497
	2023	1,721,214	954,582	2.34	490
	2024	1,879,942	1,033,946	2.31	484
	2025	2,038,670	1,113,310	2.29	479
	2026	2,181,101	1,192,506	2.29	474
100%	2027	2,319,458	1,271,686	2.29	474
	2028	2,452,722	1,350,850	2.29	474
	2029	2,579,620	1,430,000	2.29	474
	2030	**2,698,561**	**1,509,137**	**2.29**	**474**
	2031	2,809,544	1,588,270	2.29	474
	2032	2,910,978	1,667,401	2.29	474
	2033	3,000,954	1,746,519	2.29	474
	2034	3,077,179	1,825,626	2.29	474
	2035	3,141,029	1,904,732	2.29	474
	2036	3,190,646	1,983,838	2.29	474
	2037	3,223,898	2,062,944	2.29	474
	2038	3,238,328	2,142,049	2.29	474
	2039	3,238,328	2,221,164	2.29	474
	2040	**3,238,328**	**2,300,306**	**2.29**	**474**
	2041	3,238,328	2,379,471	2.29	474
	2042	3,238,328	2,458,653	2.29	474
	2043	3,238,328	2,537,851	2.29	474
	2044	3,238,328	2,617,061	2.29	474
	2045	3,238,328	2,696,283	2.29	474

Table 3 - Carbon dioxide saving and market development, 2003-2045

Year	Cumulative MW	Production (TWh)	CO_2 reduction (annual million tons)	CO_2 reduction (cumulative million tons)
2003	40,301	84.7	50.8	50.8
2004	50,731	106.7	64.0	114.8
2005	63,769	134.1	80.4	195.3
2006	80,065	175.3	105.2	300.5
2007	100,436	220.0	132.0	432.5
2008	125,900	275.7	165.4	597.9
2009	157,730	345.4	207.3	805.1
2010	197,517	433	260	1,065
2011	245,262	537	322	1,387
2012	302,556	742	445	1,832
2013	371,308	911	546	2,379
2014	453,811	1,113	668	3,047
2015	548,690	1,346	807	3,854
2016	657,800	1,613	968	4,822
2017	783,276	1,921	1,153	5,975
2018	927,575	2,275	1,365	7,340
2019	1,086,303	2,664	1,599	8,939
2020	**1,245,030**	**3,054**	**1,832**	**10,771**
2021	1,403,758	3,443	2,066	12,837
2022	1,562,486	3,832	2,299	15,136
2023	1,721,214	4,222	2,533	17,669
2024	1,879,942	4,611	2,767	20,436
2025	2,038,670	5,000	3,000	23,436
2026	2,181,101	5,350	3,210	26,646
2027	2,319,458	5,689	3,414	30,060
2028	2,452,722	6,016	3,610	33,669
2029	2,579,620	6,327	3,796	37,466
2030	**2,698,561**	**6,619**	**3,971**	**41,437**
2031	2,809,544	6,891	4,135	45,572
2032	2,910,978	7,140	4,284	49,856
2033	3,000,954	7,361	4,416	54,272
2034	3,077,179	7,548	4,529	58,801
2035	3,141,029	7,704	4,623	63,424
2036	3,190,646	8,385	5,031	68,455
2037	3,223,898	8,472	5,083	73,538
2038	3,238,328	8,510	5,106	78,644
2039	3,238,328	8,510	5,106	83,750
2040	**3,238,328**	**8,510**	**5,106**	**88,857**
2041	3,238,328	8,510	5,106	93,963
2042	3,238,328	8,510	5,106	99,069
2043	3,238,328	8,510	5,106	104,175
2044	3,238,328	8,510	5,106	109,281
2045	3,238,328	8,510	5,106	114,388

Note: Average CO_2 reduction – 0.60 kg/kWh



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