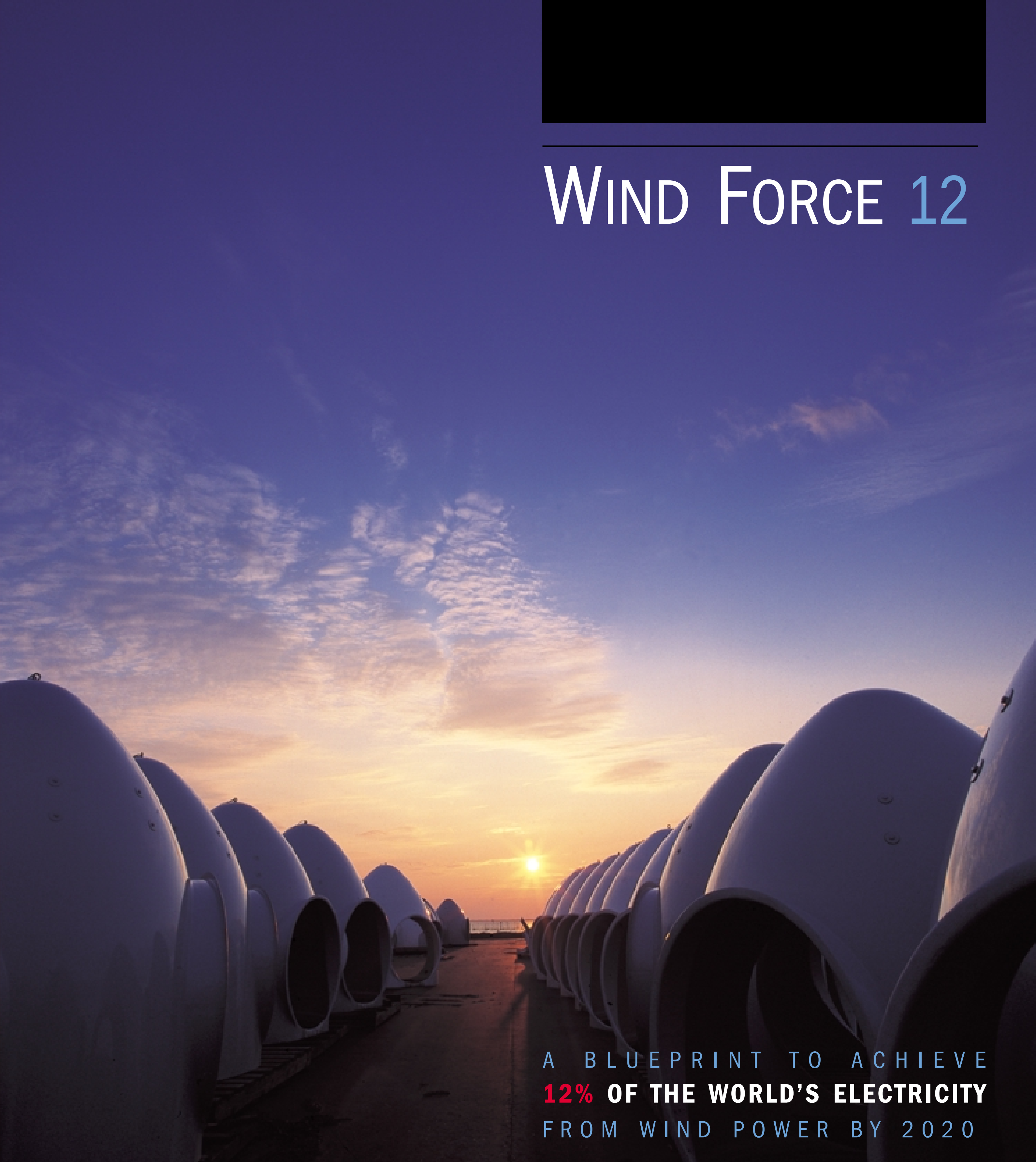

WIND FORCE 12

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

EUROPEAN WIND ENERGY ASSOCIATION / GREENPEACE

May 2003

Executive summary

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 latest update of a study originally published in 1999 (Wind Force 10), which was updated to Wind Force 12 published in May 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 2002 alone, more than 7,000 MW of new capacity was added to the electricity grid. This investment was worth more than €7 billion.

By the beginning of 2003, global wind power installations had reached a level of 32,000 MW. This provides enough power to satisfy the needs of around 16 million average European households or 40 million European citizens. Although Europe accounts for 74% of this capacity, other regions are beginning to emerge as substantial markets. Almost 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. Most countries now accept that greenhouse gas emissions must be drastically slashed in order to avoid environmental catastrophe. Wind power offers both an energy 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. Wind power can deliver industrial scale grid-connected capacity.

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 policy 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. The production cost of a kilowatt hour of wind power has fallen by 20% over the past five years alone. Wind is already 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 2,500 kW and prototypes now being built of more than 4,000 kW.

Important "success stories" for wind power 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 more than 20,000 MW 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 of up to 50% have been managed 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 period up to 2008. This is the highest growth rate during the timescale of the study, ending up with a total of 133,746 MW on line by the end of 2008.

From 2009 to 2014, the growth rate falls to 20% per annum, resulting in 462,253 MW of installed capacity by 2013. After that the annual growth rate falls to 15%, and then to 10% in 2018, 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 almost 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 151,490 MW per annum. This means that by 2040, wind power's global total will have reached roughly 3,100 GW, which by then will represent about 22% 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 energy 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 turbines installed has been close to 36%. After 2013, the scenario growth rate falls to 15% and then to 10% in 2018. 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 stable political frameworks established in emerging markets if this expansion is to be achieved.

Progress rations:

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 turbine's being installed is expected to grow over the next decade from today's figure of 1,000 kW (1 MW) to 1.3 MW in 2008 and 1.5 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 16% globally and large hydro 19%. 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.

Investment, Costs and Employment

The annual investment required to achieve the deployment of wind power outlined above starts at €7.2 billion in 2003 and increases to a peak of €75.2 billion by 2020. The total investment needed to reach a level of almost 1,200 GW of capacity by 2020 is estimated at €674 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 been reduced dramatically as manufacturing and other costs have fallen. This study starts with the basis that a “state of the art” wind turbine in 2002 in the most optimal conditions has an investment cost of €823 per installed kW and a unit cost of 3.88€ 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 2.93 €cents/kWh by 2010, assuming a cost per installed kilowatt of €623. By 2020 it is expected to have reduced to 2.34 €cents/kWh, with an installation cost of €497/kW - a substantial reduction of 40% compared with 2002.

Wind power costs are also expected to look increasingly attractive when compared with other power technologies.

The employment effect of the 12% wind power scenario is a crucial factor to weigh alongside its other costs and benefits. A total of 1.79 million jobs will have been created around the world by 2020 in manufacturing, installation and other work associated with the industry. This total is also broken down by region of the world.

Environmental Benefits

A reduction in the levels of carbon dioxide being emitted into the world’s atmosphere is an 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 1,813 million tonnes of CO_2 by 2020 and 4,860 million tonnes by 2040. The cumulative savings would be 10,921 million tonnes of CO_2 by 2020 and 85,911 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 benefit as the costs of other fuels would increase substantially.

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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.
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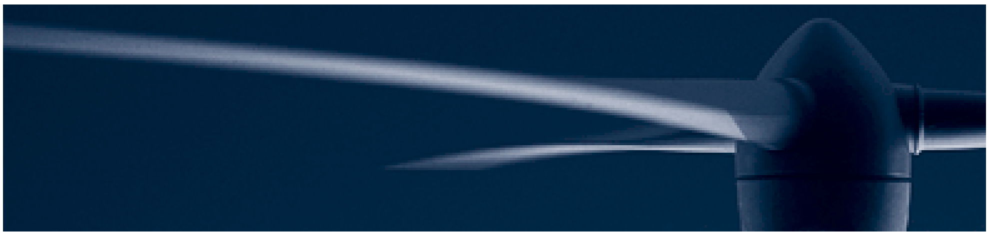
EWEA

GREENPEACE



Climate change is a major challenge to sustainable development world-wide. This is increasingly recognised by forward-looking political and business leaders. One of the tasks we are facing is a profound transformation of our energy system over the next few decades replacing fossil fuels with renewable energies and dramatically increasing energy efficiency. □ □ □ Wind Force 12 illustrates that wind energy is a critical part of the solution. Wind energy is increasingly competitive in liberalised energy markets and in good wind locations. This encourages us to envisage the same success for other renewable energies if we get the regulatory and market frameworks right. Phasing out environmentally harmful energy subsidies and internalising the environmental costs of energy production and use must be a key element in this framework. Over the next few years, off-shore developments can greatly extend the exploitable wind resource. It also responds to concerns about the visual and other impacts of the land-based exploitation of wind that we cannot ignore. □ □ □ Moving towards a sustainable energy future will necessitate the mobilisation of significant efforts by

Foreword

Margot Wallström
Member of the European Commission in charge of environment

public authorities and the private sector. Policy-makers need guiding ideas and public support in shaping policy. Business requires a stable and long-term framework to decide on heavy investments. Scenarios based on sound analysis and clear objectives as in this report contribute to the vision for our future energy system that citizens and decision-makers need and that should be the basis for forward-looking policy. A wind scenario has to be integrated into broader visions for energy in the future. A hydrogen world for example will only be environmentally sustainable if it builds on renewable energies and is complemented by an energy efficiency breakthrough. □ □ □ The European Union is the global leader in wind energy, both in installed capacity and in wind turbine manufacturing. The European wind turbine industry supplies around 90 per cent of the world market. It is a show-case for the potential of environmental technologies to give an industry a competitive edge and create export opportunities. We believe that technology is a key to the EU's and global sustainable development. □ □ □ At the Johannesburg World Summit last summer the EU launched the Johannesburg Renewable Energy Coalition. Almost 80 countries have joined it to date with the common commitment to promote renewable energies world-wide. A bottom-up process of setting targets and co-operation on the development of renewable energy technologies, markets and investment strategies are at the core of the Johannesburg Renewable Energy Coalition. New instruments for enhancing markets and increasing public and private investors' bias for renewable energy technologies are one of our objectives. Wind energy is part of the picture. □ □ □ This report provides a glimpse at an exciting future that will be better for many people around the world. I wish you interesting reading.

Introduction

Corin Millais
Chief Executive European Wind Energy Association

Sven Teske
Renewables Director Greenpeace

This report 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 €75 billion annual business by 2020, able to satisfy global energy demands and unlock a new era of economic growth, technological progress and environmental protection across the globe. □ □ □ 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 fastest growing energy business and offers the 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 has resulted in today's wind turbines being state-of-the-art modern technology - modular and rapid to install. A single wind turbine can produce 200 times more power than its equivalent two decades ago, with rotor diameters larger than a jumbo jet wingspan. Modern wind farms provide bulk power equivalent to conventional power stations and can be built in a matter of months. This blueprint would further push the boundaries of technological progress to bring far greater benefits. Wind power does not need to be invented, nor is there need to wait for any magical 'breakthrough'; it is ready for global implementation today. □ □ □ As outlined in the beginning chapters, the success of the industry to date has been largely created by the efforts of just three European countries - Denmark, Germany and Spain. It is obvious that if other countries matched these efforts, the impact would be far reaching. □ □ □ 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 an 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 existing obstacles and market distortions which currently constrain the industry's real potential. □ □ □ Following last years Earth Summit, the Johannesburg Renewable Energy Coalition was formed, consisting of more than 80 countries, proclaiming that their goal is to "substantially increase the global share of renewable energy sources" on the basis of "clear and ambitious time-bound targets". Political declarations mean little if not put into practice. Wind Force 12 is the political blueprint for action that Governments can implement, and shows what is possible with just one renewable technology. □ □ □ Wind power is world scale; it provides the required magnitude to satisfy the energy and development needs of the world without destroying it.

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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 2.93 €cents/kWh by 2010, assuming a cost per installed kilowatt of €623. By 2020 it is expected to have reduced to 2.34 €cents/kWh, with an installation cost of €497/kW - a substantial reduction of 40% compared with 2002.

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   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.

Methodology

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

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. Furthermore, the intention has been to work out 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?

This is the fourth edition of this report. The first 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 published in 2002 by EWEA and Greenpeace.

The first (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.

In last year's Wind Force 12 report, three underlying factors changed. Firstly, the adjusted projections were based on the IEA's 2000 World Energy Outlook. Since this updated forecast for future global electricity demand was slightly lower than in 1998/9, it enabled the percentage of wind power's contribution to world electricity to rise. Secondly, wind industry growth rates over the previous three years had been well above those in the original Wind Force 10 report. Thirdly, the annual growth rates projected for the period 2004 to 2015 were 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 (2003) has involved a number of fresh adjustments. Firstly, the falling annual growth rates of 25%, 20% and 15% are maintained, but the time period for each band has been increased by one year. The reason for this adjustment is that the growth of wind energy during 2002 was lower than in the previous years, the first time that the actual development in terms of annual installation (MW) was lower than indicated in the last version of the WF 12 study. Nonetheless, it should be emphasised that the chosen growth rates in this report are more moderate than those actually recorded in the market over the last five years - an average growth of about 36% per annum.

Secondly, the estimated average capacity factor has been reduced from 25 to 24% for the first three years. This is based on the fact that the average for 2002 was about 23%. Improved capacity factors result from a mixture of siting and design parameters. Future large scale offshore developments will contribute to such improvements.

Finally, the reference projection for global electricity demand from the latest World Energy Outlook 2002 has been used. This has involved only a minor change, however, as the projected demand by 2020 is about the same as in the previous WEO 2000 (25,579 TWh versus 25,878 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 2005 (see *Table 5.6 a*).

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, 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 150,000 MW/year must be established – over twenty times that of 2002. 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, and with a marginal additional cost for absorption into the utility system.

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, as was the case with nuclear and large hydro.

The Global Status of wind power

Since the original Wind Force 10 report was first published in 1999, wind power has consistently outstripped its anticipated expansion rate, and maintained its status as the world's fastest growing energy source. Among mainstream energy analysts, it now ranks as one of the most promising business opportunities for mitigating climate change and providing clean energy.

Over the past five years, global wind power capacity has continued to grow at an average cumulative rate of 33% *(Table 2-1)*. The increase in annual installations has been even higher – a year-on-year average of 35.7%. During 2002 alone, more than 7,200 MW of new capacity was added to electricity grids worldwide. This investment was worth more than €7 billion.

By the end of 2002, the capacity of wind turbines installed globally had reached a level of over 32,000 MW. This is enough power to satisfy the needs of 16 million average European households, or 40 million people. Europe accounts for 74% of this capacity, and for 85% of the growth during 2002. But other regions are beginning to emerge as substantial markets for the wind industry. Almost 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 around 90-100,000, with 70-80,000 of these in Europe.

Table 2-1: Growth in World Wind Power Market 1997-2002

Year	Installed Capacity (MW)	Increase	Cumulative Capacity (MW)	Increase
1997	1,568		7,636	
1998	2,597	66%	10,153	33%
1999	3,922	51%	13,932	37%
2000	4,495	15%	18,449	32%
2001	6,824	52%	24,927	35%
2002	7,227	6%	32,037	29%
Average growth over 5 years		**35.7%**		**33.2%**

Worldwide Markets

Within Europe, Germany is the clear market leader. During 2002, German wind capacity grew by a record 3,247 MW, taking the country's total up to almost 12,000 MW. This represents 4.7% of national electricity demand, a proportion expected to increase to 8% by 2010.

Denmark and Spain have also continued to expand, the latter by almost 1,500 MW during 2002. 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 18% of its electricity demand from the wind, the highest contribution of any country in the world.
Eight other members of the European Union – France,

Greece, Ireland, Italy, the Netherlands, Portugal, Sweden and the UK – now each have more than 150 MW installed, and have all effectively reached the take-off stage. The UK, Italy and the Netherlands have all pushed through the 500 MW barrier.

North America

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 4,674 MW.

Canada, with one of the largest wind resources in the world, is ready to expand well beyond its present level of 270 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.

Rest of the world

New markets are also opening up in other continents. Australia doubled its capacity in 2002 to reach 189 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 1,700 MW by the end of 2002. 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.

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 5.8°C over the next century, bringing flooding, droughts and violent climate swings in its wake. Most countries now accept that greenhouse gas emissions must be drastically slashed in order to limit the resulting environmental catastrophe.

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 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 15 member states of the European Union, for example, now have an overall target for 22% of their electricity to come from renewables by 2010, an increase from a baseline of 14% in 1997.

Table 2-2: Top Wind Energy Markets in 2002

Country	New capacity (MW)	Total capacity end 2002 (MW)
Germany	3,247	11,968
Spain	1,493	5,043
Denmark	530	2,880
USA	429	4,674
India	220	1,702
Netherlands	219	727
Japan	129	486
Australia	119	189
Italy	106	806
Greece	104	462
Others	632	3,100
World total	**7,227**	**32,037**

CONVENTIONAL ENERGY SOURCES RECEIVE AN ESTIMATED € 230-280 BILLION IN SUBSIDIES PER YEAR WORLD-WIDE.

In order to achieve these targets, countries in Europe and elsewhere have adopted a variety of policy 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.

Distored markets

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

OVER THE PAST FIVE YEARS ALONE, COSTS HAVE REDUCED BY SOME 20%.

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.

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 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. Over the past five years alone, costs have reduced by some 20%. On good sites, wind is already competitive with new coal-fired plants and in some locations can challenge gas.

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 7 metres per second, and a capital cost per installed kilowatt of €700, wind can be competitive with gas.

Table 2-3: Growth Rates in Top Ten Wind Energy Markets

Country	MW end 1999	MW end 2000	MW end 2001	MW end 2002	Growth rate 2001-2	3 years averege growth
Germany	4,442	6,107	8,734	11,968	37.0%	39.2%
Spain	1,812	2,836	3,550	5,043	42.1%	40.7%
USA	2,445	2,610	4,245	4,674	10.1%	24.1%
Denmark	1,738	2,341	2,456	2,880	17.3%	18.3%
India	1,035	1,220	1,456	1,702	16.9%	18.0%
Italy	277	424	700	806	15.1%	42.7%
Netherlands	433	473	523	727	39.0%	18.9%
UK	362	425	525	570	8.7%	16.4%
Japan	68	142	357	486	36.1%	92.7%
China	262	352	406	473	16.5%	21.8%
World total	**12,874**	**16,929**	**22,952**	**29,329**	**27.8%**	**31.6%**

WIND POWER TECHNOLOGY

Wind power is a deceptively simple technology. Behind the tall, slender towers and gently turning blades lies a complex interplay of lightweight materials, aerodynamic design and computerised electronic control. German industry data shows that the wind turbines themselves represent about 65% of the capital cost of an onshore project, while the rest is systems components, land costs, foundations and road construction.

EACH 2,000 KW TURBINE ALSO PRODUCES MORE ENERGY THAN 200 OF THE OLD 1980S VINTAGE MACHINES.

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 altogether 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 at the lowest cost. 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 600 up to 2,500 kW. In 2002 the average capacity of new turbines installed in Germany rose to 1,390 kW. Each 2,000 kW turbine also produces more energy than 200 of the old 1980s vintage machines.

The largest machines commercially available today are of 2,500 kW capacity, with 80 metre diameter rotors placed on 70-100 metre high towers. 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 600 households.

In the future, even larger turbines will be produced to service the new offshore market. Machines in a range from 3,000 kW 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.

Wind turbines have a design lifetime of 20-25 years, with their operation and maintenance costs typically about 3-5% of the cost of the turbine.

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 trans-European super-grid was installed to link up the many large offshore plants expected to start generating power over the next decade.

ADVANTAGES OF WIND POWER

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

Wind power success stories

Germany – World Leader

Germany is the undisputed world leader in wind power. 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 2002) stands at more than 12,000 MW. These turbines can produce enough electricity to meet 4.7% of demand in a country of 82 million people. If present trends continue, the proportion could easily reach 8% by 2010.

During 2002 alone more than 2,300 new wind turbines were connected to the grid, representing a total capacity of 3,247 MW. This was a 20% increase over the amount of new capacity installed during 2001, itself a record year. Germany has seen impressive growth rates in its wind energy market since the mid-1990s. The average annual increase in cumulative capacity over the past three years has been 37%.

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 and GE Wind having built up major manufacturing bases. An estimated 45,000 people are currently employed both directly and indirectly by the industry, with a fifth of those taken on last year. Sales in the sector were expected to have reached €3.5 billion during 2002.

Landmark legislation

Following government-sponsored research programmes during the 1980s, the big breakthrough for the German market came in 1991, when the Stromeinspeisungsgesetz - Electricity Feed Law (EFL) - was passed by parliament. This landmark piece of 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, but has done nothing to deter investors.

AN ESTIMATED 45,000 PEOPLE ARE CURRENTLY EMPLOYED BOTH DIRECTLY AND INDIRECTLY BY THE INDUSTRY, WITH A FIFTH OF THOSE TAKEN ON LAST YEAR.

National policies have also been shadowed by strong regional development plans. In the northern state of Schleswig- Holstein, for example, a target for 25% of electricity to be supplied by the wind in 2010 has already been achieved. 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 14% 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 North-Rhine Westphalia (1,445 MW installed by the end of 2001), Saxony-Anhalt (1,294 MW) and Brandenburg (1,272 MW), 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.

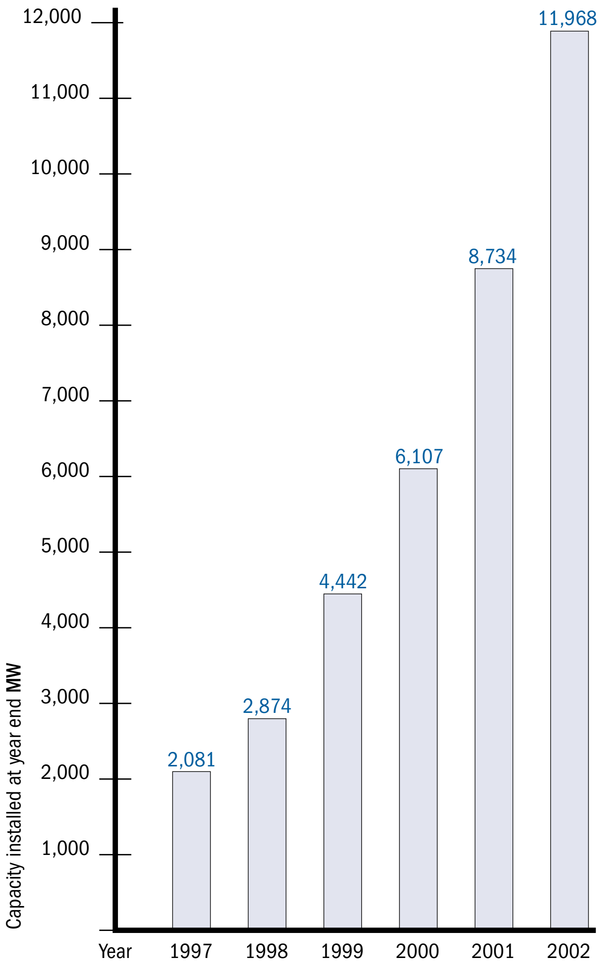
The second effect has been to open up the ownership and investment potential of wind power to a wide range of people. Many wind parks have been developed through investment funds in which shares are bought by small businessmen and companies, who in turn benefit from an investment tax rebate. One estimate is that more than 100,000 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.

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.

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 2010 wind power should be providing 8% of German electricity demand from approximately 23,000 MW of capacity.

Wind Power in Germany



Wind power success stories

United States – Waking Giant

The United States is fast becoming one of the world's leading wind power markets, following a long lull during the 1990s. There are now utility-scale wind power installations in 27 states, totaling 4,674 MW at the end of 2002. These generate enough electricity to power more than 1.3 million households.

In spite of the worst crisis to hit the broader energy sector in years, the American Wind Energy Association anticipates that wind power will forge ahead strongly again in 2003. US wind capacity has grown by an average 24.5% over the past five years (1998-2002), and some analysts and industry executives expect to see double-digit growth for the rest of the decade.

The predictable and affordable cost of wind power 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 the Florida Power and Light 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 power installations already exceed 1,000 MW in the Lone Star state.

In New York it is 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 2003, eleven 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 allowed it to expire before acting, and then only approving short extensions. This has produced a “boom and bust” cycle, resulting in cancelled projects and laid-off workers.

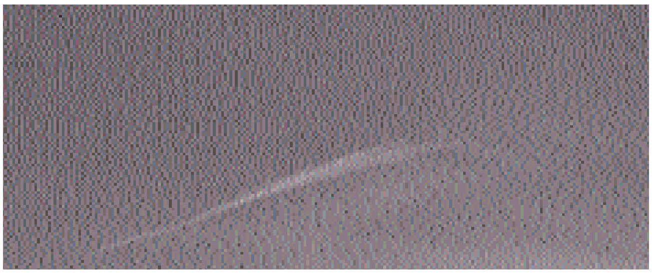
THE STATE OF NORTH DAKOTA ALONE HAS ABOUT FIFTY TIMES THE WIND RESOURCE OF GERMANY.

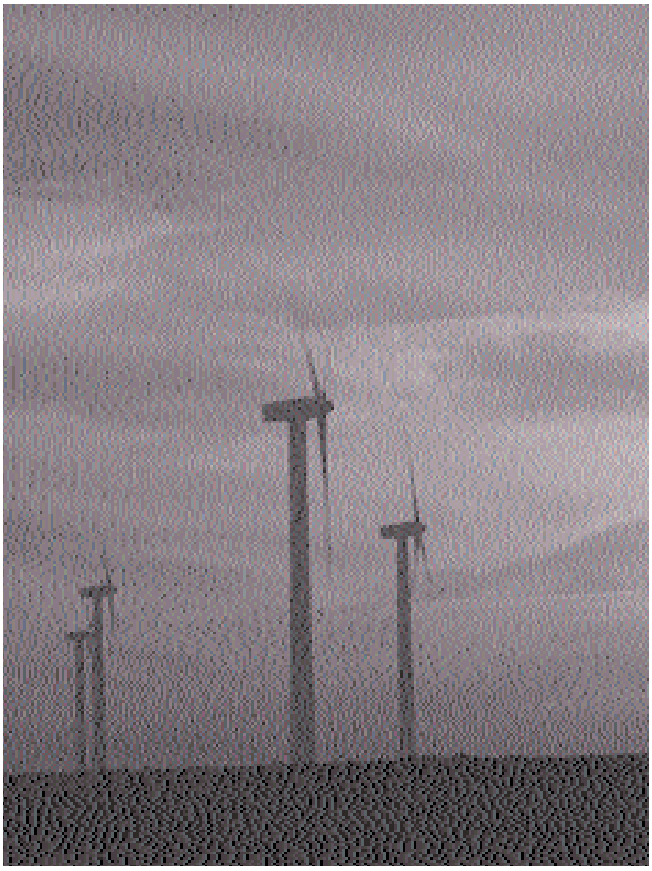
With the PTC set to expire again at the end of 2003, a multi-year extension would provide a much-needed stable market signal. Long-term stability in the wind energy market would equally be encouraged by a national renewable energy goal or renewables portfolio standard.

Unlocking transmission barriers

Transmission barriers, which have held up the expansion of wind power in many regions of the US, are beginning to recede. In order to unlock the vast wind power potential of America's heartland and bring that power to market, it is critical that electricity generators are able to gain access to the transmission network on fair terms compared with other generation technologies.

Federal regulators have proposed a dramatic overhaul of the wholesale electricity market structure that includes fair treatment of wind power in transmission pricing. Among other changes this would eliminate all penalties associated

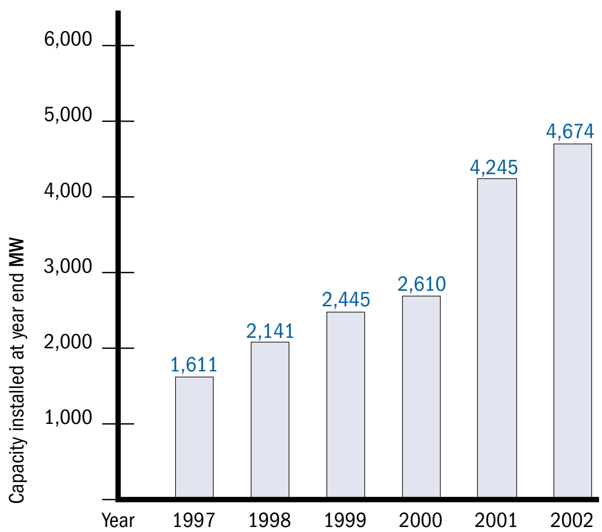




with wind's variable output when that variability does not result in increased costs to the system. However, carrying out these changes will be difficult and may not be finished in some regions for some time.

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.



Wind Power in United States

Wind power success stories

India – Developing World Pioneer

Among the countries of the developing world, India has pioneered the use of wind power as a vital alternative to its increasing dependence on fossil fuels. After a quiet period, the wind leader of Asia is now poised to leap forward again with a new generation of more powerful wind farms.

With an installed capacity of 1,702 MW, India is already the fifth largest producer of wind power in the world. Over the past three years 625 MW has been installed. Even so, given the country's vast potential, especially in the windy coastal regions, progress could be much faster than this.

The original impetus to develop wind energy in India came from 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. One estimate is that the total potential for wind power in a country of more than a billion people could be as much as 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. A 100% tax rebate on the income from power generation during the first ten years of operation was also introduced in 2002. Individual states have their own incentive schemes, including capital cost subsidies.

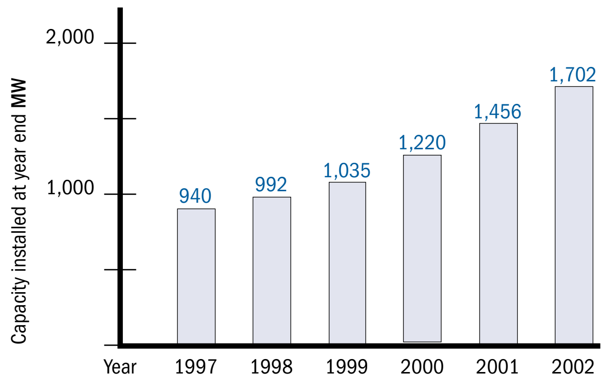
One result of these incentives has been to encourage industrial companies and businesses to invest in wind power. An important attraction is that owning a wind turbine assures them of a power supply to their factory or business in a country where power cuts are common. Wind farms in India therefore often consist of clusters of individually owned generators. The downside has been that the incentives have also attracted a number of unreliable equipment suppliers, leaving some wind schemes in poor working order and investors disillusioned.

Over the past few years, however, 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 70% 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.

Manufacturing base

More than a dozen wind turbine manufacturers are currently offering their products on the Indian market. One of them, Vestas RRB, has been operating since the mid-1980s. A successful recent entrant has been Suzlon, a company which now employs more than 800 people. It was also the first in India to market a 1 MW model.

The geographical spread of Indian wind power has so far been concentrated in a few regions, especially the southern state of Tamil Nadu, which accounts for roughly half of all installations. This is beginning to change, with other states like Maharashtra, Gujarat and Andhra Pradesh catching up. BTM Consult expects 4,000 MW to be installed in India by the end of 2007, well ahead of the government's own projections.



Wind Power in India

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 close to €3 billion, its growth rate challenges that of the internet or mobile phones. 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 major turbine manufacturers-Vestas, NEG Micon 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.

The last nine years in particular have 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 3,100MW in 2002. Despite the emergence of competing manufacturing countries, roughly half 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 the government has decided 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. The main thrust of the latest plan, "Energy 21", is for a major reduction in carbon dioxide emissions. The target now is for a 20% cut in the 1988 level of emissions by 2005 and a 50% cut by 2030. To achieve this, more than a third of all energy will have to come from renewable sources. Most of this will be wind power.

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.

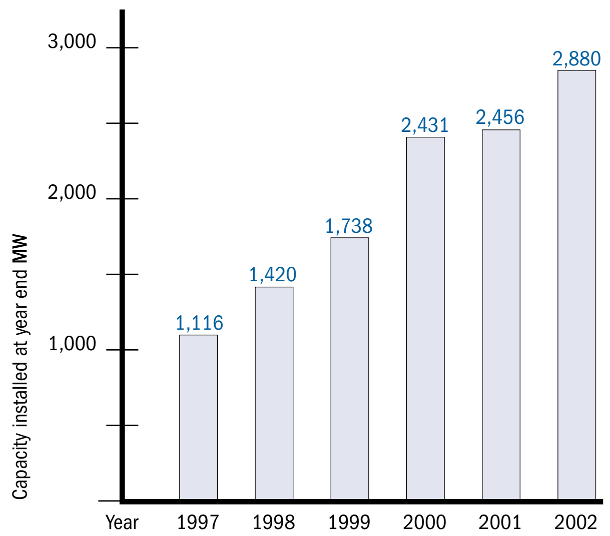
Denmark is already well on the way to achieving these objectives. 2002 was a boom year, with over 500 MW installed, increasing total capacity to 2,880 MW. In an average wind year these turbines will produce 20% of the country's electricity. This is a higher proportion than any other nation in the world.

Engineering innovation

An important element in the Danish success story has 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. 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.

Offshore frontiers

More recently, Denmark has led the world in the development of proposals to build large wind farms of turbines in its coastal waters. Working with the country's two main electricity companies, the Danish Energy Agency has elaborated plans for five offshore parks with a total capacity of about 750 MW before 2008. The first of these, at Horns Rev in the North Sea (160 MW) was built during 2002; the second, at Roedby Sand (160 MW), will be completed during 2003.Another feature of Danish development is that 80% of the turbines erected are 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 wind farm in the sea just outside Copenhagen is partly owned by a co-operative with 8,500 members.



Wind Power in Denmark

Wind power success stories

Spain – Southern Europe's Powerhouse

The Spanish wind power 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 power 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 2002, new capacity soared yet again to reach 5,043 MW, promoting Spain to the No.2 wind nation in the world.

As importantly, this development is now taking place across many regions, from the jagged Atlantic coastline in the north-west to the mountains of Navarre to the sun-drenched plains of Castilla la Mancha.

National support

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

The first piece of government legislation to provide substantial backing for renewable energy was introduced in 1994. This obliged all electricity companies to pay a guaranteed premium price for green power over a five year period, operating in a similar way to the Electricity Feed Law in Germany. At the end of 1998 the government reaffirmed its commitment to renewables with a new law designed to bring this system into harmony with the steady opening up of European power markets to full competition.

The 1998 law confirmed 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, and introduced new regulations for how each type of green electricity would be priced. For wind power producers, this means that for every unit of electricity they produce they are paid a price equivalent to 80-90% of the retail sale price to consumers. During 2003, the government agreed price is 6.2 €cents/kWh, making wind a relatively attractive investment.

Provincial plans

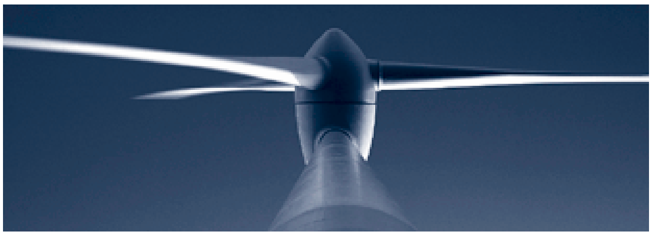
Whilst national laws are important, a crucial impetus for wind development in Spain has come from the bottom up, from regional governments keen to see factories built and local jobs created. The busiest regions have been Galicia, Aragon and Navarre, but with Castilla y Leon and Castilla la Mancha both now catching up. 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 north-western region whose coastline juts out into the Atlantic Ocean. The 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 both power utilities and turbine manufacturers, have been granted concessions to develop set quotas of capacity within 140 specified "areas of investigation".

DURING 2002, WIND ENERGY SOARED AGAIN TO REACH 5,043 MW, PROMOTING SPAIN TO THE NO.2 WIND NATION IN THE WORLD

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 2002, the region had already achieved 1,315 MW, over 30% of the target.

The mountainous province of Navarre is equally ambitious. During 2002 it reached 689 MW, already well on the way to its target for 1,536 MW. Together with other green power



sources, this would make it completely self-sufficient in renewable energy. Most of the wind farms have been built for EHN (Energia Hidroelectrica de Navarra).

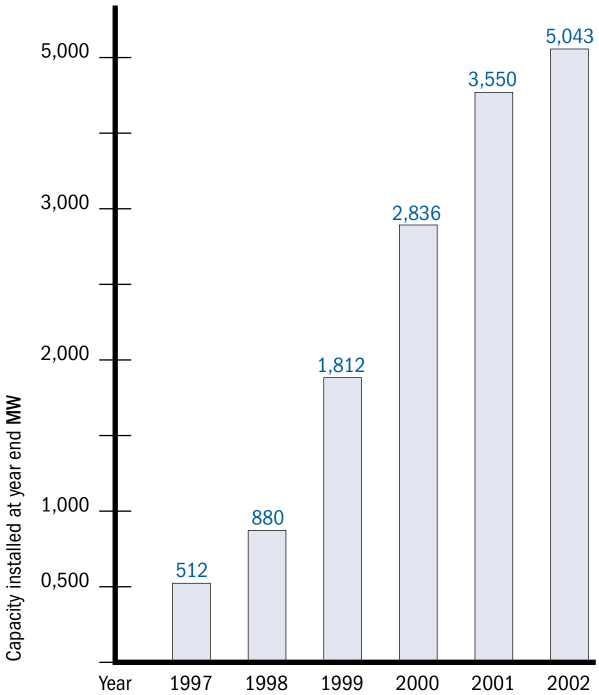
Other provinces have similar industrial development plans, with a total of more than 30,000 MW of wind capacity planned to be constructed across 14 regions by 2011. Environmental concerns have been given a different emphasis in different regions. Navarra included environmental impacts as one of the key aspects in site selection right from the start. Other provinces, such as Galicia and Castilla, have not fully dealt with these issues, leading to conflicts with organisations and residents. Other regions, such as Catalonia, have seen their plans delayed whilst awaiting a proper decision on how to address these conflicts.

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 power utilities, regional government and turbine manufacturers.

One important feature of the Spanish market is the confident approach taken by financial institutions. Major Spanish banks are relatively happy to lend on wind schemes, despite the fact that the national law does not say how long the present system of price support will last.

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. Some smaller 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.



Wind Power in Spain

Note: Due to a difference in methodology the figures presented here are different from the figures published by the Spanish Renewable Energy Association, APPA.

Wind power success stories

Offshore – The New Frontier

Offshore sites are the new frontier for the international wind industry. In northern Europe alone more than 20,000 MW of capacity is 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.

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 deliver more cost-effective standard components and facilities, driving down electricity costs, as has happened on land.

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 coast of Germany, for example, envisage total capacities of more than 1,000 MW. At the same time, individual turbines with capacities ranging from 2 MW 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 280 MW. In 2002, the largest offshore wind farm in the world 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 at Rødsand in the Baltic will start construction in 2003.

Danish plans are likely to be rapidly overtaken, however, by those of Germany. More than a dozen companies and development consortia have proposed over 12,000 MW of offshore capacity around the German coast. 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 the pilot phases of two large projects, one the beginning of a 1,000 MW development off the North Sea island of Borkum.

**THE GOAL OF THE GERMAN GOVERNMENT IS TO SEE UP TO 25,000 MW OF WIND PARKS IN THE SEA BY 2025.
THIS WOULD SATISFY ROUGHLY 15 % OF THE COUNTRY'S ELECTRICITY DEMAND.**

Guaranteed tariff

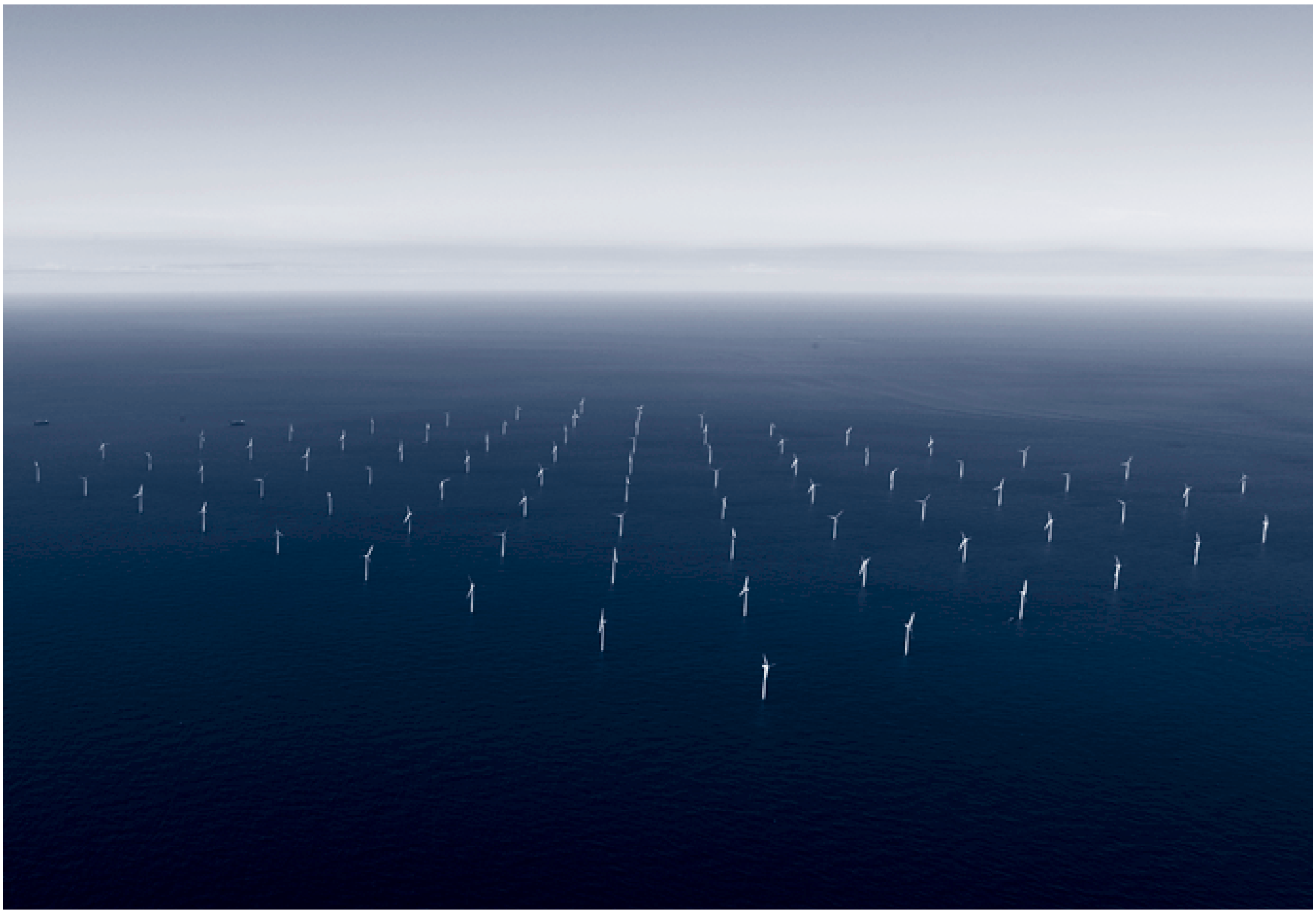
The goal of the German Government is to see up to 25,000 MW of wind parks in the sea by 2025. This would satisfy roughly 15% of the country's electricity demand. Under the Renewable Energy Law, offshore schemes started up before 2006 are also eligible to receive the guaranteed "feed-in" tariff for their output over nine years, as opposed to the normal five.

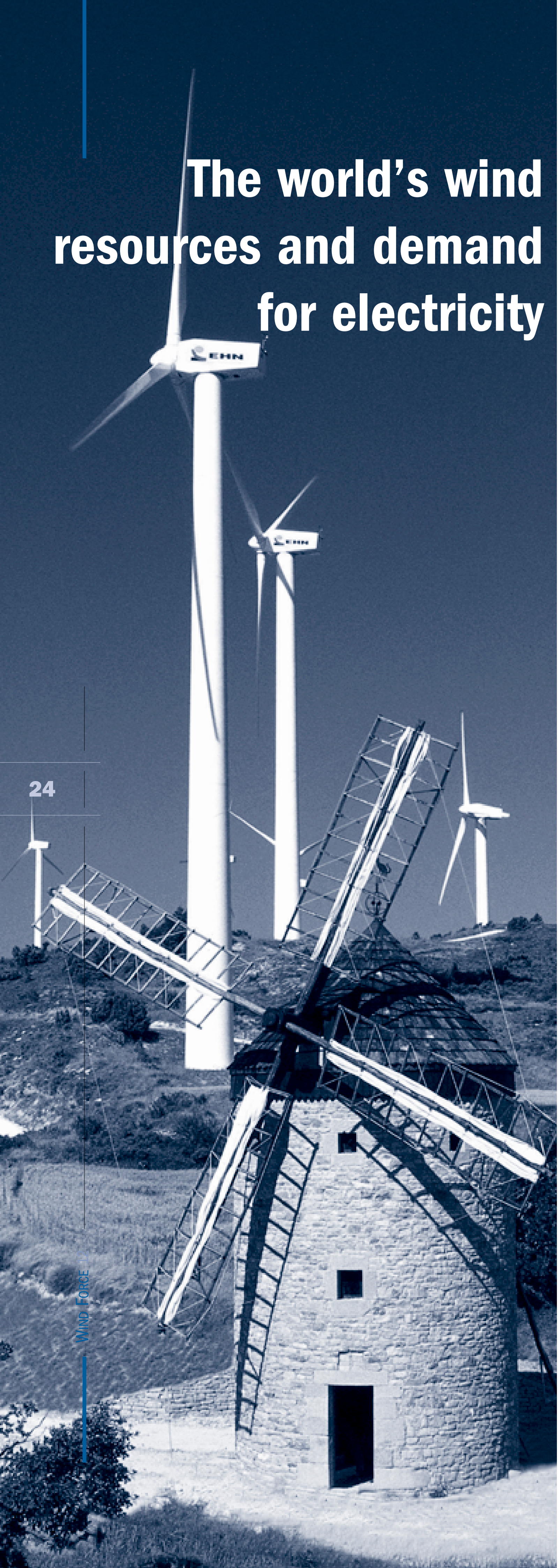
Other European countries with advanced offshore plans include the Netherlands, Belgium, Ireland, Sweden and the UK. Sweden has given approval for its largest scheme so far - 86 MW at the entrance to the Baltic Sea. Belgium has a 100 MW proposal in the pipeline, whilst Ireland has approved a giant development of up to 520 MW in a single project. In the UK, 18 consortia have been granted rights to investigate offshore sites with a total potential of at least 1,500 MW. The first 60 MW project is due to be built during 2003.

In the United States, there are also plans for the country's first offshore development, up to 420 MW of turbines near Nantucket Island off the coast of Massachusetts.

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 2003 onwards. A recent report for the UK government (The World Offshore Renewable Energy Report) concluded that the global offshore wind market could be worth almost €12 billion in the period up to 2007. If all planned projects went ahead, a total of 17,000 MW could be installed by just four European countries by 2010, the report noted.

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 electricity demand.





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 energy 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 25,578 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.

On Land Wind Resources in Europe

A 1993 Utrecht University study examined the wind potential of OECD countries. This is a very conservative scenario that restricts the "exploitable resource" considerably compared with the Grubb & Meyer study used in Figure 3-1. The reason for this is Europe's high population density and large infrastructure elements (roads, airports, railways etc.).

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.

The Utrecht University study was carried out in 1993, when the average new wind turbine was 250-300 kW in size. 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.

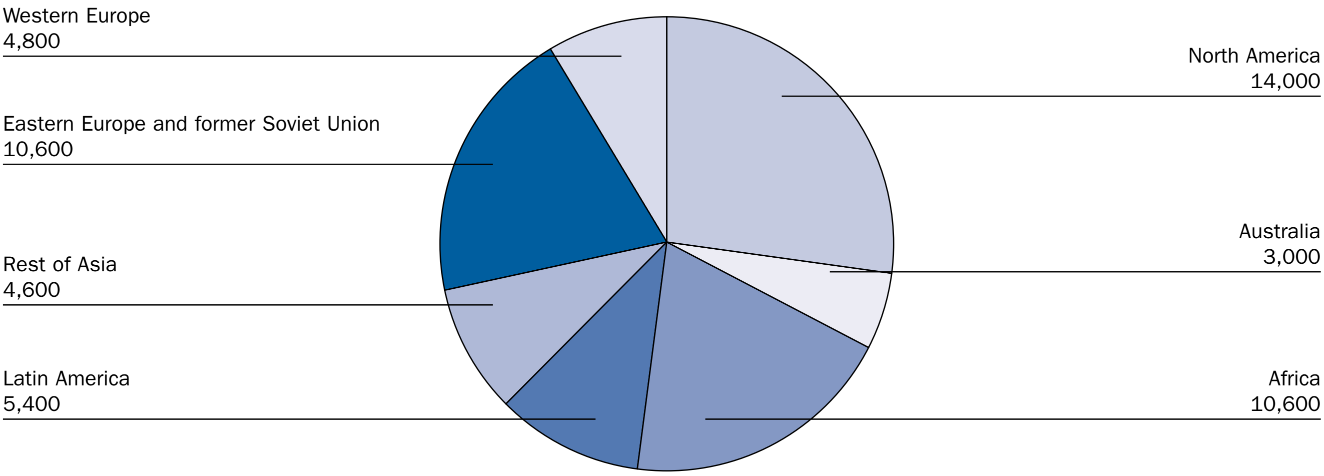
Using a geographical database developed by Garrad Hassan, this study assumes that the wind resource can be used out to a water depth of 40 m and up to 30 km from land. A reference wind turbine of 6 MW capacity and 100 m diameter rotor was used, with the spacing between turbines set at one kilometre.

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

Figure 3-1: The world's wind resources World total = 53,000 Twh



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.

The combined figure for both land and sea, taking into account 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 report 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.

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 2000 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.

Table 3-3 shows 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 3-4* 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 3-5* 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 3-1: Technical potential for onshore wind power in EU-15 plus Norway

Country	Total electricity consumption, (TWh/year[1])	Technical wind potential TWh/year, (GW capacity)	Up to 20% of consumption from wind, (TWh/year)	Surplus wind, over 20% consumption (TWh/year)
Austria	60	3 (1.5)	3	-
Belgium	82	5 (2.5)	5	-
Denmark	31	10 (4.5)	6.2	3.8
Finland	66	7 (3.5)	7	-
France	491	85 (42.5)	85	-
Germany	534	24 (12)	24	-
Great Britain	379	114(57)	75.8	38.2
Greece	41	44 (22)	8.2	(?)[2]
Ireland	17	44 (22)	3.4	40.6
Italy	207	69 (34.5)	41.4	27.6
Luxembourg	1	0	-	-
Holland	89	7 (3.5)	7	-
Portugal	32	15 (7.5	6.4	8.6
Spain	178	86 (43)	35.6	50.4
Sweden	176	41 (20.5)	35.2	22.8
Norway	116	76 (37)	23.2	
Total	**12,874**	**16,929**	**22,952**	**29,329**

(Sources: BtM Consult; technical wind potential from University of Utrecht Study Wijk and Coelingh, 1993)

1 *Electricity consumption is based on OECD/IEA figures for 1989, extended by 3% per annum to 1995. The IEA "World Energy Outlook" (1998) records a total comsumption for OECD-Europe in 1995 of 2,678 TWh.*

2 *Greece has an excess potential, but with resources scattered over many islands is unikely to be an exporter for some time.*

Table 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
10 m	551	587	596
20 m	1,121	1,402	1,523
30 m	1,597	2,192	2,463
40 m	1,852	2,615	3,028

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

Table 3-3: Projections of future world electricity demand by region

Region	2000 (TWh/year)	2010 (TWh/year)	2020 (TWh/year)	Avarage Growth 2000-2020 (%/p.a.)
OECD Europe	3,164	3,763	4,339	1.6%
OECD N. America	4,813	5,758	6,702	1.7%
OECD Pacific	1,622	2,003	2,317	1.8%
Latin America	804	1,135	1,566	3.4%
East Asia	585	970	1,461	4.7%
South Asia	635	1,001	1,505	4.4%
China	1,387	2,282	3,461	4.7%
Middle East	462	675	899	3.4%
Transition Economies	1,484	1,765	2,238	1.8%
Africa	435	684	1,091	4.7%
World	**15,391**	**20,036**	**25,579**	**2.6%**

Table 3-4: Available wind resource and future world electricity demand

Region	2000 (TWh/year)	20% of 2020 demand (TWh/year)	Wind resource (TWh/year)	Factor of resource in excess of 20% penetration by 2020
OECD Europe	4,339	867	Land: 630 Offshore: 313	1.04
OECD N. America	6,702	1,340	14,000	10.44
OECD Pacific	2,317	463	3,600	7.78
Latin America	1,566	313	5,400	17.25
East Asia	1,461	292	4,600	3,58
South Asia	1,505	301		
China	3,461	692		
Middle East	899	180	N/a	-
Transition Economies	2,238	448	10,600	23.66
Africa	1,091	218	10,600	48.62
World	**25,579**	**5,114**	**49,743**	**9.53**

(Sources: Projected demand from IEA, World Energy Outlook 2002; World wind resource from Table 3-1 and Figure 3-1)

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.

Numerous 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%.

In Denmark, peak levels of up to 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. This includes the use of interconnectors to neighbouring countries, especially Germany, Norway and Sweden. The two latter countries have large capacities of hydro power that complements wind power extremely well as hydro can serve as an efficient and cheap energy storage method.

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 3-4* 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.

Table 3-5: Projected Electricity Consumption - IEA 2002

Consumption growth rate	Year	Global TWh	Wind TWh	Penetration %
2.67%	2002	16,233	64.5	0.40%
	2003	16,666	86.3	0.52%
	2004	17,110	110.0	0.64%
	2005	17,567	139.8	0.80%
	2006	18,035	184.2	1.02%
	2007	18,516	232.5	1.26%
	2008	19,010	292.9	1.54%
	2009	19,517	365.4	1.87%
	2010	**20,037**	**452.3**	**2.26%**
2.47%	2011	20,532	556.6	2.71%
	2012	21,040	763.6	3.63%
	2013	21,560	931.9	4.32%
	2014	22,093	1,133.8	5.13%
	2015	22,639	1,366.0	6.03%
	2016	23,198	1,633.0	7.04%
	2017	23,771	1,940.1	8.16%
	2018	24,359	2,277.9	9.35%
	2019	24,961	2,649.5	10.61%
	2020	**25,578**	**3,021.1**	**11.81%**
2.11%	2021	26,118	3,392.7	12.99%
	2022	26,670	3,764.2	14.11%
	2023	27,233	4,135.8	15.19%
	2024	27,808	4,507.4	16.21%
	2025	28,396	4,844.3	17.06%
	2026	28,996	5,172.6	17.84%
	2027	29,608	5,490.1	18.54%
	2028	30,233	5,794.1	19.16%
	2029	30,872	6,084.5	19.71%
	2030	**31,524**	**6,358.7**	**20.17%**
1.50%	2031	31,997	6,613.4	20.67%
	2032	32,477	6,844.8	21.08%
	2033	32,964	7,048.1	21.38%
	2034	33,458	7,217.8	21.57%
	2035	33,960	7,357.1	21.66%
	2036	34,470	7,994.6	23.19%
	2037	34,987	8,063.7	23.05%
	2038	35,512	8,099.9	22.81%
	2039	36,044	8,099.9	22.47%
	2040	**36,585**	**8,099.9**	**22.14%**
	2041	37,134	8,099.9	21.81%

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. The summary results of this exercise can be seen in *Table 4-1.* More detailed figures are given in the Appendices.

This feasibility study takes off from the figures for cumulative wind power at the end of 2002. The total installed capacity around the world by then was just over 32,000 MW, with new installations during 2002 reaching 7,227 MW. The growth rate of new annual installation during the period 2003 to 2008 is estimated to be 25% per annum, ending up with some 133,746 MW on line by the end of 2008. This is the highest growth rate during the period. From 2009 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 1,231 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.

The scenario also projects the development of wind power forward into the fourth decade of the century, though in far less detail. These projections shows that by 2030 wind power will account for more than 20% of world electricity demand.

Beyond 2020, development continues with an annual installation rate of about 151,500 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 3,000 GW of wind power will be maintained.

Over time, an increasing share of new capacity is used for 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. Replacement activity will pick up considerable speed from 2025 onwards, and by 2040 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 state-of-the-art level, which is approximately €830 per kW of installed capacity, resulting in a cost per kWh of 3.88 €cents.

The growth rate beyond 2003 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.

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 are:

☐ 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 1999 to 2002 it has continued at an impressive average of 31%.

Based on the current rate of expansion in the wind power industry, it is quite capable of meeting a growth in demand of 25% a year for at least six years ahead. By the end of 2008 manufacturing output is expected to reach a level of 27,569 MW/year. From 2009 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 2018. The growth in manufacturing capacity levels out in 2020 at a figure of 151,490 MW annually.

An important factor in Europe is the likely opening up of offshore development from 2003 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 stable political frameworks established for wind power development in emerging markets around the world before entering 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

Table 4.1: 12% wind powered electricity worldwide by 2020

Year	Average annual growth rate %	Annual new capacity MW	Cumulative new capacity MW	Annual wind electricity production TWh	Projected world electricity demand TWh	Wind power penetration of world electricity %
2002	25	7,227	32,037	64.5	16,233	0.40
2003	25	9,034	41,071	86.3	16,666	0.52
2004	25	11,292	52,363	110.1	17,110	0.64
2005	25	14,115	66,478	139.8	17,567	0.80
2006	25	17,644	84,122	184.2	18,035	1.02
2007	25	22,055	106,177	232.5	18,156	1.26
2008	25	27,569	133,746	292.9	19,010	1.54
2009	20	33,083	166,829	365.4	19,517	1.87
2010	20	39,699	206,528	452.3	20,037	2.26
2011	20	47,639	254,167	556.6	20,532	2.71
2012	20	57,167	311,333	763.6	21,040	3.63
2013	20	68,600	379,933	931.9	21,560	4.32
2014	20	82,320	462,253	1133.8	22,093	5.13
2015	15	94,668	556,922	1366.0	22,639	6.03
2016	15	108,868	665,790	1633.0	23,198	7.04
2017	15	125,199	790,988	1940.1	23,771	8.16
2018	10	137,718	928,707	2277.9	24,359	9.35
2019	10	151,490	1,080,197	2649.5	24,961	10.61
2020	0	151,490	1,231,687	3021.1	25,578	11.81
2030	0	151,490	2,592,424	6358.7	31,524	20.17
2040	0	151,490	3,082,167	8099.9	36,585	22.14

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.

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 economies of scale, 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.

□ Future growth of wind turbine size

Table 4-2 shows the rapid growth of wind turbine size in the commercial market over the past six years. From this it can be seen that in the leading markets, especially Germany, Denmark and Spain, the average size of turbine being installed has more than doubled since 1997.

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 MW to 1.5 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 turbines 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 23% 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.

□ Comparisons with other technologies

If wind power 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 powerstations 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 16% and 19% 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. Wind power is today a commercial industry that is capable of becoming a mainstream electricity power source. 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

Table 4-2: Average size of wind turbines installed in selected markets (kW)

Year	China	Denmark K	Germany Y	India	Spain	Sweden	UK	USA
1997	472	560	623	279	422	550	514	707
1998	636	687	783	283	504	590	615	723
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

is that the maximum commercial unit size today of a wind turbine is 2.5 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 power suitable for many different types of electricity infrastructure, from isolated instalations to huge national and transnational grids.

Seen from this viewpoint it is quite feasible that wind power 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. Both are 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 0.80.
- Wind turbines – from 1982 to 1987, achieved a progress ratio of 0.80.
- Gas turbines – progress ratio of 0.80 for the first 1,000 MW installed, then 0.90 from 1963 to 1980, when 90,000 MW was installed

Breakdown of the 12% Scenario by Region

The general guideline followed in the 12% scenario has been to distribute the 1,231 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 major investments in transmission lines.

The expected geographical distribution of the roughly 1,200 GW of wind power available by the end of 2020 is shown in *Table 4-3*.

Table 4-3: 12 % wind power in 2020 - regional breakdown

Region (IEA definitions)	Share of 1,200 GW of wind power in 2020 (GW)	Share of 1,200 GW of wind power in 2020 (%)	Total electricity production in 2020 (TWh)
OECD - Europe	230	19.2%	4,339
OECD - North America USA (250,000) Canada (60,000)	310	25.8%	6,702
OECD Pacific	90	7.5%	2,317
Latin America	100	8.3%	1,566
East ASIA	70	5.8%	1,461
South ASIA	50	4.2%	1,505
China	170	14.2%	3,461
Middle East	25	2.1%	899
Transition Economies	130	10.8%	2,238
Africa	25	2.1%	1,091
World	**1,200**	**100 %**	**25,579**

12% wind power by 2020 - investment, costs & employment

Investment Value

This feasibility study shows the investment value of the projected growth in wind energy on a yearly basis, starting with about €7 billion in 2003 and increasing to a peak of €75 billion by 2020. The total investment (at 2002 prices) required to reach a level of 1,231 GW of wind power worldwide in 2020 is estimated at €674 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 energy development will be heading towards a coverage of 20% of electricity demand, equal to that of hydro power today.

Table 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 price level in 2002 taken as €823 per kW of installed capacity. By 2020 the investment cost falls to €504/kW, a substantial reduction of 39% compared to today.

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 *Table 4-3*. 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.

Table 5-2 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 (*Table 5-3*).

Cost Reductions

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

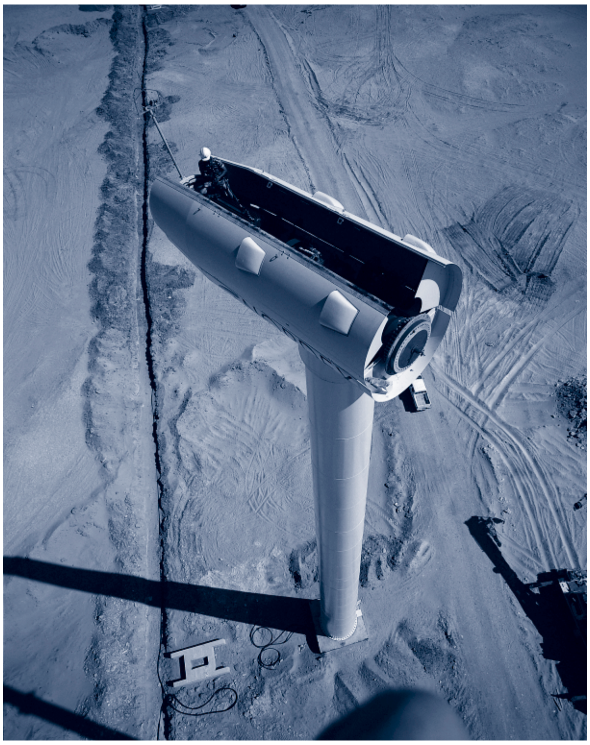


Table 5.1: 12% wind powered electricity worldwide by 2020

Year	Annual Installation	Cost € / kW	Investment € billion/year	Cumulative Investment € billion	Employment Job-year
2002	7,227	823	5,947	5,947	141,505
2003	9,034	797	7,198	13,145	171,286
2004	11,292	770	8,690	21,834	206,780
2005	14,115	746	10,525	32,360	250,460
2006	17,644	721	12,714	45,074	302,543
2007	22,055	695	15,319	60,393	364,528
2008	27,569	670	18,466	78,859	439,416
2009	33,083	645	21,349	100,208	508,025
2010	39,699	623	24,725	124,933	588,348
2011	47,639	608	28,973	153,906	689,430
2012	57,167	594	33,930	187,836	807,402
2013	68,600	580	39,777	227,613	946,532
2014	82,320	566	46,601	274,214	1,108,924
2015	94,668	553	52,342	326,556	1,245,524
2016	108,868	540	58,809	385,365	1,399,406
2017	125,199	528	66,093	451,458	1,572,732
2018	137,718	516	71,131	522,589	1,692,633
2019	151,490	506	76,627	599,216	1,823,416
2020	**151,490**	**497**	**75,233**	**674,449**	**1,790,233**

capacities of up to 2,500 kW (2.5 MW). It is estimated that costs have fallen 20% in the last five years.

Based on market and industry experience, this study has taken the following reference figures for "state of the art" wind turbines in 2002 under optimum conditions:

- Investment cost: €823 per installed kW
- Unit cost for electricity: 4.04 €cents/kWh

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

1. The average size of turbines on the commercial market will grow from 1,000 kW (1 MW) today to 1.2 MW by 2005, 1.4 MW by 2010 and later to 1.5 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 23% to 28% after 2012.

This feasibility study therefore envisages a cost reduction in wind electricity from today's 4 €cents/kWh to a level of 3 €cents/kWh by 2010, assuming a cost per installed kilowatt of €628. This is comparable with current cost levels for combined cycle gas generation. By 2020, the figure will have fallen to 2.34 € cents per unit of electricity produced (€497 per kW). The year by year cost reductions can be seen in Appendices.

Comparison with other generation technologies

How do the costs of wind power compare with other generation technologies already in widespread use? The most recent data (*Figure 5-1*) is from the annual survey of cost comparisons by Windpower Monthly, published in January 2003. At current electricity prices, the cheapest wind plants - those with easy access and economies of scale - are now fully competitive with gas, if sites have good average wind speeds of 7m/s and an investment cost below €700/kW. The price of electricity from new thermal plant is based on US and European data, and has not changed dramatically over the past year. The costs of nuclear, however, do not fully account for public sector liability, waste and decommissioning issues.

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. Therefore wind power is relatively capital intensive and initial investments are relatively high. On the other hand there is no fuel cost during the lifetime of wind plant and operating and maintenance costs are very low.

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

Table 5-2: Average investment per kW of wind power, 2001 to 2020

Period	Average investment €/kW			
2003 to 2006	**751 €**			**557 €**
2007 to 2011	**640 €**		**548 €**	
2011 to 2017	**554 €**	**533 €**		
2018 to 2020	**505 €**			

Table 5-3: Distribution of investment by region up to 2020

Region	Take-off year for large scale development	Total installed by 2020 (MW)	Average installation cost €/kW	Cumulative investment by 2020 € billion
OECD Europe	on track	230,000		128.1
OECD N. Am.	on track	310,000	557€	175.2
OECD Pacific	on track	90,000		50.8
Latin America	2006	100,000	555€	55.5
East Asia	2006	70,000		38.8
South Asia	2004	50,000	560€	28.0
China	2004	170,000		95.2
Middle East	2006	25,000		13.6
Transition economies	2006	130,000	545€	70.9
Africa	2006	25,000		13.6
World		**1,200,000**		**669.7**

Note: Key figures in € are judged on time for takeoff and pace of development. Figures for cumulative investiment are rounded.

The main outcome from the scenario is that a total of 1.8 million jobs will have been created around the world by 2020.

Employment Potential

The employment effect of the 12% wind energy scenario is a crucial factor to weigh alongside its other costs and benefits, and is likely to feature strongly in any political decision-making over different energy options.

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 had 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 man-years are created for every MW of wind power 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 *Tables 5-6a and b.* These are directly based on the assumptions above and the actual new installation of wind power expected in the years 2005, 2010, 2015 and 2020. In the intermediate period, from 2005 to 2020, it is assumed that some regions will start their large scale development of wind energy later than OECD countries already on track for a major deployment.

The main outcome from the scenario is that a total of 1.8 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 *Table 5-6b* 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 *Table 5-6a*, the total installation quota of wind power is divided by regions into periods of five years. 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 five years 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 *Table 5-6b*. 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 necessary to explain the difference between the 141,000 job years 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 subsuppliers. However this estimate cannot capture every single job or part-job created by wind power. The 141,000 job years is based on a statistical model comparing jobs, investment and MW which covers all wind-related employment.

Table 5-6a: Distribution of annual installed capacity by region at five year intervals

Year Region	2005 MW/year	2010 MW/year	2015 MW/year	2020 MW/year
OECD Europe	8,000	10,000	14,000	15,000
OECD N. America	3,000	10,000	23,000	30,000
OECD Pacific	1,000	3,000	8,000	10,000
Latin America	500	3,200	7,500	15,000
East Asia	100	1,000	4,500	10,000
South Asia	600	3,200	7,500	16,500
China	500	5,000	13,000	27,000
Middle East	100	600	1,700	3,000
Transition Economies	200	3,000	13,000	22,000
Africa	100	700	2,500	3,000
Total MW per Year:	14,100	39,700	94,700	151,500
Annual installation (According to *Table 4-1*)	14,115	39,699	94,668	151,490
Job-year/MW	**17.7**	**14.8**	**13.1**	**11.8**

Table 5-6b: Distribution of employment by region at five year intervals

	Job-years x 1000			
Year **Region**	**2005**	**2010**	**2015**	**2020**
OECD Europe	141.6	148.0	170.3	177.0
OECD N. America	53.1	148.0	288.2	354.0
OECD Pacific	17.7	44.4	104.8	118.0
Latin America	8.9	47.4	85.2	177.0
East Asia	1.8	14.8	59.0	118.0
South Asia	10.6	47.4	85.2	194.7
China	8.9	74.0	170.3	318.6
Middle East	1.8	8.9	22.3	47.2
Transition Economies	3.5	44.4	170.3	259.6
Africa	1.8	10.4	32.8	37.8
Total Employment Job-year:	**250.5**	**588.3**	**1,245.5**	**1,790.2**
Annual installation MW/year (*Table 4-1*)	14,115	39,699	94,668	151,490
Job-year/MW	**17.7**	**14.8**	**13.1**	**11.8**

12% wind power by 2020 - the environmental benefits

Global Carbon Dioxide Reductions

A reduction in the levels of carbon dioxide (CO_2) being emitted into the global atmosphere is an 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 four months of operation.

The benefit to be obtained from CO_2 reductions is dependent on which other generation method wind power is substituting for. Calculations by the World Energy Council show a range of CO_2 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 CO_2 reduction to be obtained from wind generation.

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 38.7 million tonnes CO_2 in 2002 to 1,813 million tonnes CO_2 in 2020.
- By 2010, a cumulative reduction of 1,157 million tonnes CO_2.
- By 2020, a cumulative reduction of 10,921 million tonnes CO_2.
- By 2040, wind power will contribute an annual reduction of 4,860 million tonnes CO_2 resulting in a cumulative reduction of 85,911 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 25% 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" per year to 2,500-2,600 hours/year. Future offshore installations are expected to perform even better – in the range of 3,000-4,000 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 CO_2 reductions from the feasibility study calculated year by year up to 2044.

BY 2020, A CUMULATIVE REDUCTION OF 10,921 MILLION TONNES CO_2.

Value of CO_2 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 mariginal 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 power 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 the external costs, or from intrinsic benefits from embedded generation.

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 latter 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 2001, outlined the external costs as:

nuclear	***0.2 - 0.7 € cents/kWh***
gas	***1 - 4 € cents/kWh***
coal	***2 - 15 € cents/kWh***
wind power	***0 - 0.25 € cents/kWh***
oil	***3 - 11 € cents/kWh***

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

Policy Recommendations

INTRODUCTION

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. Only 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.

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. 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 traditional technologies. 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 power.

In several countries, policies which support renewable energy are achieving dramatic results, as outlined in the earlier sections of this report. Germany, for example has created over 40,000 jobs from wind power. Denmark has created a € 3 billion dollar export industry.

The following is an overview of the political challenges facing the industry and the policies which must be adopted to unlock wind power's vast potential.

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 indicative targets for each member country. 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.

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.

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, and is stable, long term, providing low investor risk and a sufficient return on investment.

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:

1.2.1 Fixed tariff systems

Tariff systems based on a fixed price paid per kWh of production have been enormously successful at catalysing wind energy markets. They are enshrined in law in Germany, Spain and other countries. In Germany, legislation fixes the price of electricity from renewable energy in relation to the generation costs of renewable technologies. 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 input from 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. A main advantage of fixed tariff systems is that they put pressure on manufacturers 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 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.

Table 7-1: European Union indicative targets for electricity from renewable sources in 2010

Country	Renewables % in 1997	Target for 2010
Austria	70.0	78.1
Belgium	1.1	6.0
Denmark	8.7	29.0
Germany	4.5	12.5
Greece	8.6	20.1
France	15.0	21.0
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
Finland	24.7	31.5
Sweden	49.1	60.0
Spain	19.9	29.4
United Kingdom	1.7	10.0
EU	13.9%	22.1%

1.2.2 Renewables portfolio standards (RPS)

Under an RPS, such as those operating in Texas or the UK, power companies or electricity customers are obliged to buy a number of green certificates in proportion to their total electricity consumption. The certificates are bought from the producers of renewable energy - the wind turbine owners - who receive certificates in proportion to their electricity delivery, for example one certificate per delivered kWh. The system implies that part of the payment to the wind turbine owners is made in a special currency - green certificates. The price of the certificates is set in a market where buyers' demand and sellers' supply determines the price.

An RPS can be technology neutral or broken down further into fractions to come from specific technologies, such as wind, solar etc. The RPS market only starts, however, if penalties for not purchasing green certificates are sufficiently high to deter non-compliance. To ensure sustained investment, the RPS needs to include long term market expansion.

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.

1.2.3 Competitive bidding, tendering or auctions

Under bidding systems, governments define a fixed amount of funds available and invite tenders for projects, which can be technology neutral or specific. Projects are then allocated up to the level of the available funds. Power purchase agreements are entered into for an agreed period, typically 15 years. There is normally a politically decided quantity of capacity available for development, often offered for tender in successive bidding rounds, and which the power companies or customers must purchase. 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.

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.

1.2.4 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.

1.2.5 Investment subsidies

Usually this support is given on the basis of the rated power (in kW) of the generator. Investment subsidies are typically used at an early stage of development, when little or no additional incentives are in place. These systems can be problematic because a subsidy is given whether or not production is efficient. In some countries (for example India and California in the 1980s) this type of payment resulted in poor siting of wind turbines, and manufacturers followed customer demands to use very large generators, which improved project profitability but reduced production. The global tendency is to avoid investment subsidies as a sole policy choice and adopt either fixed price tariffs or an RPS system, which essentially fix either price or quantity.

Furthermore, because such systems are often based on the availability of government funds and ongoing political goodwill, they may not provide the long-term security and stability that industry and financiers require.

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 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 acknowledged to cause local and regional environmental and social impacts; fossil fuels also have global impacts on the climate.

The reforms needed to address market barriers to renewables include:

- Streamlined and uniform planning procedures and permitting systems and least cost network planning.
- Fair access to the grid at fair 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 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. Power prices today do not reflect the full costs of electricity production, or the full environmental benefits of wind power and other renewables.

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 $70,000 per miner. Subsidies artificially reduce the price of power, keep renewables out of the market place, and prop up increasingly uncompetitive technologies and fuels. In May 2003, the European Commission decided not to object to a German €3,3 billion aid package to its coal industry for the year 2003.

Halting all direct and indirect subsidies to fossil fuels and nuclear power will create a more 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."

3.2.2 Internalise the social and environmental costs of polluting energy

The real cost of electricity 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 equal to a subsidy of up to $3.4 billion annually.

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."

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: Market Development

Growth ratio	Year	Cummulative MW	Annual MW	Annual average WTG (MW)	Cumulative no,of units	Capacity factor (%)	Production TWh	Progress ratio	Replacement MW	Units
	2002	32,037	7,227	1.0	61,500	23%	64.5			
	2003	41,071	9,034	1.0	70,534	24%	86.3			
	2004	52,363	11,292	1.0	81,826	24%	110.1			
25%	2005	66,478	14,115	1.2	93,589	24%	139.8			
	2006	84,122	17,644	1.2	108,292	25%	184.2			
	2007	106,177	22,055	1.2	126,671	25%	232.5	**0.85**		
	2008	133,746	27,569	1.3	147,878	25%	292.9			
	2009	166,829	33,083	1.3	173,326	25%	365.4			
	2010	206,528	39,699	1.4	201,683	25%	452.3			
20%	2011	254,167	47,639	1.4	235,710	25%	556.6			
	2012	311,333	57,167	1.4	276,544	28%	763.6			
	2013	379,933	68,600	1.5	322,277	28%	931.9			
	2014	462,253	82,320	1.5	377,157	28%	1,133.8			
	2015	556,922	94,668	1.5	440,269	28%	1,366.0			
15%	2016	665,790	108,868	1.5	512,848	28%	1,633.0			
	2017	790,988	125,199	1.5	596,314	28%	1,940.1			
	2018	928,707	137,718	1.5	688,126	28%	2,277.9			
10%	2019	1,080,197	151,490	1.5	789,119	28%	2,649.5	**0.90**		
	2020	**1,231,687**	**151,490**	1.5	890,113	28%	3,021.1			
	2021	1,383,177	151,490	1.5	991,106	28%	3,392.7			
	2022	1,534,667	151,490	1.5	1,092,100	28%	3,764.2			
	2023	1,686,158	151,490	1.5	1,193,093	28%	4,135.8			
	2024	1,837,648	151,490	1.5	1,294,087	28%	4,507.4			
	2025	1,975,023	151,490	1.5	1,394,929	28%	4,844.3		14,115	11,763
0%	2026	2,108,869	151,490	1.5	1,495,760	28%	5,172.6		17,644	14,703
	2027	2,238,304	151,490	1.5	1,596,579	28%	5,490.1		22,055	18,379
	2028	2,362,225	151,490	1.5	1,697,386	28%	5,794.1		27,569	21,207
	2029	2,480,633	151,490	1.5	1,798,189	28%	6,084.5		33,083	25,448
	2030	2,592,424	151,490	1.5	1,898,985	28%	6,358.7		39,699	28,356
	2031	2,696,275	151,490	1.5	1,999,777	28%	6,613.4		47,639	34,028
0%	2032	2,790,599	151,490	2.0	2,075,315	28%	6,844.8		57,167	40,833
	2033	2,873,489	151,490	2.0	2,150,847	28%	7,048.1		68,600	45,733
	2034	2,942,659	151,490	2.0	2,226,374	28%	7,217.8		82,320	54,880
	2035	2,999,481	151,490	2.0	2,301,904	28%	7,357.1		94,668	63,112
	2036	3,042,103	151,490	2.0	2,377,437	30%	7,994.6	**1.00**	108,868	72,579
0%	2037	3,068,395	151,490	2.0	2,452,972	30%	8,063.7		125,199	83,466
	2038	3,082,167	151,490	2.0	2,528,517	30%	8,099.9		137,718	91,812
	2039	3,082,167	151,490	2.0	2,604,070	30%	8,099.9		151,490	100,993
	2040	3,082,167	151,490	2.0	2,679,645	30%	8,099.9		151,490	100,993
	2041	3,082,167	151,490	2.0	2,755,237	30%	8,099.9		151,490	100,993
0%	2042	3,082,167	151,490	2.0	2,830,844	30%	8,099.9		151,490	100,993
	2043	3,082,167	151,490	2.0	2,906,462	30%	8,099.9		151,490	100,993
	2044	3,082,167	151,490	2.0	2,982,090	30%	8,099.9		151,490	100,993

Table 2: Contributions by region

Region	Installed wind capacity by 2020 GW	Annual Electricity production from wind power TWh/year	Penetration of wind power by 2020 of electricity consumption %	Cumulative investment € billion	Annual reduction of CO2 by 2020 Million Tonnes/Year	Employment in the region by 2020 Man-year/year (x 1000)	Comments / corrections
OECD Europe	230	564.0	13%	129.9	338.4	177.0	Incl. 70,000 MW offshore
OECD N. America	310	760.1	11.3%	175.2	456.1	354.0	
USA (incl. in N. America)	(250)	(613.0)	(13%)	(140.2)	(367.8)	(283.0)	
OECD Pacific	90	220.7	9.5%	50.8	132.4	118.0	
Latin America	100	245.2	15.7%	61.0	147.1	177.0	Investment + 10%
East Asia	70	171.7	11.7%	42.7	133.9	141.6	Employment: +20% Investment: +10% CO2 Reduction: +30%
South Asia	50	122.6	8.1%	30.8	95.6	233.6	
China	170	416.9	12.%	104.7	325.2	382.3	
Middle East	25	61.3	6.8%	13.6	36.8	47.2	
Transition Economies	130	318.9	14.2%	78.0	229.6	311.5	Employment: +20% Investment : +10 % CO2 Reduction: + 20%
Africa	25	61.3	5.6%	15.0	36.8	37.8	
World - total :	**1,200**	**3,021.1**	**11.81%**	**702.6**	**1,931.9**	**1,980**	**Totals including Corrections**

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

Table 3: Cost reduction according to penetration

Progress ratio	Year	Cummulative MW	Cumulative no,of units	Electricity €cent/kWh	Capacity €/kW
	2002	32,037	61,500	3.88	823
	2003	41,071	70,534	3.75	797
a = 0.300	2004	52,363	81,826	3.62	770
X0 = 61,500	2005	66,478	93,589	3.51	746
b = 0.2345	2006	84,122	108,292	3.39	721
	2007	106,177	126,671	3.27	695
85%	2008	133,746	147,878	3.15	670
	2009	166,829	173,326	3.04	645
	2010	**206,528**	**201,683**	**2.93**	**623**
	2011	254,167	235,710	2.86	608
	2012	311,333	276,544	2.80	594
	2013	379,933	322,277	2.73	580
	2014	462,253	377,157	2.67	566
	2015	556,922	440,269	2.60	553
	2016	665,790	512,848	2.54	540
a = 0.222	2017	790,988	596,314	2.49	528
X0 = 235,710	2018	928,707	688,126	2.43	516
90%	2019	1,080,197	789,119	2.38	506
b = 0.1525	**2020**	**1,231,687**	**890,113**	**2.34**	**497**
	2021	1,383,177	991,106	2.30	489
	2022	1,534,667	1,092,100	2.27	481
	2023	1,686,158	1,193,093	2.24	475
	2024	1,837,648	1,294,087	2.21	469
	2025	1,975,023	1,394,929	2.18	464
	2026	2,108,869	1,495,760	2.18	464
	2027	2,238,304	1,596,579	2.18	464
	2028	2,362,225	1,697,386	2.18	464
	2029	2,480,633	1,798,189	2.18	464
a = 0.169	**2030**	**2,592,424**	**1,898,985**	**2.18**	**464**
X0 = 1,495,760	2031	2,696,275	1,999,777	2.18	464
100%	2032	2,790,599	2,075,315	2.18	464
b = 0.001	2033	2,873,489	2,150,847	2.18	464
	2034	2,942,659	2,226,374	2.18	464
	2035	2,999,481	2,301,904	2.18	464
	2036	3,042,103	2,377,437	2.18	464
	2037	3,068,395	2,452,972	2.18	464
	2038	3,082,167	2,528,517	2.18	464
	2039	3,082,167	2,604,070	2.18	464
	2040	**3,082,167**	**2,679,645**	**2.18**	**464**
	2041	3,082,167	2,755,237	2.18	464
	2042	3,082,167	2,830,844	2.18	464
	2043	3,082,167	2,906,462	2.18	464
	2044	3,082,167	2,982,090	2.18	464

Cost (DKK/kWh) = a (XIX0)-b*

20.2.03
1 US $ = € 0.9328
1 US $ = kr 6.94
1 € = kr 7.43

Table 4: Average CO_2 reduction: 0,60 kg/kWh

Year	Cummulative MW	Production TWh	CO_2 Reduction annual mill. ton	CO_2 Reduction Cum. mill. ton
2002	32,037	64.5	38.7	38.7
2003	41,071	86.3	51.8	90.5
2004	52,363	110.1	66.1	156.6
2005	66,478	139.8	83.9	240.4
2006	84,122	184.2	110.5	351.0
2007	106,177	232.5	139.5	490.5
2008	133,746	292.9	175.7	666.2
2009	166,829	365	219	885
2010	206,528	452	271	1,157
2011	254,167	557	334	1,491
2012	311,333	764	458	1,949
2013	379,933	932	559	2,508
2014	462,253	1,134	680	3,188
2015	556,922	1,366	820	4,008
2016	665,790	1,633	980	4,988
2017	790,988	1,940	1,164	6,152
2018	928,707	2,278	1,367	7,519
2019	1,080,197	2,650	1,590	9,108
2020	1,231,687	3,021	1,813	10,921
2021	1,383,177	3,393	2,036	12,957
2022	1,534,667	3,764	2,259	15,215
2023	1,686,158	4,136	2,481	17,697
2024	1,837,648	4,507	2,704	20,401
2025	1,975,023	4,844	2,907	23,308
2026	2,108,869	5,173	3,104	26,411
2027	2,238,304	5,490	3,294	29,705
2028	2,362,225	5,794	3,476	33,182
2029	2,480,633	6,084	3,651	36,832
2030	2,592,424	6,359	3,815	40,648
2031	2,696,275	6,613	3,968	44,616
2032	2,790,599	6,845	4,107	48,723
2033	2,873,489	7,048	4,229	52,951
2034	2,942,659	7,218	4,331	57,282
2035	2,999,481	7,357	4,414	61,696
2036	3,042,103	7,995	4,797	66,493
2037	3,068,395	8,064	4,838	71,331
2038	3,082,167	8,100	4,860	76,191
2039	3,082,167	8,100	4,860	81,051
2040	3,082,167	8,100	4,860	85,911
2041	3,082,167	8,100	4,860	90,771
2042	3,082,167	8,100	4,860	95,631
2043	3,082,167	8,100	4,860	100,491
2044	3,082,167	8,100	4,860	105,351