WIND FORCE 12

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

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Energy is essential to modern life. There is no doubt that we can and must use it more efficiently, but there is equally no doubt that the developing world will need more energy to address very pressing needs. The challenge which faces all of us is how to meet this growing demand for energy while at the same time addressing the equally urgent threat of climate change.

This report highlights the significant role that wind energy can play in that challenge. As technology advances wind is competitive in increasing areas and is therefore growing rapidly. This is not just something to look forward to with hope for the future - it is here today as sound and growing businesses all over the world deliver wind power.

The G8 Task Force report (www.renewabletaskforce.org) emphasised the need to grow renewable energy in the markets of the developed world. It is in these markets where we have the scale which is needed to develop technologies by going down the classic learning curve which reduces costs – learning by doing. That is exactly what we see happening in wind. The report demonstrates the exciting technological progress which has been made in the last few years in a technology which humans have used for centuries. And this progress will continue, including the current move to large offshore wind farms. As wind energy becomes "normal business" in the industrialised world, so it will become an equally familiar option in other parts of the world, allowing countries to leapfrog to the latest technologies, just as so many have been able to do with mobile telephone communications.

As the excellent country by country reviews in this report show, this progress is not something which just happens. It comes from a combination of a supportive regulatory framework – setting clear and binding targets - within which the market is free to operate, releasing creativity and competition to deliver the most cost effective solutions. For wind and other renewable energy sources to spread worldwide, we have to ensure that the international financial institutions and export credit agencies are as willing to make finance available for renewable energy projects as they have been for what was conventional power. And as the report points out, we also have to ensure that market distorting subsidies are removed.

The report rightly addresses the limitations imposed for electricity grids by a fluctuating supply. As we develop other energy storage and transport mechanisms, perhaps through some of the exciting current developments in hydrogen and fuel cells, these limitations will be gradually removed. They are not however critical up to the levels envisaged in this report.

Greenpeace and the European Wind Energy Association are to be commended on the report which highlights for policy makers and business people alike the real potential of wind energy. Greenpeace is also to be commended for their ongoing efforts to engage the popular imagination. For in the end it is only through the engagement of consumers and voters that we will develop the sustainable energy systems that we need.

Sir Mark Moody-Stuart
Co-Chair G8 Renewable Energy Task Force 2001-2

INTRODUCTION

Wind energy has come of age. It is the world's fastest growing energy source, and is a beacon of hope for a future based on sustainable, pollution-free electricity.

Around the world today, wind power already meet the electricity needs of around 14 million households, more than 35 million people.

Over the past few years, new installations of wind power have surpassed new nuclear installation. There are over 55,000 wind turbines installed today. Globally, the industry employs around 70,000 people, is worth more than US $5 billion and is growing at a rate of almost 40% per year.

This report outlines the success story of wind power today and the untapped success stories of tomorrow. Wind Force 12 is a global blueprint for action which proves that, even in a business as usual future where global electricity consumption doubles within two decades, wind energy can supply 12% of the world's electricity.

This report is an update of the original Wind Force 10 analysis, published in 1999, which demonstrated that wind power could provide 10% of the world's entire electricity demand within two decades.

Since then, a small reduction of the IEA's global electricity growth forecast has resulted in wind power increasing its global proportion of electricity to 12%. Also, the wind power industry has progressed even more rapidly than we had then envisaged. Growth rates over the past three years have been well above those in the original report. And this new scenario is based on a more conservative industry growth rate for the short and medium term. All these factors provide us with a new target of Wind Force 12, and gives us even greater confidence that our ambitions for wind energy can be achieved.

Global benefits

The many benefits wind energy offers the world are compelling: environmental protection, economic development, diversity and security of supply, rapid deployment, technology transfer and innovation, and industrial scale on-grid electricity. Above all, compared with other options, the fuel is abundant, free and inexhaustible.

In order to unlock these benefits, however, action is urgently needed at a political level. Governments around the world need to grasp the opportunity offered by wind energy to provide both a secure power supply and to combat global climate change.

One key political forum for action is the United Nations World Summit on Sustainable Development, to be held in Johannesburg in September 2002. UN Secretary-General Kofi Annan describes this meeting of world governments as "an opportunity to rejuvenate the quest to build a more sustainable future".

Global problems need global solutions, and wind power can deliver on the scale required to make a real difference. In the process it can help to satisfy the energy and development needs of the world without destroying it.

The world now has the opportunity to harness the natural energy of the wind for the benefit of all. Wind Force 12 shows what can be achieved if we make that choice today.

Arthouros Zervos, President
EWEA

Sven Teske
Greenpeace

EWEA

GREENPEACE

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 an update of a previous study published in 1999. Like its predecessor 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 Wind Force 10 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 2001 alone, close to 6,800 MW of new capacity was added to the electricity grid.

By the beginning of 2002, global wind power installations had reached 25,000 MW. This provides enough power to satisfy the needs of around 14 million households, more than 35 million people. Although Europe accounts for 70% of this capacity, other regions are beginning to emerge as substantial markets. Over 45 countries around the world now contribute to the global total, whilst the number of people employed by the industry is estimated to be around 70,000.

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 energy offers both a power source which completely avoids the emission of carbon dioxide, the main greenhouse gas, but also produces none of the other pollutants associated with either fossil fuel or nuclear generation. Wind power can deliver industrial scale on-grid 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 market support mechanisms. These range from premium payments per unit of output to more complex mechanisms based on an obligation on power suppliers to source a rising percentage of their supply from renewables.

As the market has grown, wind power has shown a dramatic fall in cost. The production cost of a kilowatt hour of wind power is one fifth of what it was 20 years ago. 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 machine now reaching 2,500 kW.

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

Important "success stories" for wind energy can be seen in the experiences of Germany, Spain and Denmark in Europe, the United States in the Americas and India among the countries of the developing world. A new market sector is about to emerge offshore, with 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 potential 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 2000 World Energy Outlook shows that by 2020, under a "Business as Usual" scenario, world demand will reach 25,800 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 Energy

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 during the period 2002 to 2007. This is the highest growth rate during the period of the study, ending up with a total of 120,600 MW on line by the end of 2007.

From 2008 to 2012, the growth rate falls to 20% per annum, resulting in 352,241 MW of installed capacity by 2012. After that the annual growth rate falls to 15%, and then to 10% in 2016, although by this time the expansion of wind power will be taking place at a high level of annual installation.

From 2020 onwards the annual installation rate will level out at 150,000 MW per annum. This will mean that by 2030-40, wind energy's global total will have reached roughly 3,000 GW, which by then will represent about 20% 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 were:

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 5 years average annual growth rates of turbines installed have been close to 40%. After 2013, the scenario growth rate falls to 15% and then to 10% in 2016. In Europe an important factor will be the opening up of the offshore wind market. As far as developing countries are concerned, a clear message from the industry is that it would like to see a stable political framework established in emerging markets if this expansion is to be achieved.

PROGRESS RATIOS: Industrial learning curve theory suggests that costs decrease by some 20% each time the number of units produced doubles. The progress ratios assumed in this study start at 0.85 up until 2010. After that the ratio is reduced to 0.90 and then to 1.0 in 2026.

GROWTH OF WIND TURBINE SIZE: The average size of new turbine 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 2007 and 1.5 MW in 2012. 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.

12% Wind Energy by 2020 – Investment, Costs and Employment

The annual investment required to achieve the deployment of wind energy outlined above starts at $5.2 billion in 2001 and increases to a peak of $67 billion by 2020. The total investment needed to reach a level of 1,200 GW by 2020 is estimated at $628.6 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 $170-200 billion. The future investment required globally has also been broken down on a regional basis.

The cost per unit of wind-powered electricity has already reduced dramatically as manufacturing and other costs have fallen. This study starts with the basis that a “state of the art” wind turbine in 2001 in the most optimal conditions has an investment cost of $765 per installed kW and a unit price for its output of 3.61 UScents/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 2.62 UScents/kWh by 2010, assuming a cost per installed kilowatt of $555. By 2020 it is expected to have reduced to 2.11 UScents/kWh, with an installation cost of $447/kW by 2020 - a substantial reduction of 41% compared with today.

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

The employment effect of the 12% wind energy scenario is a crucial factor to weigh alongside its other costs and benefits. A total of 1, 475 million jobs will have been created around the world by 2020 in manufacture, installation and other work associated with the industry. This total is also broken down by region of the world at five yearly intervals.

12% Wind Energy by 2020 – The Environmental Benefits

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

On the assumption that the average value for carbon dioxide saved by switching to wind power is 600 tonnes per GWh, the annual saving under this scenario will be 1,856 million tonnes of $CO_2$by 2020 and 4,800 million tonnes by 2040. The cumulative savings would be 11,768 million tonnes of CO_2 by 2020 and 86,469 million tonnes by 2040.

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

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

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

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 energy 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?

An initial study was carried out by BTM Consult for the Danish Forum for Energy & Development (FED) in 1998. This was the model for a more detailed analysis carried out the following year for FED, Greenpeace and the European Wind Energy Association. This present publication is an update of the 1999 Wind Force 10 report.

The first (1998) study approached the potential for 10% wind penetration by working with two different scenarios for total world electricity demand. In the more detailed (1999) report only one parameter of future demand was taken – the International Energy Agency's 1998 "World Energy Outlook", a conservative projection which assumes "business as usual" and in which electricity consumption is expected to double by 2020.

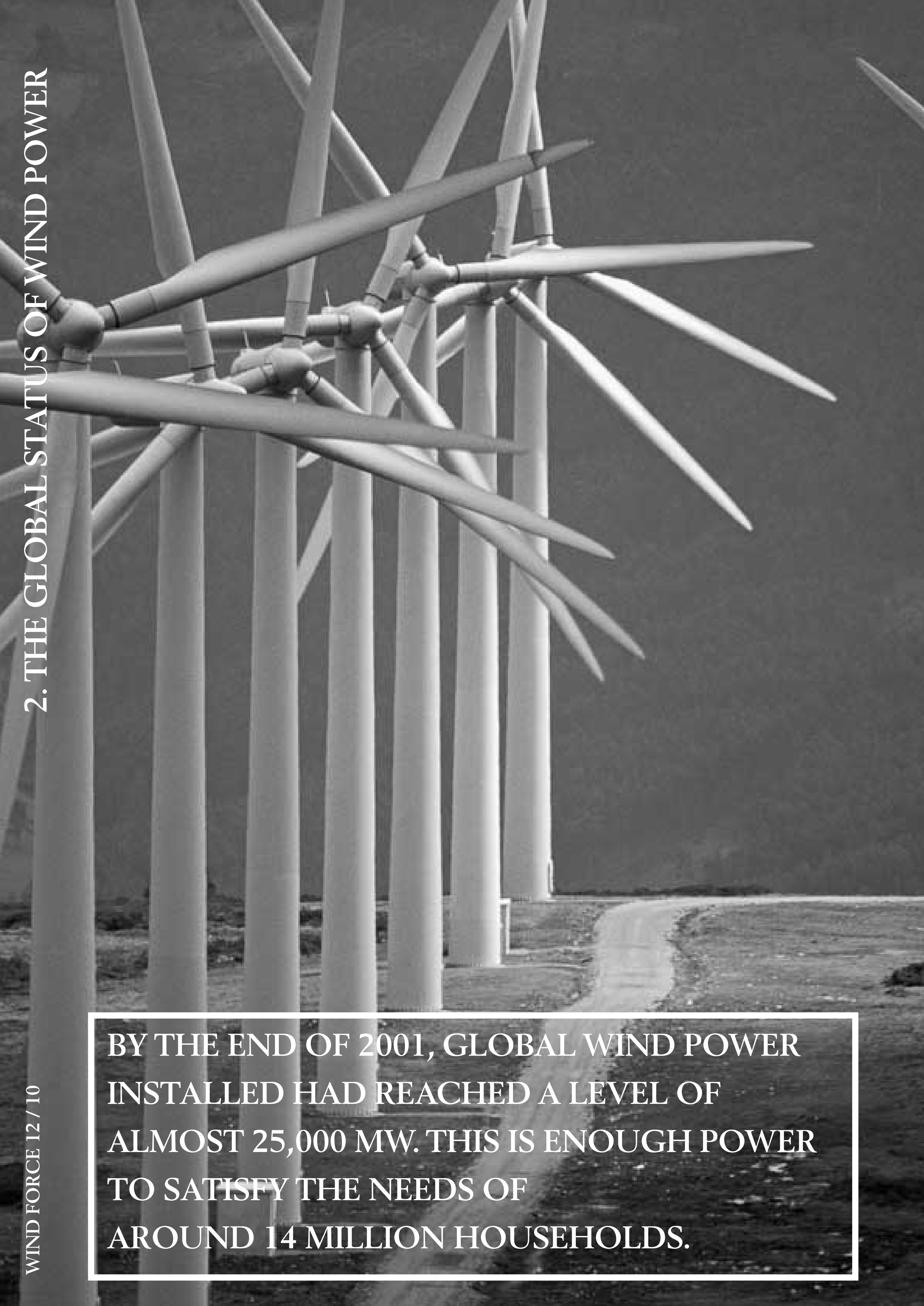
In the present study, three factors are different. First, the adjusted projections from the IEA's 2000 World Energy Outlook are used. Because this updated forecast for future global electricity demand is slightly lower than in 1998, it alters the total percentage of wind power's contribution to world electricity to 12%. Second, wind industry growth rates over the past three years have been well above those in the original report. Third, this updated scenario has reduced annual growth rates in the period 2004 to 2015 compared to Wind Force 10, which makes the scenario even more conservative. For example in the years 2008 to 2010 growth rates are now 20%, not 30%, a substantial reduction. All these factors provide us with a new target of Wind Force 12.

The report also compares the development of wind energy 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 eventual 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 150,000 MW/year must be established – over twenty times that of 2001. 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 energy beyond 2020 has not been assessed in detail with regard to 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 experiences and successes of the wind industry today. It is a feasibility study taking into account the essential physical limitations facing large-scale development of wind power. It assesses and compares actual industrial growth patterns seen in the sector so far with those in other energy technology developments. Over the past half century, generation technologies such as large scale hydro and nuclear power have achieved a high penetration in a relatively short time-scale. The actual pattern of wind energy development, however, will be determined by political initiatives taken at a broad global level.



BY THE END OF 2001, GLOBAL WIND POWER INSTALLED HAD REACHED A LEVEL OF ALMOST 25,000 MW. THIS IS ENOUGH POWER TO SATISFY THE NEEDS OF AROUND 14 MILLION HOUSEHOLDS.

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. Wind energy companies have emerged as profitable and secure investments, challenging the dominance of conventional power suppliers in some countries.

Since 1996, global wind power capacity has continued to grow at an annual cumulative rate close to 40% Over the past decade, installations have roughly doubled every two and a half years. During 2001 alone, close to 6,800 MW of new capacity was added to the electricity grid world-wide.

By the end of 2001, global wind power installed had reached a level of almost 25,000 MW. This is enough power to satisfy the needs of around 14 million households, over 35 million people. Europe accounts for around 70% of this capacity, and for two-thirds of the growth during 2001. But other regions are beginning to emerge as substantial markets for the wind industry. Over 45 countries around the world now contribute to the global total, and the number of people employed by the industry world-wide is estimated to be around 70,000.

Table 2-1: Growth in World Wind Power Market 1996-2001

Year	Installed (MW)	Increase %	Cumulative (MW)
1996	1,292	%	6,070
1997	1,568	21%	7,636
1998	2,597	66%	10,153
1999	3,922	51%	13,932
2000	4,495	15%	18,449
2001	6,824	52%	24,927
Average growth over 5 years		**39.5%**	

Table 2-2: Top Wind Energy Markets during 2001

Country	New Installation (MW)	Total installation end 2001 (MW)
Germany	2,627	8,734
USA	1,635	4,245
Spain	1,050	3,550
Italy	276	700
India	236	1,456
Japan	217	357
Denmark	115	2,456
UK	107	525
Greece	84	358
China	75	406
Others	402	2,140
World, total	**6,824**	**24,927**

World-wide Markets

Within Europe, Germany is the market leader. During 2001, German wind capacity grew by a record 2,627 MW, taking the country's total up to 8,734 MW. This represents 3.3% of national electricity demand, a proportion expected to increase to 5% by 2003.

Denmark and Spain have also continued to expand, the latter by more than 1,000 MW during 2001. 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.

Seven other members of the European Union – Italy, the Netherlands, Sweden, Greece, Portugal, Ireland and the UK – now each have more than 100 MW installed, and have effectively reached the take-off stage. France also looks set to expand dramatically, the Government having introduced an improved tariff system during 2001 and has set a target of 10,000 MW by 2010.

In the Americas, the United States market has experienced a major revival, leaving previous records in the dust with 1,635 MW installed during 2001. Over half of that was in the "Oil State" of Texas. Total US capacity has now reached 4,245 MW.

Table 2-3: Growth rates in the "Top-Ten" wind energy markets

Country	MW end 1998	MW end 1999	MW end 2000	MW end 2001	Growth rate 2001-2002 %	3 years average growth %
Germany	2,874	4,442	6,107	8,734	43%	45%
Spain	880	1,812	2,836	3,550	25%	59%
USA	2,141	2,445	2,610	4,245	63%	26%
Denmark	1,420	1,738	2,341	2,456	5%	20%
India	992	1,035	1,220	1,456	19%	14%
Netherlands	379	433	473	523	11%	11%
UK	338	362	425	525	24%	16%
Italy	197	277	424	700	65%	53%
R.P. China	200	262	352	406	15%	27%
Greece	55	158	274	358	31%	87%
Total "Top-Ten"	**9,476**	**12,964**	**17,062**	**22,953**	**35%**	**34%**

Source: BTM Consult ApS - March 2002

Canada is ready to expand from its present level of 198 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 prompted the Brazilian government to launch its “Proeolica” programme; over 3,600 MW of projects were quickly approved. Argentina’s vast potential is waiting for similar stimulation. Spanish companies lead those providing the development expertise.

New markets are also opening up in other continents. Australia has seen an increase in activity. In Asia, the Indian market has revived after a quiet period in the late 1990s, 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-sponsored Intergovernmental Panel on Climate Change projects that average temperatures around the world will increase by up to 5.8ºC over the next century. Many 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 a global cut of 5.2% from 1990 levels by the period 2008-2012, a series of greenhouse gas reduction targets has cascaded down to regional and national levels. These in turn have been translated into targets for introducing an increasing proportion of renewables into the supply mix. The 15 member states of the European Union, for example, now have an overall target of 22% of their electricity to come from renewables by 2010, from a baseline of 14% in 1997.

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

The argument behind these mechanisms is two-fold. Firstly, there is the need to stimulate a market to the point where a substantial industry can been established. Secondly, there is the historic distortion of the market in favour of both fossil fuels and nuclear. Conventional energy sources receive an estimated $250-300 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 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, and wind power offers an opportunity to provide industrial scale on-grid electricity and to leap-frog dirty technology to aid clean industrial development.

Falling costs

As the market has grown, wind power has shown a dramatic fall in cost. The production cost of a kilowatt hour of wind power is one fifth of what it was 20 years ago. Over the past five years alone, costs have reduced by some 20%. Wind is already competitive with new coal-fired plants and in some locations can challenge gas, currently the cheapest option. In the UK, for instance, developers have contracted to build wind farms for a price of less than 3 US cents/kWh, comparable with that of gas.

The cost of wind power generation falls as the average wind speed rises, and as recent analysis from industry magazine Windpower Monthly shows, at an average site with a speed of 7.5 metres per second, and a cost per installed kilowatt of $700, wind can be cost competitive with gas.

As its economic attraction has increased, wind energy has become big business. The major wind turbine manufacturers are now commissioning multi-million dollar factories around the world in order to satisfy demand. Five of the leading companies have been floated on the European stock market, prompting keen interest in their shares. Market leader Vestas had a turnover in 2001 of roughly $1.2 billion.

Most importantly, the wind energy business is attracting serious interest from outside investors. At the beginning of 2002, for example, a consortium of banking, insurance and legal interests announced that it would invest up to $1.3 billion in wind farms planned round the UK coastline. Turbine manufacturer Enron Wind has been bought by General Electric, one of the world’s largest corporations. Just as significant is the decision by a number of oil companies to take a stake in wind power. Shell’s Renewables division has already taken up over 140 MW of wind capacity in the US. These deals are evidence that wind is becoming established in the mainstream of the energy market.

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.

Although a number of variations continue to be explored, the most common configuration has become the horizontal three bladed turbine with its rotor positioned upwind – on the windy side of the tower. Within this broad envelope, continuing improvements are being made in the ability of the machines to capture as much energy as possible from the wind. These include more powerful rotors, larger blades, improved power electronics, better use of composite materials and taller towers. Some turbines operate at variable speed or avoid a gearbox altogether by direct drive.

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 typical size range sold today is 750-1,300 kW. In the year 2000 the average new turbine installed in Germany rose above 1,000 kW for the first time. The largest machines commercially available are of 2,500 kW capacity, with 80 metre diameter rotors placed on 70-80 metre high towers. Each 2,000 kW turbine produces more energy than 200 of the old 1980 vintage. One result is that many fewer turbines are required to achieve the same power output.

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 2002 the German company Enercon is scheduled to erect 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% per annum 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, the wind accounts for up to 50% of power generation in the western part of Denmark, for example, but the grid operators have managed it successfully. It would improve the effectiveness and reliability of the European wind input, however, if a new super-grid was installed to link up the many large offshore plants expected to start generating power over the next decade.

The Advantages of Wind Energy

- **Low cost - wind can be competitive with nuclear, coal and gas**
- **No fuel needed - no resulting carbon dioxide emissions**
- **Avoids fuel price shocks, reliance on imported fuels**
- **Modular and quick to install**
- **Provides large, industrial on-gird electricity supply**
- **Land friendly – agricultural/ industrial activity can continue around it**
- **More jobs per MW installed and per dollar spent than nuclear power or fossil fuel**

Germany – World Leader

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

The current figure for installed wind power capacity in Germany by the end of 2001 stands at more than 8,734 MW. These 11,000 turbines can produce enough electricity to meet 3.3% of demand in a country of 82 million people. As importantly, if present trends continue, the proportion could easily reach 5% by 2003.

During 2001 alone more than 2,000 new wind turbines were connected to the grid, representing a total capacity of 2,659 MW. This was a 60% increase over the level of new capacity installed during 2000, and a better result than even most experts had predicted. Germany has seen spectacularly high growth rates in its wind energy capacity over the past seven years. The average annual increase since 1998 has been 43%.

No other development in the history of the country's electricity industry can compare with this. The German Wind Energy Association compares 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, Nordex and Enron Wind having built up major manufacturing bases. An estimated 35,000 people are currently employed both directly and indirectly by the industry. Sales in the sector were expected to have reached $3 billion during 2001.

Landmark legislation

Following government-sponsored 100 MW and 250 MW wind programmes during the 1980s, the big breakthrough came in 1991, when the Stromeinspeisungsgesetz – Electricity Feed Law (EFL) was passed by the German parliament. This landmark piece of legislation guaranteed to all renewable energy producers up to 90% of the current domestic sale price of electricity for every kilowatt hour they generate. 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.

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 10% 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 Westfalia (1,010 MW installed by the end of 2001), Saxony-

AN ESTIMATED 35,000 PEOPLE ARE CURRENTLY EMPLOYED BOTH DIRECTLY AND INDIRECTLY BY THE INDUSTRY.

Anhalt (796 MW) and Brandenburg (769 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 energy to a wide range of people. Other larger wind parks have been developed through investment funds in which more substantial shares have been 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.

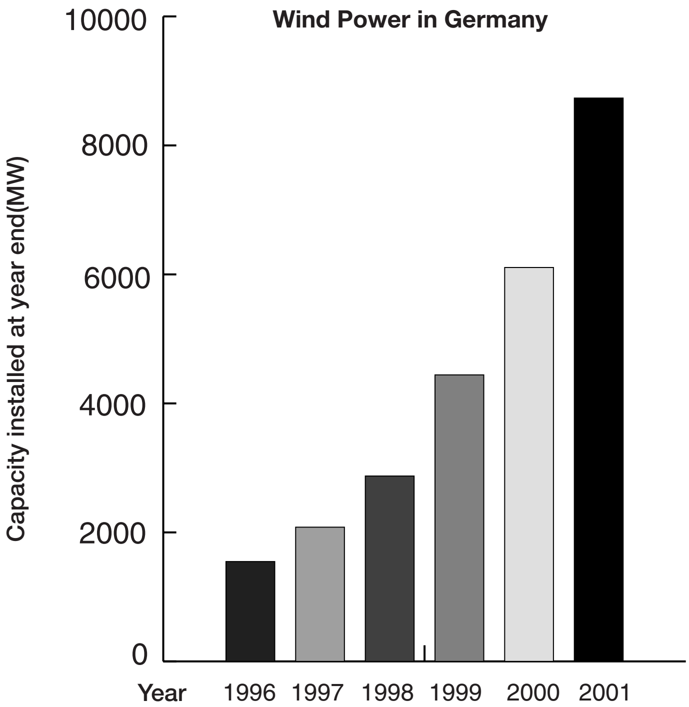
In countries with very high density of wind turbines – such as Germany and Denmark – local populations support the development of wind power. In many regions wind power has become an important income for farmers.

Green policies

Support for wind power is found in the strong political influence wielded by environmentalists, including the Greens, who currently share Government with the Social Democrats. Green-Social Democrat coalitions also control a number of the individual states.

The most recent 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. Currently 3,000 MW offshore wind is confirmed for development in the North Sea by 2010. The industry expects to reach 16,000 MW on land by 2005, where the market will then switch to repowering existing older machines and the development of offshore sites. By 2010 wind power could be providing 10% of German electricity demand from approximately 20,000MW capacity.



(Source BTM Consult)

United States – Waking Giant

The United States wind energy market is on the rise, following a slow installation rate in the 1990s. During 2001, the industry left previous records in the dust, installing nearly 1,700 MW of new generating equipment worth $1.7 billion across 16 states. The final tally, reaching a total of 4,245 MW, was more than double that of the previous record year of 1999.

Wind farms across America now generate about 10 billion kilowatt hours annually, enough to power one million households. The industry is growing at such a rapid rate (an average 23% over the past five years) that the American Wind Energy Association current target is for wind power to account for 6% of the U.S. electricity supply by 2020 – a figure that could easily be exceeded with strong and consistent policy support.

Federal and state policies

Some of this development has been encouraged by the federal government's key incentive, the production tax credit (PTC). The PTC, which was first available in 1994, is an inflation-adjusted tax credit of 1.5 U.S. cents per kWh of wind power produced during the first ten years of a project's operation. Although the government allowed the PTC to expire in June 1999 and at the end of 2001, it was eventually extended in early 2002 for a further two years. The PTC has resulted in a boom-bust cycle for the industry.

Individual state policies have played a critical role in fostering wind energy. In Texas, the 1999 introduction of a minimum renewable energy content requirement (Renewables Portfolio Standard, or RPS), that grows over time has jump-started the development of wind power, the least-cost renewable energy in that state. More new capacity was installed in Texas in 2001 (over 900 MW) than has ever been installed in the entire United States in any single year. Texas is now on its way to meeting its goal for 2,000 MW of new renewables by 2009, several years ahead of schedule. Eleven other states also have an RPS or similar mechanism, exemplifying what could be achieved at a national level with similar legislation, especially if combined with the PTC. Other important state incentives have included rebates and investment tax credits (particularly for small wind), and net metering (which enables those who provide wind-generated electricity to the grid to receive the retail rate in payment, up to the level of their own consumption).

Economically attractive

With the market's dramatic upturn, large U.S. energy companies which had mostly shunned wind in the past are looking again at the technology. FPL Energy, for example, a subsidiary of Florida Power and Light that owns and operates large nuclear and gas plants, was responsible for building and financing about half of the new wind farms installed in 2001. American Electric Power, a large conventional power utility, has built a 150 MW wind farm and acquired another, both in Texas. Dallas-based TXU, whose portfolio covers gas, coal and nuclear power, is now one of the largest purchasers of wind power. In early 2002, the giant General Electric conglomerate bought up Enron Wind Corp., the profitable subsidiary of the now-bankrupt Enron. Such companies invest in large projects that benefit from economies of scale. The cost of electricity from large wind farms at good sites, in Texas and elsewhere, is now below 5 U.S. cents/kWh, within a range that is competitive with conventional power sources. Recent long-term contracts have actually been signed for less than 4 cents/kWh.

Not only can wind energy turn in a profit for the companies involved, it also brings welcome benefits to the economy as a whole. Many rural communities welcome wind farms, which

WIND FARMS ACROSS AMERICA NOW GENERATE ABOUT 10 BILLION KILOWATT HOURS ANNUALLY, ENOUGH TO POWER ONE MILLION HOUSEHOLDS.

allow farmers and ranchers to earn additional income ($2,000 or more per turbine per year) while continuing to grow crops or graze livestock up to the foot of the towers.

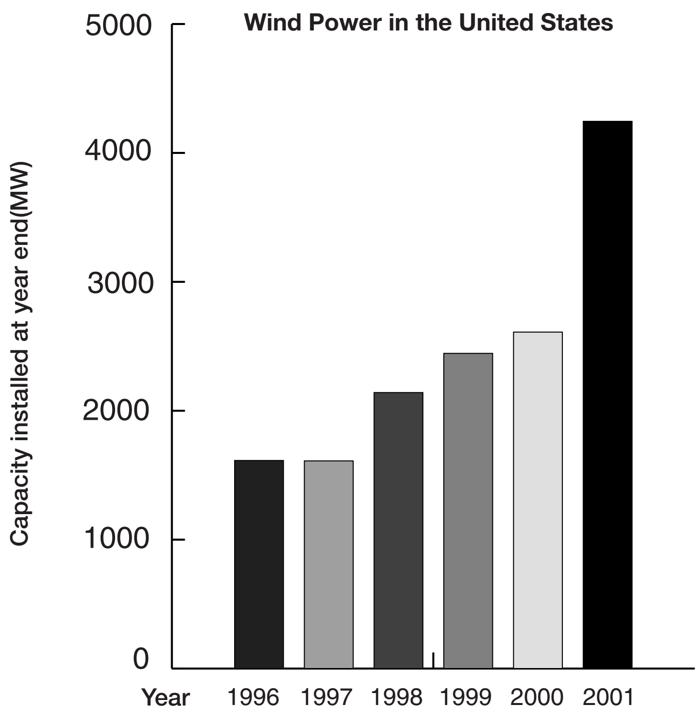
Spreading across the United States

Most of the new wind development in the United States is occurring outside of California, the home of the wind energy boom of the 1980s. At the end of 2001, utility-scale wind turbines were operating in 26 out of 52 states. California and Texas both boasted over 1,000 MW, Iowa and Minnesota stood at about 320 MW, whilst capacity exceeded 100 MW in Washington, Oregon, Wyoming and Kansas.

At the same time, according to U.S. government estimates, the U.S. wind potential is ample enough to meet more than twice the country's total current electricity consumption. Development of only a fraction of that would allow the country to significantly boost its electricity supply without emitting additional carbon dioxide, sacrificing air quality standards, further jeopardising human health, or accelerating the depletion of natural resources.

Despite the recent boom in the United States, the country has been falling behind Europe. With significantly more wind energy potential the U.S. now has less than half the wind capacity of Germany. North Dakota alone has an estimated 50 times more wind resources than Germany.

What happens in the United States over the next several years will, to a significant extent, be the result of government policy at a Federal and State level.



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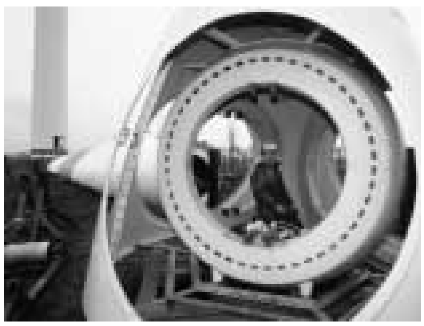


India – Developing World Pioneer

Among the countries of the developing world, India has pioneered the use of wind energy 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 over 1,500 MW, India is already the fifth largest producer of wind power in the world. During 2001 it had one of its best years ever, with 240 MW installed and a 28% increase over the year before. Even so, given the 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

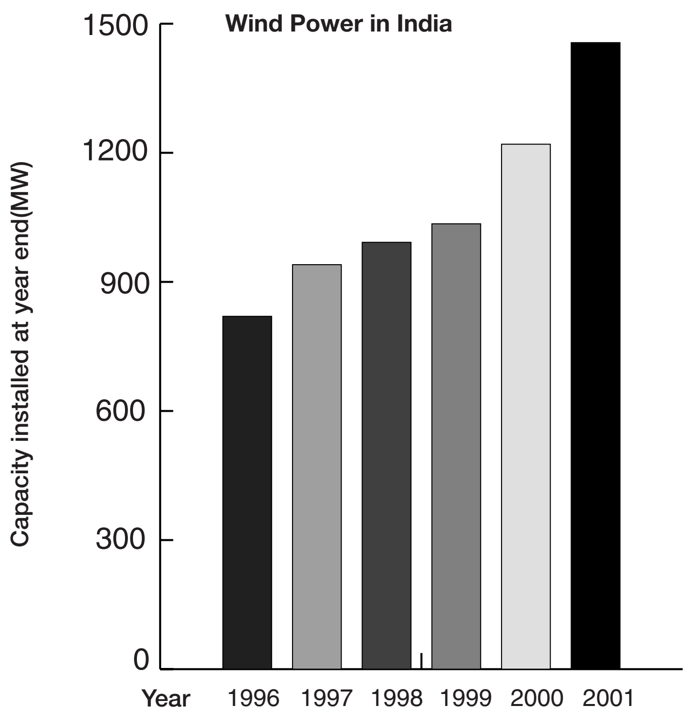
In order to pinpoint the best resources, MNES established a country-wide network of wind speed measurement stations. A number of financial incentives have also been provided for investors, including depreciation of capital costs and exemptions from excise duties and sales tax. A 100% tax rebate on the income from power generation during the first ten years of operation is being introduced during 2002. Individual states have their own incentive schemes, including capital subsidies in some states.

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 some investors disillusioned.

Over the past few years both the government and the wind energy 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 wind 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.

More than a dozen wind turbine manufacturers are currently offering their products on the Indian market. One of them, Vestas has been operating since the mid 1980's. A successful recent entrant has been Suzlon (based on technology from Sudwind Energie System, Germany), a company which now employs 800 people at two factories. Achieving the status of ninth position in the "top ten" list of global turbine suppliers during 2000, the company has also been 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 a third of total installations. This is beginning to change, with other states like Maharashtra,Karnataka and Rajasthan are catching up. The forecast by BTM Consult for capacity in India at the end of 2001 has been easily exceeded; by 2006, BTM expects 2,800MW to be installed, well in advance of the Indian Government's own projections.



(Source BTM Consult)

Denmark – Commercial Success

Denmark's wind energy industry is a major commercial success story. From a standing start in the 1980s to a turnover of $2.6 billion in 2001, 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, Nordex 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 20,000 people in Denmark and a further 8,000 in component supply and installation work around the world.

The last eight 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 almost tenfold from 368 MW in 1994 to 3,000 MW in 2001. Despite the emergence of competing manufacturing countries, almost 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 reached three years early with less than 5,000 turbines with an average size of 230 kW. The main thrust of the latest plan, called Energy 21 (published in 1996), 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.

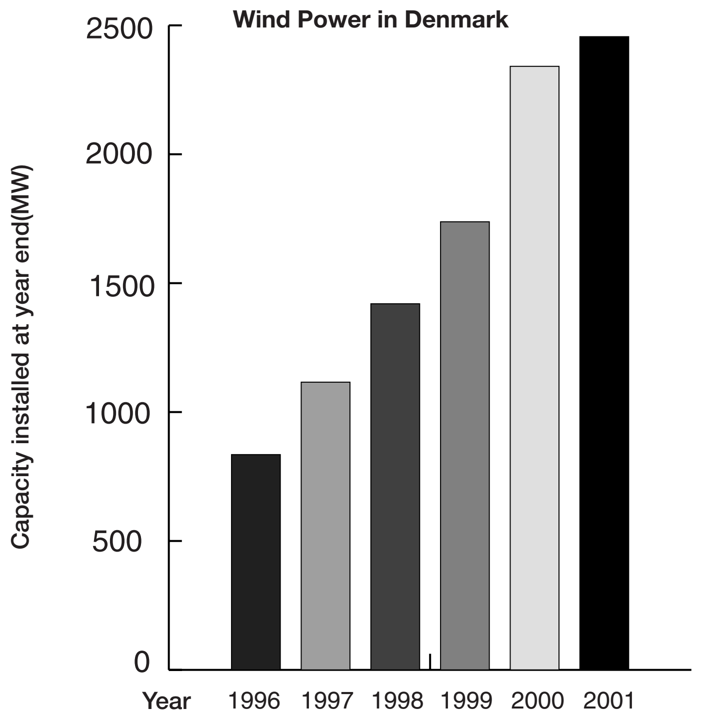
Record proportion

Denmark is already well on the way to achieving these objectives. By the end of 2001 installed wind energy capacity had risen to 2,417 MW. In an average wind year these turbines will produce 18% of the country's electricity. The Danish Wind Industry Association anticipates that Denmark will be able to satisfy more than 20% of its demand from wind generated electricity by 2003. This is a higher proportion than any other nation in the world.

Through the use of wind power, Denmark has already achieved one third of its required reductions under the Kyoto Protocol. This reduction is equivalent to about 7% of all Danish greenhouse gas emissions.

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



(Source BTM Consult)

familiar three-bladed design with the rotor and blades set upwind (on the windy side of the tower) is now the classic concept against which all others are judged.

More recently, Denmark has led the world in the development of proposals to build large wind farms of turbines in its coastal waters. 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 Government has so far approved the first two parks. The eventual aim is for up to 4,000 MW of offshore schemes by 2030.

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

Spain – Southern Europe's Powerhouse

The Spanish wind energy industry has forged ahead in recent years more successfully than any other in southern Europe. A sparsely populated countryside combined with strong government policies have together made Spain a powerhouse for both manufacture and development.

In 1993 just 52 MW of wind energy capacity was operating in the Spanish landscape, much of that concentrated in the windy district of Tarifa facing out towards Africa across the straits of Gibraltar. By the end of 2000 the total had mushroomed to 2,836 MW, over a third installed in that one year alone. During 2001, wind energy soared again to reach 3,550 MW, maintaining Spain's position as No.2 in Europe.

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, in the shadow of the Pyrenees, 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 in 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 energy 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 2001, the government agreed price was 5.4 US cents/kWh, making wind an 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 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.

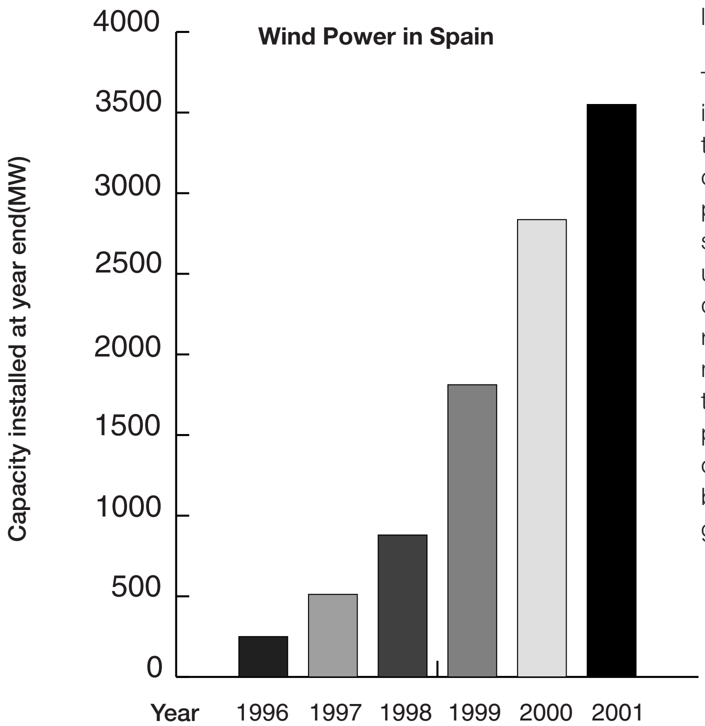
A pioneer of this approach has been Galicia, the north-western region whose coastline juts out into the Atlantic Ocean. Starting from 1997, the regional government's grand plan has been to install a capacity of 2,800 MW within ten years. This represents about 45% of the province's power capacity. To achieve this, ten promoting companies, including

FROM A FEW HUNDRED WORKERS IN 1981 THE INDUSTRY NOW PROVIDES JOBS FOR 20,000 PEOPLE IN DENMARK AND A FURTHER 8,000 IN COMPONENT SUPPLY AND INSTALLATION WORK AROUND THE WORLD.

both power utilities and turbine manufacturers, have been granted concessions to develop set quotas of capacity within 98 specified “areas of investigation”. The total investment value could reach over $2.6 billion.

Galicia’s aim is that at least 70% of this investment should be made within its borders, creating more than 2,000 direct and 3,000 indirect jobs. As a result, factories making blades, components and complete turbines have sprouted up around the province. By the end of 2001, the region had already achieved 973 MW, almost 30% of the national total.

The mountainous province of Navarre is equally ambitious. During 2001 it reached 596 MW, already well on the way to its target for 650 MW by 2010. 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 11,500 MW of wind capacity planned to be constructed in the period up to 2012. One of the newest plans was announced by Valencia, which allocated concessions for 15 sites totaling 2,000 MW.



(Source BTM Consult)

Environmental concerns have been given a different emphasis in different regions.Navarra included environmental impacts as one of the key aspects in site selection at 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. Spain now boasts one of the world’s largest wind developers, Energias Eolicas Europeas, a joint venture between EHN and Iberdrola, which has plans to reach over 1,000 MW in the next few years. During 2001 the company signed a record deal worth $800 m to construct 31 wind farms in Castilla la Mancha.

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

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.

DURING 2001, WIND ENERGY SOARED AGAIN TO REACH 3,550 MW, MAINTAINING SPAIN’S POSITION AS NO.2 IN EUROPE.

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 about 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.

The flip side of the coin is that it is currently more expensive to build 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 will be able to substitute cheaper 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 half the current installed capacity of just under 100 MW. This year, the largest offshore wind farm in the world is being constructed at Horns Rev, between 14 and 20 kilometres from the Danish North Sea coast. With eighty 2 MW turbines this will have a capacity of 160 MW. A similarly sized development at Rødsand in the Baltic is planned to 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. The first construction permit from the national maritime authority was granted in 2001 to the 60 MW pilot phase of a 1,000 MW development off the North Sea island of Borkum.

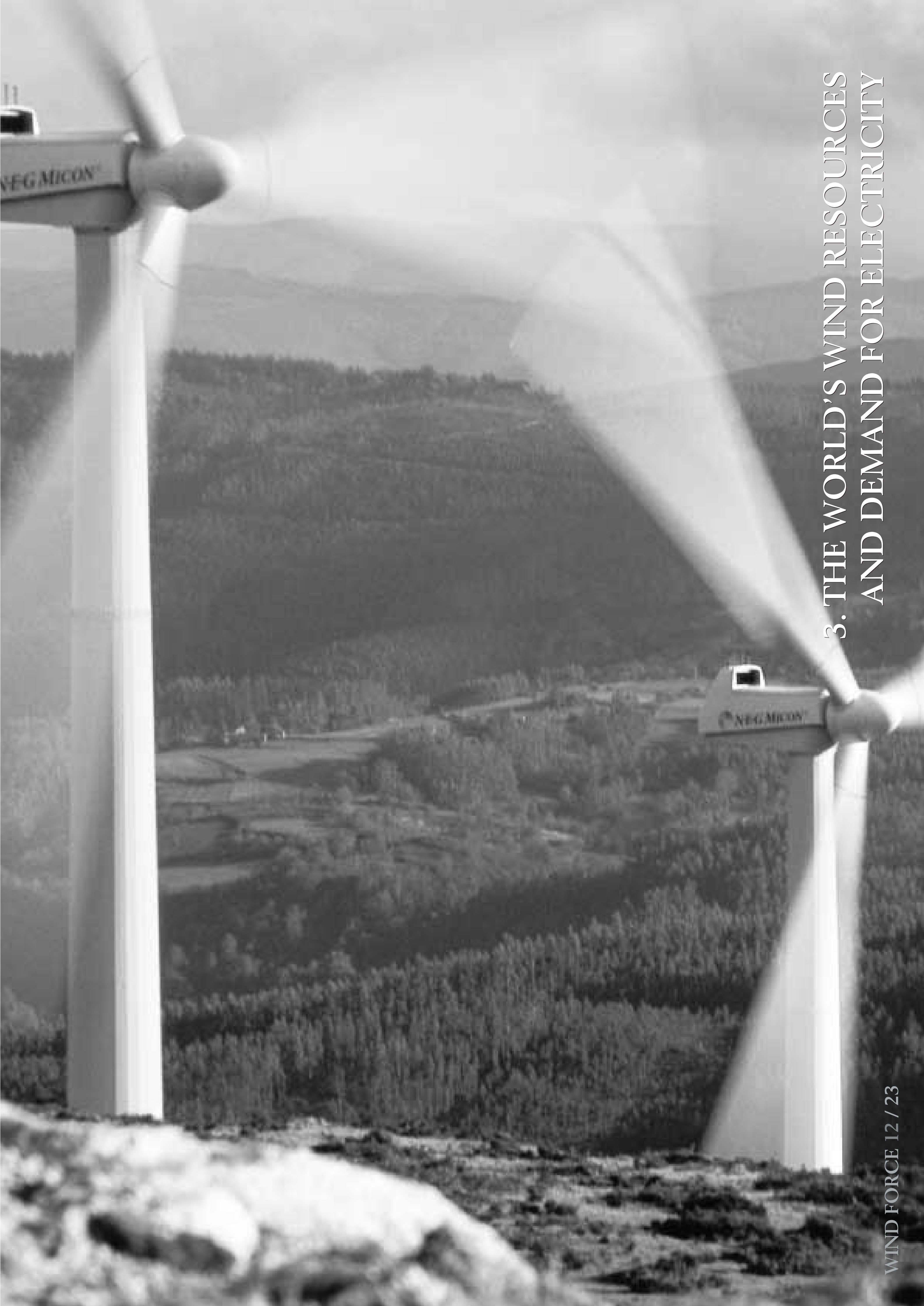
Guaranteed tariff

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 recently 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.

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

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.



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

Is There Enough Wind?

If wind energy 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 25,818 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.

Onshore 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 incapacity . It is obvious that with the upscaling since then to an average size closer to 1,000kW, 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 onshore 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.

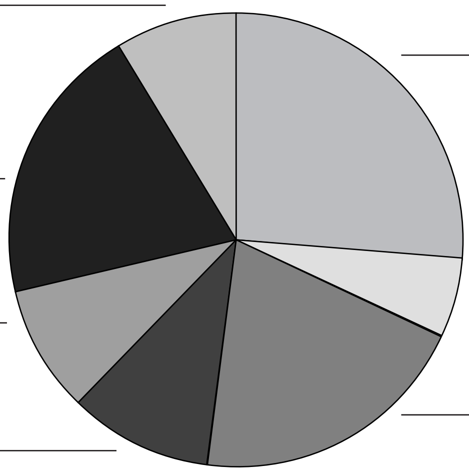


Figure 3-1 The world's wind resources World total = 53,000 TWh

Source: Wind resources from Michael Grubb and Niels Meyer, 1994

Note: The total potential (land with an average wind speed above 5.1 m/s at 10 m height) has been reduced by 90 % to take into account other uses, population density etc. The assessment does not include Greenland, the Antarctic or offshore areas. Figures not available for OECD Pacific Region (Australia, NZ and Japan) and Middle East.

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 (38)	23.2	
Total	**2,500**	**630 (315)**	**366.4**	**244.8**

Source: 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 consumption for OECD-Europe in 1995 of 2,678 TWh.
2 Greece has an excess potential, but with resources scattered over many islands is unlikely to be an exporter for some time.

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. The European wind turbine manufacturing industry is also focussing its current R&D effort on producing new designs specially adapted for the emerging offshore market. This is expected to seriously take off in northern Europe from 2003 onwards.

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 exceeds the total electricity consumption within the Union's 15 current 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 expense involved, particularly in foundation work, all water depths over 20 m have been excluded. Sites less than 10 km from the shore have been reduced by 90% to be sensitive to visual concerns.

- The resource within the range 10-20 km from the shore has been reduced by half in order to allow for potential visual restrictions and adequate spacing between wind farms, whilst the 20-30 km resource has also been reduced by

50% on the assumption that the expense of lengthy power cable connections will deter smaller developers.

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

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.

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 electricity demand by region

Region	1997 (TWh per year)	2010 (TWh per year)	2020 (TWh per year)	Average Growth 1997-2020 (per year)
OECD Europe	2,925	3,863	4,515	1.9%
OECD N. America	4,246	5,159	5,729	1.3%
OECD Pacific	1,249	1,533	1,745	1.5%
Latin America	863	1,468	2,041	3.8%
East Asia	757	1,361	2,081	4.5%
South Asia	541	1,081	1,695	5.1%
China	1,163	2,408	3,691	5.1%
Middle East	366	614	907	4.0%
Transition Economies	1,440	1,883	2,615	2.6%
Africa	399	619	864	3.4%
World	**13,949**	**19,989**	**25,883**	**2.7%**

Source : IEA, World Energy Outlook 2000

Table 3-4 : Available wind resources and future electricity demand

Region of the world	Electricity demand by 2020 (TWh/year)	20 % of 2020 demand (TWh/year)	Wind resource (TWh/year)	Factor of the resource exceeding 20% penetration by 2020
OECD Europe	4,515	903	Land: 630 Offshore:313	1.04
OECD N. America	5,729	1,146	14,000	12.2
OECD Pacific	1,745	349	3,600	10.3
Latin America	2,041	408	5,400	13.2
East Asia	2,081	416		
South Asia	1,695	339		
China	3,691	738		
Middle East	907	181	n.a	-
Transition Economies	2,615	523		
Africa	864	173	4,600	3.1
World	25,883	5,177		

Sources: Projected consumption : IEA, World Energy Outlook 2000. Worlds Wind Resource : According to Table 3-1 and Figur

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. Wind Force 10 was based on the IEA scenario “World Energy Outlook 1998”. In this study there is only one scenario for projected future electricity demand, described as “Business as Usual”. The choice of a “Business as Usual” scenario clearly reflects the cautiousness of the IEA over the world community’s future efforts to reduce electricity consumption. Nonetheless, this projection was taken for our starting point for the 10% scenario in 1999.

The profile of the IEA projection was updated in 2000, and future demand according to this analysis is shown in Table 3-5 The new IEA projection data still shows an effective doubling of global electricity consumption by 2020.

The scenario was updated with the newer IEA figures. Therefore with a slightly lower projected total future electricity consumption and the same amount of wind electricity, the relative proportion of wind power would increase – hence the new outcome of Wind Force 12. In addition, it is important to note that the industry growth rates in the year 2004-2015 were reduced to make the scenario even more conservative.

The 3,093 TWh (the “12%”) represents nearly 20% of current 2001 global electricity consumption, highlighting the significant additional benefits of wind power if additional electricity consumption does not increase.

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%.

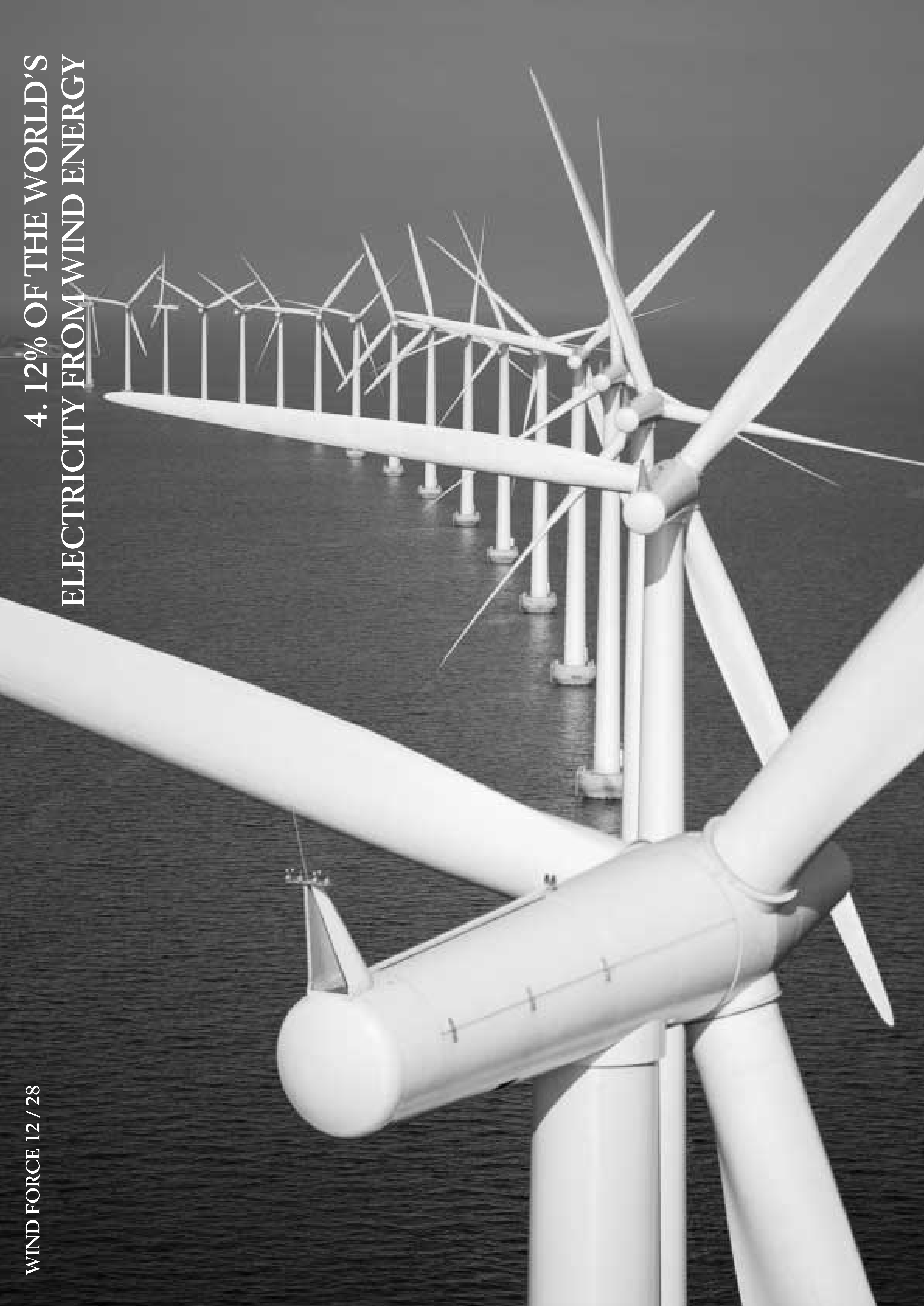
In Denmark, peak levels of up to 50% wind power have been successfully incorporated by grid managers in the western part of the country during very windy periods. The Danish Energy Plan includes a goal to consistently cover 50% of the country’s electricity consumption from wind energy by 2030 by balancing imports and exports. This includes the use of interconnectors to neighbouring countries, especially Norway and Sweden, both of which have large capacities of hydro power that complement the wind load profile.

The cautious assumption adopted here is that a 20% limit is an acceptable figure to be taken into account in the potential penetration of wind power into the world’s grid networks. Table 3-4 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 2000

Consumption growth rate	Global TWh	Year	Wind TWh	Penetration
	15,578	2001	54.5	0.35%
	16,014	2002	73.1	0.46%
	16,463	2003	96.4	0.59%
	16,924	2004	125.5	0.74%
	17,397	2005	161.9	0.93%
2.80%	17,885	2006	207.3	1.16%
	18,385	2007	264.1	1.44%
	18,900	2008	332.3	1.76%
	19,429	2009	414.1	2.13%
	19,973	2010	512.3	2.56%
	20,493	2011	705.7	3.44%
	21,025	2012	864.0	4.11%
	21,572	2013	1,046.0	4.85%
	22,133	2014	1,255.4	5.67%
	22,708	2015	1,496.2	6.59%
2.60%	23,299	2016	1,761.1	7.56%
	23,905	2017	2,052.4	8.59%
	24,526	2018	2,372.9	9.68%
	25,164	2019	2,725.4	10.83%
	25,818	2020	3,093.4	11.98%
	26,334	2021	3,461.3	13.14%
	26,861	2022	3,829.2	14.26%
	27,398	2023	4,197.1	15.32%
	27,946	2024	4,532.5	16.22%
2.00%	28,505	2025	4,859.7	17.05%
	29,075	2026	5,176.7	17.80%
	29,657	2027	5,481.0	18.48%
	30,250	2028	5,772.6	19.08%
	30,855	2029	6,048.9	19.60%
	31,318	2030	6,306.8	20.14%
	31,788	2031	6,542.8	20.58%
	32,264	2032	6,752.4	20.93%
	32,748	2033	6,938.3	21.19%
	33,240	2034	7,096.8	21.35%
1.50%	33,738	2035	7,739.9	22.94%
	34,244	2036	7,850.4	22.92%
	34,758	2037	7,932.4	22.82%
	35,279	2038	7,983.2	22.63%
	35,808	2039	7,999.7	22.34%
	36,346	2040	7,999.7	22.01%

4. 12% OF THE WORLD'S ELECTRICITY FROM WIND ENERGY



Outline of the 12% Scenario

The initial sections of this report have described the current status of wind energy 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 world-wide 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 energy at the end of 2001. The total installed capacity around the world by then was 24,900 MW, with new installations during 2001 reaching 6,800 MW. The growth rate of new annual installation during the period 2002 to 2007 is estimated to be 25% per annum, ending up with some 120,600 MW on line by the end of 2007. This is the highest growth rate during the period. From 2008 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 1,260 GW (1.26 million MW) will have been achieved, with an annual production capable of matching 12% of the world's demand for electricity, as projected by the IEA.

Beyond 2020, development continues with an annual installation rate of 150,000 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 energy 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 5% of capacity each year.

Growth rates for wind energy are based on a mixture of historical figures and information obtained from leading companies in the wind turbine market. The exploitable wind potential worldwide and the level of electricity consumption in different regions of the world have also been assessed. Future cost reductions in wind technology are based on expectations of "learning rates" and take off from today's level, which is approximately $765 per kW of installed capacity resulting in a price per kWh of 3.61 US cents – this is state of the art under optimum conditions.

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 from both the wind energy industry and from other technological developments in the energy field. The main assumptions are presented below:

■ 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 2001 it has continued at an impressive average of 35%.

Based on the current rate of expansion in the wind energy industry, it is quite capable of meeting a growth in demand of 25% a year for at least five years ahead. By the end of 2007 manufacturing output is expected to reach a level of 25,940 MW/year. From 2008 onwards the annual growth rate of new capacity slows down in the scenario to 20%, then to 15% in 2013 and finally to 10% in 2016. The growth in manufacturing capacity levels out in 2020 at a figure of 150,000 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 a stable political framework established for wind power development in emerging markets around the world before it enters local manufacturing through joint ventures.

■ Progress ratios

The general conclusion from industrial learning curve theory is that costs decrease by some 20% each time the number of units produced doubles. A 20% decline is equivalent to a progress ratio of 0.80. Studies of the past development of the wind power industry show that progress through R&D efforts and by learning resulted in a 15-20% price reduction – equivalent to a progress ratio of 0.85 to 0.80. In the calculation of cost reductions in this report, experience has been related

to numbers of units, i.e. turbines and not megawatt capacity. The increase in average unit size is therefore also taken into account.

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

The reason for this graduated assumption, particularly in the early years, is that the manufacturing industry has not so far gained the full benefits from series production, especially due to the rapid upscaling of products. Neither has the full potential of future design optimisations been utilised. Even so, the cost of wind turbine generators has still fallen significantly, and the industry is recognised as having entered the "commercialisation phase", as understood in learning curve theories.

■ Future growth of wind turbine size

Table 4-2 shows the rapid growth of wind turbines size in the commercial market over the past seven years. From this it can be seen that in the leading markets – Germany, Denmark, Spain and the United States – the average size of wind turbines being installed has grown by a factor of three to four.

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 915kW to 1.5 MW. By the middle of the first decade of the scenario this development will be pushed even harder by the emerging offshore sector. Wind turbines for that market are expected to be in the size range up to 5 MW. Most importantly, the development of larger sizes reduces the number of turbines needed for a given capacity and decreases the progress ratio.

■ Increases in capacity factor

The capacity factors of wind turbines have already increased from 20% to 25% 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, modelling and cost. This scenario foresees average capacity factors increasing further to 28% by 2011 and 30% by 2035.

■ Comparisons with Other Technologies

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

The most commonly used power plants in the world's electricity supply are "large scale technologies" such as thermal power stations fired with coal, gas or oil, nuclear reactors and large scale hydroelectric plants. Both nuclear power stations and large scale hydro are technologies which have been mainly developed since the middle of the twentieth century. They have now reached a penetration of 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 energy 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 is that wind power is a small scale technology, with a maximum commercial unit size today of 2.5 MW, although the modularity of wind power therefore makes it ideal for all sizes of installations, from a single unit to huge wind farms. On the supply side this gives a greater potential for cost reduction, with serial production of units. It also makes wind energy suitable for many different types of electricity infrastructure, from isolated loads fed by diesel power to huge national and transnational grids.

Seen from these viewpoints it is quite feasible that wind energy can penetrate to a level of 12%. The amount of installed

capacity would then in fact be equivalent to that of hydro power today – even though on paper it appears some 50% higher. This is because of wind power's lower capacity factor which in this study we have taken a range rising from 25% to 30%. The capacity factor for hydro power is typically 60%.

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

The relative progress of new power technologies has been

Table 4-1 : 12% wind-powered electricity worldwide by 2020

Year ratio	Average annual growth rate	Annual new capacity MW	Cumulative capacity by end of year MW	Annual wind electricity production TWh	World electricity demand %	Wind power penetration of global electricity TWh
2001		6,800	24,900	54.5	15,578	0.35
2002	25%	8,500	33,400	73.1	16,014	0.46
2003		10,625	44,025	96.4	16,463	0.59
2004		13,281	57,306	125.5	16,924	0.74
2005		**16,602**	**73,908**	**161.9**	**17,397**	**0.93**
2006		20,752	94,660	207.3	17,885	1.16
2007		25,940	120,600	264.1	18,385	1.44
2008	20%	31,128	151,728	332.3	18,900	1.76
2009		37,354	189,081	414.1	19,429	2.13
2010		**44,824**	**233,905**	**512.3**	**19,973**	**2.56**
2011		53,789	287,694	705.7	20,493	3.44
2012		64,547	352,241	864.0	21,025	4.11
2013	15%	74,229	426,470	1,046.0	21,572	4.85
2014		85,363	511,833	1,255.4	22,133	5.67
2015		**98,168**	**610,001**	**1,496.2**	**22,708**	**6.59**
2016	10%	107,985	717,986	1,761.1	23,299	7.56
2017		118,783	836,769	2,052.4	23,905	8.59
2018		130,661	967,430	2,372.9	24,526	9.68
2019		143,727	1,111,157	2,725.4	25,164	10.83
2020		**150,000**	**1,261,157**	**3,093.4**	**25,818**	**11.98**
2030	0%	150,000	2,571,277	6,306.8	31,318	20.14
2040		150,000	3,044,025	7,999.7	36,346	22.01

Table 4-2: Average size of wind turbines installed each year (kW)

Year	China	Denmark	Germany	India	Spain	Sweden	UK	USA
1995	326	493	473	208	297	448	534	327
1996	400	531	530	301	420	459	562	511
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

The average turbine for supply to the entire world in 2001 was: 915 kW



assessed in the study "Global Energy Perspectives", produced by the Austrian institute IIASA and the World Energy Council in 1998. The report gives the following examples, all from the United States:

- Photovoltaics – from 1981 to 1992, achieved a progress ratio rate of 20% (0.80)
- Wind turbines – from 1982 to 1987, achieved a progress ratio of 20% (0.80)
- Gas turbines – progress ratio of 20% for the first 1,000 MW installed, then 10% from 1963 to 1980, when 90,000 MW was installed

Penetration levels based on the above assumptions have been used in Table 4-1.

Breakdown of the 12% Scenario by Region

The general guideline followed in the 12% Scenario has been to distribute the 1,260 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.

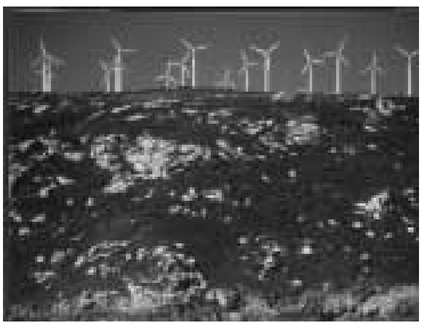
Another consideration has been the quality of wind resources in terms of regional share of "high average wind speed regimes". Areas with extremely high annual wind speeds will be more interested in developing wind power than large geographical areas with moderate wind speeds, even if the absolute resources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

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

The expected geographical distribution of 1,260 GW of wind power by end of the year 2020 is shown in Table 4-3.

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

Region (IEA definition)	Share of 1,200 GW of wind energy in 2020 (MW)	Share of 1,200 GW of wind energy in 2020 (%)	Total electricity demand in 2020 (TWh)
OECD - Europe	230,000	18.3%	4,514
OECD - North America	310,000	24.6%	5,729
USA (250,000)		(19.8%)	
Canada (60,000)		(4.8 %)	
OECD Pacific	90,000	7.1%	1,745
Latin America	100,000	7.9%	2,041
East ASIA	80,000	6.3%	2,081
South ASIA	60,000	4.8%	1,695
China	190,000	15.1%	3,691
Middle East	25,000	2.0%	907
Transition Economies	150,000	11.9%	2,615
Africa	25,000	2.0%	864
World	**1,260,000**	**100%**	**25,882**



5. 12% WIND ENERGY BY 2020 — INVESTMENT, COSTS AND EMPLOYMENT

Investment Value

This feasibility study shows investment on a yearly basis, starting with about $5 billion in 2001 and increasing to a peak of $67 billion in 2020. The total investment (at 2002 prices) required to reach a level of 1,260 GW of wind power worldwide in 2020 is estimated at $628.6 billion. This is a very large figure, although it should be borne in mind that it is cumulative over the whole 20-year period. It must also be placed in a global energy context, where the annual investment in the power sector was some $170-200 billion each year during the 1990s.

These figures for wind power investments appear high but they account for only a fraction of total global power sector investments. By 2020 it might represent a more substantial fraction, 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 12% penetration by the year 2020. Investment costs are based on the progress assumptions used in the Appendices, with the average price level in 2001 taken as $765 per kW of installed wind energy. The progress ratio starts at 0.85 and is later reduced to 0.90 in 2011. By 2020 the investment cost falls to $447/kW, a substantial reduction of 41% 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, and it is desirable to get at least some local manufacturing in place before major investments are made.

In order to make this analysis, 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 reduced dramatically as manufacturing and other costs have fallen. Between 1981 and 1995, for example, according to an evaluation of wind turbines installed in Denmark published by the RISØ National Research Laboratory, the cost per unit fell from 16.9 UScents/kWh to 6.15 UScents/kWh, a decrease of two thirds. The reasons included improved design of turbines and better siting.

Since these calculation were done, 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 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 2001 under optimum conditions:

- Investment cost: $765 per installed kW
- Unit price for electricity: 3.61 UScents/kWh

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

Table 5.1 Investment, installation and employment of 12% of the world's electricity by 2020

Year	Annual Installation (MW/year)	Cost (US$/kW)	Investment (US$ billion/year)	Cumulative Investment (US$ billion)	Employment (Job-year)
2001	6,800	765	5,202	5,202	114,453
2002	8,500	740	6,291	11,493	138,403
2003	10,625	714	7,588	19,081	166,926
2004	13,281	691	9,184	28,265	202,040
2005	16,602	668	11,086	39,350	243,886
2006	20,752	643	13,349	52,699	293,667
2007	25,940	620	16,082	68,781	353,809
2008	31,128	597	18,585	87,366	408,860
2009	37,354	576	21,515	108,880	473,324
2010	44,824	555	24,882	133,763	547,413
2011	53,789	542	29,135	162,897	640,962
2012	64,547	529	34,150	197,047	751,294
2013	74,229	517	38,372	235,419	844,186
2014	85,363	505	43,128	278,547	948,813
2015	98,168	494	48,484	327,031	1,066,645
2016	107,985	483	52,193	379,224	1,148,243
2017	118,783	473	56,237	435,461	1,237,212
2018	130,661	464	60,641	496,101	1,334,097
2019	143,727	455	65,432	561,533	1,439,502
2020	**150,000**	**447**	**67,082**	**628,616**	**1,475,808**
2021	150,000	440	66,021	694,637	1,452,464
2022	150,000	434	65,075	759,712	1,431,649
2023	150,000	428	64,223	823,934	1,412,896

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

Period	Average investment (US$/kW)			
2001 to 2006	688			Average: 506
2007 to 2011	571		Average: 493	
2012 to 2017	496	Average: 478		
2018 to 2020	455			

Source: BTM Consult

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

Region	Take-off year for large scale development	Total installation by 2020 (MW)	Average installation cost USD/KW	cumulative investment by 2020 (USD billion)
OECD Europe	on track	230,000	506	116.4
OECD N. America	on track	310,000	506	156.9
OECD Pacific	2002	90,000	506	45.5
Latin America	2004	100,000	506	50.6
East Asia	2006	80,000	493	39.4
South Asia	2002	60,000	506	30.4
China	2004	190,000	506	96.1
Middle East	2006	25,000	493	12.3
Transition Economies	2006	150,000	493	74.0
Africa	2003	25,000	506	12.7
World		**1,260,000**		**634.3**

Note: Figures for cumulative investment are rounded.

1. The average size of turbine on the commercial market will grow from 1,000 kW (1 MW) today to 1.2 MW by 2005, 1.4 MW by 2009 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 25% to 28% after 2010.

This feasibility study therefore indicates a cost reduction in wind electricity from today’s 3.61 UScents/kWh to a level of 2.62 UScents/kWh by 2010 (assuming a cost per installed kilowatt of $555). This is the same as current cost levels for combined cycle gas generation. By 2020, the figure will have fallen to 2.11 US cents per unit of electricity produced ($447 per kW). The year by year cost reductions can be seen in the Appendix.

Comparison with other generation technologies

How do the costs of wind energy compare with other generating technologies already in widespread use? The most recent data in Figure 5.1 is from the annual survey of cost comparisons by Wind Power Monthly, published in January 2002. At current electricity prices, the cheapest wind plant – those with easy access and economies of scale –are now fully competitive with gas, if sites have an average good wind speeds of 7.5m/s. The price of electricity from new thermal plant is based on US and European data, and has changed little since 2001,with gas on an upward price trend. The costs of nuclear do not 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. This tends to make wind energy more expensive in the initial phase of the life cycle. On the other hand there is no fuel cost during the lifetime of a wind power generating plant.

Wind energy 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. Also the direct cost comparison is not the whole picture, as it does not deal with externalities, as outlined in the next chapter.

Employment Potential

The employment effect of the 12% wind energy scenario is a crucial factor to weigh alongside its other costs and benefits. High unemployment rates continue to be a major drain on the economies of nearly every country in the world. Any technology which demands a substantial level of both skilled and unskilled labour is therefore of considerable economic importance, and likely to feature strongly in any political decision-making over different energy options.

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 – a shortage of labour – then it is equally important to know how much employment different activities require. There are good reasons, therefore, for knowing the employment figures involved in a long term technological development such as this.

Several assessments of the employment effects of wind power have been carried out in Germany, Denmark and the Netherlands. The most comprehensive study to date has been by the Danish Wind Turbine Manufacturers Association (DWTMA) in 1996.

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

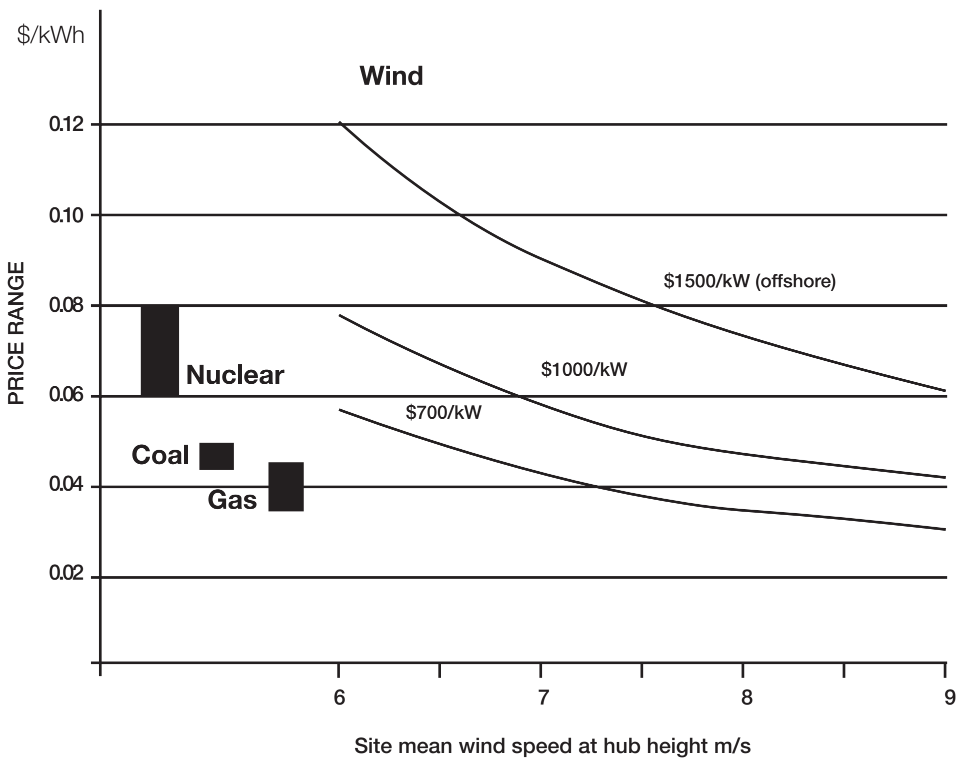
One good reason for using the Danish figures is that the country's wind turbine industry has been the most successful on the supply side, with a world market share consistently close to 50%. It is reasonable to assume, however, that the methodology will be valid for the other main turbine manufacturing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

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

In order to allow for greater efficiency in design, manufacture and installation – resulting in a reduction in employment – it has been chosen to let the labour consumption follow the total value of wind energy 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 Appendix.

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.

Figure 5-1: Prices for different generating technologies.



It is also important to emphasize 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, with 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 energy 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 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 114,000 job years and the estimated 70,000 jobs in the global industry today. The 70,000 figure is an estimate based on specific individual national data of direct and indirect employment – i.e. for primary industry and major sub-suppliers. However this estimate cannot capture every single job or part-job created by wind power.

The 114,000 job years is based on a statistical model comparing jobs, Dollars and MW which would cover all wind-related employment.

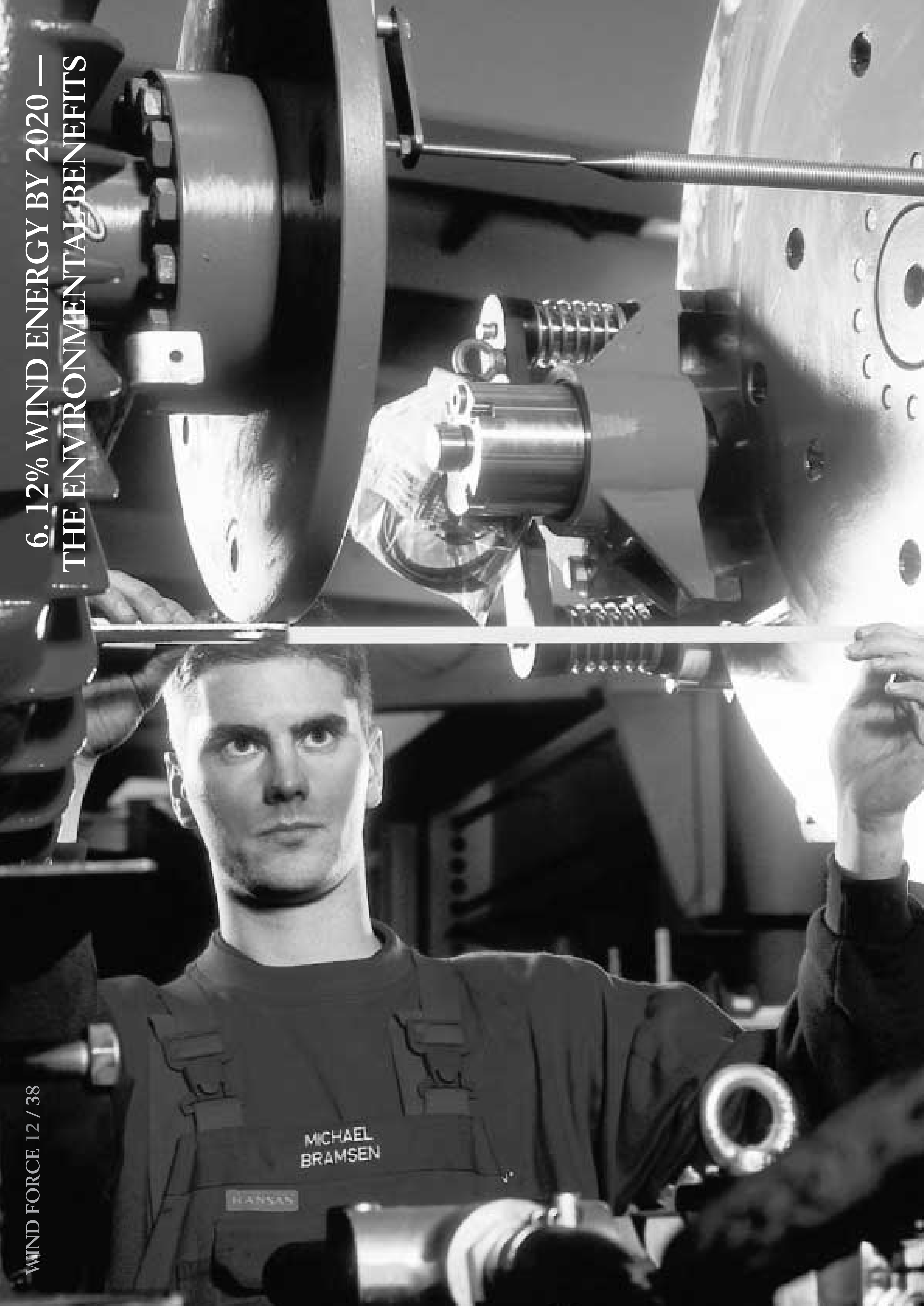
Table 5-6 a : Distribution of annual installed capacity by region at five year intervals

Year Region	2005 MW/year	2010 MW/year	2015 MW/year	2020 MW/year
OECD Europe	8,600	10,000	14,000	15,000
OECD N. America	4,000	12,000	25,000	30,000
OECD Pacific	600	3,000	8,000	10,000
Latin America	500	4,500	8,000	16,000
East Asia	200	2,000	6,000	10,000
South Asia	800	3,000	6,000	15,000
China	800	5,500	13,000	25,000
Middle East	300	800	2,000	4,500
Transition Economies	500	3,500	14,000	21,000
Africa	300	500	2,000	3,500
Total MW per Year:	**16,600**	**44,800**	**98,000**	**150,000**
Annual installation According to Table 4-1)	**16,602**	**44,824**	**98,168**	**150,000**
Job-year/MW	**14.7**	**12.2**	**10.9**	**9.8**

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

Year Region:	Job-years x 1000 2005	2010	2015	2020
OECD Europe	126.4	122.0	152.6	147.0
OECD N. America	58.8	146.4	272.5	294.0
OECD Pacific	8.8	36.6	87.2	98.0
Latin America	7.4	54.9	87.2	156.8
East Asia	2.9	24.4	65.4	98.0
South Asia	11.8	36.6	65.4	147.0
China	11.8	67.1	141.7	245.0
Middle East	4.4	9.8	21.8	44.1
Transition Economies	7.4	42.7	152.6	205.8
Africa	4.4	6.1	21.8	34.3
Total Employment Job-year:	**244.1**	**546.6**	**1,068.2**	**1,470.0**
Annual installation MW/year	**16,602 MW**	**44,824 MW**	**98,168 MW**	**150,000 MW**
Job-year/MW	**14.7**	**12.2**	**10.9**	**9.8**

6. 12% WIND ENERGY BY 2020 — THE ENVIRONMENTAL BENEFITS



Global Carbon Dioxide Reductions

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

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

The benefit to be obtained from carbon dioxide reductions is dependent on which other generation method wind power is substituting for. Calculations by the World Energy Council show a range of carbon dioxide emission levels for different fossil fuels (Table 6-1) On the assumption that coal and gas will still account for the majority of electricity generation in 20 years' time – with a continued trend for gas to take over from coal – it make sense to use a figure of 600 tonnes per GWh as an average value for the carbon dioxide reduction to be obtained from wind generation.

This assumption is further justified by the fact that 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 32.7 million tonnes CO_2 in 2001 to 1,856 million tonnes CO_2 in 2020
- By 2010, a cumulative reduction of 1,345 million tonnes CO_2.
- By 2020, a cumulative reduction of 11,768 million tonnes CO_2.
- By 2040, wind power will contribute an annual reduction of 4,800 million tonnes CO_2 resulting in a cumulative reduction of 86,469 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 2011 and 2035 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 Appendix shows the carbon dioxide reductions from the feasibility study calculated year by year up to 2020.

Value of Carbon Dioxide Reductions

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

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

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

External Costs

Direct cost comparisons of wind power and fossil fuels or nuclear power are misleading as they do not account either for the external costs, or from intrinsic benefits from 'embedded' generation.

Table 6-1: CO2 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

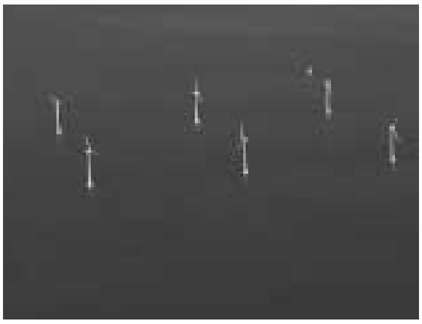
Source: WEC statistics cited in "Wind Energy - The Facts", Volume 4, 1998, EWEA/European Commission

The “external costs” to society and the environment derived from burning fossil fuels or from nuclear generation are not included in electricity prices. These costs have both a local and a global component, the former mainly related to the eventual consequences of climate change. There is a lot of uncertainty, however, about the magnitude of such costs in dollar 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 July 2001, outlined the external costs as

nuclear	0.2 - 0.6 cents kWh
gas	1 - 4 cents kWh
coal	2 – 15 cents kWh
wind power	0.05- 0.25 centskWh

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.



7. 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 polluting 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 energy.

In several countries, policies which support renewable energy are achieving dramatic results, as outlined in the earlier chapters of this report. Germany, for example has created over 35,000 jobs from wind power. Denmark has created a $2.5 billion dollar export industry.

The following is an overview of the political challenges facing the industry and the policies which must be adopted to support wind power.

NATIONAL POLICIES

1.ESTABLISH LEGALLY BINDING TARGETS FOR RENEWABLE ENERGY

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

The most ambitious target has been set by the European Union. In 2001 the European Council and the European Parliament adopted a Renewable Energy Directive establishing national targets for each member country, although these targets are not legally binding. 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 new EU Directive as a percentage of gross national electricity consumption:

With most of the large hydro potential in Europe already exploited in Europe, the majority of the increase in renewable energy in Europe will mainly 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 market measures for establishing new wind power markets is where the market for generated power is clearly defined and enshrined in national laws, stable, long term, provides low investor risk and sufficient returns on investments.

Table 7.1 European Union indicative targets for electricity produced from Renewable Energy Sources (RES-E 2010)

Country	RES-E in 1997	RES-E 2010	Country	RES-E in 1997	RES-E 2010
Belgium	1.1%	6.0%	Luxembourg	2.1%	5.7%
Denmark	8.7%	29.0%	Netherlands	3.5%	9.0%
Germany	4.5%	12.5%	Austria	70.0%	78.1%
Greece	8.6%	20.1%	Portugal	38.5%	39.0%
Spain	19.9%	29.4%	Finland	24.7%	31.5%
France	15.0%	21.0%	Sweden	49.1%	60.0%
Ireland	3.6%	13.2%	United Kingdom	1.7%	10.0%
Italy	16.0%	25.0%	**Community**	**13.9%**	**22.1%**

Today it is estimated that the direct and indirect employment in the industry world wide is around 70,000 people. 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 of wind energy.

1.2.1 FIXED TARIFF SYSTEMS

Tariff systems based on a fixed price paid per kWh produced have been enormously successful at catalysing wind energy markets and are enshrined in law in Germany, Spain and Denmark. 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 for including a significant amount of renewable energy in the electricity system.

As production costs decline, for instance as a result of improved technology and economies of scale, lower wind speed sites become profitable, expanding wind power further. 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 for renewable energy is that they facilitate planning of new renewable energy plant for the investors in renewable energy. 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. Germany has avoided the problem in the 1999 revision of the Stromeinspeisungsgesetz Electricity Feed in Law by guaranteeing payments for 14-20 years.

1.2.2 RENEWABLE PORTFOLIO STANDARDS (RPS)

Under an RPS, such as the one 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 will 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 seller’s supply determines the price.

An RPS can be technology neutral or broken down further into fractions to come from specific technologies 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 renewables are introduced in the electricity supply 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

Governments define a fixed amount of funds and tenders for projects which can be technology neutral or specific. It accepts projects tendered up to the level of the available funds Under auction, or tendering, systems, power purchase agreements are entered into for an agreed period – typically 15 years. In this system there is a politically decided quantity, usually a constantly increasing quota of electricity from renewable energy sources which the power companies or the customers must purchase. This is achieved by letting the suppliers of electricity from renewable energy sources (the wind turbine owners) compete for the power purchase agreements.

The system, to a large degree, removes much of the political risk for investors if the price is agreed upon for a defined period such as 15 years, and the power purchasing 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 a limited set of 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 the support is given on the basis of the rated power (in kW) of the generator. These 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 investment subsidies resulted in poor siting of wind turbines, and manufacturers followed customer demands of using 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, due to the short-term nature of governments, 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 REMOVE ELECTRICITY SECTOR BARRIERS TO RENEWABLES

Current energy legislation on planning, certification and grid access has been built around the existence of large centralised power plants, including extensive licensing requirements and specifications for access to the grid. This favours existing large scale electricity production and represents significant market barriers to renewables. Furthermore it does not recognise the value of not having to transport decentralised power generation over large distances. Legislation needs to reflect the following recent changes:

IN TECHNOLOGY: renewables and gas generation have emerged as the fastest growing electricity generation technologies.

IN FUELS: coal and nuclear power are becoming increasingly less competitive.

IN SIZE: small modular renewable and gas generating plants are now producing competitively priced power.

IN LOCATION: the new modular technologies can be distributed throughout a network.

IN ENVIRONMENTAL AND SOCIAL IMPACTS: fossil fuel and nuclear power sources are now widely acknowledged to cause local and regional environmental and social impacts; fossil fuels also have global impacts on the climate.

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 REMOVE 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, in Germany 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.

Halting all direct and indirect subsidies to fossil fuels and nuclear power will create a more level playing field across the energy sector. For example the 1998 OECD study Improving the Environment through Reducing Subsidies noted that, "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 social and environmental costs of polluting energy.
The real cost of energy production by conventional energy includes expenses absorbed by society , such as health impacts, local and regional environmental degradation – from mercury pollution to acid rain causing environmental, infrastructural and human health damage – as well as global impacts from climate change. For example, more than 30,000 Americans die prematurely every year due to emissions from electric power plants. It also includes the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear operators ; for example the Price-Anderson Act, which limits the liability of US nuclear power plants in the case of an accident amounts 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 KYOTO PROTOCOL RATIFICATION
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 ofcarbon-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 particularly true in developing countries, which rely heavily on export credit agencies (ECAs) and multi-lateral development banks to provide financing for energy and other industrial projects. To be consistent with the emerging international regime for limiting greenhouse gas emissions, ECAs and other international financial institutions which support or underwrite projects around the world must have policies consistent with the need for limiting greenhouse gas emissions and climate change protection. At the same time there needs to be a transition plan and flexible time frames to avoid undue hardships on developing country economies overly reliant upon conventional energy sources and exports; and recognising that meeting the development goals for the world's poorest will require subsidies for the foreseeable future.

The G8 Task Force report which acknowledged the role of the international financial institutes and ECAs makes significant recommendations which would go some way to addressing this issue. It states: “Modern energy access and environmental considerations should be integrated into the IFI’s 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.” And further that “The G8 should extend so called “sector arrangements” for other 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.”

Such policies 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. 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 Reform
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.

Table 1 Market penetration

Growth ratio	Year	Cumulative MW	Annual MW	Annual avg. WTG (MW)	Cumulative No. of units (%)	Capacity factor	Production TWh	Progress ratio	Replacement MW	Units
	2001	24,900	6,800		56,000	25%	54.5			
	2002	33,400	8,500	1.0	64,500	25%	73.1			
	2003	44,025	10,625	1.0	75,125	25%	96.4			
	2004	57,306	13,281	1.2	86,193	25%	125.5			
25%	2005	73,908	16,602	1.2	100,027	25%	161.9			
	2006	94,660	20,752	1.2	117,321	25%	207.3	0.85		
	2007	120,600	25,940	1.3	137,274	25%	264.1			
	2008	151,728	31,128	1.3	161,219	25%	332.3			
	2009	189,081	37,354	1.4	187,900	25%	414.1			
20%	2010	233,905	44,824	1.4	219,917	25%	512.3			
	2011	287,694	53,789	1.4	258,338	28%	705.7			
	2012	352,241	64,547	1.5	301,369	28%	864.0			
	2013	426,470	74,229	1.5	350,855	28%	1,046.0			
15%	2014	511,833	85,363	1.5	407,764	28%	1,255.4			
	2015	610,001	98,168	1.5	473,209	28%	1,496.2			
	2016	717,986	107,985	1.5	545,199	28%	1,761.1			
	2017	836,769	118,783	1.5	624,388	28%	2,052.4			
10%	2018	967,430	130,661	1.5	711,495	28%	2,372.9	0.90		
	2019	1,111,157	143,727	1.5	807,313	28%	2,725.4			
	2020	1,261,157	150,000	1.5	907,313	28%	3,093.4			
	2021	1,411,157	150,000	1.5	1,007,313	28%	3,461.3			
	2022	1,561,157	150,000	1.5	1,107,313	28%	3,829.2			
	2023	1,711,157	150,000	1.5	1,207,313	28%	4,197.1			
	2024	1,847,876	150,000	1.5	1,307,159	28%	4,532.5		13,281	11,068
0%	2025	1,981,274	150,000	1.5	1,406,993	28%	4,859.7		16,602	13,835
	2026	2,110,522	150,000	1.5	1,506,816	28%	5,176.7		20,752	17,293
	2027	2,234,583	150,000	1.5	1,606,627	28%	5,481.0		25,940	19,954
	2028	2,353,455	150,000	1.5	1,706,434	28%	5,772.6		31,128	23,945
	2029	2,466,101	150,000	1.5	1,806,236	28%	6,048.9		37,354	26,681
	2030	2,571,277	150,000	1.5	1,906,032	28%	6,306.8		44,824	32,017
0%	2031	2,667,488	150,000	2.0	1,980,824	28%	6,542.8		53,789	38,421
	2032	2,752,941	150,000	2.0	2,055,609	28%	6,752.4		64,547	43,031
	2033	2,828,712	150,000	2.0	2,130,398	28%	6,938.3		74,229	49,486
	2034	2,893,349	150,000	2.0	2,205,188	28%	7,096.8	1.00	85,363	56,909
	2035	2,945,181	150,000	2.0	2,279,981	30%	7,739.9		98,168	65,445
0%	2036	2,987,197	150,000	2.0	2,354,783	30%	7,850.4		107,985	71,990
	2037	3,018,414	150,000	2.0	2,429,593	30%	7,932.4		118,783	79,189
	2038	3,037,752	150,000	2.0	2,504,409	30%	7,983.2		130,661	87,107
	2039	3,044,025	150,000	2.0	2,579,231	30%	7,999.7		143,727	95,818
	2040	3,044,025	150,000	2.0	2,654,066	30%	7,999.7		150,000	100,000
0%	2041	3,044,025	150,000	2.0	2,728,917	30%	7,999.7		150,000	100,000
	2042	3,044,025	150,000	2.0	2,803,781	30%	7,999.7		150,000	100,000
	2043	3,044,025	150,000	2.0	2,878,657	30%	7,999.7		150,000	100,000

Table 2 Contributions by Region

Region	Installed wind capacity by 2020 MW	Annual Electricity production from wind power TWh/year	Penetration of wind power by 2020 of electricity consumption %	Cumulative investment US$ billion	Annual reduction of CO_2 by 2020 Million tonnes/ year	Employment in the region by 2020 Man-year/ year (x1000)	comments corrections
OECD Europe	230,000	564.0	12.5 %	116.4	338.4	147.0	Including 70,000 MW offshore
OECD N. America	310,000	760.1	13.3%	156.9	456.1	294.0	
USA (including N. America)	(250,000)	(613.0)	(13.0%)	(126.5)	(367.8)	(235.0)	
OECD Pacific	90,000	220.7	12.6%	45.5	132.4	98.0	
Latin America	100,000	245.2	12.0%	55.6	147.1	156.8	Investment + 10%
East Asia	80,000	196.2	9.4%	43.3	153.0	117.6	Employment: +20% Investment: +10% CO_2 Reduction: +30%
South Asia	60,000	147.1	8.7%	33.4	114.7	176.4	
China	190,000	465.9	12.6%	105.7	363.4	294.0	
Middle East	25,000	61.3	6.7%	12.3	36.8	44.1	
Transition Economies	150,000	367.8	14.1%	74.0	264.8	226.4	Employment: +20% Investment : +10 %
Africa	25,000	61.3	7.1%	14.0	36.8	41.1	
World Total :	**1,260,000**	**3089.6**	**11.9%**	**657.1**	**2,043.5**	**1,595.4**	**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

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

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

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

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

Cost (DKK/kWh) = a * (X/X0)^-b

USD 1 = 1.1494
USD 1 = kr 8.30

Progress ratio	Year	Cumulative MW	Cumulative no. of units	USD cent/kWh	Electricity EURO cent/kWh	Capacity USD/kW	Capacity Euro/kW	Electricity DKK/kWh	Capacity DKK/kW
	2001	24,900	56,000	3.61	4.15	765	879	0.300	6,350
a = 0.300 X0 = 56,000 b = 0.2345 85%	2002	33,400	64,500	3.50	4.02	740	851	0.290	kr 6,143
	2003	44,025	75,125	3.37	3.88	714	821	0.280	kr 5,927
	2004	57,306	86,193	3.27	3.75	691	795	0.271	kr 5,739
	2005	73,908	100,027	3.15	3.63	668	768	0.262	kr 5,542
	2006	94,660	117,321	3.04	3.49	643	739	0.252	kr 5,339
	2007	120,600	137,274	2.93	3.37	620	713	0.243	kr 5,146
	2008	151,728	161,219	2.82	3.24	597	686	0.234	kr 4,955
	2009	189,081	187,900	2.72	3.13	576	662	0.226	kr 4,781
	2010	233,905	219,917	2.62	3.01	555	638	0.218	kr 4,607
a = 0.218 X0 = 219,917 90% b = 0.1525	2011	287,694	258,338	2.56	2.94	542	623	0.212	kr 4,496
	2012	352,241	301,369	2.50	2.87	529	608	0.207	kr 4,391
	2013	426,470	350,855	2.44	2.81	517	594	0.203	kr 4,291
	2014	511,833	407,764	2.39	2.74	505	581	0.198	kr 4,193
	2015	610,001	473,209	2.33	2.68	494	568	0.194	kr 4,099
	2016	717,986	545,199	2.28	2.62	483	556	0.190	kr 4,012
	2017	836,769	624,388	2.24	2.57	473	544	0.186	kr 3,930
	2018	967,430	711,495	2.19	2.52	464	533	0.182	kr 3,852
	2019	1,111,157	807,313	2.15	2.47	455	523	0.179	kr 3,779
	2020	1,261,157	907,313	2.11	2.43	447	514	0.175	kr 3,712
	2021	1,411,157	1,007,313	2.08	2.39	440	506	0.173	kr 3,653
	2022	1,561,157	1,107,313	2.05	2.36	434	499	0.170	kr 3,601
	2023	1,711,157	1,207,313	2.02	2.33	428	492	0.168	kr 3,554
	2024	1,847,876	1,307,159	2.00	2.30	423	486	0.166	kr 3,511
	2025	1,981,274	1,406,993	1.98	2.27	418	481	0.164	kr 3,472
a = 0.164 X0 = 1,406,993 100% b = 0.001	2026	2,110,522	1,506,816	1.98	2.27	418	481	0.164	kr 3,472
	2027	2,234,583	1,606,627	1.98	2.27	418	481	0.164	kr 3,471
	2028	2,353,455	1,706,434	1.98	2.27	418	481	0.164	kr 3,471
	2029	2,466,101	1,806,236	1.98	2.27	418	481	0.164	kr 3,471
	2030	2,571,277	1,906,032	1.98	2.27	418	481	0.164	kr 3,471
	2031	2,667,488	1,980,824	1.98	2.27	418	481	0.164	kr 3,471
	2032	2,752,941	2,055,609	1.98	2.27	418	481	0.164	kr 3,471
	2033	2,828,712	2,130,398	1.98	2.27	418	481	0.164	kr 3,471
	2034	2,893,349	2,205,188	1.98	2.27	418	481	0.164	kr 3,471
	2035	2,945,181	2,279,981	1.98	2.27	418	481	0.164	kr 3,471
	2036	2,987,197	2,354,783	1.98	2.27	418	481	0.164	kr 3,471
	2037	3,018,414	2,429,593	1.98	2.27	418	481	0.164	kr 3,471
	2038	3,037,752	2,504,409	1.98	2.27	418	481	0.164	kr 3,471
	2039	3,044,025	2,579,231	1.98	2.27	418	481	0.164	kr 3,471
	2040	3,044,025	2,654,066	1.98	2.27	418	481	0.164	kr 3,470
	2041	3,044,025	2,728,917	1.98	2.27	418	481	0.164	kr 3,470
	2042	3,044,025	2,803,781	1.98	2.27	418	481	0.164	kr 3,470
	2043	3,044,025	2,878,657	1.98	2.27	418	481	0.164	kr 3,470

Table 4 CO_2 REDUCTION

Average CO_2 reduction: 0.60 kg/kWh

Year	Cumulative MW	Production TWh	CO2 Reduction annual mill. ton	CO2 Reduction Cum. mill. ton
2001	24,900	54.5	32.7	32.7
2002	33,400	73.1	43.9	76.6
2003	44,025	96.4	57.8	134.5
2004	57,306	125.5	75.3	209.8
2005	73,908	161.9	97.1	306.9
2006	94,660	207.3	124.4	431.3
2007	120,600	264.1	158.5	589.7
2008	151,728	332	199	789
2009	189,081	414	248	1,038
2010	233,905	512	307	1,345
2011	287,694	706	423	1,768
2012	352,241	864	518	2,287
2013	426,470	1,046	628	2,914
2014	511,833	1,255	753	3,668
2015	610,001	1,496	898	4,565
2016	717,986	1,761	1,057	5,622
2017	836,769	2,052	1,231	6,853
2018	967,430	2,373	1,424	8,277
2019	1,111,157	2,725	1,635	9,912
2020	1,261,157	3,093	1,856	11,768
2021	1,411,157	3,461	2,077	13,845
2022	1,561,157	3,829	2,298	16,143
2023	1,711,157	4,197	2,518	18,661
2024	1,847,876	4,532	2,719	21,380
2025	1,981,274	4,860	2,916	24,296
2026	2,110,522	5,177	3,106	27,402
2027	2,234,583	5,481	3,289	30,691
2028	2,353,455	5,773	3,464	34,154
2029	2,466,101	6,049	3,629	37,784
2030	2,571,277	6,307	3,784	41,568
2031	2,667,488	6,543	3,926	45,494
2032	2,752,941	6,752	4,051	49,545
2033	2,828,712	6,938	4,163	53,708
2034	2,893,349	7,097	4,258	57,966
2035	2,945,181	7,740	4,644	62,610
2036	2,987,197	7,850	4,710	67,320
2037	3,018,414	7,932	4,759	72,080
2038	3,037,752	7,983	4,790	76,870
2039	3,044,025	8,000	4,800	81,669
2040	3,044,025	8,000	4,800	86,469
2041	3,044,025	8,000	4,800	91,269
2042	3,044,025	8,000	4,800	96,069
2043	3,044,025	8,000	4,800	100,869

Table 5 Hydro Power and Nuclear Power — Historical Penetration

Year	Hydro Growth ratio	Hydro Cumulative MW	Hydro Annual MW	Nuclear Growth ratio	Nuclear Cumulative MW	Nuclear Annual MW
1950		44,956				
1951						
1952						
1953						
1954						
1955		67,857				
1956						
1957						
1958						
1959						
1960		157,080			1,000	1,000
1961					1,000	0
1962					2,000	1,000
1963					2,000	0
1964					3,000	1,000
1965		214,023			5,000	2,000
1966		223,997	9,974		6,000	1,000
1967		236,088	12,091		8,000	2,000
1968		251,249	15,161		9,000	1,000
1969		266,900	15,651		13,000	4,000
1970		290,607	23,707		16,000	3,000
1971		295,564	4,957		24,000	8,000
1972		305,339	9,775		32,000	8,000
1973		335,561	30,222		45,000	13,000
1974		339,271	3,710		61,000	16,000
1975		371,495	32,224		71,000	10,000
1976		383,667	12,172		85,000	14,000
1977		396,426	12,759		99,000	14,000
1978		423,601	27,175		114,000	15,000
1979		443,836	20,235		121,000	7,000
1980		466,938	23,102		135,000	14,000
1981		483,938	17,000		155,000	20,000
1982		505,041	21,103		170,000	15,000
1983		517,899	12,858		189,000	19,000
1984		540,244	22,345		219,000	30,000
1985		560,956	20,712		250,000	31,000
1986		575,665	14,709		276,000	26,000
1987		596,262	20,597		297,000	21,000
1988		618,186	21,924		310,000	13,000
1989		631,374	13,188		320,000	10,000
1990		641,731	10,357		328,000	8,000
1991		656,094	14,363		325,000	-3,000
1992		670,829	14,735		327,000	2,000
1993		685,907	15,078		336,000	9,000
1994		697,839	11,932		338,000	2,000
1995		708,931	11,092		340,000	2,000
1996		714,602	5,671		343,000	3,000
1997					343,000	0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