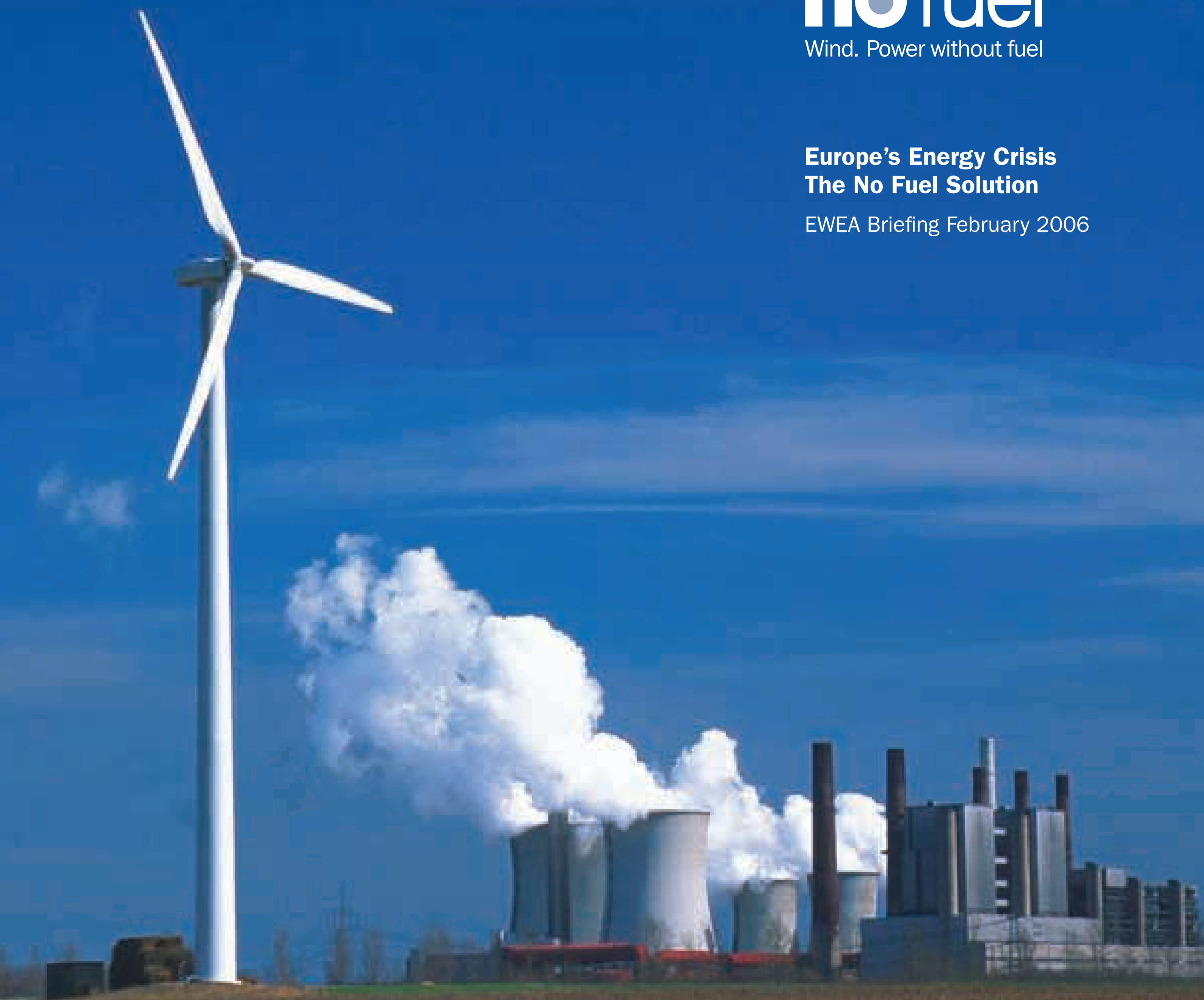
EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

no fuel

Wind. Power without fuel

Europe's Energy Crisis
The No Fuel Solution

EWEA Briefing February 2006



Overview

1. Europe is facing an energy crisis. We now live in an era of energy uncertainty. The days of cheap and abundantly available energy are over.
2. Europe is running out of indigenous energy resources at a time of increased prices, diminishing resources and their concentration into fewer, more geopolitically sensitive regions, and greater international competition for energy resources.
3. At the same time demand for power is increasing, and many power plants will be retired, so combined the total demand for new electricity generation capacity across Europe is predicted to increase by 760 GW by 2030.
4. Limiting the effects of climate change requires a reduction in carbon emissions from the power sector.
5. Europe is an energy intensive region heavily reliant on imports; already today, it imports 50% of its energy needs, projected to increase to 70% within two decades. By 2030, oil imports would rise from 76% to 88% and gas imports from 50% to 81%, compared to 2000. Indigenous fossil fuel resources, such as the North Sea oil and gas reserves, are in rapid decline.
6. Europe's dependency on imported fossil fuels has become a threat to economic stability because of the impact of increased fuel prices on the cost base.
7. Europe is the world leader in renewable energy and in the most promising and mature renewable energy technology, wind power.
8. Europe is wealthy in wind energy resources – there is enough resources to power the entire continent.
9. Wind energy has made rapid progress in recent years - in technology, in costs and in market deployment. Yet its exploitation remains low in Europe.
10. Wind energy ensures that the economic future of Europe can be planned on the basis of known and predictable cost of electricity derived from an indigenous energy source free of all the security, political, economic and environmental disadvantages associated with oil, coal, gas and nuclear.
11. A prevailing myth is that wind cannot be mainstream because it is intermittent. The capacity of European power systems to absorb significant amounts of wind power is determined more by economics and regulatory rules than by technical or practical constraints.
12. A large contribution from wind energy to European power generation is feasible in the same order of magnitude as coal, gas or nuclear.
13. Wind energy is ready to serve as one of the leading solutions for European energy needs – for security of supply, for energy independence as well as meeting climate goals and rising demand for energy.

no fuel
Wind. Power without fuel

no geo-political risk
no external energy dependence
no energy imports
no fuel costs
no fuel price risk
no exploration
no extraction
no refining
no pipelines
no resource constraints
no CO_2 emissions
no radioactive waste

no fuel
Wind. Power without fuel

No fuel. Wind power has unique characteristics: it has zero fuel price risk, zero fuel costs and extremely low operation and maintenance costs.

In addition, wind power provides total protection and zero risk from carbon costs, and zero geo-political risk associated with supply and infrastructure constraints or political dependence on other countries. Wind power has no resource constraints; the fuel is free and endless.

Unlike conventional fuels, wind energy is a massive indigenous power source permanently available.

Wind power stations can be constructed and deliver power far quicker than conventional sources.

Clean, free, indigenous, inexhaustible

Electricity production from wind turbines avoids the risks of using conventional fuels, for the self-evident reason that there is no fuel. Wind is clean, free, indigenous, and inexhaustible.

Clean...

...does not just mean zero carbon emissions. It also means no environmental risk or degradation from the exploration, extraction, transport, shipment, processing or disposal of fuel.

Free...

...means no fuel costs. It also means no uncertainty over the future cost of electricity, because most of the costs of wind power are fixed and known, in contrast to the highly variable and unpredictable cost of fossil fuels. Wind energy eliminates the economic impacts and risks associated with volatile and uncertain fuel prices.

Indigenous...

...means no import dependence, which means no political risk to European electricity supplies, no need to compete with the rest of the world for distant fuel supplies, no geo-political dimension to our electricity consumption. Wind energy can reduce international energy policy conflicts, as there is no need to compete over a supply that exists everywhere.

Inexhaustible...

...removes massive uncertainty about depleting fuel resources, and reduces the need for speculative long-term R&D investments in possible alternative energy sources. Right now - today - there is enough wind blowing across Europe to power all of Europe's electricity needs. And there always will be.

The key point to be emphasised about developing onshore and offshore wind power in Europe is that it will isolate the European economy from escalating energy costs and periodic fuel shortages. Once developed, wind power will provide Europe with electricity generated from a free fuel source.

Competitively, the exploitation of its own wind reserves and resources would mean that Europe would be independent of demand patterns in China, India and the United States.

Rising energy demand

According to the European Commission's Baseline business-as-usual scenario, electricity demand will increase 52% between 2000 and 2030.

Total installed power generation capacity will increase by about 400 GW, from 656 GW in 2000 to 1,118 GW in 2030, and additionally about 365 GW of current power stations are to be retired or decommissioned.

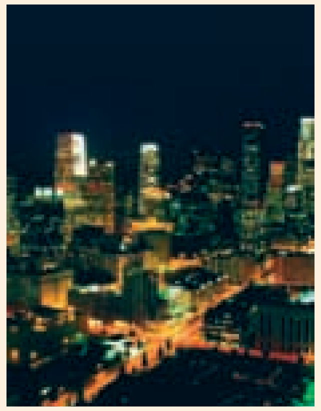
The total new build requirement in Europe to 2030 is 761 GW, more than the entire European power capacity in existence today.

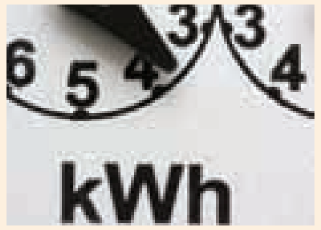
Some 80% of incremental energy consumption to 2030 is predicted to be met by gas.

A dramatic increase in power consumption will require substantial investments in generation assets.

According to the International Energy Agency (IEA) the EU will need to invest €100 billion in transmission networks and €340 billion in distribution networks for reinforcement, asset replacements and new connections over the three decades from 2001-2030.

Irrespective of whatever policy is chosen by the EU, massive investments in generation plants and grids are required. For policy-makers, the question is the priority to be assigned to different technologies.





Energy security

Europe is facing an energy crisis. We now live in an era of energy uncertainty. The days of cheap and abundantly available energy are over.

Europe is running out of indigenous energy resources at a time of increased prices, diminishing resources and their concentration into fewer, more geopolitically sensitive regions, and greater international competition for the remaining energy resources.

The price of oil and gas remained fairly static for nearly two decades and this lulled many into a false sense of security.The prices of oil and gas have more than tripled since 2001. The last three global recessions were caused by oil price rises. The IMF says that "oil prices will continue to present a serious risk to the global economy".

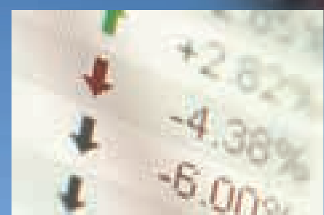
At the same time, there are concerns about the real level of known and realisable oil and gas reserves, and when peak production and the associated price increases occur.

This coincides with fears over the security of supply coming from politically unstable regions, and a reduction in countries that have resources.

Europe is an energy intensive region heavily reliant on imports; already today, it imports 50% of its energy needs, projected to increase to 70% within two decades. By 2030, oil imports would rise from 76% to 88% and gas imports from 50% to 81%, compared to 2000. Indigenous fossil fuel resources, such as in the North Sea, are in rapid decline. Global known uranium reserves amount to two and a half million tonnes, equal to 40 years' demand at present consumption rates. The European Union is home to barely 2 % of the world's natural uranium reserves.

In 2000, when fuel prices were far lower than today, the European Commission's Green Paper on Security of Supply recognised the potential of renewable energy sources:

"Renewable sources of energy have a considerable potential for increasing security of supply in Europe.. [...] In the medium term, renewables are the only source of energy in which the European Union has a certain amount of room for manoeuvre aimed at increasing supply in the current circumstances." It continued: "Effectively, the only way of influencing [European energy] supply is to make serious efforts with renewable sources."



Climate security

Climate change poses one of the greatest challenges to the world community, and energy technology will play a central role. Implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change is the driving policy framework for the EU.

The 2005 Spring Council endorsed the target of limiting the future global average temperature increase to 2ºC above pre-industrial level and indicated its willingness to explore with other countries the possibility of reducing greenhouse gas emission from industrialised countries by 15-30% by the year 2020.

CO_2 is by far the most important greenhouse gas in the EU, accounting for 82% of total greenhouse gas emissions. Of that, electricity and heat production comprises the largest source. Since 1990, CO_2 emissions in the EU15 have increased by 3.4% and from 2002-2003 increased by 1.8%, 59 million tonnes. This was mainly due to an increase in power production using coal.

Renewable energies such as wind power are today providing a central role. The European Environment Agency (EEA) assessment on greenhouse gas emission trends in Europe concluded that "the promotion of renewable energy has the greatest impact on emissions in most EU Member States for both implemented and planned policies". According to EEA analysis, "the largest emissions savings for the EU-15 are projected to be from renewable energy policies, followed by the landfill directive".

By 2010, wind energy in Europe is predicted to have saved over 500 million tonnes of CO_2. The 75 GW of wind energy installed in Europe by 2010 is expected to meet one third of the EU's 2010 Kyoto target.

Limiting carbon from fossil fuels is at the heart of climate change policies. Wind energy is a leading part of the solution.

The strong progress of wind energy

At a given site, a single modern wind turbine annually produces

180

times more electricity and at less than half the cost per kWh than its equivalent twenty years ago.

Wind technology has made major progression from the prototypes of just 25 years ago.

Wind energy has come of age, and now constitutes a mainstream power technology that is largely underexploited.

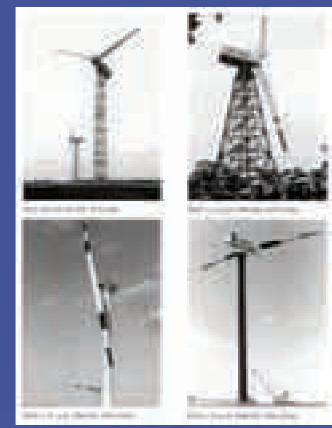
Two decades of technological progress have resulted in today's wind turbines acting much more like conventional power stations, in addition to being modular and rapid to install.

At a given site, a single modern wind turbine annually produces 180 times more electricity and at less than half the cost per kWh than its equivalent twenty years ago.

The wind power sector includes some of the world's largest energy companies.

Effective regulatory and policy frameworks have been developed and implemented in many countries, and Europe is the world leader in wind energy.

Whilst progress to date has been proven, it is the tip of the iceberg in terms of the true deployment potential of wind power.

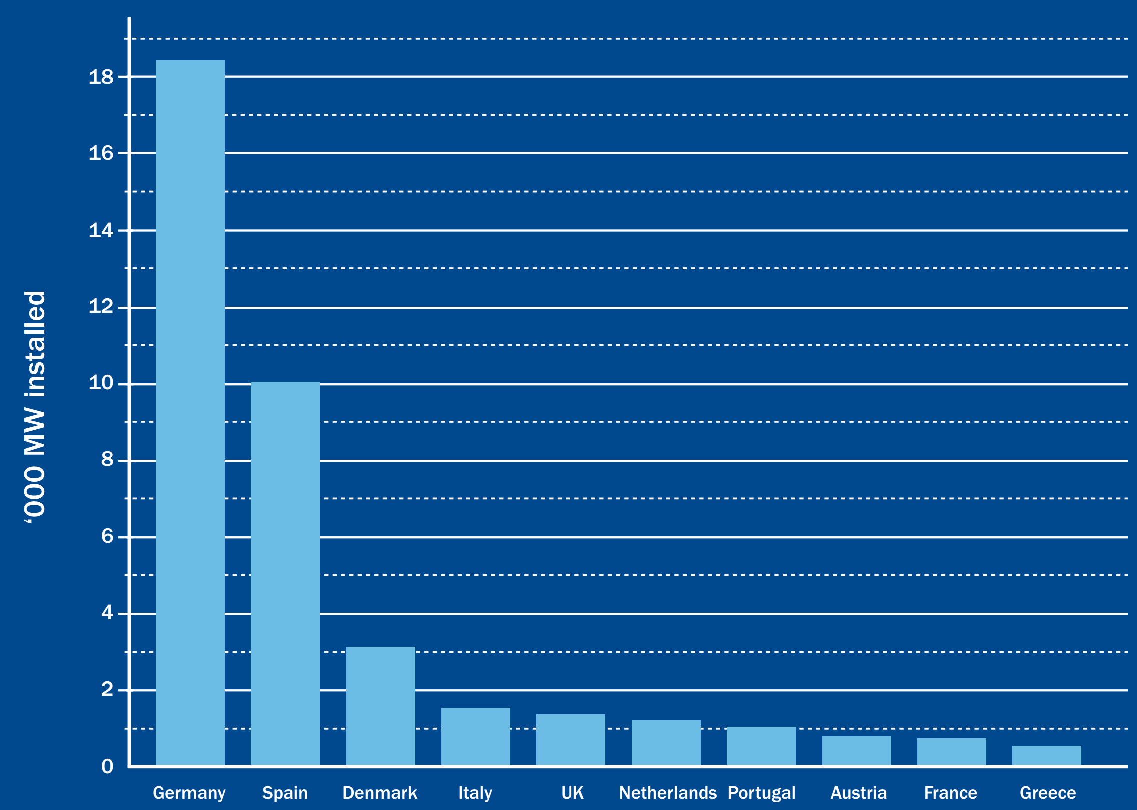


The progress of wind energy markets in Europe

Europe leads the world in developing wind energy as a pollution-free fuel for electricity generation. Over the past decade wind power has proved the most successful of all the new renewable sources.

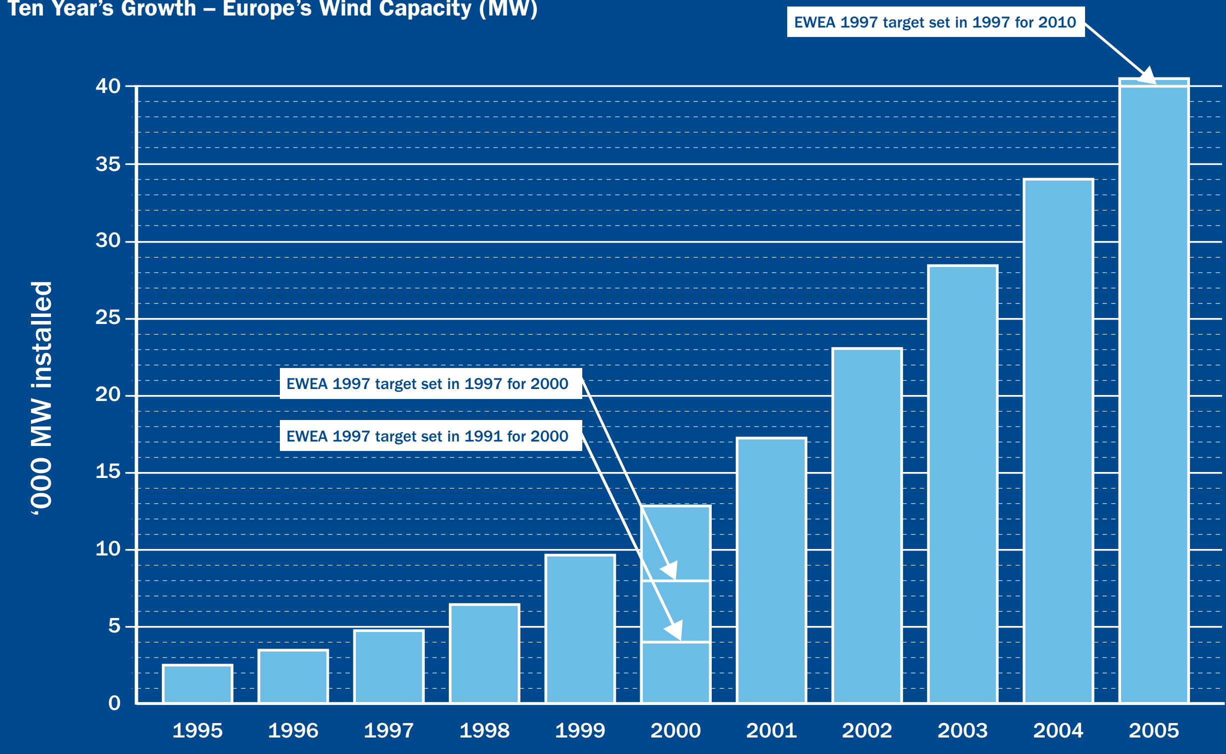
- In 1994 there was 1,683 MW of wind energy installed across the EU. By the end of 2005 the figure had increased 24 times to 40,504 MW
- The average annual growth rate in cumulative installation over the past decade (1995-2005) was 32%
- European companies are world leaders in the manufacturing of wind turbines and their components
- Seven of the top ten turbine manufacturing companies are based in Europe. In 2004 they accounted for 82% of the global market for wind turbines.

European Leaders – Top Ten Wind Power Markets (end 2005)



	Germany	Spain	Denmark	Italy	UK	Netherlands	Portugal	Austria	France	Greece
MW Installed	18,428	10,027	3,122	1,717	1,353	1,219	1,022	819	755	573

Ten Year's Growth – Europe's Wind Capacity (MW)



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
MW Installed	2,497	3,476	4,753	6,453	9,678	12,887	17,315	23,159	28,567	34,205	40,504

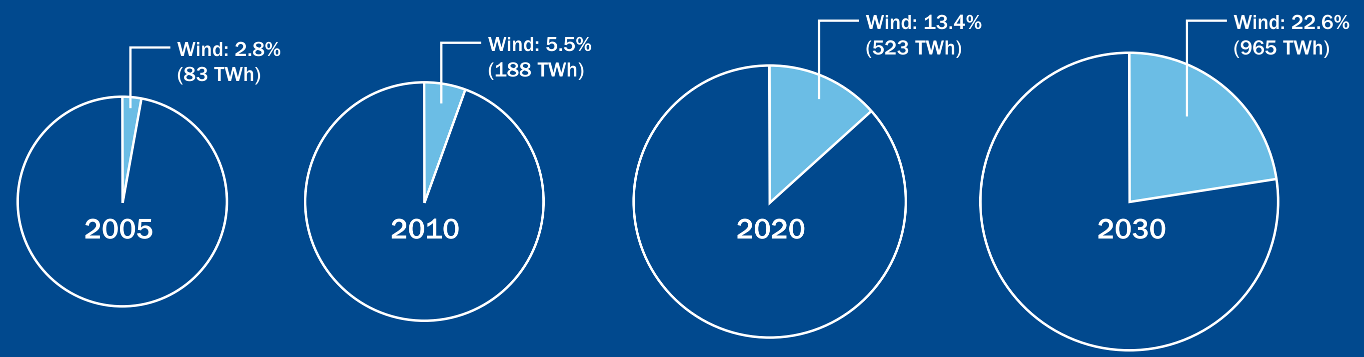
Europe has installed **40,504 MW** of wind energy by the end of 2005. Industry scenario projections show that this can reach;

75,000 MW by 2010
180,000 MW by 2020
300,000 MW by 2030

Contribution of wind energy to European electricity consumption 2005-2030

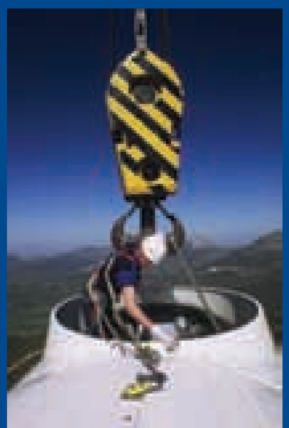
The electricity production from wind energy and its contribution to meeting European electricity consumption is:

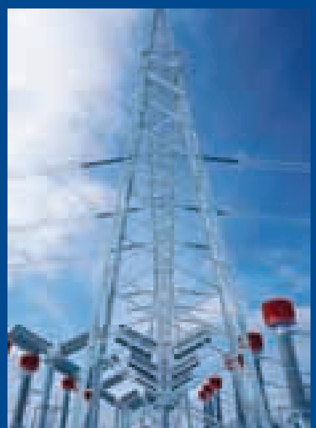
83 TWh in 2005 (2.8% of European electricity demand),
to 188 TWh in 2010 (5.5%),
to 523 TWh in 2020 (13.4%),
to 965 TWh in 2030 (22.6%).



	2005	2010	2020	2030
Wind (GW installed)	40.5	75	180	300

Between 2000 and 2030 total electricity consumption is expected to increase an expected 52% under a business-as-usual scenario.





The percentage contribution wind can make to European power supply is to a large degree influenced by the overall electricity consumption. This can be demonstrated by looking at the 965 TWh from wind power generated in 2030. **In that year this will provide 22% of future European electricity needs, and is equal to 32% of present European electricity consumption.**

The 300 GW would be half on shore and half offshore.

EWEA targets

EWEA targets

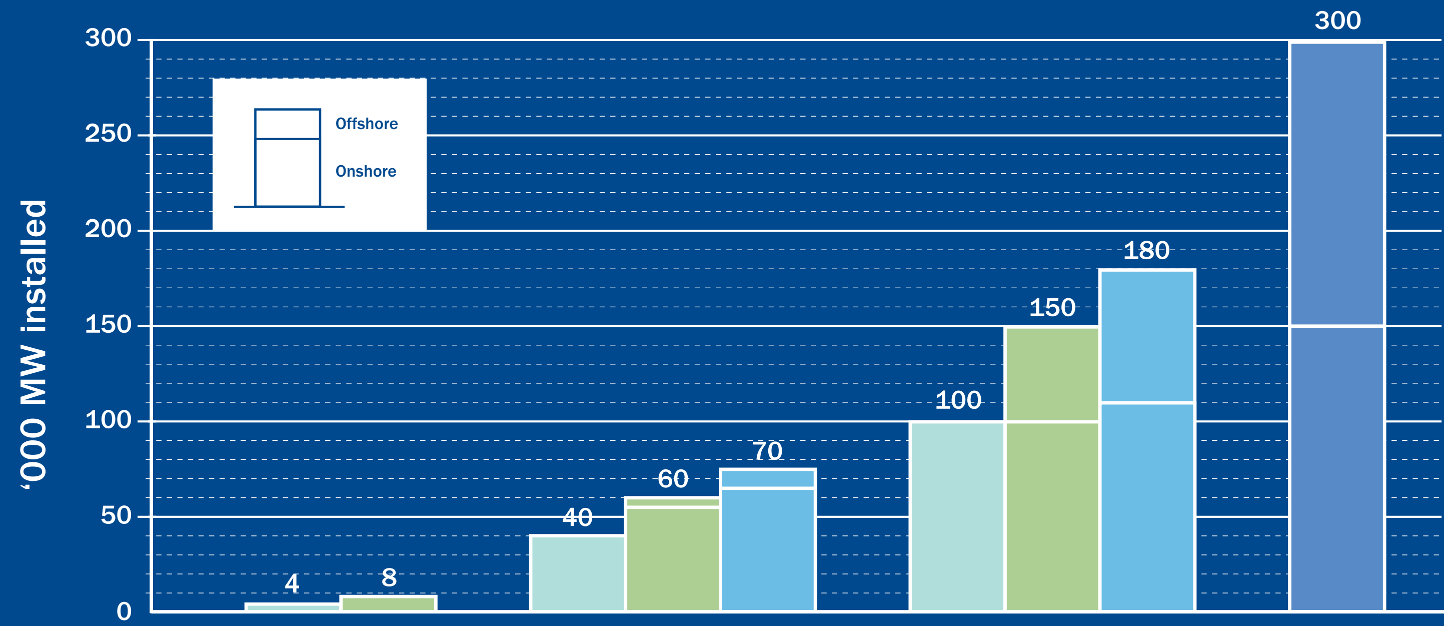
In 1991 EWEA set a target to install 4,000 MW of wind in 2000. This was revised in 1997 to 8,000 MW. In 2000 the actual wind installed in Europe was 12,887 MW three times higher than the figure set nine years previously.

In 1997 EWEA set a target of 40 GW installed in 2010 (the same target as the Commission White Paper) and 100 GW in 2020. In 2000 EWEA set a target of 60 GW in 2010 and 150 GW in 2020.

Three years later in 2000 EWEA revised its target to 60,000 MW by 2010 (including 5,000 MW offshore) and 150,000 MW by 2020 (including 50,000 MW offshore).

In 2003, EWEA further revised its target to 75,000 MW by 2010 and 180,000 MW by 2020 (including 70,000 MW offshore).

Today in 2005, EWEA has updated this target and extended the period to 2030, resulting in a total installation of 300 GW, 150,000 MW of this offshore.



	Targets for 2000		Targets for 2010			Targets for 2020			Targets for 2030
	Set in 1991	Set in 1997	Set in 1997	Set in 2000	Set in 2003	Set in 1997	Set in 2000	Set in 2003	Set in 2003
onshore	4,000	8,000	40,000	55,000	65,000	100,000	100,000	110,000	150,000
offshore	-	-	-	5,000	10,000	-	50,000	70,000	150,000

Official scenarios

For long-term energy scenarios, there are two established authorities. The European Commission has been publishing its long-term energy scenarios since the 1990s. The International Energy Agency (IEA) has published its World Energy Outlook which has a Reference Scenario and recently, Alternative Scenario. EWEA provides wind energy data for Europe.

To date, all targets and future projections for wind energy set by the European Commission, by IEA and by EWEA have been surpassed.

European targets - background

In 1997 the European Commission White Paper on Renewable Sources of Energy set the goal of doubling the share of renewable energy in the EU from 6% to 12% by 2010. One of the targets of the Commission's White Paper was to increase the EU electricity production from renewable energy sources from 337 TWh in 1995 to 675 TWh in 2010. Within this target, the goal for wind power was for 40,000 MW (40 GW) of installed capacity in 2010. This target was reached in 2005.

The EU Renewables Directive from 2001 that followed the White Paper set national indicative targets for the contribution of electricity from renewable energy sources as a percentage of gross electricity consumption. The overall Community goal is to increase renewables' share of electricity from 14% in 1997 to 21% in 2010.

EU Commission and International Energy Agency (IEA) - reference scenarios on wind energy

Reference or baseline scenarios are not presented as business-as-usual or fixed outcomes, but typically are used for comparison, and present the theoretical case where no action is taken, which is not considered a politically realistic viewpoint. The IEA Reference scenario "*takes into account all government policies and initiatives that had been adopted by mid-2004. It does not include policy initiatives that might be adopted in the future. Energy markets will probably evolve in different ways from those depicted in this scenario, because the policy landscape will change.*"

Similarly the 2003 EU Energy scenario "*takes into account existing policies and those in the process of being implemented at the end of 2001*" and does not include the Renewables Directive and "*additional policies to reduce greenhouse gas emissions*".

Baseline scenarios provide a reference comparison for a range of alternative scenarios and energy policy options. The reference scenario from IEA and the Commission on wind power are described here. In earlier reports the data was not separated from other renewables such as solar and geothermal.

The European Commission made no estimates for wind energy in 1992.

In 1996 under a 'Conventional wisdom' scenario it projected a market for wind and solar to be 4.38 GW in 2000, 6.1 GW in 2005, 8.01 GW in 2010, 10.1 GW in 2015 and 12.34 GW in 2020. **The 2020 figure was reached in 2000 by wind alone.**

The 1996 'advanced scenario' projected a market of 6.82 GW in 2000, 11.62 GW in 2005, in 2010, 17.68 GW in 2010, 23.67 GW in 2015 and 30.28 in 2020. **The 2020 figure was reached in early 2004 by wind alone.**

The 1999 Commission base scenario projections for wind, solar and geothermal was 9.4 GW in 2000, 16 GW in 2005, 23 GW in 2010, 34.4 GW in 2015 and 46.2 GW in 2020. **The 2015 figure has already been reached at the end of 2004 by wind alone.**

In 2003 the Commission Baseline scenario projections for wind and solar were 28.6 GW in 2005, 74 GW in 2010, 92.6 GW in 2015, 105.3 GW in 2020, 126.4 GW in 2025 and 149.4 GW in 2030

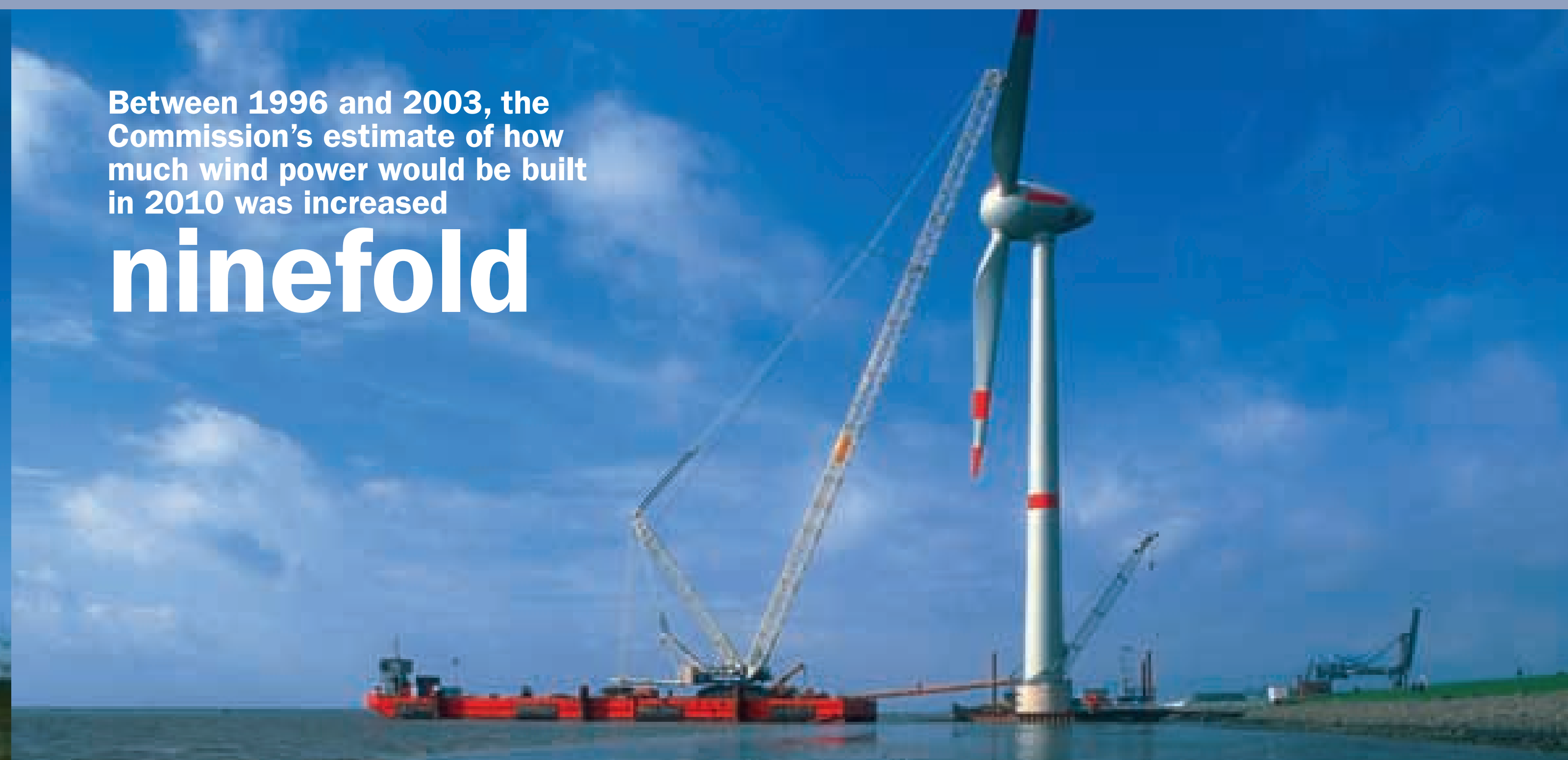
Between 1996 and 2003, the Commission's estimate of how much wind power would be built in 2010 was increased ninefold.

In 2004 the Commission Baseline scenario projections for wind and solar were 28 GW in 2005, 73.2 GW in 2010, 91.7 GW in 2015, 104.1 GW in 2020, 125.2 GW in 2025 and 149.2 GW in 2030.

The International Energy Agency (IEA) estimations in its Reference Scenario, presented in 2002 for wind energy was for 33 GW in 2010, 57 GW in 2020 and 71 GW in 2030.

In 2004, the IEA Reference Scenario projections were updated to 66GW in 2010, 131 GW in 2020 and 170 GW in 2030.

Within two years the IEA forecast for wind power installed in the EU for 2010 were doubled.



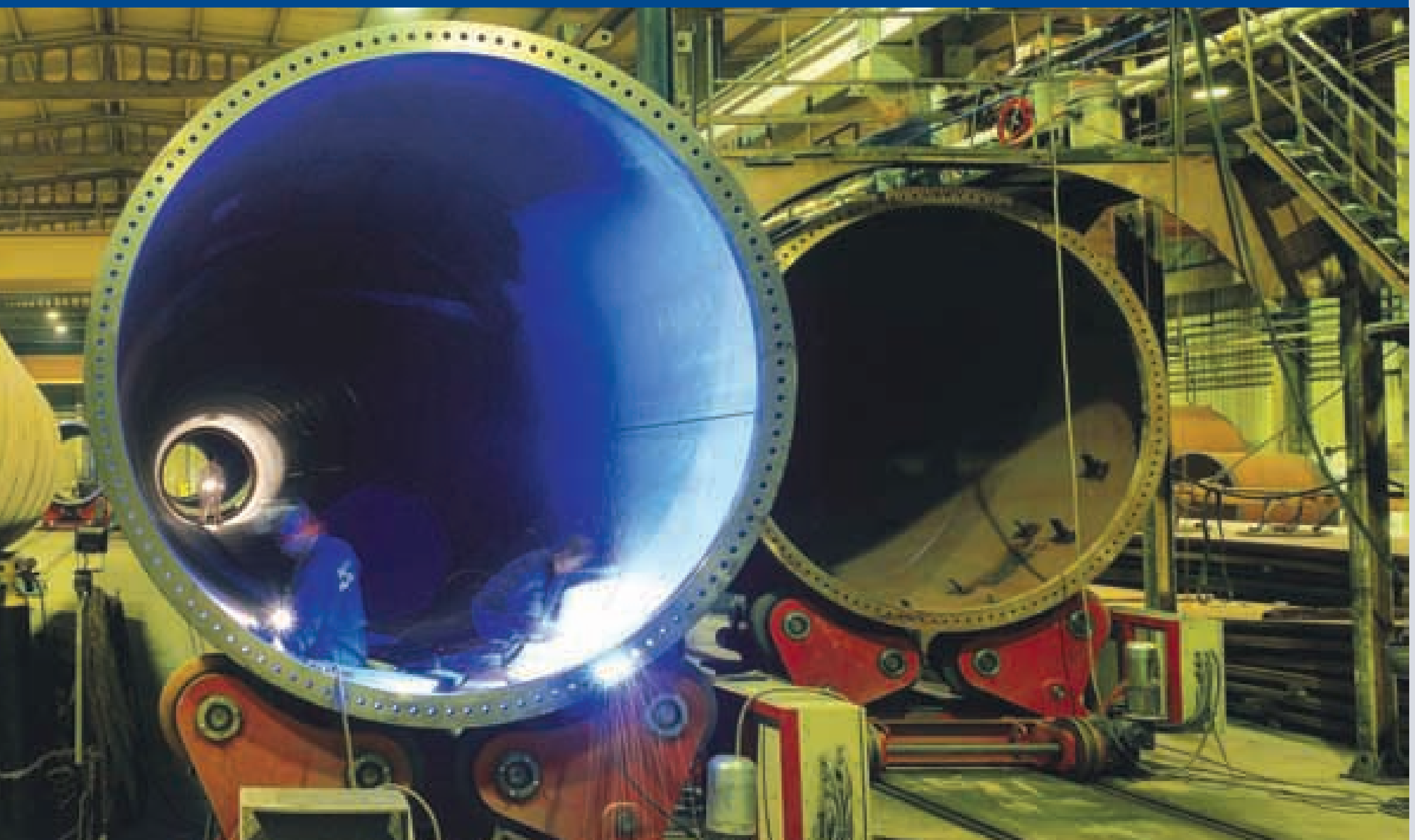
EU Commission and International Energy Agency (IEA) - advanced scenarios on wind energy

The IEA Advanced Scenario *"considers those policies and measures that countries are currently considering or might reasonably be expected to adopt taking account of technical and cost factors, the political context and market barriers. The aim is to present a consistent picture of how global energy markets might evolve if governments decide to strengthen their environmental and energy-security policies."*

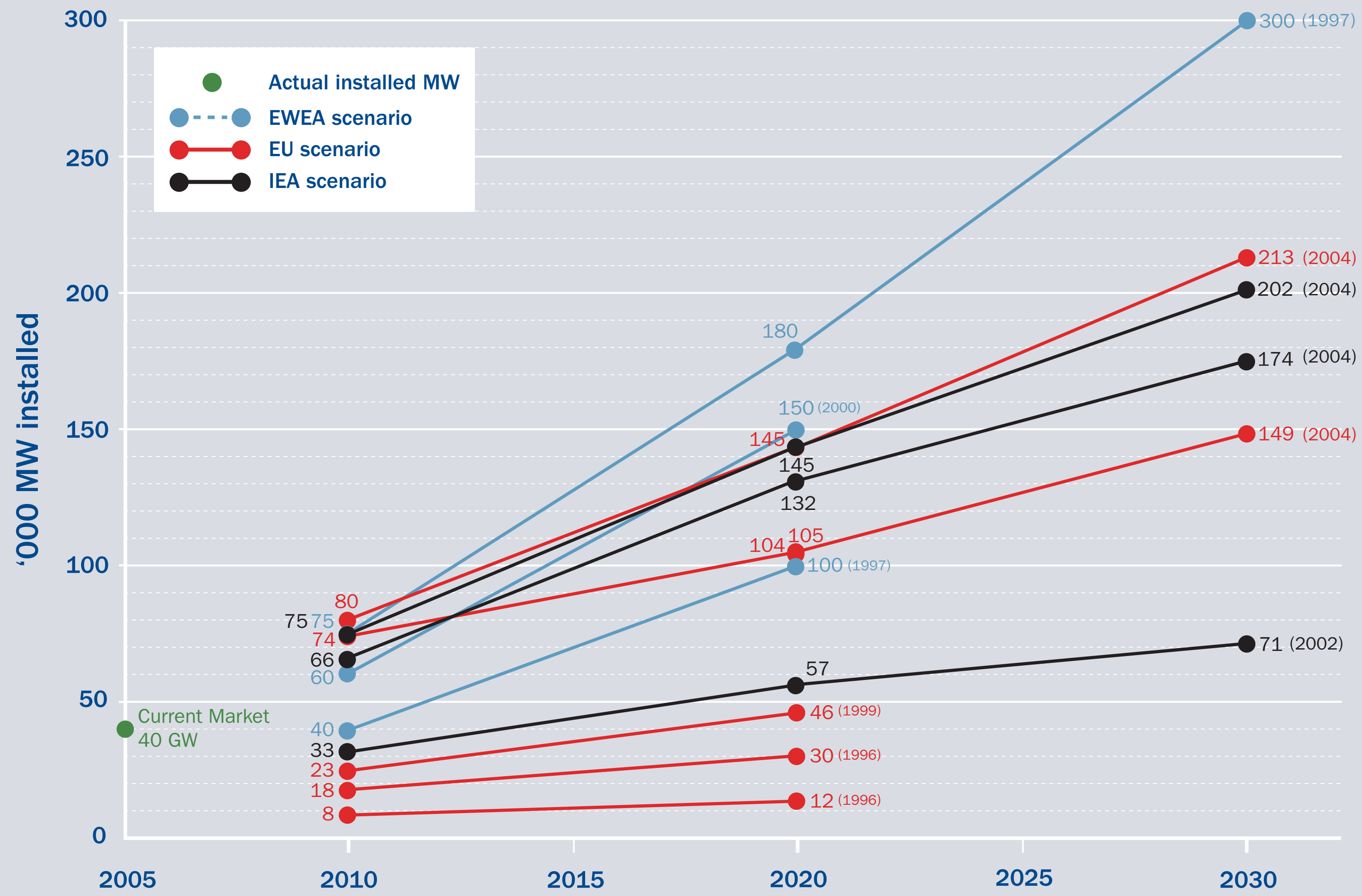
The 2003 European Commission scenario presented a number of different scenarios with an increased role for renewables and wind energy. The advanced scenario is 'Gothenburg type targets' which provides details for wind energy on its own.

The 'Gothenburg type targets' projected installed wind energy capacity of 79.8 GW in 2010, 144.8 GW in 2020 and 213.5 GW in 2030.

The IEA Advanced scenario projected a wind energy market of 75 GW in 2010, 145 GW in 2020 and 202 GW in 2030.



Varying future estimates of wind power in Europe (IEA, EU Commission, EWEA)



Year	2000	2005	2010	2020	2030
Actual Installed MW		40			
1997 EWEA scenario EU			40	100	
2000 EWEA scenario EU			60	150	
2006 EWEA scenario EU			75	180	300
1996 EU 15 conventional scenario (including solar)	4	6	8	12	
1996 EU 15 advanced scenario (including solar)	7	12	18	30	
1999 EU 15 scenario (including solar and geothermal)	9	16	23	46	
2003 EU 25 baseline scenario (includes solar)	13	28	74	105	149
2004 EU 25 Gothenburg type targets (wind only)			80	145	213
2002 IEA reference scenario			33	57	71
2004 IEA conventional scenario			66	132	174
2004 IEA advanced scenario			75	145	202

Wind energy success in European markets

The leading wind energy nations are Germany, Spain and Denmark.

Following their success, a second wave of countries is now making its mark. These include Austria, France, Greece, Ireland, Italy, the Netherlands, Portugal, Sweden and the UK. Countries that have recently passed 1,000 MW installed capacity are Portugal, UK, Italy and the Netherlands. All European governments have adopted targets for renewable energy, including wind power.

In Denmark, wind power already satisfies 20% of electricity consumption

Spain is a leading case study of how successful wind energy has become in Europe. The government targets for installed wind power in Spain have been increasing, as a result of its continued success. In 1999 the target was for 8.9 GW in 2010, which was considered ambitious at the time, and the previous Spanish government target of 13 GW by 2011 has now been increased to 20 GW.

In Spain the installed wind capacity already exceeds nuclear and combined cycle gas, and will this decade overtake coal and large hydro.

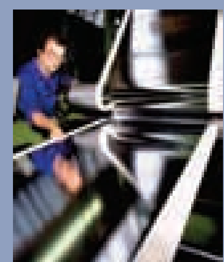
Currently around 8% of national electricity is provided by wind power in Spain. That will increase to 15% by 2010. During 2004 more new capacity (2,065 MW) was installed than in any other country.

Germany has been the world leader in wind energy deployment since the mid-1990s. A strong Renewable Energy Law has encouraged a flourishing wind industry.

Production from Germany's more than 17,000 MW of wind power capacity is expected to contribute 5.7% of national electricity demand by the beginning of 2006.

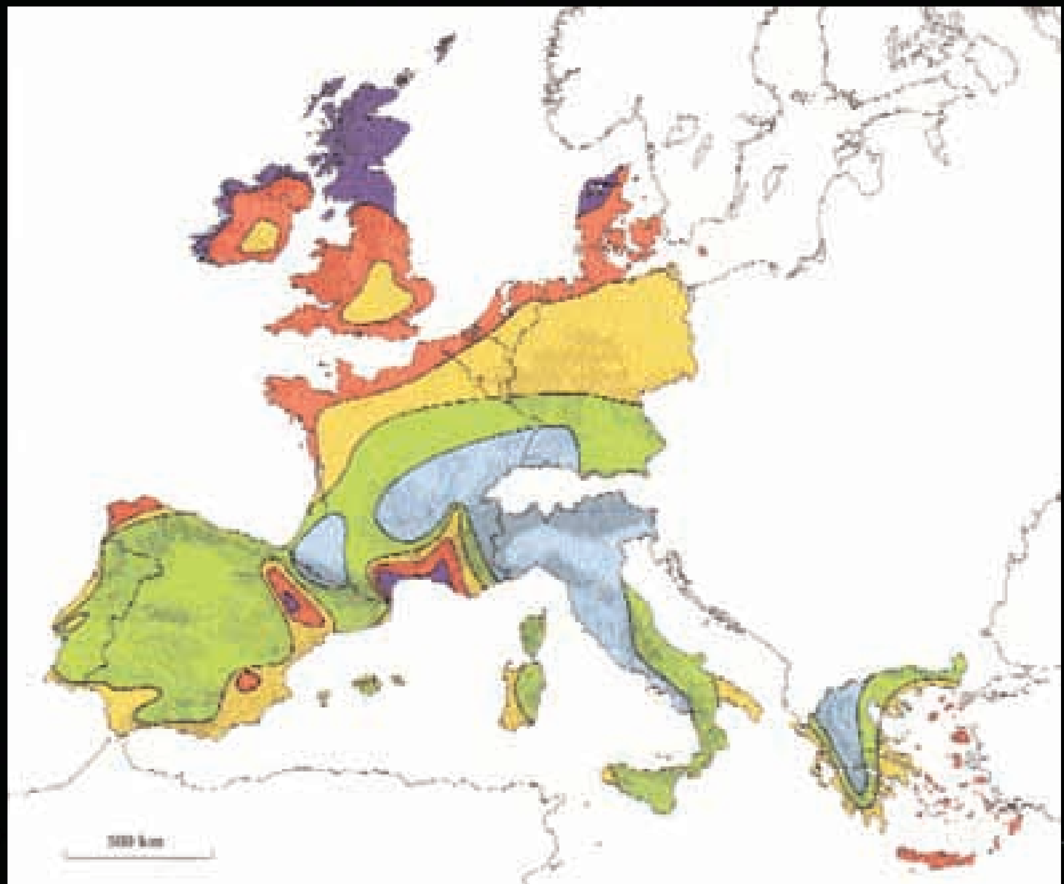
In northern Germany, the federal state of Schleswig-Holstein gets 30% of its power supply from the wind.

By 2030, according to government projections, wind power could be providing 30% of German electricity from approximately 54,000 MW of capacity. Over half of this would be operating out at sea.



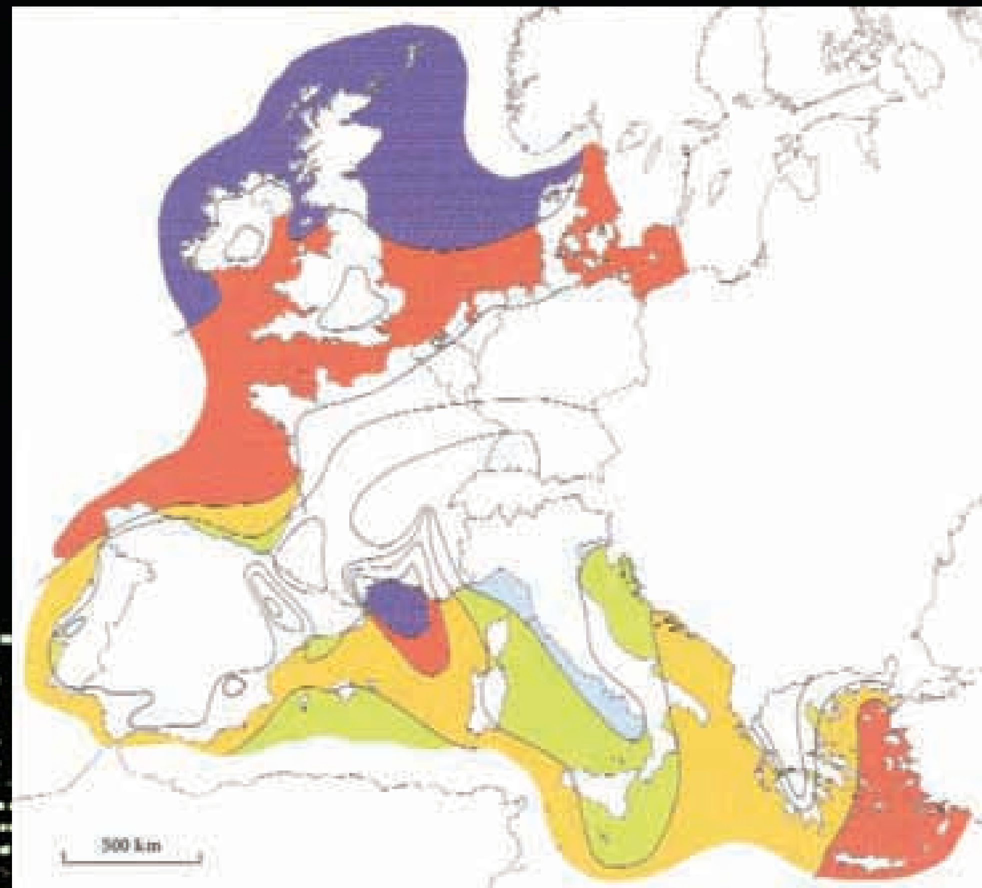
The European wind resource

There is enough wind energy resources to power all of Europe, whose current consumption is 2,900 TWh.



Wind resources at 50 metres above ground level for five different topographic conditions

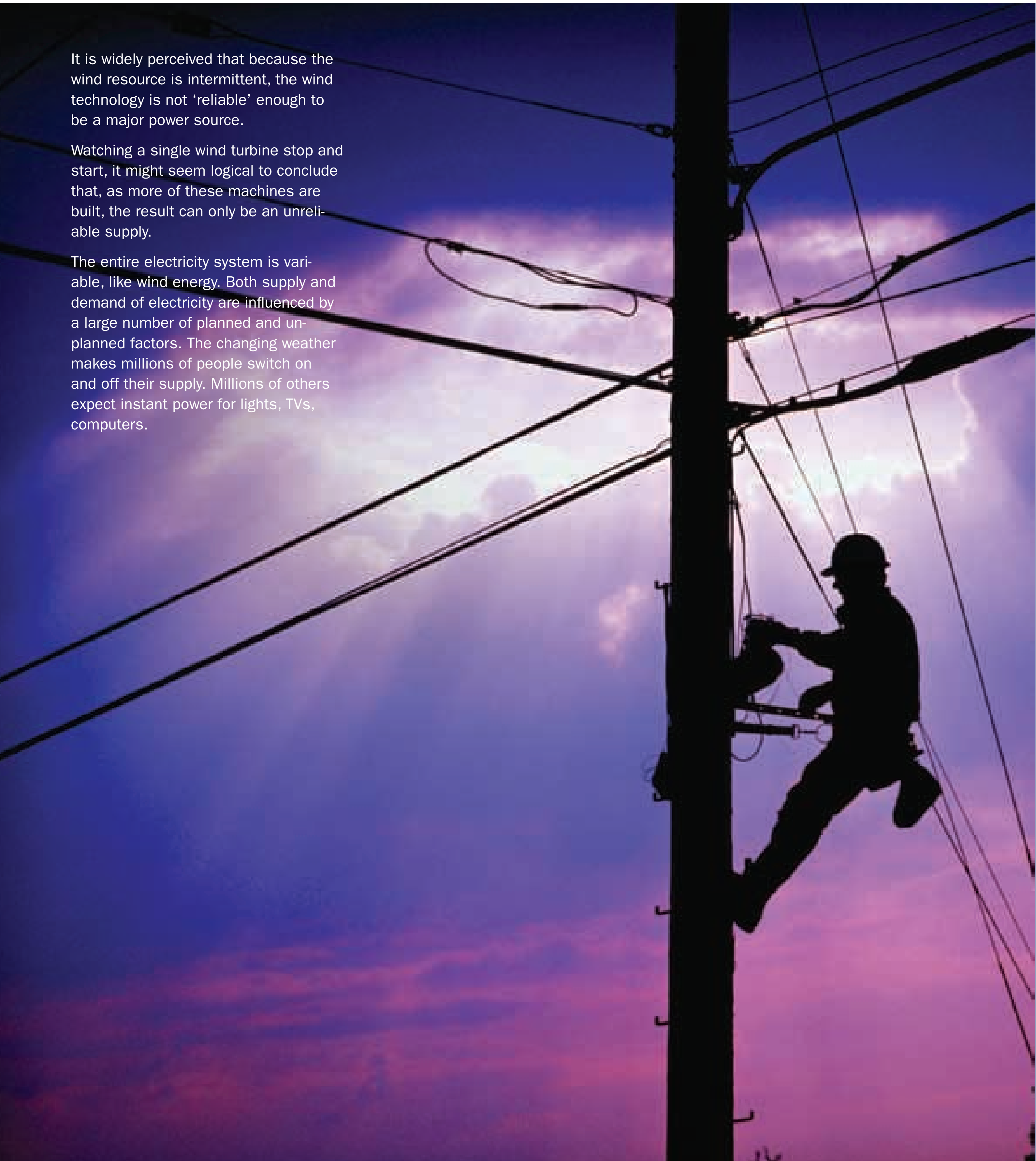
	Sheltered terrain		Open plain		At sea coast		Open sea		Hills and ridges	
	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0 - 6.0	150 - 250	6.5 - 7.5	300 - 500	7.0 - 8.5	400 - 700	8.0 - 9.0	600 - 800	10.0 - 11.5	1200 - 1800
	4.5 - 5.0	100 - 150	5.5 - 6.5	200 - 300	6.5 - 7.0	250 - 400	7.0 - 8.0	400 - 600	8.5 - 10.0	700 - 1200
	3.5 - 4.5	50 - 100	4.5 - 5.5	100 - 200	5.5 - 6.5	150 - 250	5.5 - 7.0	200 - 400	7.0 - 8.5	400 - 700
	< 3.5	< 50	< 4.5	< 100	< 5.5	< 150	< 5.5	< 200	< 7.0	< 400



Wind resources over open sea (more than 10 kilometres offshore) for five standard heights

	10 metres		25 metres		50 metres		100 metres		200 metres	
	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}
	> 8.0	> 600	> 8.5	> 700	> 9.0	> 800	> 10.0	> 1100	> 11.0	> 1500
	7.0 - 8.0	350 - 600	7.5 - 8.5	450 - 700	8.0 - 9.0	600 - 800	8.5 - 10.0	650 - 1100	9.5 - 11.0	900 - 1500
	6.0 - 7.0	250 - 300	6.5 - 7.5	300 - 450	7.0 - 8.0	400 - 600	7.5 - 8.5	450 - 650	8.0 - 9.5	600 - 900
	4.5 - 6.0	100 - 250	5.0 - 6.5	150 - 300	5.5 - 7.0	200 - 400	6.0 - 7.5	250 - 450	6.5 - 8.0	300 - 600
	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 6.0	< 250	< 6.5	< 300

Tackling the myth of intermittency



It is widely perceived that because the wind resource is intermittent, the wind technology is not 'reliable' enough to be a major power source.

Watching a single wind turbine stop and start, it might seem logical to conclude that, as more of these machines are built, the result can only be an unreliable supply.

The entire electricity system is variable, like wind energy. Both supply and demand of electricity are influenced by a large number of planned and unplanned factors. The changing weather makes millions of people switch on and off their supply. Millions of others expect instant power for lights, TVs, computers.

Conventional power sources are intermittent.

On the supply side, no power station of whatever type is completely reliable. Large power stations that go off-line, whether by accident or for maintenance, do so instantaneously, causing immediate loss of power. When a fossil fuel or nuclear power plant trips unexpectedly, it takes a capacity of up to 1,000 MW off the network instantly. That is true intermittency.

Power systems have always had to deal with these sudden output variations, as well as variable consumption, and the procedures put in place by network operators can be applied to deal with variations in wind power production as well.

Variability and intermittency are different concepts.

Variations in wind energy are smoothed by the fact that there are hundreds or thousands of units in operation, making it easier for the system operator to predict and manage changes as they occur. The system will not notice the shut down of a 2 MW wind turbine, but it will have to respond to the removal of a 500 MW coal fired plant or a 1,000MW nuclear plant. Wind energy does not suddenly trip off the system.

So the issue is not one of variability in itself, but how to predict, manage and ameliorate electricity variability and what tools can be utilised to improve efficiency. Wind power is variable in output, but this can be predicted to an increasingly accurate extent.

The electricity system, not the turbine, is what matters.

It is the net output of all wind turbines on the system or large groups of wind farms that matters for electricity needs. Wind power has to be considered relative to the overall variability of demand and the intermittency of other power generators.

- **The wind does not blow continuously in one place, yet there is little overall impact if the wind stops blowing somewhere – it is always blowing somewhere else.**
- **Therefore wind can be harnessed to provide reliable electricity even though the wind is not available 100% of the time at one particular site. In terms of overall power supply it is largely unimportant what happens when the wind stops blowing at a single wind turbine or wind farm site.**
- **The more wind farms that are built over a wider geographical location, the more reliable wind energy is.**

The EWEA report "*Large scale integration of wind energy in the European power supply*" analyses these issues in depth. The report's main conclusions are that the capacity of Europe's power systems to absorb significant amounts of wind power is determined largely by economics and regulatory rules rather than technical or practical constraints. **Already today, it is generally considered that wind energy can meet in the region of 20% of electricity demand on a large electricity network without posing any serious technical or practical problems – as proven by the example of Denmark.**

How many turbines are required?

- **At the end of 2005, an estimated 47,000 wind turbines were installed in Europe, generating 83 TWh of electricity, equal to about 2.8% of European electricity demand.**
- **The average size of turbines delivered to the European market in 2004 was about 1.3 MW onshore and 2.1 MW offshore. Under the assumption that by 2030, the average size of a wind turbine will be 2 MW onshore and 10 MW offshore, this will result in a total of 90,000 turbines (75,000 onshore and 15,000 offshore machines) to fulfil the 300 GW target.**
- **In 2030, 90,000 wind turbines would generate 965 TWh, and provide 23% of European electricity demand in 2030.**
- **This takes into account rising demand, so the 90,000 machines would meet 32% of current European electricity demand.**
- **By doubling the number of turbines in Europe from 2005 to 2030, 12 times more electricity can be generated.**

At a given site, a single modern wind turbine annually produces

180

times more electricity and at less than half the cost per kWh than its equivalent twenty years ago.

Denmark

In the early 1980s it would have taken 100,000 of that time's wind turbines to provide 10% of Denmark's power. At the end of 2004 5,590 turbines covered 20% of the country's demand.

An increase of wind energy to provide 50% of Denmark's power demand could be delivered from 1,750 turbines.

A 2004 political agreement is expected to increase wind power's share of Danish power consumption from 20% in 2004 to 25% in 2008. Beyond 2008 it is expected that any further development will have to be offshore and replacement of older turbines ("repowering").

The 5,590 wind turbines operating in Denmark in 2005 produced about 20 % of Danish power demand. The Danish Wind Turbine Owners' Association has proposed to incorporate a goal of 50% wind power by 2025 in the Danish energy plans. An analysis from the association published in 2005 shows that wind power's share of Danish electricity consumption could be increased from 20% (7.5 TWh) in 2004 to 50% (19 TWh), while reducing the number of wind turbines by more than two thirds, from about 5,590 to 1,750 of which 1,230 onshore. The turbine types onshore are (rather conservatively) assumed to be 1 MW, 1.5 MW and 3 MW machines, all commercially available today, while the offshore turbines are assumed to be 4 MW and 6 MW turbines.

One 5 MW machine offshore will generate 17 Gigawatt hours, enough power to meet the needs of 4,500 households, or 13,500 people.

Area required to satisfy one fifth of European electricity demand from 300 GW wind energy by 2030

Surprisingly few modern turbines are required to supply future European electricity needs.

It is assumed 150 GW onshore and 150 GW offshore in 2030.

Parameter	Units	Onshore	Offshore
Density	MW/km^2	15	10
Turbine size	MW	2	10
Number of turbines	#	75,000	15,000
Electricity production	TWh	387	578
Machines per km^2	#/km^2	7.5	1
Installed capacity 2030	GW	150	150
Surface needed	(km^2)	10,000	15,000
Square needed	(km)	100x100	122x122

Wind farms onshore can be installed with a density of approximately 15 MW/km^2.

Offshore the density is less because of larger spacing needed to avoid wake effects. 10 MW/km^2 is assumed here.

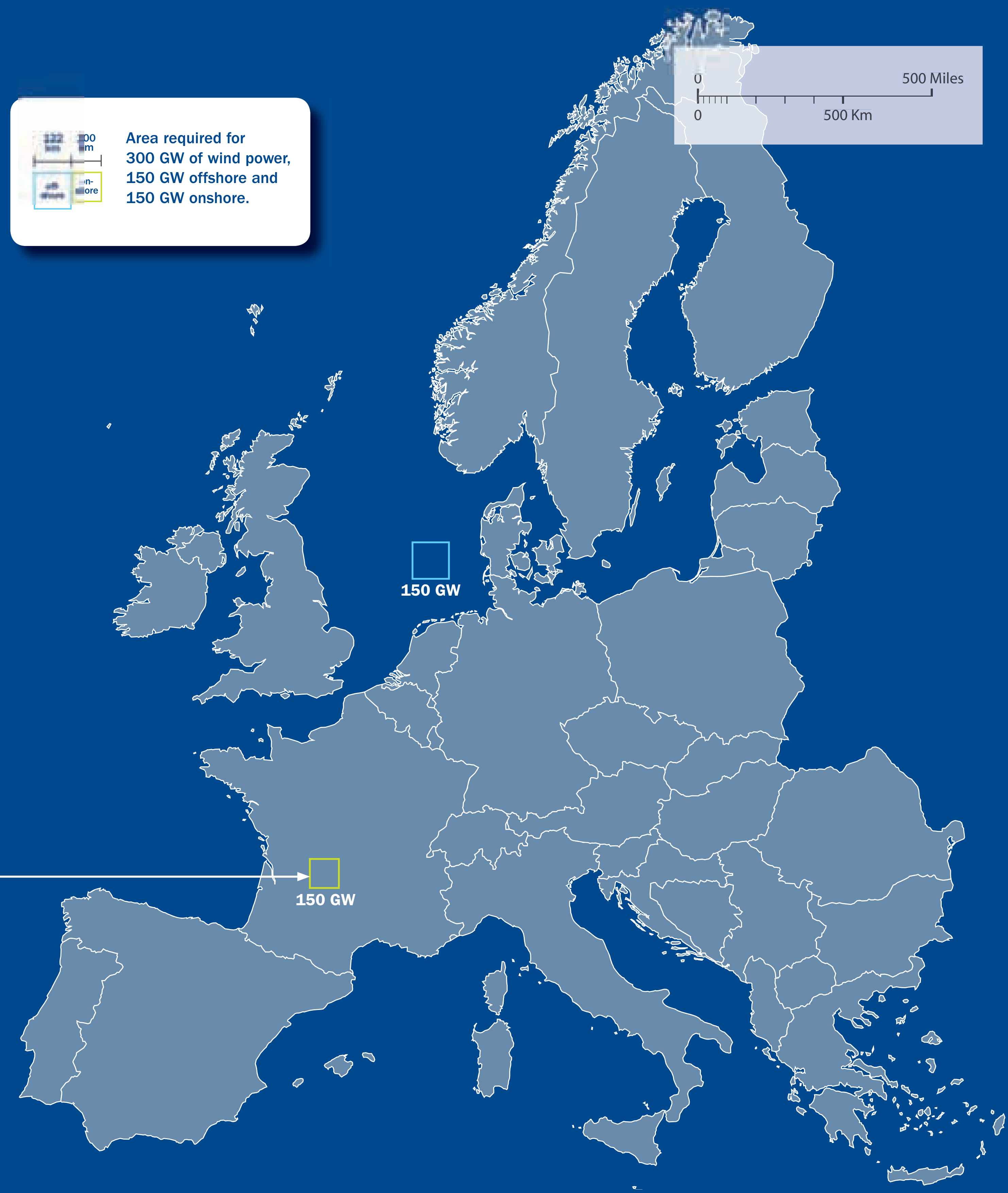
Under these assumptions, 150 GW requires 10 000 km^2 onshore and 15 000 km^2 offshore - see map opposite.

In practice, wind farms occupy approximately 1% of the land surface (foundations, roads, control buildings etc). The net required surface is very low because often wind farms are installed in rows on hill crests and along roads etc. When installed in clusters, it is usually in agricultural area, where the land between the turbines still can be utilised for farming and other purposes.

The net onshore area needed to install 150 GW wind power, assuming the surface between wind turbines can be used for agriculture or so is in the order of (a few) hundred square kilometres.

In practice, wind farms occupy about 1% of the land surface area, so the actual land use needed for wind farms and roads, other services is in the region of a few hundred square kilometres.

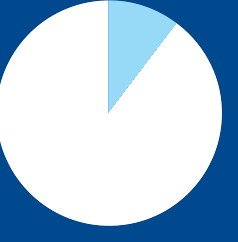
Area required to satisfy one fifth of European electricity demand from 300 GW wind energy by 2030



More power from less turbines - Denmark

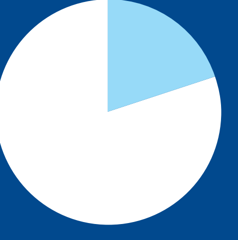
Denmark:

1980s: 100,000 turbines



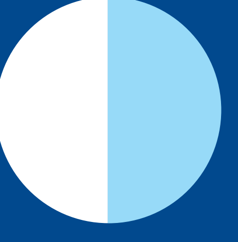
to satisfy **10%** of Danish electricity use

2004: 5,590 turbines



provides **20%** of Danish electricity use

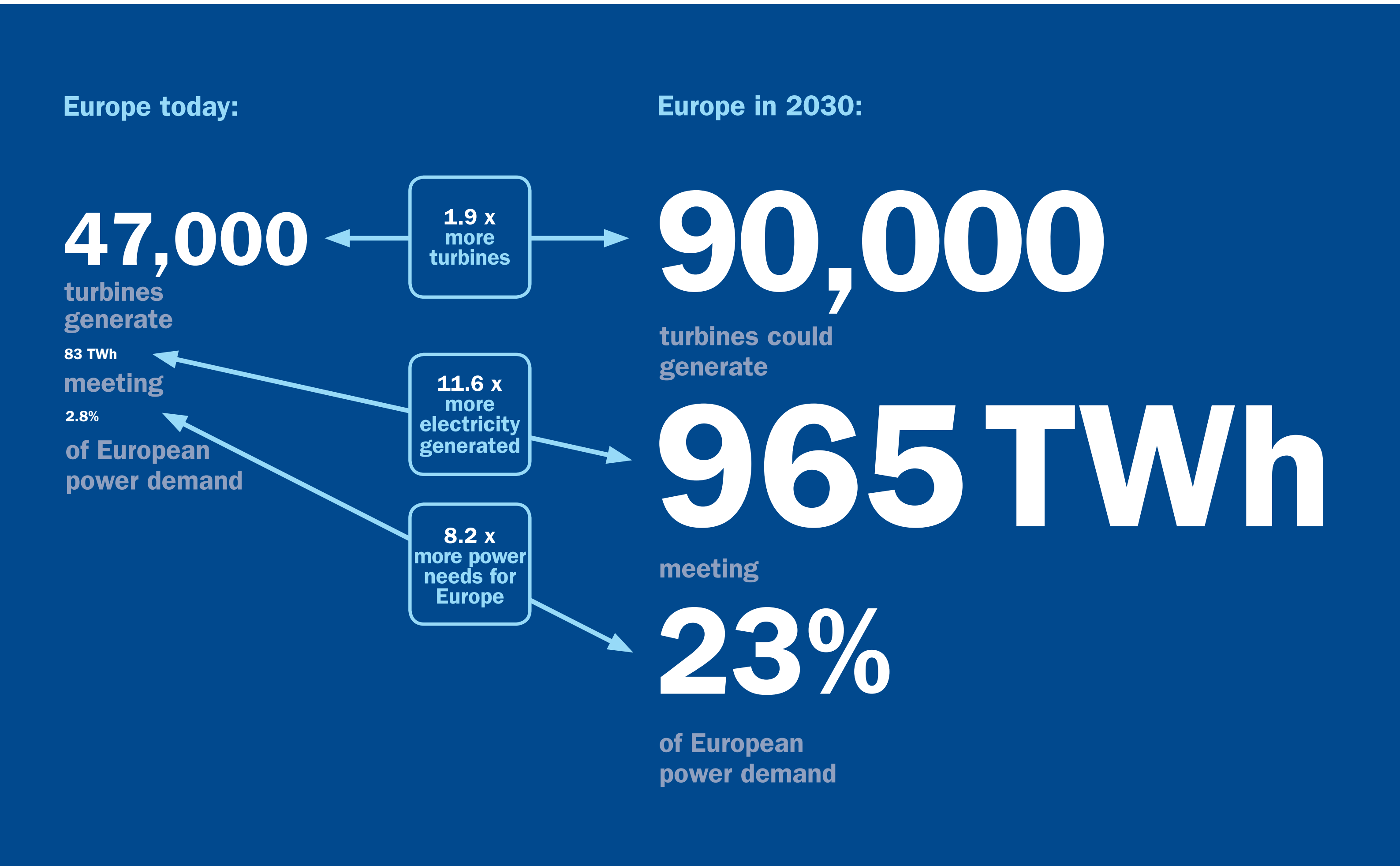
2025: 1,750 turbines



could satisfy **50%** of Danish electricity use

Parameter	1980	2005 Current Status	2025
Number of turbines	100,000	5590	1,750 (including 1,230 offshore)
Amount of national electricity generated by wind power.	10%	20%	50%

More power from less turbines - Europe



no fuel
Wind. Power without fuel

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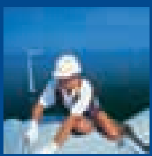

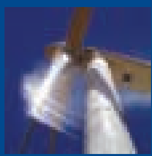
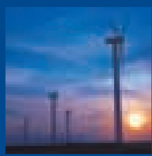

About EWEA

EWEA is the voice of the wind industry - promoting the best interest of the sector in Europe and worldwide.

EWEA members include manufacturers covering 98% of the global wind power market, as well as component suppliers, research institutes, national wind and renewables associations, developers, electricity providers, finance and insurance companies and consultants. The combined strength of more than 250 members from over 40 countries makes EWEA the world's largest renewable energy association.

Located in Brussels, the EWEA Secretariat co-ordinates international policy, communications, research and analysis. EWEA manages European programmes, hosts events and supports the needs of its members.

EWEA is a founding member of the European Renewable Energy Council (EREC) which groups the 8 key renewable industry and research associations under one roof, and is a founding member of the Global Wind Energy Council (GWEC).

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