WIND ENERGY - THE FACTS

VOLUME 3

INDUSTRY & EMPLOYMENT

Acknowledgments

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1 INDUSTRY STATUS

1.1 Introduction

Since the last *Wind Energy - The Facts* report published in 1999, the European wind energy industry has made significant progress. There are several ways of monitoring this progress, such as measuring electricity output in MW or kW hours. However, the usual method is to use a measurement of installed capacity, so this chapter demonstrates national markets and their growth in terms of MW capacity installed.

Wind experienced a surge of growth in California in the 1980s thanks to a combination of state and federal energy and investment tax credits[1]. From 1980 to 1995, around 1,700 MW of wind capacity was installed and, although there were some turbines of poorer quality, the boom period provided a major export market for European manufacturers, and did much to establish the credibility of the industry. Since then, Europe has turned the tables and consolidated its position as the global market leader. Within Europe, certain countries are particularly strong: the top five in terms of installed capacity being Germany, Spain, Denmark, The Netherlands and Italy.

1.1.1 NEW DEVELOPMENTS

There have been significant changes in the industry over the last five years, and it is still in a state of considerable flux. Some major structural changes are taking place within the sector as it matures; these are significant for any company wishing to participate in the wind industry over the long term.

The unit size, both of individual turbines and of wind farms has grown significantly. Five years ago, a wind farm of 20 MW would be considered large. Now, particularly as the North American market reopens, the Spanish market continues to grow, new markets open, and the offshore market takes off, very large wind farms are being introduced, in the scale of hundreds of MW.

The definition of a wind farm is somewhat vague, but if a wind farm is considered, somewhat artificially, as a single financing, then the year 2001 saw a major breakthrough, with a single financing in Spain of more than 1,000 MW (1 gigawatt, GW). With a more limited definition - that of a single location - then the King Mountain project in Texas is the largest single installation, at 278 MW. Continued activity in the US suggests that such large projects, although unlikely to become commonplace, will certainly occur more frequently.

Growth in wind farm size has, to a degree, followed growth in wind turbine (WT) size. These same large wind farms cannot, however, be installed in all markets, and space requirements in some hitherto very active European markets will ultimately limit growth onshore. This constraint has now been recognised by several northern European governments, and active plans for the development of offshore projects have begun. Indeed, the construction of Denmark's second large-scale offshore projects has been completed with a capacity of 160 MW.

1.1.2 MARKET CHANGES

Structural changes to the industry have taken place in recent years, and new companies have arrived. The increased size of wind farms, growth of business at approximately 30% per annum, improved technology and, in particular, improved turbine availability, have all allowed the wind energy business to be considered seriously by main players in the conventional power industry: Shell has formed a wind energy subsidiary, Shell Wind Energy; and the Enron subsidiary, Enron Wind Corporation, was purchased by General Electric to form GE Wind Energy.

SIIF, a French company 35% owned by Electricité de France, is emerging as a major player with global aspirations, recently purchasing the US operations and maintenance provider and developer enXco. Substantial construction by the Italian conglomerate EDENS, as well as ongoing activity by FPL and most of the Spanish utilities, all underline the nature of today's wind developers, as compared with those of the previous decade, which tended to be small and independent.

The last year has also seen the separation of Gamesa Eolica, the leading supplier in the Spanish market, from its Danish partner, Vestas. This step has produced a major new competitor worldwide. The Indian company, Suzlon, has also emerged on the world market as a turbine supplier.

Over the past decade, the wind turbine manufacturing industry has become increasingly concentrated. This was emphasised by the announcement of a merger in December 2003 between the world's largest and third largest manufacturers Vestas Wind Systems and NEG Micon. If approved, they will have a combined global market share of approximately 35%.

1.2 Demand Drivers

1.2.1 MARKET TYPES

The market may be split into two separate segments, the "conscience" market and the "needs" market.

Conscience Market

In the conscience market, the driver for development of wind energy has hitherto been a desire to produce electricity by cleaner means. This has been supported by incentives, described in volume 5 chapter 1, and, hence, has been essentially a political market. There are signs, however, that as the cost of wind energy continues to fall there are some applications for which wind energy is competitive in its own right and the nature of these markets will therefore change.

Needs Market

For the needs market, motivations are somewhat different. Such markets are characterised by a growing, and unsatisfied, need for energy, and a limited amount of new generating capacity coming online. In these markets, wind energy is considered as one of several alternatives. Given the relative ease with which wind technology adapts to different countries and requirements, and the relatively short time between initiating construction and delivering power, it has become the most attractive alternative for some.

A good example of this latter category is wind power's initial development in India. The way in which the Indian market developed in the mid 1990s shows that there can be a danger in too rapid development of a new technology. Quality problems arose, both in initial manufacture, which were later revealed in severe storms in Gujarat and also, perhaps more severely, in inadequate preparation of projects. In particular, inadequate measurement was carried out of the wind resource on project sites. Whereas in industrialised countries it is normal to have several years' wind data before a project is built, in India there was, at best, only a few months' and, in some cases, no data at all. This is a dangerous position.

Another major flaw in the Indian framework of the 1990s, was the existence of a subsidy to wind turbine owners which was based on the rated capacity of the wind turbines rather than an incentive to optimise production of the renewable electricity. That proved problematic because a subsidy was given whether or not production was efficient. This incentive resulted in poor siting of wind turbines, and manufacturers followed customer demands to use very large generators, which improved project profitability but reduced production and also attracted manufacturers with highly dubious products, which gave the entire technology a bad name. India has since corrected the inherent flaws of its incentive scheme and the market has started to develop again.

With the experience of these mistakes, it is noticeable that the second round of incentives in the Indian market is rather different, and the market is presently being much more tightly controlled, both in terms of development qualifications and also in quality control of the turbines produced. As a result, wind energy in India now has a sustainable future. Other countries in this category presently considering serious development of wind energy include Brazil, Tunisia, China, Egypt, Morocco, the Philippines, Turkey and Vietnam.

The key difference between the two market types is that, for the conscience market, comparisons are always made between wind costs and, say, combined cycle gas costs whereas, for the needs market, the comparison may be the cost of having power rather than not having power. The conditions for commercial viability are, therefore, quite different.

1.2.2 POLITICAL RISK

There are many examples of political uncertainty in both the needs and the conscience markets: a few examples are given here.

The risks associated with establishing a wind farm in a developing country are similar to those encountered with any other form of development. There is political risk, technology risk and financial risk. There is also, in the case of wind energy, an additional risk that the technology will be copied and an indigenous product developed without a license agreement.

In both the conscience and the needs market there is political risk. The cost of wind energy has declined sharply over the last decade, but still requires some form of incentive to encourage its widespread development. This incentive is inevitably political in nature although it may be drafted in any number of different ways, from tax credits to premium prices, to tradable green certificates. If the political attitude changes in any one of the active countries, the market in that country can undergo radical alteration. This has, indeed, been seen on many occasions. For example, in Germany, there was some uncertainty in 1999 about the planning regime within which wind energy developments were built. Whilst that uncertainty was being clarified, the market declined, but it has since recovered and achieved three record years. When US President Carter left office in the early 1980s, the market stopped overnight. Early in 2003, the premium price in Spain fell, although this was coupled with an increase in pool price and hence the composite kWh (kilowatt hour) price was almost unchanged. Nevertheless, the risk of price change was accentuated.

In the case of the EU, underpinning individual domestic policies for renewable energy and environmental policy, there is strong support from both the European Commission and the Parliament. Targets for renewable energy have been set and enshrined in EU law. Hence, at a higher level of policy, significant support exists for ongoing development of renewables, including wind. Wind energy is particularly well received in this context as it has demonstrated an ability both to reduce its price significantly with increases in volume, and to create significant employment.

The wind power industry has experienced the risk of relying too heavily on one single market. In the middle of the 19980s, manufacturers were entirely relying on the Californian market. In the 1990s, they found themselves equally dependant on the Indian market for wind power technology. When those two markets collapsed due to political and economic turmoil, many manufacturers went bankrupt. Today, the global wind power market is more geographically spread. However, the three largest markets still accounts for app. 70% of the global market (2002).

1.3 The Onshore Market

1.3.1 MARKET STATUS (CUMULATIVE MARKET)

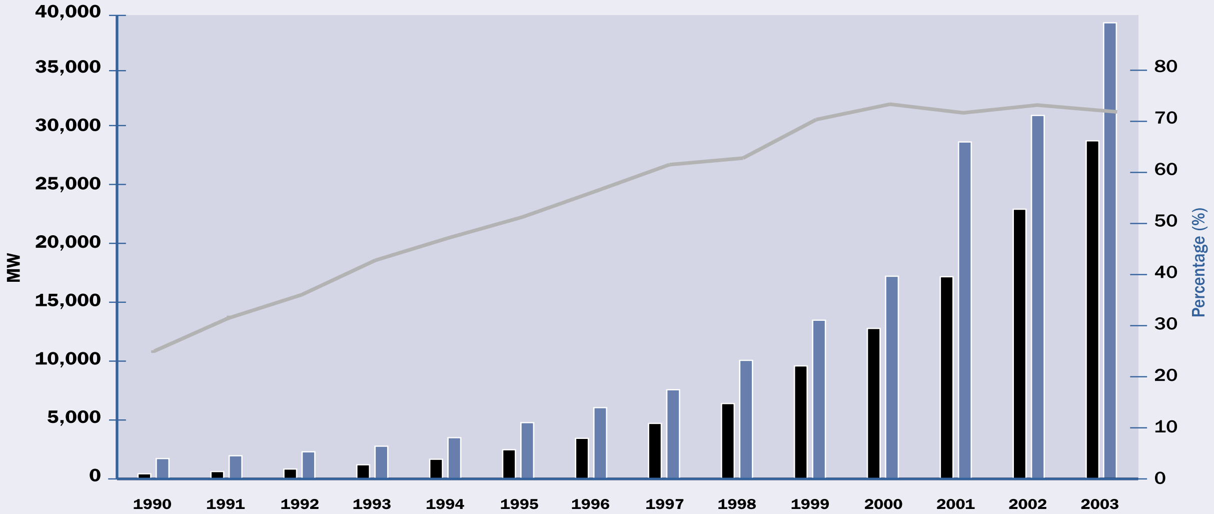
The progress of wind power around the world in recent years has been impressive. By the end of 2003 more than 39,400 MW of electricity-generating WTs were operating in 50 countries. Of these, more than 28,000 MW were installed in the EU, enough to meet 2.4% of EU-15 electricity demand.

Europe dominates the global wind market, with European manufacturers controlling 90% of the global market in 2002. The most successful markets for wind power in recent years have been Germany, Spain and Denmark. Outside the EU, India and the US are leading markets, but over 70% of the market remains in the EU. Between 1992 and 2002, cumulative installed capacity multiplied 27 times. 2002 itself was a record year for EU installations, with over 5,800 MW of new capacity.

Wind energy is now established across parts of western and southern Europe, and installations are beginning to take off in the new member states of central and eastern Europe, for example in Latvia and Poland. Figure 1.1 shows installed MW capacity in the EU-15, compared with that installed worldwide.

The curve demonstrates the percentage of global installed capacity installed in the EU-15: in 1990 this figure stood at 25%. Over the last five years, the European market has grown by an average 30% per annum and, by the end of 2002, EU-15 countries represented 74% of installed capacity worldwide.

Figure 1.1: EU-15 and Global Cumulative Installed Wind Capacities (MW)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
EU-15	439	629	844	1,211	1,683	2,497	3,476	4,753	6,453	9,678	12,887	17,315	23,098	28,440
WORLD	1,743	1,983	2,321	2,801	3,531	4,821	6,104	7,636	10,153	13,594	17,357	28,857	31,128	39,500
EU % of world	25	32	36	43	48	52	57	62	64	71	74	73	74	72

Table 1.1: EU-15 Cumulative Installed Capacities (MW) by Country

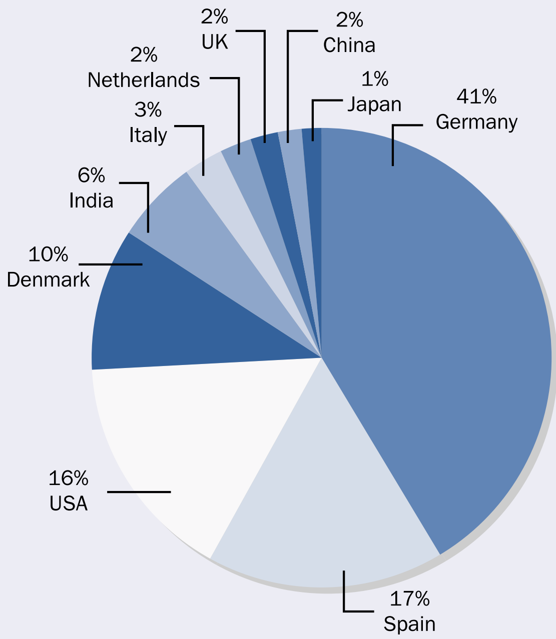
Country	1995	1996	1997	1998	1999	2000	2001	2002	2003
Austria	5	10	20	30	34	77	94	140	415
Belgium	4	4	4	6	6	13	31.6	35	68
Denmark	619	842	1,129	1,443	1,771	2,417	2,489	2,889	3,110
Finland	6	7	12	17	39	39	39	43	51
France	3	6	10	19	25	66	93	148	239
Germany	1,132	1,552	2,081	2,875	4,442	6,113	8,754	11,994	14,609
Greece	28	29	29	39	112	189	272	297	375
Ireland	7	11	53	73	74	118	124	137	186
Italy	32	70	103	180	277	427	682	788	904
Luxembourg	2	2	2	9	10	10	15	17	22
Netherlands	249	299	319	361	433	446	486	693	912
Portugal	8	19	38	60	61	100	131	195	299
Spain	133	249	512	834	1,812	2,235	3,337	4,825	6,202
Sweden	69	103	122	174	220	231	293	345	399
UK	200	273	319	333	362	406	474	552	649
EU-15 Total	**2,497**	**3,476**	**4,753**	**6,453**	**9,678**	**12,887**	**17,315**	**23,098**	**28,440**

Table 1.2: New Member State Cumulative Installed Capacity (MW)

	1995	1996	1997	1998	1999	2000	2001	2002[1]	2003[1]
Cyprus [2]	0	0	0	0	0	0	0	2	2
Czech Republic [3]	11	11	11	11	11	6	7	3	10
Estonia [4]	0	0	0	0	0	0	0	2	3
Hungary [5]	0	0	0	0	0	0	1	3	3
Latvia [6]	1	1	1	1	1	1	1	24	24
Lithuania	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0
Malta	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0
Poland [7]	1	1	2	2	3	4	22	27	57
Slovakia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	3
Slovenia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0
EU New Members Total	13	13	14	10	17	18	33	61	102

[1] All data for 2002 - 2003 from EWEA
[2] Data for 1995 - 2001 from Cyprus Institute of Energy
[3] Data for 1995 - 2001 from Czech Society for Wind Energy
[4] Data for 1995 - 2001 from Latvian Wind Energy Association
[5] Data for 1995 - 2001 from Horvath Engineering, Hungary
[6] Data for 1995 - 2001 from Latvian Wind Energy Association
[7] Data for 1995 - 2001 from Vis Venti Association for Supporting Wind Energy, Poland

Figure 1.2: Top 10 Cumulative Global Market Shares in 2002 (MW)

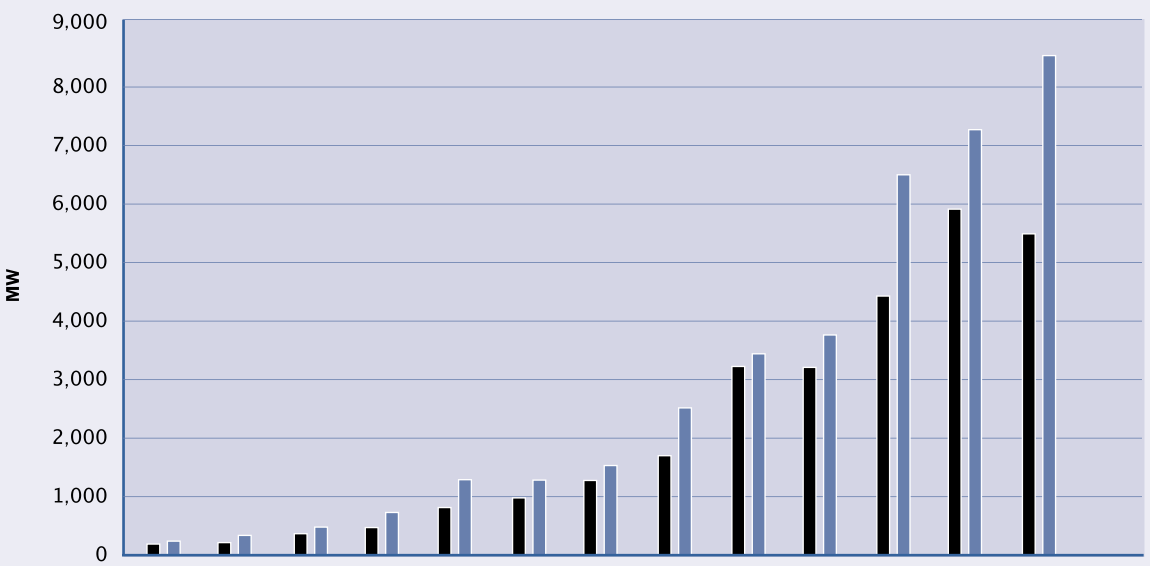


Country	Cumulative Installed Capacity End, 2002	% Share
Germany	12,001	41.4
Spain	4,830	16.7
USA	4,685	16.2
Denmark	2,880	9.9
India	1,702	5.9
Italy	785	2.7
Netherlands	688	2.4
UK	552	1.9
China	468	1.6
Japan	415	1.4
Total	**29,006**	**100.0**

1.3.2 MARKET GROWTH (ANNUAL MARKET)

Germany, Spain and Denmark accounted for almost 80% of the wind power capacity installed in Europe in 2003 (see Table 1.3). With 2,645 MW, Germany accounted for 49% of the installed capacity, reaching a total of 14,609 MW by the end of 2003, enough to meet 6% of national electricity needs from wind power. Spain followed with 1,377 MW, to achieve a total of 6,202 MW. Denmark installed 243 MW to reach 3,110 MW, and the industry association expects that wind will meet approximately 20% of the country's electricity needs in 2004.

Figure 1.3: EU-15 and Global Annually Installed Wind Capacity (MW)



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
EU-15	190	215	367	472	814	979	1,700	1,700	3,225	3,209	4,428	5,913	5,411
WORLD	240	338	480	730	1,290	1,283	2,517	2,517	3,441	3,763	6,500	7,271	8,400

Table 1.3: EU-15 Annually Installed Capacity by Country

Country	1996	1997	1998	1999	2000	2001	2002	2003
Austria	5	10	10	4	43	17	46	276
Belgium	0	0	2	0	7	19	3	33
Denmark	223	287	314	328	646	72	506	243
Finland	1	5	5	22	0	0	4	8
France	3	4	9	6	41	27	55	9
Germany	420	529	794	1,567	1,671	2,641	3,247	2,645
Greece	1	0	10	73	77	83	25	78
Ireland	4	42	20	1	44	6	13	49
Italy	38	33	77	97	150	255	106	116
Luxembourg	0	0	7	1	0	5	2	5
Netherlands	50	20	42	72	13	40	222	226
Portugal	11	19	22	1	39	31	64	107
Spain	116	263	322	978	423	1,102	1,488	1,377
Sweden	34	19	52	46	11	62	52	54
UK	73	46	14	29	44	68	87	103
EU-15 Total	**979**	**1,277**	**1,700**	**3,225**	**3,209**	**4,428**	**5,913**	**5,411**

Table 1.4: New Member State Annually Installed Capacity (MW)

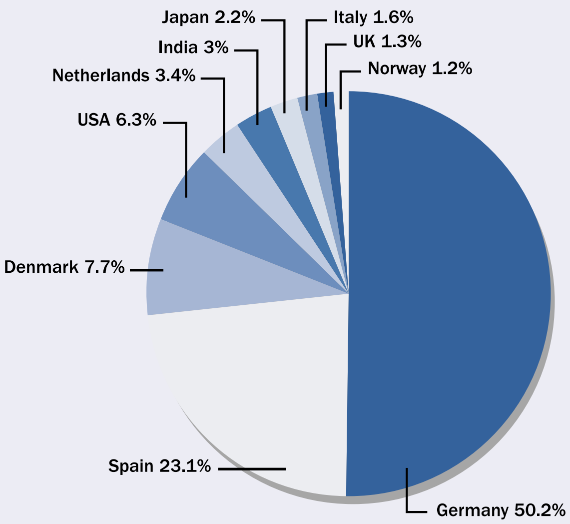
	1996	1997	1998	1999	2000	2001	2002	2003[1]
Cyprus [2]	0	0	0	0	0	0	0	0
Czech Republic [3]	0	0	0	0	-5	0	0	7
Estonia [4]	0	0	0	0	0	0	2	1
Hungary [5]	0	0	0	0	0	1	1	0
Latvia [6]	0	0	0	1	0	0	20	0
Lithuania	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
Malta	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
Poland [7]	0	1	0	1	1	18	5	30
Slovakia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3
Slovenia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
EU New Members Total	0	1	-4	7	1	15	29	41

[1] All data for 2003 from EWEA
[2] Data for 1995 - 2002 from Cyprus Institute of Energy
[3] Data for 1995 - 2002 from Czech Society for Wind Energy
[4] Data for 1995 - 2002 from Latvian Wind Energy Association
[5] Data for 1995 - 2002 from Horvath Engineering, Hungary
[6] Data for 1995 - 2002 from Latvian Wind Energy Association
[7] Data for 1995 - 2002 from Vis Venti Association for Supporting Wind Energy, Poland

Table 1.5: Offshore Installed Capacities

Location	Country	Installed Capacity (MW)	Year	Cumulative Installed Capacity (MW)
Vindeby	Denmark	5	1991	5
Lely	Ijsselmeer, The Netherlands	2	1994	7
Tunø Knob	Jutland, Denmark	5	1995	12
Dronton	IJsselmeer, The Netherlands	17	1997	29
Bockstigen-Valor	Gotland, Sweden	3	1998	32
Blyth	United Kingdom	4	2000	36
Middelgrunden	Copenhagen, Denmark	40	2000	76
Utgrunden	Sweden	10	2000	86
Yttre Strengrund	Sweden	10	2001	96
Samsø	Denmark	23	2003	119
North Hoyle	United Kingdom	60	2003	179
Horns Rev	Denmark	160	2003	339
Nysted	Denmark	158.4	2003	497.4
Arklow Bank	Ireland	25	2003	522.4

Figure 1.4: Top 10 Global Annual Market Shares in 2002 (installed MW per annum)



Country	Annual 2002	% Share 2002
Germany	3,247	50.2
Spain	1,493	23.1
Denmark	497	7.7
USA	410	6.3
Netherlands	217	3.4
India	195	3.0
Japan	140	2.2
Italy	103	1.6
UK	87	1.3
Norway	80	1.2

1.4 Offshore Market

To date, only Europe has installed wind capacity offshore, although projects are planned for the US. Fourteen projects are now operating in four EU countries with a total capacity of 522 MW.

Since the first offshore turbines were installed in 1991, development has been gradual. 2003 saw the world's first major offshore wind farm installed at Horns Rev off the Danish coast.

Figure 1.5 demonstrates the great leap made in 2003, chiefly thanks to the installation of the three Danish wind farms - Horns Rev, Nysted and Samsoe, while Table 1.6 below gives an impression of the potential for offshore wind farms in the EU up to 2006 - a little under 9 GW (9,000 MW). Worldwide, the database prepared by

Douglas-Westwood show the current planned offshore windfarms to total around 50 GW up to 2010. It should be noted that these figures are for identified projects alone and those currently under development - and the potential exists for much more.

As demonstrated by the existing level of its onshore installed capacity (57 MW) Poland is moving ahead with wind installations faster than the other new member states, and it is the only new member state to have an off-shore installation in the planning phase (see Table 1.6).

Figure 1.5: Annual and Cumulative Offshore Capacity, 1991 - 2003

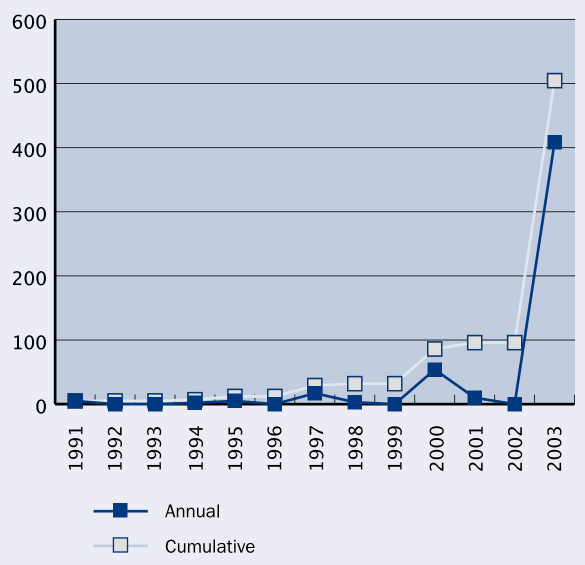


Table 1.6: EU-25 Planned Offshore Installations up to 2006

Country	Name/Location	Date	MW
Germany	Nördlicher Grund phase 1	2004	360.0
Belgium	Thornton Bank	2005	216.0
Finland	Kokkola	2005	207.0
Germany	Borkum Riffgrund phase 1	2005	231.0
Germany	Nordergründe	2005	266.0
Germany	Sky 2000	2005	150.0
Ireland	Arklow Bank phase 2	2005	216.0
Netherlands	Near Shore wind park	2005	99.0
Netherlands	Q7-WP	2005	120.0
Poland	Bialogora	2005	120.0
Sweden	Fladen	2005	140.0
UK	Barrow	2005	108.0
UK	Cromer	2005	108.0
UK	Gunfleet Sands	2005	108.0
UK	Lynn	2005	108.0
UK	Robin Rigg (Solway Firth)	2005	108.0
France	Ile de Groix	2006	100.0
Germany	Adlergrund phase 1	2006	320.0
Germany	Amrumbank West	2006	288.0
Germany	Arkona-Becken Südost phase 1	2006	195.0
Germany	Beltsee	2006	249.0
Germany	Borkum Riffgrund West phase 1	2006	280.0
Germany	Butendiek	2006	240.0
Germany	DanTysk phase 1	2006	400.0
Germany	He Dreiht	2006	535.5
Germany	Meerwind phase 1	2006	262.5
Germany	Nordsee Ost phase 1	2006	400.0
Germany	North Sea Windpower phase 1	2006	166.5
Germany	Riffgat	2006	198.0
Germany	Sandbank 24 phase 1	2006	360.0
Germany	Uthland	2006	400.0
Ireland	Arklow Bank phase 3	2006	263.0
UK	Shell Flat	2006	324.0
Other	**Less than 100 MW in size**	**-**	**1072.8**
Total	**-**	**-**	**8719.3**

Source: The World Offshore Wind Database, Douglas-Westwood (2003).

1.5 Domestic Market

Europe continues to play a dominant role, both in the development and manufacture of WTs and in the exploitation of its wind resource through the development of wind farms. The top three EU-15 markets - Germany, Spain and Denmark - as well as promising new member states markets are discussed below.

Germany

Germany continues to be the leader in terms of cumulative and annual MW installed. 2003 saw a notable drop in the annual MW installed from 3,247 to 2,645 in 2003, however that rate of decline is not forecast for the coming years (see Table 1.3). The wind sector is large, and the political commitment to wind energy remains strong - the revision of the EEG is likely to reflect that, albeit with some tougher conditions, for example for lower wind speed sites at inland sites. The decline of the onshore market will occur this decade, and an increase in offshore wind farms and the rise of a repowering market. This changing market will create ups and downs in the figures, but Germany remains the major wind market in Europe this decade.

The presence of a strong German industry is also important, as is the potential for repowering. Furthermore, Germany has significant offshore plans, the development of which may continue to buoy up its domestic market, even as the onshore market begins to decline over the next decade.

Spain

Spain has been the next most active market after Germany. Now, more than 4% of Spain's electricity is supplied by wind power. As is to be expected, the most energetic sites were largely used in the early days of development and, hence, those presently being developed do not have the same level of resource. Nevertheless, the cost of installation is reducing, and this has allowed the exploitation of less energetic sites to be undertaken with a similar return on capital. Informed commentators consider that it is unlikely that the Spanish government will wish to undermine the market for what is now a considerable Spanish industry by withdrawing the present beneficial tariff system. A notable achievement of the wind industry in Spain is the very high level of Spanish manufacturing content, which is now starting to export elsewhere. A notable event in 2001 was the separation of the market leader in Spain, Gamesa, from its previous joint venture partner, Vestas of Denmark. Gamesa Eolica is now competing on the international market.

Galicia, in the north west led the country in terms of installed capacity in 2002 - installations in this region alone amounted to 341.5 MW. Castilla La Mancha follows, while Aragón, Navarra and Castilla y León are also thriving. Spain's wind power boom has been spurred on by a thriving turbine manufacturing industry. Three of the country's manufacturers, Gamesa, Made and Ecotecnia are among the world's top 10, with Gamesa achieving fourth position in the global league table, according to the latest report from BTM Consult (2003).

The situation in Spain is rather different to that in Germany, since the winds are higher and there is more space available. Commentators expect to see the present level of the market sustained in Spain until it is limited by other concerns, possibly that of grid connection. This limitation is already seen in some large-scale projects currently being developed.

Denmark

Denmark continues to dominate the manufacturing side of the industry worldwide, and has also benefited from a buoyant home market. Denmark is a relatively small country with a high population density and already has a high level of penetration: 20% of Danish electricity consumption is covered by wind power. In 2003, some 243 MW were installed. A broad majority of the Danish Parliament has agreed on a long-term strategy for wind power - "Energy 21" from 1996. The goal is that by 2030, 40-50 percent of the Danish electricity consumption should be covered with power from wind turbines. Denmark is following a strategy on the one hand to expand wind power offshore, and on the other hand to replace some of the smaller, less productive turbines that were installed during the 1980's (machines up to 150 kW). Early Danish development was based on individual turbines sited near their owners and, hence, there were many such turbines scattered across the Danish countryside. A repowering incentive is intended to tidy up this arrangement, and to use bigger turbines to replace a larger number of small ones. It has also allowed the better use of the more energetic sites which, again, were the first to be exploited. The Danish repowering programme has been running for a couple of years, and has been extremely successful not least due to good planning procedures. Three offshore projects have been constructed in 2003. The framework for the future Danish offshore tenders is expected to be published in the beginning of 2004.

Poland

Poland was the first eastern European country to make any real progress in the exploitation of its wind resource (see Table 1.2). The reasons for this pioneering step are three-fold. First, its immediate neighbour, Germany, has been the leading market for some years, and some components for the German and, indeed, the Danish industry are made in Poland. Second, the wind resource is very similar to that of its immediate neighbour, with developments along the North Sea expected. And third, the political and commercial position within Poland is generally favourable for external investors. It would probably be premature to suggest that the level of development could be comparable to that in northern Germany, but commentators expect to see Poland undertaking large developments, continuing to participate in the industry in terms of manufacture and, perhaps, taking a leading role in the development of the infrastructure for some offshore wind farms. The activity associated with the planned offshore wind farm will result in a closer connection with the industry as a whole. Several leading WT manufacturers are considering the possibility of establishing Polish factories. A law exists requiring utilities to connect wind farms to the grid, but there is not yet any well functioning tariff structure set for the purchase of electricity.

Other New Member States

There is no doubt that there will be activity in several new member states, including the Czech Republic, the Slovak Republic and several Baltic states, as well as accession countries such as Romania. Wind energy can be a key tool in the process of cleaning up new member states' electricity production systems which are, at present, heavily reliant on nuclear power and fossil fuels.

Wind energy associations have been established in six new member states: Estonia[2], the Czech Republic, Hungary, Latvia, Poland[3], and Slovakia[4]. The objective of these associations is to establish greater wind capacities in their respective countries.

1.6 Export Market

The export market is extensive and includes both countries falling into the conscience market and those constituting the needs market. The figures in Table 1.7 from BTM Consult are computed on the basis that an export market is one outside the manufacturer's base country. The Table shows the total number of MW by manufacturer exported and installed domestically, as well as the resulting export percentage of their sales. As the report from BTM points out, these figures do not express actual cross border sales as some manufacturers are producing outside their base country and within the "export" market, for example Vestas manufacturing in Italy and GE Wind in Germany (national base of the now defunct Enron Wind bought by General Electric).

The existing export market for the EU-25 as a whole includes Norway, which recently installed two 40 MW wind farms. Key non-European markets include the US, Canada, India, Japan, China and Australia. Other markets set to emerge in the future are discussed in volume 5 chapter 2.

Table 1.7: Export of Manufacturers Worldwide in 2002					
Company	**Country**	**Installed 2002 (MW)**	**Domestic 2002 (MW)**	**Export 2002 (MW)**	**Export Share (%)**
Vestas	Denmark	1,605	266	1,338	83.4
NEG Micon	Denmark	1,033	166	867	83.9
GE Wind	US	638	62	576	90.4
Bonus	Denmark	509	74	435	85.5
Enercon	Germany	1,334	1,103	230	17.3
Nordex	Germany	504	284	220	43.7
Lagerwey	Netherlands	114	4	111	96.9
Mitsubishi	Japan	30	5	25	84
Gamesa	Spain	854	839	15	1.8
Made	Spain	247	234	13	5
Dewind	Germany	86	80	7	7.8
Repower	Germany	223	221	2	0.7
Ecotecnia	Spain	120	120	0	0
Suzlon	India	60	60	0	0
Fuhrlander	Germany	47	47	0	0

Source: BTM Consult (2003).

1.7 Industry Segments

1.7.1 MANUFACTURERS – MEGAWATT SCALE

Nine of the top 10 turbine manufacturing companies are European. Wind energy is an outstanding European success story, with European companies manufacturing more than 90% of the turbines sold worldwide in 2002. In terms of electricity generation, in 2003 WTs generated 2.4% of EU-15 electricity, in Denmark this figure is 20%, while in Germany it is 6%, and in Spain in 2002 the figure stood at 4%.

Table 1.8 shows the top 10 megawatt scale Turbine suppliers in 2002.

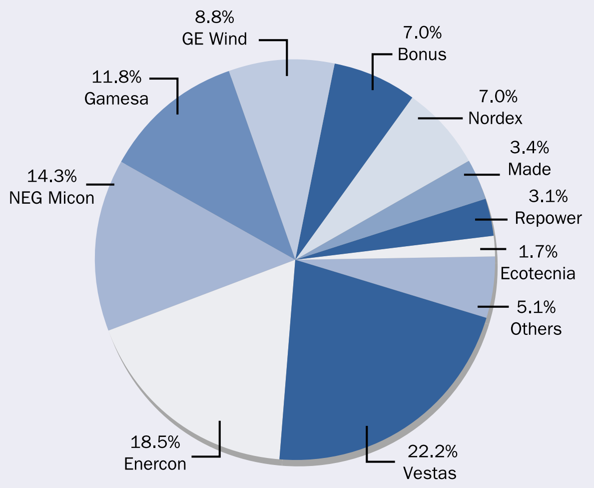
1.7.2 MANUFACTURERS – SMALL TURBINES

Smaller turbines may be installed in small wind farm configurations or as individual units. The vast majority of small WTs are less than 30 kW in capacity, with rotor diameters from 1 m up to around 15 m. Small turbines usually satisfy an individual power demand or property.

Table 1.8: Top 10 MW Scale WTG Suppliers 2002[5]						
Company	**Country**	**Accumulated MW 2001**	**Installed MW 2002**	**Share MW Installed 2002**	**Accumulated MW 2002**	**Share of Total MW Installed %**
Vestas	Denmark	4,983	1,605	22.2%	6,588	20.6%
Enercon	Germany	3,206	1,334	18.5%	4,540	14.2%
NEG Micon	Denmark	4,510	1,033	14.3%	5,543	17.3%
Gamesa	Spain	2,125	854	11.8%	2,979	9.3%
GE Wind	USA	2,288	638	8.8%	2,925	9.1%
Bonus	Denmark	2,306	509	7.0%	2,815	8.8%
Nordex	Germany	1,473	504	7.0%	1,978	6.2%
Made	Spain	783	247	3.4%	1,030	3.2%
Repower	Germany	379	223	3.1%	602	1.9%
Ecotecnia	Spain	362	120	1.7%	482	1.5%
Others		3,677	371	5.1%	4,048	12.6%
Total		**26,092**	**7,436**	**103.00%**	**33,528**	**105.0%**

Source: BTM Consult (2003).

Figure 1.6: Top 10 MW Scale WTG Suppliers 2002



Source: BTM Consult (2003).

Included in this market sector are turbines that may be lowered in high winds, making them safe options for electricity generation in areas prone to storms. They may also be installed without the use of cranes - previously a limiting factor as many developing countries lack access to such hardware.

The small WT sector can be divided into five segments:

- Individual use
- Isolated communities and industries
- Connected to basic grids
- Connected to distribution grids
- Power source for water pumps

1.8 Wind Farm Developers

The Principal European Wind Farm Developers include:

Airtricity	Ireland
Elsam	Denmark
Energia Hidroelectrica de Navarra (EHN)	Spain
Italia Vento Power Corporation (IVPC)	Italy
National Wind Power	UK
Nuon Renewable Energy Projects	The Netherlands
P&T Technology	Germany
Renewable Energy Systems (RES)	UK
SIIF Energies	France
Windkraft Nord (WKN)	Germany

Airtricity is developing wind farms in the Republic of Ireland, Northern Ireland and Scotland. It is also developing the largest offshore wind farm in the world, off the Arklow coast in Ireland.

Elsam's offshore wind farm at Horns Rev comprises 80 wind turbines located 14-20 kilometres off the coast in the North Sea. It is the largest wind farm of its kind and produces enough electricity to supply 150,000 households, year-round.

At the end of 2002, Energia Hidroelectrica de Navarra (EHN) had installed a total of 1,380 MW. This represented approximately 30% of Spain's installed capacity. The group, at the time of writing, has plans for a further 1000 MW to be installed in the next few years. The wind energy production of the EHN group in 2003 was 1,376 GW hours, with a production share in Spain of 14%.

Italia Vento Power Corporation (IVPC) has 10 wind farms in the regions of Foggia and Benevento in Southern Italy, with an installed capacity of approximately 170 MW.

P&T Technology has primarily concentrated on securing wind farm locations under leasehold agreements. In addition, a range of wind farms has been constructed: since 2000, this amounts to approximately 210 MW.

Renewable Energy Systems (RES) has projects in the UK, Europe, North America, the Caribbean and Asia. At the end of 2003 RES had over 790 MW of wind energy capacity built and more than 6,000 MW under development.

SIIF Energies operates the largest wind farm in Portugal (Pinheiro and Cabril), is selecting potential sites in Europe (France, Italy, Spain) and Latin America (Mexico and Brazil), and has interests in the US and Scandinavia.

2 EMPLOYMENT IN THE WIND TURBINE SECTOR

Assumptions

1. The following chapters relate only to employment through manufacture, installation, operation and maintenance of wind turbines in EU countries. This excludes employment not associated with an input to the manufacture, installation and maintenance of turbines.

2. The total direct and indirect employment for the EU is calculated based on the installation of turbines in Europe. Employment in Europe and elsewhere associated with exports of turbines outside the EU is not included.

2.1 Direct and Indirect Employment Effects

The production structures of wind turbine (WT) manufacturers vary considerably. Some, for example, manufacture components, including blades, whereas others design and assemble components purchased from different sub-contractors. Because sub-contractors and component suppliers are a key link in the WT manufacturing process - from basic raw materials to the finished product - their inclusion in this analysis provides a more accurate assessment of the employment effects of the WT manufacturing sector in the EU as a whole. This measure is based on national account statistics (Eurostat, 2000) and input-output methodology.

Employment in WT manufacturing includes both direct as well as indirect employment.

2.2 Direct Employment in Wind Turbine Manufacturing

Within the EU, employment in manufacturing is concentrated in a few countries, with Germany, Denmark and Spain accounting for more than 90%. The WT manufacturing sector's share of total manufacturing employment is, on average, approximately 0.1% for the EU-15, but for countries with a large WT manufacturing sector, this share may be much higher. For example, in Denmark in 2002, the wind industry's share of total manufacturing employment was 1.2%, more than cement and steel production.

Figures for direct employment in Italy and the Netherlands have not been included in this analysis due to lack of data, although some WT manufacturing does take place in both these countries.

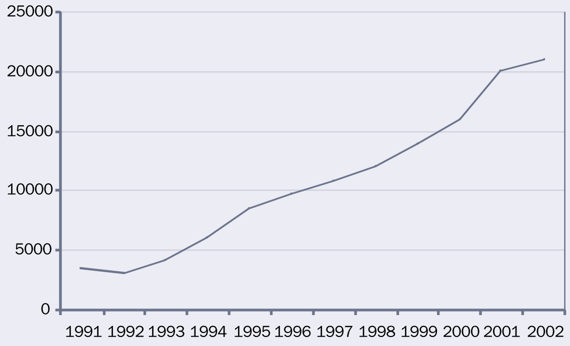
Employment throughout the manufacturing sector has been increasing considerably in the EU since the beginning of the 1990s, as exemplified by the Danish experience.

Table 2.1: Direct Employment in WT Manufacturing in Europe for 2002

Employment within EU	Turbine Manufacturing	Share
Total	30,946	100%
Austria	720	2.3%
Denmark	6,624	21.4%
UK	1,150	3.7%
France	756	2.4%
Germany	10,439	33.7%
Portugal	60	0.2%
Spain	11,197	36.2%

Source: EWEA (2003b)

Figure 2.1: Direct and Indirect Employment in Danish Turbine Manufacture



Source: Danish Wind Industry Association (2002).

Table 2.2: Direct Employment in WT Installation in Europe for 2002

Employment within EU	Turbine Installation
Austria	213
Denmark	1,500
UK	800
France	340
Germany	5,771
Greece	30
Portugal	100
Spain	4,500
Others	1,395
Total	14,649

Source: EWEA (2003b), own calculations.

The Danish Wind Industry Association estimates that direct and indirect employment in WT manufacturing in Denmark increased from around 2,900 in 1991 to 21,000 in 2002, a relative surge not experienced by any other manufacturing industry. It has brought WT manufacturing to the fore as an important sector for the Danish economy, and has contributed to reducing unemployment.

In recent years, the growth of employment in WT manufacturing in Germany and Spain has been higher than in Denmark with nearly a doubling in the numbers employed over the period 2000 to 2002.

2.3 Direct Employment in Wind Turbine Installation

WT installation itself offers significant employment opportunities, although there are differences in employment effect depending on the type of WT, the location and the country of installation. An estimate of the employment impact of WT installation is given in Table 2.2.

The employment effects of WT installation in other EU countries has been calculated, based on the average employment per MW installed. The variation in employment between the countries is shown in Figure 2.2, reflecting the same differences as those seen in the cost variation for installation included in the volume on costs and prices (Volume 2). As with costs, installation seems to require the highest employment figures in the UK.

The UK figures are considerably higher than earlier Danish studies suggest (Krohn, 1998 and Danish Wind Industry Association, 1995 and 1997). In these studies, the global employment figures for installation were found to be in the region of five individuals per MW in 1998. The largest part of installation activity is construction. For this activity, direct employment accounts for around two-thirds of the total employment related to the construction part of installation. The multiplier shows total employment in the EU associated with €1 million of output in the construction sector, including employment in all the sectors supplying inputs to the construction sector. Furthermore, the employment content will be reduced as a result of cost reductions achieved from 1998 to 2002. The employment factor used for countries not included in the Figure is three individuals per MW. This figure is within the range of the averages included in Figure 2.2.

Figure 2.2: Direct Employment Associated with WT Installation in Selected European Countries for 2002

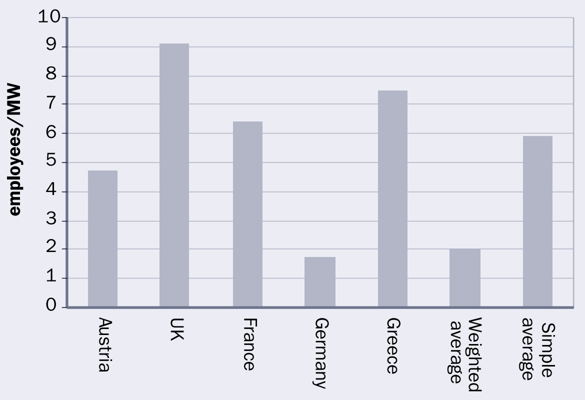


Table 2.3: Direct Employment in Maintenance in Europe for 2002

Employment within EU	Maintenance
Austria	60
Denmark	300
UK	50
France	44
Germany	1,010
Greece	90
Portugal	30
Spain	966
Others	218
Total	2,768

Source: EWEA (2003b), own calculations.

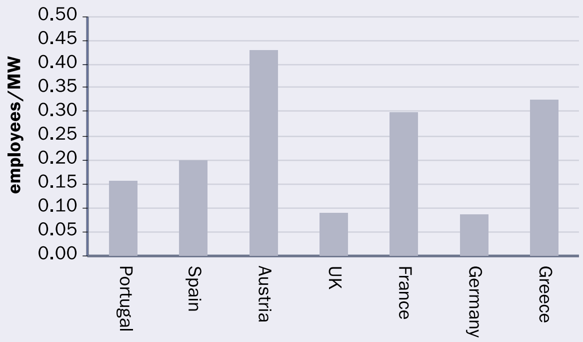
The high employment figure for WT installation in the UK can be partly attributed to the remote siting of wind parks that require quite extensive road construction and grid infrastructure investment.

2.4 Direct Employment in Maintenance Activities

Employment related to operation and maintenance (O&M) will increase considerably as installed capacity increases. However, present employment related to this activity is still small compared to that associated with manufacturing and installation.

The O&M employment calculation for the "other country" group is based on a conservative value of 0.1 person per MW of installed capacity in each of these countries (see Figure 2.3). The fluctuation in employment per MW capacity in Figure 2.3 is quite high. This could partly be caused by the difference in age of installed turbines or could be a function of wind turbine size and wind park grouping.

Figure 2.3: Employment in Maintenance of WTs in Selected European Countries for 2002



It seems from Figure 2.3 that maintenance is more employment-intensive in countries with the least installed capacity, namely Austria, France and Greece. It is noticeable that the UK has low maintenance employment figures compared to other countries, whereas its installation-related employment is the highest in the EU.

2.5 Indirect Employment in Manufacturing

Individual assessments of indirect employment in WT manufacturing have been made by the national associations in Denmark and Germany. For Germany, an indirect employment total of approximately 24,000 people for 2002 has been estimated and, for Denmark, 14,500.

Alternatively, the estimate of indirect employment content within different sectors is based on national account statistics from Eurostat's input-ouput tables (2002).

Input Structure for WT Manufacturing

Firstly, we have to establish the composition of intermediate inputs to the manufacture of WTs. The input structure varies a great deal both for individual manufacturers and for EU member states. The following is based on responses received from the national associations and earlier Danish data:

Table 2.4: Input Structure in the Danish WT Manufacturing Sector

Input structure	Denmark 1995 (%)
Generator	4
Gearbox	12
Rotor	18
Tower	18
Brakes	1.5
Electronic	4
Nacelle (remainder)	42.5
Total	**100**

The contributing sector of the 25 sector level data from the EU input-output table (see Appendix J) have been associated with the production inputs by judgement and based on Danish studies (Krohn, 1998; Danish Wind Industry Association, 1995 and 1997). Only limited data for the input structure of WT manufacturing in different EU countries are available.

Calculations of Indirect Employment in Manufacturing

All calculations in this section are based on installation of turbines in Europe and not the actual turnover figures which were not available. Estimated turnover is based on the investment cost for wind turbines given in Volume 2.

Calculated direct and indirect employment can be compared to direct employment figures reported by national associations. Reported direct employment is aggregated at European level and constitute 60% of the total direct and indirect employment totals found in Table 2.5. This is partly caused by omitting from the calculations the export element of turbine manufacturing activity in Europe.

For 2002, the figure for total European manufacturing and installation employment is closer to 12 individuals per MW installed. The global employment effect is somewhat higher than 12 per MW, because of imports of raw materials, etc. to Europe, which create employment abroad.

The calculations here might understate employment slightly because of the high import quota implicit in the employment multipliers for Europe.

2.6 Indirect Employment in WT Installation

Again, the direct employment reported by the national wind associations varies a great deal per MW installed capacity, and has, in a number of cases, been difficult to estimate. Therefore, a calculation based on the different elements of installation activities has been carried out in order to provide an alternative measure of employment. The different elements of installation activities have been estimated from national association data and other sources (Danish Wind Industry Association, 1997).

The question of divergence in installation cost composition between onshore and offshore wind turbines has not been addressed. If the cost composition is identical for the two locations, the different level of installation costs has no effect on employment per € million of installation costs.

Table 2.5: Calculation of Direct and Indirect Employment for WT Manufacturing

	Input Structure	Contributing Sector	Employment Multiplier 1995	Employment Multiplier 2002	Employment 2002
Generator	4%	Electrical goods	14.22	10.81	1,836
Gearbox	12%	Industrial machinery	13.6	10.33	5,268
Rotor	18%	Rubber and plastic products	14.27	10.84	8,292
Tower	18%	Metal products	19.84	15.08	11,528
Brakes	1.5%	Industrial machinery	13.6	10.33	659
Electronic	4%	Office and data processing machines	10.72	8.15	1,384
Nacelle (remainder)	42.5%	Industrial machinery	13.6	10.33	18,658
Total	**100%**				**47,625**

Source: Eurostat (2003).

In respect of the cost components, each one must be related to the national accounts sector that supplies the service. As construction is the major employment contributor during the installation phase, there will only be minor differences in the employment effect, even if the composition of cost differs between the countries. The aggregate employment effect is, however, also dependent on possible differences in the employment content for each € cost in the different countries. Labour productivity varies among EU member states, especially for non-traded goods such as construction activities and services. This aspect is not included in the calculations that use EU level statistics for labour content in construction.

Calculation of Indirect Employment in Wind Turbine Installation in Europe

1995 EU data for employment as part of the national accounts has been used with calculated multipliers as shown in Appendix J. The multipliers reflect the difference in indirect and direct employment for the various elements of WT installation. For example, construction of the foundations directly and indirectly employed 13.78 individuals per € million in 2002.

The basic assumption behind the calculation is that the composition of installation costs as an EU average did not change from 1995 to 2002. For the employment multiplier, an assumption of a 1.5% increase in labour productivity per year has been made. This implies that the employment multiplier per current cost unit (€) has decreased by around 4% per year.

2.7 Total Direct and Indirect Employment (Manufacturing, Installation and Maintenance in Europe)

The calculations in sections 2.2 - 2.6 provide an estimate for employment in the wind industry in Europe, including all activities such as sub-contractors, etc., associated with the installation activity in the EU.

The figures relating to maintenance employment have been adjusted to include indirect employment as it is estimated that only around 25% of maintenance costs are related to wages. If the manufacturing employment element relating to turbine export had been included, the total employment figures would have been somewhat higher.

Finally, it must be stressed that total employment relating to wind is considerably higher than the 72,000 given for Europe in Table 2.8, not only as a result of production and installation outside the European region, but also due to the indirect employment effects of imported inputs to European WT manufacturing.

Table 2.6 Installation Costs for Wind Turbines 2002

2002	Foundations	Infrastructure Roads, etc.	Electrical Installations, etc., Connections	Grid Reinforcement	Other Installation Costs	Total Installation Cost Excluding Turbine
France	34%	14%	42%	0%	9%	100%
Denmark (1995)	16%	5%	55%	16%	9%	100%
Spain	23%		54%		23%	100%
Portugal	22%	22%	22%	33%	0%	100%

Table 2.7 Calculation of Direct and Indirect Employment for Turbine Installation in Europe for 2002

	Average Share of Costs 2002 (Simple Average)	Contributing Sector Multiplier 1995	Employment Multiplier 2002	Employment 2002	Employment
Foundations	24%	Construction	18.14	13.78	4,706
Infrastructure Roads etc.	14%	Construction	18.14	13.78	2,665
Electrical Installations etc., Connections	40%	Construction/ Industrial machinery	15.87	12.06	6,790
Grid Reinforcement	16%	Construction	18.14	13.78	3,210
Other Installation Costs	6%	Other Market Services	57.61	43.78	3,780
Total	**100%**				**21,150**

Table 2.8: Total Direct and Indirect Employment Related to WT Manufacture in Europe for 1998-2002

	Employment in WT Manufacturing (for Home Market)	Employment in WT Installation	Employment in WT Maintenance	Total Employment
1998	16725	7400	950	25,075
2002	47625	21150	3500	72,275
Growth 1998-2002	185%	185%	268%	188%

Source: Own calculations based on installation of WTs in Europe and Eurostat (2000).

3 EMPLOYMENT PREDICTION AND METHODOLOGY

The history of employment relating to wind energy in the EU is very positive. Employment has been growing rapidly in recent years, and the sector has thus contributed to reducing unemployment in the region.

A broader understanding of employment in the wind energy sector is, however, not straightforward as there is great uncertainty about what this employment covers. Here, we have chosen to use a notion of direct and indirect employment and to separately examine the manufacture of turbines, their installation and employment arising from O&M. The use of different terms and the applied methodology is described in the section below.

The objective has been to examine the magnitude of employment in the sector directly producing WTs and employment associated with the production of inputs to turbine manufacturing. This is not a calculation of the employment created by WT manufacturing, as parts of the workforce in the WT sector today would certainly have been employed in other activities had the wind sector not existed. A similar approach would be to evaluate the net employment effect by deducting the employment associated with alternative electricity producing technologies from the employment associated with wind-based electricity production. This approach would result in a net employment lower than the gross employment associated with wind-based electricity production. The net effect is, however, assumed to be of a considerable size as the employment content is somewhat higher in WT manufacturing and installation.

Some might argue that the input-output approach does not address the wider employment effects of WTs. The argument is based on the fact that the income generated in the sector via wages paid and rents extracted will contribute to demand for other goods that, again, will generate employment. However, such arguments should lead to a consideration of how WT development is being financed. The funds used for WT investment might have been invested in other electricity producing equipment, or even in totally different sectors. These investments would have created jobs, as in the wind sector, and the net effect may have been higher or lower depending on the labour intensity of the activities in which the investment takes place.

One way of addressing these more complex economic linkages is to use macroeconomic general equilibrium models. However, these models very seldom include details of WT manufacturing.

Consequently, this work has focused on employment in activities directly producing WTs and those supporting and supplying to the wind sector. This is, therefore, not an attempt to address the employment created by the WT sector, or to give an overall figure for the *net employment* effect. Instead, this chapter tries to estimate the employment directly or indirectly associated with the WT manufacturing sector.

3.1 Direct and Indirect Employment

Direct employment relates to employment within WT manufacturing companies and sub-contractors whose main activity is supplying WT components etc., for example blade manufacturers. However, companies producing intermediates or components for the WT industry are deemed as providing indirect employment if this is only a minor part of their activities.

There is an important distinction between national and global employment patterns in WT manufacturing. Direct and indirect employment at national level does not include employment associated with imports. For small, open economies, this means that there will be a large difference between national and global employment content. For a larger country, or for the entire EU, the difference between national and global employment content will lessen as trade flows between countries are consolidated, with the effect being included in indirect employment at EU level. If direct and indirect employment effects for EU countries are amalgamated, this figure will be less than the direct and indirect employment effects calculated at the EU level.

3.2 Input-Output Methodology

The calculation of employment effects is based on input-output methodology used by economists. The basic idea is to include the effects from suppliers of inputs (raw materials, etc.) to obtain a better measure of the total effect of the activity in question - in this case, WT manufacturing. Direct employment in manufacturing activities having WT-related products as their main output is seen as the first link in a chain of employment effects. Secondary links are employment associated with the production of components and raw materials used in the production of turbines. These secondary effects continue with employment used for extracting raw materials needed for products that are later used as WT components. The secondary effects diminish the further back in the production chain we go.

The employment used is the number of employees per output unit measured in € million.

Example:

- 1 MW installed capacity at a price of €1 million
- €0.75 million of wind turbine output in 2002 (the rest is installation costs, etc.):

Direct employment + indirect employment:
€0.75 million x 7.94 employees per € million

+ level 1 input: (input from sector "industrial machinery" x industrial machinery employment coefficient per € million output) + input from sector 2 x employment coefficient + input sector 3…

+ level 2 inputs: (input from sector 2 to sector "electric machinery" x employment coefficient in sector 2 per € million output in sector 2…

The calculation could continue indefinitely but, instead, we use the input-output methodology for calculating the inverse matrix and multiplying by the employment coefficients. The employment coefficient is the direct employment per output in the sector.

We have in this case calculated the direct and indirect employment effects from Eurostat's national account statistics for 1995. By using input-output methodology, we can calculate the necessary production increases in 20 sectors of the economy to produce an additional €1 million of output for each of the sectors. These production changes are then multiplied by the direct employment in each of the 20 sectors per € million of output.

To reach 2002 levels of employment multipliers, the calculated figures for 1995 must be projected forward. This can be done individually for the multipliers of all sectors, for example, by using trends in multipliers, or by assuming "productivity" increases. The latter approach was chosen here.

National Versus EU Employment

One important aspect is the distinction between national and global employment effects. If considered nationally, the employment effect would include the direct employment effect, but all the indirect effects would exclude the part of inputs that are being imported. Thus, the smaller the country, the larger the imported share of production inputs. In this way, the indirect employment effect is less for small, open economies. For larger countries or for a group of countries such as the EU, the indirect employment effect is larger as a much higher fraction of the inputs to the sector will originate within the EU. Then, if all the countries added the national (direct and indirect) employment effects, the sum of these would still be less than the direct and indirect effects for the entire EU, as this also includes employment effect of the intra regional trade flows.

Using Input-Output for Projections of Employment

The input-output methodology used for projections of employment allows the use of different assumptions on developments in productivity for different sectors, as well as possible shifts in the composition of inputs from other sectors in the manufacturing of WTs.

The productivity and composition changes are closely linked to assumptions that can be made about the overall cost reduction of WT manufacture. There must be consistency between the assumptions made on cost reductions and on reduction in employment per MW.

3.3 Projection/Prediction Parameters

In order to make consistent projections of employment, there are a number of parameters that have to be addressed. These include activity parameters as well as parameters of technological progress.

Turnover or Indicators for Output in MW

The total turnover for the WT manufacturing sector in the EU can be projected using a variety of methods. One method is to use the installation forecast for MW globally and then add the European market share of manufacturing (see below). Then, there needs to be a conversion from MW installation to turnover in € where 1 MW installed capacity might equal €1 million at today's prices, but the cost reductions should reduce this figure by at least 2% a year (according to experience curve and cumulated installation). These figures are in fixed price terms, which means that the cost of WTs decrease by 2% annually, compared to the price of other goods and services.

However, this also includes an assumption of an unchanged mix of WT categories between those with low investment cost relative to production and those with higher investment cost per MW, but higher production per installed MW. In some cases this can be observed as the larger machines have higher investment cost per MW, but lower investment cost per produced kWh.

Share of Production Taking Place in Europe

As the European market dominates both in terms of annual installed capacity, and in terms of manufacturing activity, the installation has been equal to European production and then some additional production for exports could be added. The share of worldwide production taking place in Europe will in the future be reduced and this development should be addressed by making explicit assumptions. Even though market shares are still high for the European producers, a larger fraction of manufacturing will take place locally at the markets where they are to be installed.

Labour Productivity

Apart from the cost reductions per MW, there will be increases in labour productivity. In the long term, a 2% annual increase in labour productivity (employment per output unit in fixed prices) is a reasonable assumption for the European economies. This also reduces the future employment effect per MW of installed wind capacity.

Input Composition in WT Manufacturing

Finally, the composition of inputs in WT manufacturing can be addressed. In many cases, there will not be the necessary amount of information to separately project this parameter. Thus, only overall cost reductions will be projected and equally distributed on all inputs. This implies a constant technical coefficient in the input-output system.

3.4 Sensitivity – Main Parameters

For all projections, there is a need to identify the most important parameters with respect to their possible variations and their impact on total employment in the sector in Europe.

Wind Turbine Market Growth and Regional Distribution

Future growth of the WT market is the main assumption for employment as it is clearly the driver for production. However, it is associated with some uncertainty since the market size in 15 years' time has a possible variation of a factor of 10.

Productivity/Cost Reductions

The sensitivity of employment projections to assumptions of cost reductions is less obvious than the sensitivity to market projection. In the longer term, assumptions about technological progress and cost reductions are, however, of a considerable accumulated size, and have a large impact on employment forecasts. With experience curves suggesting a 15% cost reduction per electricity output and a 10% cost reduction for turbine costs for every doubling of installed capacity, these cost reductions must partly attribute to reductions in the use of labour input in the production of turbines. Moreover, the installation of turbines will become less labour intense due to productivity growth within all sectors of the economy.

The link between cost reductions and accumulated installation makes the cost reductions sensitive to wind market development, in addition to the uncertainty that relates to the experience curve itself. Cost reductions that reduce labour input in manufacturing are for installed MW and not relative to electricity production. Therefore, it is the 10% cost reduction mentioned above that is the relevant figure here. If market growth corresponds to a doubling of installed capacity in five years, then cost reductions per installed MW will decline by approximately 2% per year. This figure might just as well be 1% or 3% depending on market expansion and the "real" experience curve.

European Production Share

As wind energy develops and becomes more widespread, the European share of total installation will decline. Even though European producers will maintain a high market share, a larger part of their manufacturing activity will take place outside Europe. These foreseeable changes are very difficult to project, depending as they do on both market forces/demand and strategic developments/reorganisation of the WT manufacturing sector. The most likely development is that a larger proportion of European manufacturers' activities will take place outside Europe. The impact will be to reduce the growth of European employment within the WT manufacturing sector. European market share and location of production facilities is thus an important parameter for sensitivity analyses.

If long term projections are made, it is unclear how much European companies' manufacturing will take place in the country of installation.

4 SCENARIOS FOR EMPLOYMENT IN THE WIND TURBINE SECTOR

Based on scenarios for the future development of wind in Europe and globally, it is possible to identify corresponding employment scenarios.

4.1 Projection of Employment based on Wind Energy Installation in Europe and Globally

Based on assumptions for the parameters, etc. described in chapter 3 above, it is possible to develop a scenario for European employment in the wind sector. Here, a very simple scenario with the majority of composition parameters remaining unchanged will be presented.

Some basic assumptions are identical to those in *Wind Force 12* (EWEA, 2003c). The scenario projects European and global installation activity in 2020 as follows:

- Annual global installation will increase to approximately 150,000 MW in 2020, of which 15,000 will be in Europe.
- The European share of global WT manufacturing is assumed to decline to 25% by 2020.
- Turbine manufacturing input is assumed to have constant composition in Europe.
- Installation activity is assumed to have constant composition (no change from increased offshore expansion).
- Cost reduction is assumed at a rate of 2% annually.

An annual 2% growth in labour productivity is assumed for both manufacture and installation.

In this scenario, where a great deal of the employment increase will come from expansion of markets outside Europe, it will be mainly increases in manufacturing employment that are responsible for overall employment growth.

Manufacturing Employment

Global installation of 150,000 MW in 2020 and a European share of 25%, including those for the European market would require:

€1 million per MW in 2002 reduced by 1/1.02^18. This equals a total investment cost in 2020 of €26,256 million, of which 75% will consist of WTs produced in Europe (installation will not generate employment in Europe apart from that included below). WT manufacturing in Europe will be €19,692 million.

The employment multiplier for 2002 of 11.21 employees per € million of activity has to be reduced by the general productivity increase of 2% annually resulting in a multiplier for 2020 of 7.79 person per € million.

The resulting employment in WT manufacturing for the year 2020 will therefore be 7.79 x 19,692 = 153,400 employees.

Installation Employment

In 2020, 15,000 MW will be installed in Europe. Installation employment from 2002 has to be adjusted for the general increase in labour productivity and the reduced employment input that has contributed to lowering the total costs of installing WTs. This means that the cost reduction is assumed to be at a similar level for both manufacturing and installation.

Following on from this, the employment multiplier for installation in 2002 has to be adjusted. We assume that the composition between the components of installation activity is unchanged from Table 2.7, and that the employment multipliers for the contributing sectors all follow the same trend with a 2% annual reduction.

15,000 MW installed in Europe at a total cost of €1 million per MW in 2002 reduced by 1/1.02^18 equals a total investment cost in 2020 of €10,502 million.

Installation cost constitutes an unchanged share of 25% of this amount and the employment multiplier for installation is 14.89 in 2002 reduced with the annual productivity increase of 2% resulting in a multiplier for 2020 of 10.42 per € million of installation activity.

Direct and indirect employment in European WT installation for 2020 would therefore be 27,400.

Maintenance

By 2020, an accumulated 230,000 MW will have been installed in Europe. With the conservative value of 0.1 employees per MW in 2002, this would mean a considerable increase in employment for maintenance. The employment content also has to be adjusted for the general productivity increase of 2% annually. In maintenance, only the general productivity increase is assumed and there are no additional cost reductions.

With these assumptions, employment in O&M in Europe in 2020 would be 16,100.

Employment Scenario Results

For the scenario described above, employment in 2020 has increased considerably from that in 2002.

Total employment related to manufacturing, installation and O&M in Europe will be 196,900 in 2020 for this scenario, based on a considerable expansion of wind energy.

This is more than a doubling of today's employment in the European sector, but it is not the full employment story. However, it must be stressed that employment growth will be even higher in the regions outside Europe where installation growth is also highest. The employment effect in these countries will probably be even higher than in Europe due to lower productivity and wages.

European Scenario for Employment up to 2010

To illustrate the employment effects of wind turbine installation in Europe another scenario is included. Calculations are performed according to the above scenario (see Table 4.1). This scenario includes only employment effects in Europe from installation activity in Europe. The European WTs are thus assumed to be entirely manufactured in Europe. Furthermore the employment effect from export of European produced WTs is excluded.

Table 4.1 illustrates that even with moderate growth in WT installation, employment will be stable around the present level if export activity is not included. The reduction in employment associated with manufacture of WTs is balanced by the increase in employment associated with maintaining the already installed capacity.

Table 4.1: Direct and Indirect Employment Associated with European WT Installation

	2003	2004	2005	2006	2007	2008	2009	2010
Europe Cumulative Installed MW	29,116	35,216	41,516	47,966	54,566	61,316	68,216	75,216
Europe Annual Installation	5,900	6,100	6,300	6,450	6,600	6,750	6,900	7,000
Employment Manufacturing	45,300	45,017	44,687	43,975	43,250	42,515	41,772	40,732
Employment Installation	20,520	20,799	21,060	21,139	21,206	21,263	21,309	21,194
Employment Maintenance	2,854	3,385	3,912	4,431	4,942	5,445	5,939	6,420
Total	**68,674**	**69,201**	**69,659**	**69,545**	**69,398**	**69,223**	**69,020**	**68,346**

5 DEVELOPMENT & INNOVATION

Development and innovation have contributed to the fast progress of the WT manufacturing sector. One of the reasons for this is the ability of the sector to adapt technology from other sectors.

Technology transfer from the WT industry to other sectors has been more modest. One example, however, from Denmark, is the expansion of small-scale machine manufacturers to larger companies, based on their activities in the wind industry. These small companies, often characterised as “smiths”, have expanded their expertise with the technology developed for the wind sector. As these companies have often been located outside traditional business centres, this development has been seen as very positive trend to broader industrial development.

Along with the manufacturing of WTs, a range of specialised service suppliers for transport, installation, maintenance and insurance has developed.

One promising technology cross-over area is in aerodynamics where the use of new materials and the cost reductions associated with them has transferred from the aeronautic industry to WT blade manufacturers.

An EU-funded research project (Neij *et al.*, 2003) has analysed the possibility of using experience curve forecasts from the wind energy sector to predict possible developments within other renewable energy sectors. This is based on the idea that some of the technological innovations found for wind energy technology can be applied to other fields.

The turbines manufactured from the mid 1980s until the late 1990s were mainly constructed using standard components, the only major exception being the blades, which were designed and constructed for specific turbine use. But in the late 1990s the turbines had grown so large in size and were being manufactured in such large numbers, that special components started being designed and manufactured for turbine use only (see below).

Ball Bearings

As mentioned above, components such as ball bearings used for WTs were, until recently, mainly standard products. But with the development of 2-3 MW turbines it became necessary to produce special large ball bearings, designed to the specific requirements of WTs.

Another niche area in this industry is the bearings that support pitch-regulated blades. Because of the very small rotation angle of these WT components compared to their use in other kinds of machinery, the loads on these bearings are very high. To limit wear, specialised bearings are being developed that perform well within small rotation angles.

Blades

In turbine up-scaling, the weight of components such as blades, nacelles and towers is of the utmost importance. To keep loads down it is necessary to keep weight down. This is especially important for the blades; the longer the blades, the more the need for lightweight materials. Initially, blades were manufactured using glass fibre materials with weight reduced mainly through design improvements. But to manufacture blades longer than 40-50 m for 2-3 MW machines requires the use of reinforced composites. One of the most common new blade materials is glass fibre reinforced with carbon fibre, but hybrid versions using glass fibres and wood are also being used. Finally, a number of new technologies are being introduced to blade production.

Gearboxes

The gearboxes used in turbines were also, until recently, standard components. But the large numbers of turbines produced nowadays, and the need for lighter materials to reduce the weight of the nacelle and thus the loads on larger turbines have driven production of lighter and more compact gearboxes designed specifically for WTs.

Installations of Offshore Turbines

Installation of offshore turbines presents a fresh challenge and demands a new approach. Specially designed and constructed vessels have been developed that can carry two or more turbines from the nearest harbour to the offshore site and erect the turbine towers, nacelles and rotors. These vessels are continuously being improved to carry more turbine components, thus reducing the installation time.

These examples are all closely related to the WT sector itself; technology cross-over to other sectors should not be neglected, and deserves more research activity.

Endnotes

1 A form of financial support mechanisms instigated by some national governments to assist in the development of renewable energy technologies.

2 See www.tuuleenergia.ee (for further information).

3 See www.visventi.org.pl (for further information).

4 See www.save.apis.sk (for further information).

5 It should be noted that BTM Consult and EWEA figures of installed capacity vary slightly due to different methodologies in their compilation.