EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

Pure Power

Wind Energy Scenarios up to 2030

By the European Wind Energy Association

Text and analysis: Arthouros Zervos and Christian Kjaer
Project Coordinator: Sarah Clifford
Design: www.inextremis.be

Pure Power®

Wind Energy Scenarios up to 2030

By the European Wind Energy Association

MARCH 2008

Table of Contents

Redefining the global energy game

The world is facing an energy and climate crisis.

Globally, the energy sector emits 26 billion tonnes of CO_2 each year and electricity production alone accounts for 41% of emissions. The International Energy Agency expects CO_2 emissions in 2030 to have increased by 55% to reach more than 40 billion tonnes of CO_2. The share of emissions coming from electricity production will increase to 44% in 2030, reaching 18 billion tonnes of CO_2[1].

Europe is going to be importing a growing share of its energy at unpredictable but most likely higher prices, from unstable regions, in ever-fiercer competition with the rest of the world and at staggering environmental cost.

Spare electricity generating capacity is at a historic low. Europe has to invest in new capacity to replace ageing plants and meet future demand. In the period 2005-2030, the EU needs to install 862 GW of new electricity generating capacity. 427 GW of generating capacity will be retired in the EU and an additional 435 GW will be needed to satisfy the growing demand for power. The required capacity exceeds the total capacity operating in Europe (723 GW).

Satisfying our energy needs over the coming decades will be a big challenge. For a region that currently imports 56%[2] of its energy – and is on track to reach 70% in the next 20 to 30 years[3] – the challenge is big. Our own fossil fuel resources are running out fast, fuel prices are increasing and the environment is suffering as result of our current energy supply structure. In 2030 the EU will be importing 84% of its gas, 59% of its coal and 94% of its oil.

Every day, European companies and consumers are paying the price of external control of their energy supply. Europe's annual gas import bill alone is already €50 billion higher today than when the oil price was $20 per barrel a few years ago.

Europe must seize the opportunity created by the large turnover in electricity generating capacity that will take place over the next two decades to secure a truly indigenous clean energy supply based on renewable sources of energy – the only resources that will be left in abundance in the near future. Combined with more ambitious energy efficiency measures, renewable heating and biofuels, it is the only way for Europe to turn the looming energy and climate crisis into an opportunity to benefit the welfare of our citizens.

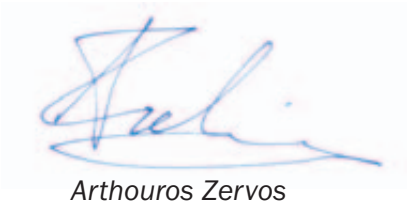
Europe simply does not have the fossil fuel resources to emerge as a winner in the battle for the world's remaining and diminishing fuel supplies. But it does have enormously rich renewable energy resources, and European industries are world leaders at turning those resources into energy.

1 IEA World Energy Outlook 2006
2 Eurostat, News Release 126/2006 21 September 2006
3 European Commission, A European Strategy for Sustainable, Competitive and Secure Energy, 8 March 2006

There is an opportunity for Europe to take the lead in redefining the rules of the future energy game. It is a game that will be won not by the few countries that control the diminishing fossil fuel resources, but by the regions of the world that understand how to develop, utilise and export technology that can convert their natural renewable resources into energy.

The economic future of Europe can be planned on the basis of known and predictable energy costs, derived from an indigenous wind energy source free from all the security-related, political, economic and environmental disadvantages associated with the current energy supply structure.

This report looks at what the change towards large-scale wind energy will mean in concrete terms. It presents new scenarios for wind energy up to 2030, examining the effects they would have on electricity, greenhouse gas emissions and the EU economy. By assessing potential impacts, Europe can take informed decisions and go into the future with its eyes open, certain of the real advantages that seizing the wind energy opportunity today will bring the citizens of tomorrow.



Arthouros Zervos
EWEA President

Christian Kjaer
EWEA Chief Executive Officer

Executive Summary: A new scenario for wind energy

Over the last eight years, only new gas capacity has exceeded new wind power capacity in the EU. Since 2000, 30% of all installed electricity generating capacity in the EU has been wind power. While wind energy today meets 3.7% of EU's electricity demand, the technology is already the second largest contributor to economic activity and employment in the area of power plant manufacturing.

In 2003, the European Wind Energy Association set the target of 75,000 MW installed in the EU-15 by 2010 and 180,000 MW by 2020[4]. Back then, it was expected that 54,350 MW would be operating by the end of 2006. The actual figure for end 2007 was 55,860 MW in EU-15.

In this updated scenario, the term "target" has been changed for 2010 to "prediction" in order to reflect that 2010 is only three years into the future. Consequently there is more certainty that the 2010 projections will materialise than in the previous scenario in 2003. This scenario will continue to refer to the 2020 and 2030 projections as "targets" given the substantially higher uncertainty at that time scale.

The new 2010 prediction for wind energy in Europe has been updated to include the 12 new Member States, which are expected to add 2,050 MW to the EU total by 2010, while the EU-15 will have 4% more capacity installed by 2010 (77,950 MW), compared to the previous target of 75,000 MW. In total, EWEA believes that 80,000 MW of wind power will be operating in the EU-27 by the end of the decade. Offshore wind energy is expected to reach 3,500 MW (4% of total capacity) in 2010 compared to 1,080 (2% of total capacity) by the end of 2006.

The European Commission's 1997 White Paper on Renewable Sources of Energy set a target for 40,000 MW of wind power to be installed in the EU by 2010. That target was reached in 2005, five years ahead of schedule. The overall White Paper target included an increase in electricity production from renewable energy sources of 338 TWh between 1995 and 2010. As EWEA's analysis shows, wind power is expected to produce 177 TWh in 2010, thereby meeting 52% of the overall White Paper target.

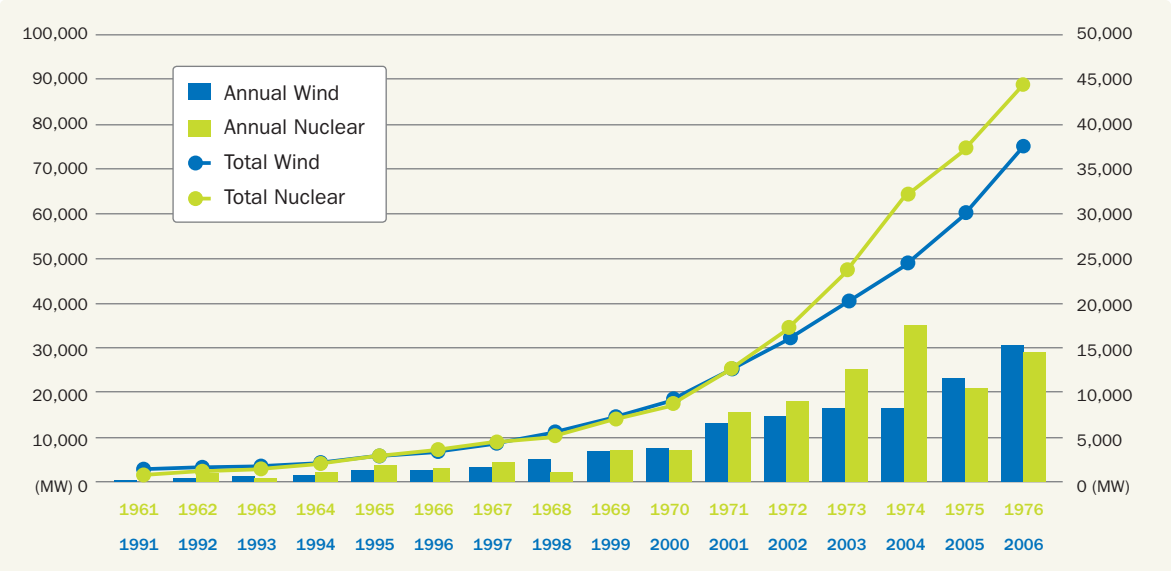
EWEA maintains the target it set in 2003 of 180,000 MW by 2020. In addition, the analysis has been expanded to include a target for the year 2030 of 300,000 MW, 40% of which is expected to be offshore wind power. There is, however substantial uncertainty regarding the 2020 and 2030 targets and much depends on the timing and scale of the offshore segment of the business.

Wind power has experienced dramatic growth over the last years, and in 2007 there are five EU countries – Denmark, Spain, Portugal, Ireland and Germany – which have more than 5% of their electricity demand covered by wind energy. The development of wind power is not different from the initial development stages of other power sources. Fig 0.1 shows the global development of wind energy (1961-1976) compared with nuclear power (1991-2006).

The strong development of wind power to date can continue in the coming years as long as the clear commitment of the European Union and its Member States to wind power development continues to strengthen, and as long as this support is translated into the construction of wind farms. It is vital for the future development of wind power in Europe that the European Parliament and the Council swiftly adopt the new EU Renewables Energy Directive (tabled by the European Commission on 23 January 2008).

4 EWEA Briefing: Wind Power Targets for Europe: 75,000 MW by 2010, October 2003

FIG 0.1: **16 years of global wind energy development (1991-2006) compared to the first 16 years of nuclear development (1961-1976)**



The European Parliament has for many years been calling for a mandatory 25% target for renewable energy by 2020. The gradual implementation of the 2001 Renewable Electricity Directive in the Member States, as well as the European Council's unanimous decision for a 20% share of renewable energy in the EU by 2020 at its Spring Summit in March 2007, are all steps in the right direction and indicators of increased political commitment. The share of renewable energy needs to go up from 8.5% in 2005 to 20% in 2020, which means that more than one third of the EU's electricity will need to come from renewables, up from 15%. It is already clear that wind energy will be the largest contributor to the increase. The 20% target, combined with the dramatic increases in fossil fuel prices experienced since our 2003 analysis indicate that the long-term future for wind power remains promising and that Europe could achieve 300 GW of wind power capacity by 2030 if regulatory uncertainty can be minimised.

The European Commission[5] expects a 73% decline in EU oil production between 2000 and 2030. Gas production will fall by 59% and coal by 41%. By 2030, the EU will be importing 94% of its oil, 84% of its gas and 59% of its coal.

Europe can go a long way towards an energy supply that is superior to the business-as-usual scenario, offering greater energy independence, lower energy costs, reduced fuel price risk, improved competitiveness and more technology exports. Over the coming 25 years, wind energy will play a major role in that development.

The following tables show the wind industry's targets for the EU-27 in 2007, 2010, 2020 and 2030 in terms of installed capacity. They also demonstrate what this means in terms of electricity supply, CO_2 savings, avoided fuel costs and investments in wind energy machinery.

5 European Energy and Transport; Trends to 2030 – update 2005: European Commission May 2006

Wind industry targets for the EU in 2007, 2010, 2020 and 2030

Summary of the wind energy market in the EU-27 in 2007

- 56 GW installed capacity, including 1.08 GW offshore
- Annual installations of 8.5 GW, including 0.2 GW offshore
- Electricity production of 119 TWh, including 4 TWh offshore
- Meeting 3.7% of total EU electricity demand
- 40.3% of the annual new electricity generating capacity
- 55% of annual net increase in installed electricity generating capacity
- 7.3% of total installed electricity generating capacity
- Providing power equivalent to the needs of 30 million average EU households (15% of EU households)
- Avoiding 91 Mt of CO_2 – equivalent to taking 46 million cars off the road (21% of the EU car fleet) and equal to 26% of the EU-15's Kyoto obligation
- Annual avoided fuel cost of €3.9 billion
- Annual avoided CO_2 costs of approximately €2 billion
- Annual investments in wind turbines of €11.3 bn
- Total life-time avoided fuel costs of wind power capacity installed in 2007 of €16 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2007 of €6.6 billion (assuming CO_2 price of €25/t)
- European manufacturers have a 75% share of the global market for wind turbines (2006)[1]

1 BTM World Market Update 2006, March 2007

Summary of the wind industry prediction for the EU-27 in 2010

- 80 GW installed capacity, including 3.5 GW offshore
- Annual installations of 8.2 GW, including 1.3 GW offshore
- Electricity production of 177 TWh, including 13 TWh offshore
- Meeting between 5% and 5.2% of total EU electricity demand (depending on 2010 demand)
- 9.9% of total installed electricity generating capacity
- 39% of total new electricity generating capacity installed (2005-2010)
- Providing power equivalent to the needs of 43 million average EU households (21% of EU households)
- Avoiding 133 Mt of CO_2 – equivalent to taking 65 million cars off the road (30% of the EU car fleet in 2004) and equal to 38% of the EU-15's Kyoto obligation
- Annual avoided fuel cost of €8.3 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Annual avoided CO_2 costs of €3.3 billion (€25/t CO_2)
- Annual investments in wind power capacity of €11 billion
- Total wind power investments of €31 billion (2008-2010)
- Total life-time avoided fuel costs of wind power capacity installed in 2008-2010 of €51 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2008-2010 of €21 billion (assuming €25/t CO_2)

Summary of the wind industry target for the EU-27 in 2020

- 180 GW installed capacity, including 35 GW offshore
- Annual installations of 16.8 GW, including 6.8 GW offshore
- Electricity production of 477 TWh, including 133 TWh offshore
- Meeting between 11.6% and 14.3% of total EU electricity demand (depending on 2020 demand).
- 18.1% of total installed electricity generating capacity in the EU
- 32% of total new electricity generating capacity installed (2011-2020)
- Providing power equivalent to the needs of 107 million average EU households (49% of EU households)
- Avoiding 328 Mt of CO_2 – equivalent to taking 165 million cars off the road (76% of the EU 2004 car fleet) and equal to 44% of the EU's GHG reduction target (20%)
- Annual avoided fuel cost of €20.5 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Annual avoided CO_2 costs of €8.2 billion (€25/t CO_2)
- Annual investments in wind power capacity of €16.9 billion
- Total wind power investments of €120 billion (2011-2020)
- Total life-time avoided fuel costs of wind power capacity installed in 2011-2020 of €277 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2011-2020 of €114 billion (assuming €25/t CO_2)

Summary of the wind industry target in EU-27 in 2030

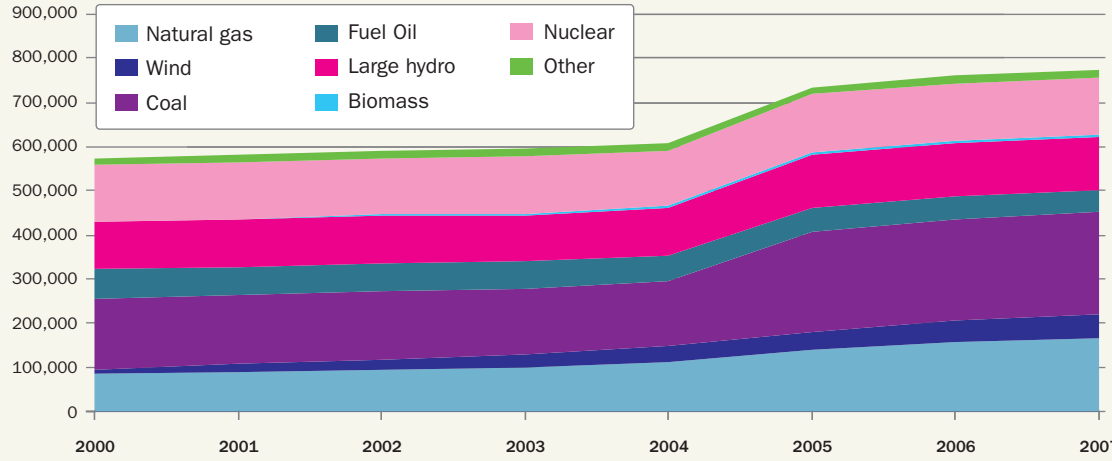
- 300 GW installed capacity, including 120 GW offshore
- Annual installations of 19.5 GW, including 9.6 GW offshore
- Electricity production of 935 TWh, including 469 TWh offshore
- Meeting between 20.8% and 28.2% of total EU electricity demand (depending on 2020 demand).
- 25.5% of total installed electricity generating capacity in the EU
- 46% of total new electricity generating capacity installed (2021-2030)
- Providing power equivalent to the needs of 195 million average EU households (84% of EU households)
- Avoiding 575 Mt of CO_2 – equivalent to taking 285 million cars off the road (132% of the EU 2004 car fleet)
- Annual avoided fuel cost of €34.6 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Annual avoided CO_2 costs of €14.4 billion (€25/t CO_2)
- Annual investments in wind power capacity of €19.4 billion
- Total wind power investments of €187 billion (2021-2030)
- Total life-time avoided fuel costs of wind power capacity installed in 2021-2030 of €455 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2021-2030 of €187 billion (assuming €25/t CO_2)

1. The EU energy mix

Between 2000 and 2007 total EU power capacity increased by 200 GW to reach 775 GW by the end of 2007. The most notable change in the mix of capacity is the near doubling of gas capacity to 164 GW. Wind energy more than quadrupled from 13 GW to 57 GW[6].

The addition of ten new Member States in May 2004 put another 112 GW into the EU generation mix in 2005, including 80 GW of coal, 12 GW of large hydro, 12 GW of natural gas, 6.5 GW of nuclear and 186 MW of wind power.

FIG 1.1: **Installed power capacity EU 2000-2007 (in MW)**



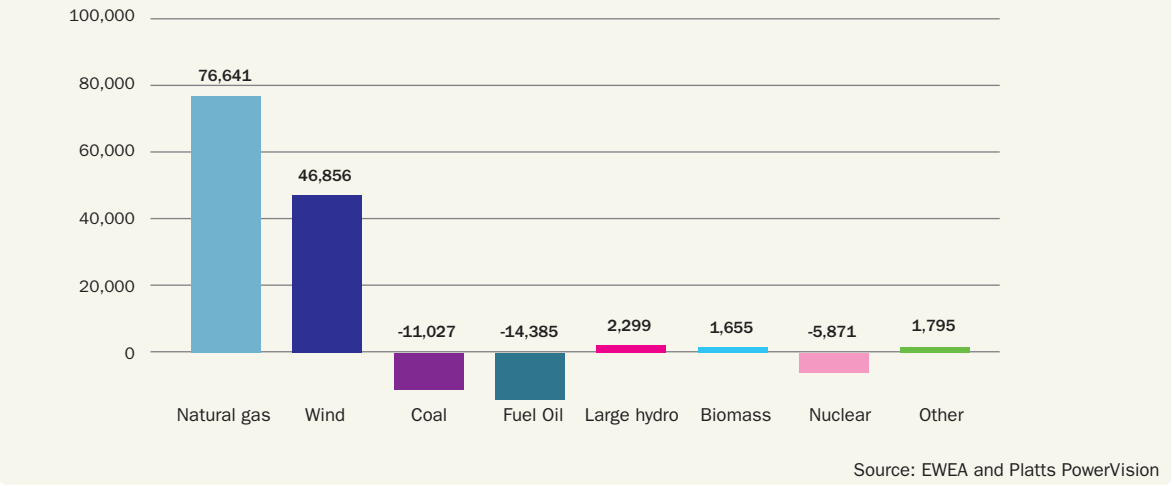
Source: EWEA and Platts PowerVision

Changes in net installed capacity among the various electricity generating technologies are shown in Figure 1.1. The figures include the EU-10 from 2005 and EU-12 from 2007. The growth of natural gas and wind power has happened at the expense of fuel oil, coal and, to a lesser extent, nuclear power. In 2007, 21.2 GW of new capacity was installed in the EU-27 of which 10.7 GW was gas (50%) and 8.6 GW was wind power (40%).

Gas and wind power also lead the field if decommissioning of old capacity is taken into account. Net installation of power capacity in the EU totalled 98 GW between 2000 and 2007. Gas and wind power accounted for 77 GW and 47 GW respectively while more oil (-14 GW net), coal (-11 GW net) and nuclear (-6 GW net) capacity has been removed than installed since 2000.

6 Source: Platts PowerVision and EWEA, January 2008.

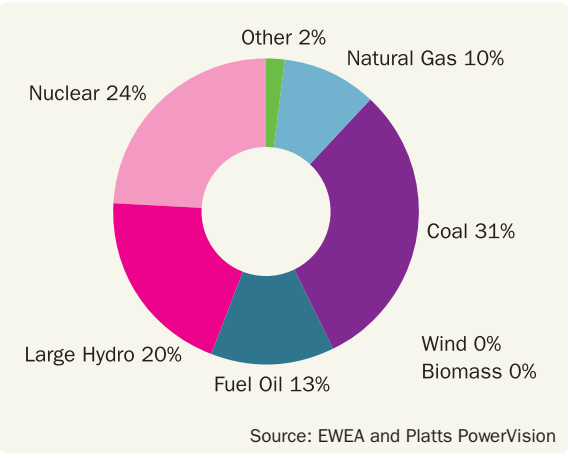
FIG 1.2: **Net increase/decrease in power capacity EU 2000-2007 (in MW)**



Source: EWEA and Platts PowerVision

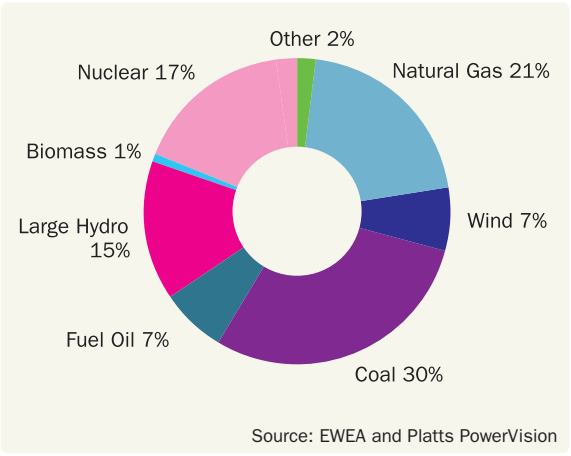
The share of total EU capacity from natural gas has more than doubled since 1995 to reach 21%. Coal's share is unchanged while oil, large hydro and nuclear have all decreased their share. Wind energy's share has increased from 0% in 1995 to 7% in 2007.

FIG 1.3: **EU Energy mix 1995 (Total 532 GW)**



Source: EWEA and Platts PowerVision

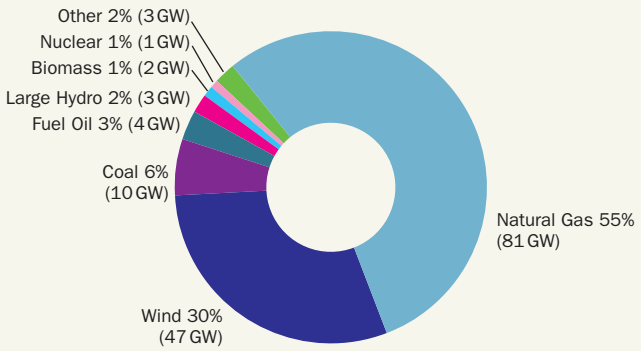
FIG 1.4: **EU Energy mix end 2007 (Total 775 GW)**



Source: EWEA and Platts PowerVision

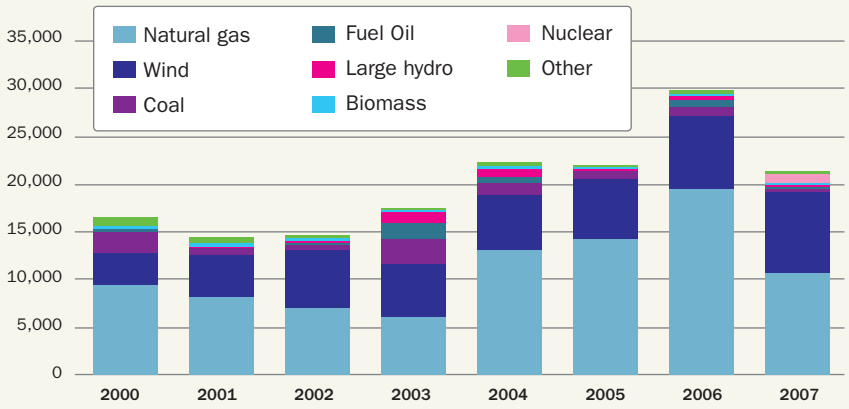
Wind energy increased its share of total capacity in the EU to 7% in 2007, and has a significant share of new generation capacity. 30% of all power capacity installed since 2000 has been wind power, making it the second largest contributor to installation of EU capacity over the last eight years after natural gas (55%). 6% of all new capacity over the eight year period was coal, 3% fuel oil, 2% large hydro and nuclear and biomass come in at 1% each. So while wind energy today meets 3.7% of EU electricity demand, the technology is already the second largest contributor to economic activity and employment in power plant manufacturing.

FIG 1.5: **New power capacity EU 2000-2007**



Source: EWEA and Platts PowerVision

FIG 1.6: **New power capacity EU 2000-2007 (in MW)**

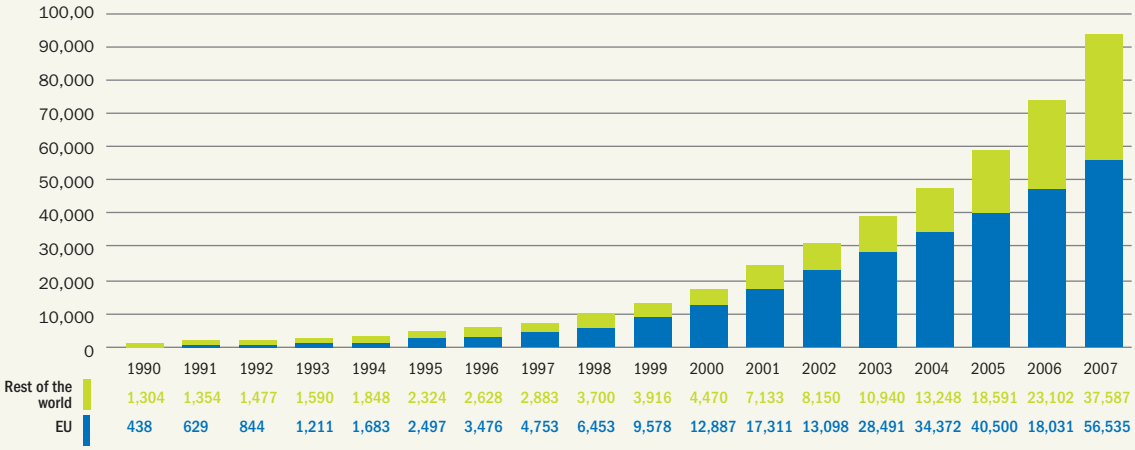


Source: EWEA and Platts PowerVision

2. Wind power – current status

20,073 MW of wind power capacity was installed globally during 2007 to reach a total of 94,122 MW by the end of the year. The global market for wind turbines increased by 31% in 2007, following growth of 33% and 41% in 2006 and 2007 respectively[7].

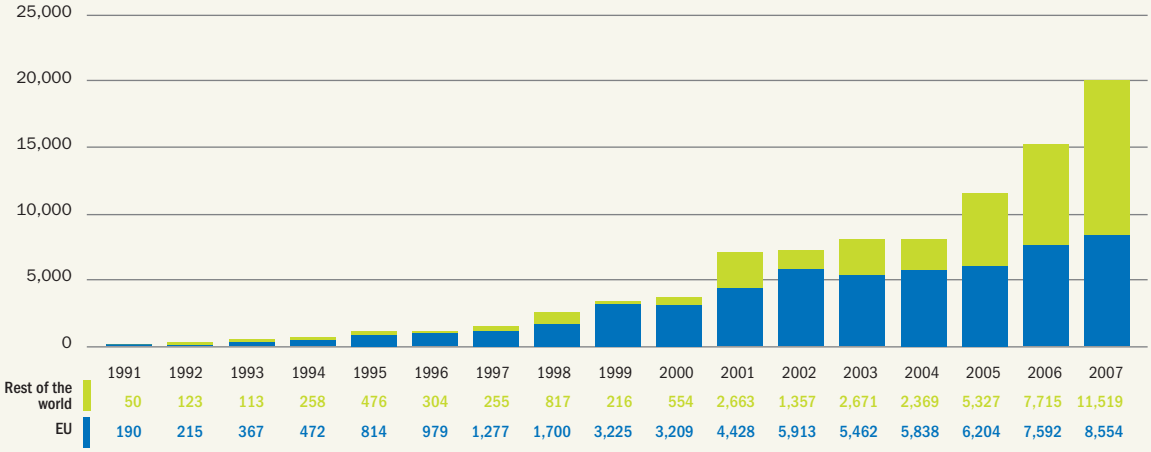
FIG 2.1: **Global cumulative wind power capacity 1990-2007 (in MW)**



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Rest of the world	1,304	1,354	1,477	1,590	1,848	2,324	2,628	2,883	3,700	3,916	4,470	7,133	8,150	10,940	13,248	18,591	23,102	37,587
EU	438	629	844	1,211	1,683	2,497	3,476	4,753	6,453	9,578	12,887	17,311	13,098	28,491	34,372	40,500	18,031	56,535

Source: GWEC/EWEA

FIG 2.2: **Global annual wind power capacity 1991-2007 (in MW)**



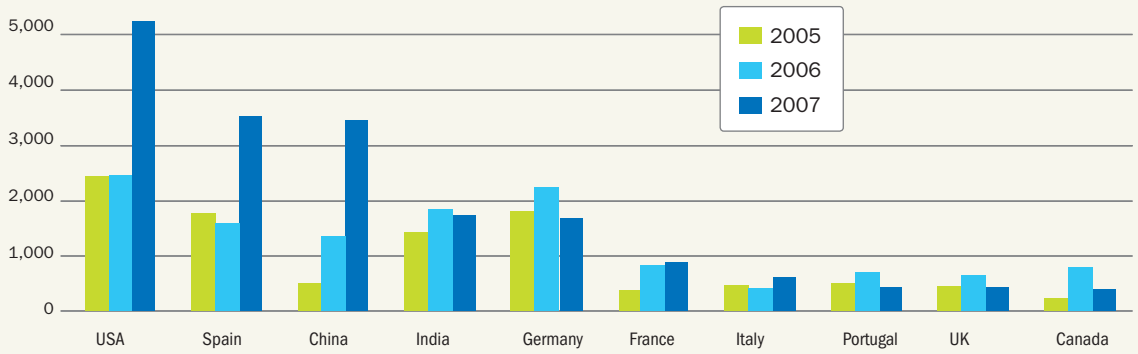
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Rest of the world	50	123	113	258	476	304	255	817	216	554	2,663	1,357	2,671	2,369	5,327	7,715	11,519
EU	190	215	367	472	814	979	1,277	1,700	3,225	3,209	4,428	5,913	5,462	5,838	6,204	7,592	8,554

Source: GWEC/EWEA

7 Global Wind Energy Council (GWEC); Global Wind 2006 Report

The graph below shows the top ten markets worldwide and the wind energy capacity installed annually in 2005, 2006 and 2007, in descending order of the wind capacity installed in 2007 in each country.

FIG 2.3: **Top 10 annual markets in the world (MW)**



Source: EWEA/GWEC

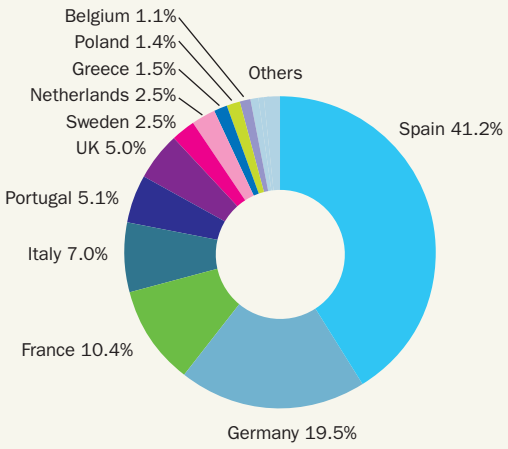
The European Commission's 1997 White Paper target of 40,000 MW wind power capacity by 2010 in the EU was reached in 2005, five years ahead of time.

By the end of 2007, there was 56,535 MW of wind power capacity installed in the EU-27, of which 55,860 MW was in the EU-15. EWEA's previous scenario, drawn up in October 2003, expected 54,350 MW to be installed in the EU-15 by the end of 2007. Thus the total capacity was underestimated by 1,510 MW over the five year period. In 2003 EWEA expected total annual installations in 2007 to be 6,600 MW, whereas the actual market was significantly higher at 8,291 MW in the EU-15 (8,554 MW in the EU-27).

In the EU, installed wind power capacity has increased by an average of 25% annually over the past eleven years, from 4,753 MW in 1997 to 56,535 MW in 2007. In terms of annual installations, the EU market for wind turbines has grown by 19% annually, from 1,277 MW in 1997 to 8,554 MW in 2007.

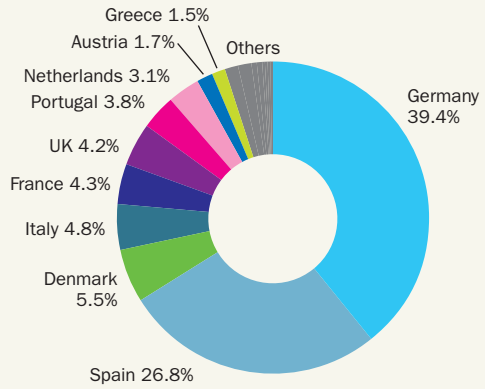
In 2007, Spain (3,522 MW) was by far the largest market for wind turbines, followed by Germany (1,667 MW), France (888 MW) and Italy (603 MW). Eight countries – Germany, Spain, Denmark, Italy, France, the UK, Portugal, and the Netherlands – now have more than 1,000 MW installed. Germany, Spain and Denmark – the three pioneering countries of wind power – are home to 72% of the EU's installed wind power capacity. That share is expected to decrease to 62% of installed capacity in 2010.

FIG 2.4: **2007 Member State market shares for new capacity**



Others			
Czech Republic	0.7%	Cyprus	0.0%
Ireland	0.7%	Denmark	0.0%
Estonia	0.3%	Hungary	0.0%
Finland	0.3%	Latvia	0.0%
Bulgaria	0.4%	Luxembourg	0.0%
Austria	0.2%	Malta	0.0%
Lithuania	0.1%	Slovakia	0.0%
Romania	0.1%	Slovenia	0.0%

FIG 2.5: **End 2007 Member State market shares for total capacity**



Others			
Ireland	1.4%	Lithuania	0.1%
Sweden	1.4%	Luxembourg	0.1%
Belgium	0.5%	Latvia	0.0%
Poland	0.5%	Romania	0.0%
Czech Republic	0.2%	Slovakia	0.0%
Finland	0.2%	Cyprus	0.0%
Bulgaria	0.1%	Malta	0.0%
Hungary	0.1%	Slovenia	0.0%
Estonia	0.1%		

Cumulative installations of wind power in the EU (MW)

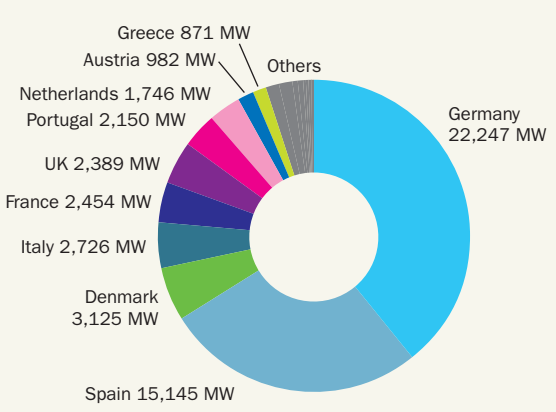
Country	2000	2001	2002	2003	2004	2005	2006	2007	2010 (est)
Austria	77	94	140	415	606	819	965	982	1,200
Belgium	13	32	35	68	96	167	194	287	800
Bulgaria					10	10	36	70	200
Cyprus			0	0	0	0	0	0	0
Czech Republic			3	9	17	28	54	116	250
Denmark	2,417	2,489	2,889	3,116	3,118	3,128	3,136	3,125	4,150
Estonia			2	2	6	32	32	58	150
Finland	39	39	43	52	82	82	86	110	220
France	66	93	148	257	390	757	1,567	2,454	5,300
Germany	6,113	8,754	11,994	14,609	16,629	18,415	20,622	22,247	25,624
Greece	189	272	297	383	473	573	746	871	1,500
Hungary			3	3	3	17	61	65	150
Ireland	118	124	137	190	339	496	746	805	1,326
Italy	427	682	788	905	1,266	1,718	2,123	2,726	4,500
Latvia			24	27	27	27	27	27	100
Lithuania			0	0	6	6	48	50	100
Luxembourg	10	15	17	22	35	35	35	35	50
Malta			0	0	0	0	0	0	0
Netherlands	446	486	693	910	1,079	1,219	1,558	1,746	3,000
Poland			27	63	63	83	153	276	1,000

Cumulative installations of wind power in the EU (MW)									continued from previous page
Country	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2010** (est)
Portugal	100	131	195	296	522	1,022	1,716	2,150	3,500
Romania			1	1	1	2	3	8	50
Slovakia			0	3	5	5	5	5	25
Slovenia			0	0	0	0	0	0	25
Spain	2,235	3,337	4,825	6,203	8,264	10,028	11,623	15,145	20,000
Sweden	231	293	345	399	442	510	571	788	1,665
UK	406	474	552	667	904	1,332	1,962	2,389	5,115
EU Accumulated*	12,887	17,315	23,098	28,491	34,372	40,500	48,031	56,535	80,000

* From 2004 EU-25; from 2007 EU-27

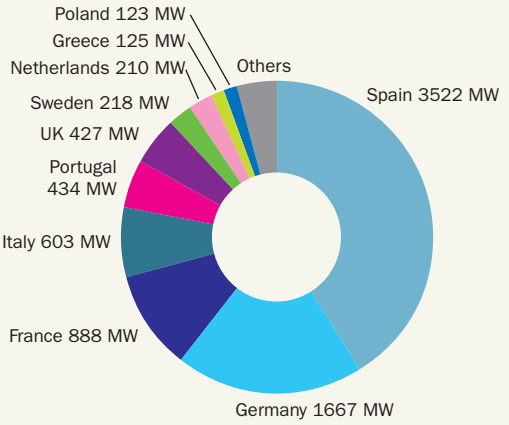
Germany and Spain continue to attract the majority of investments. In 2007 these two countries represented 61% of the EU market. However, there is a healthy trend towards less reliance on Germany and Spain although the trend was broken in 2007 due to unprecedented Spanish growth. In 2000, 468 MW of European wind power capacity was installed outside Germany, Spain and Denmark. In 2007, the figure was 3,362 MW.

FIG 2.6: **End 2007 total installed capacity (in MW)**



Others			
Ireland	805 MW	Lithuania	50 MW
Sweden	788 MW	Luxembourg	35 MW
Belgium	287 MW	Latvia	27 MW
Poland	276 MW	Romania	8 MW
Czech Republic	116 MW	Slovakia	5 MW
Finland	110 MW	Cyprus	0 MW
Bulgaria	70 MW	Malta	0 MW
Hungary	65 MW	Slovenia	0 MW
Estonia	58 MW		

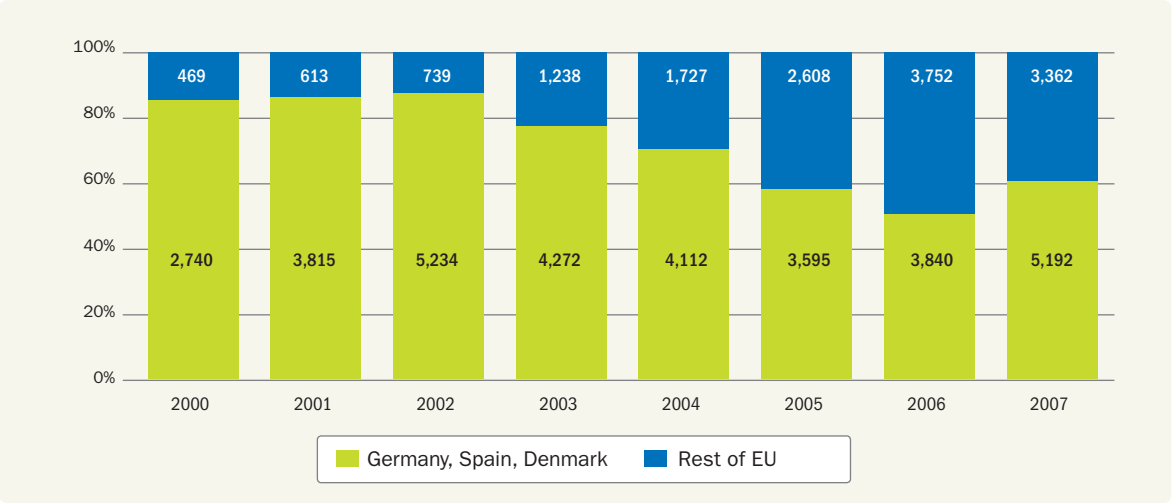
FIG 2.7: **New capacity installed in 2007 (in MW)**



Others			
Belgium	93 MW	Hungary	4 MW
Czech Republic	63 MW	Denmark	3 MW
Ireland	59 MW	Cyprus	0 MW
Bulgaria	34 MW	Latvia	0 MW
Estonia	26 MW	Luxembourg	0 MW
Finland	24 MW	Malta	0 MW
Austria	20 MW	Slovakia	0 MW
Lithuania	7 MW	Slovenia	0 MW
Romania	5 MW		

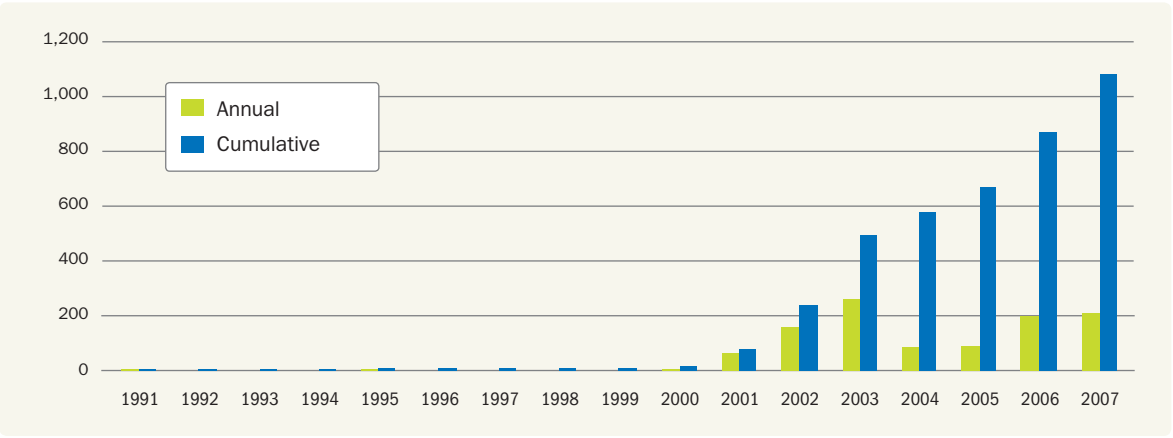
Excluding Germany, Spain and Denmark, there has been an almost fivefold increase in the annual market in the past five years, confirming that a second wave of European countries is investing in wind power, partly as a result of the EU Renewable Electricity Directive passed in 2001.

FIG 2.8: **Germany, Spain and Denmark's share of EU market 2000-2007 (in MW)**



With 1,080 MW by the end of 2007, offshore accounted for 1.9% of installed EU capacity and 3.5% of the electricity production from wind power in the EU. The market is still below its 2003 level and development has been shown to be slower than previously anticipated.

FIG 2.9: **Offshore wind in the EU (MW)**

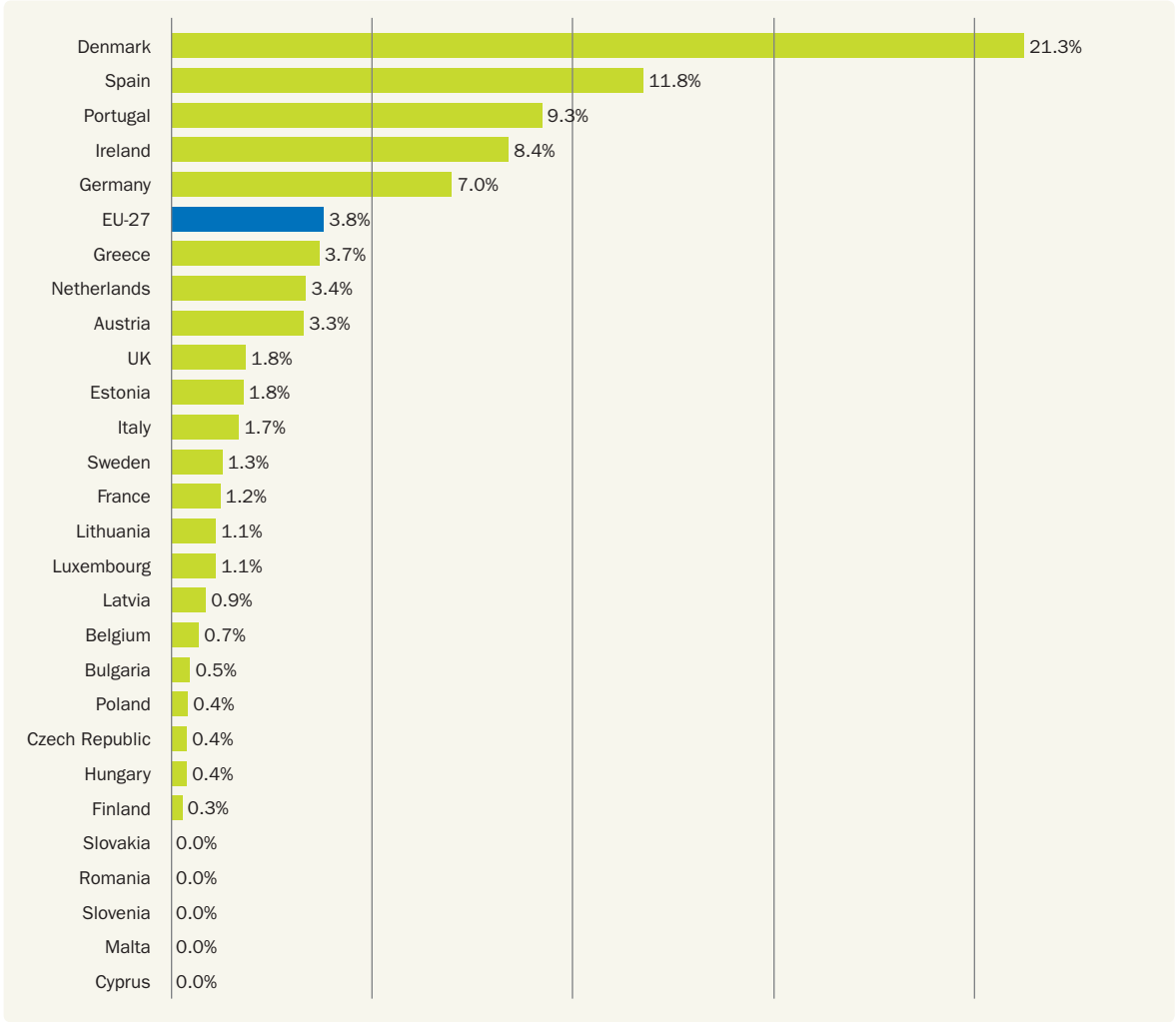


With 409 MW, Denmark has the most offshore wind capacity but the UK (404 MW) is a very close second, having installed 100 MW in 2007. Sweden installed 110 MW in 2007. The Netherlands and Ireland also have operating offshore wind farms.

Country	Total installed by end 2007	Installed in 2007
Denmark	409.15	0
United kingdom	404	100
Sweden	133.25	110
Netherlands	108	0
Ireland	25.2	0
TOTAL	1079.6	210

The total wind power capacity installed at the end of 2007 will produce 3.7% of the EU-27 electricity demand in a normal wind year. Wind power in Denmark covers more than 20% of its total electricity consumption, by far the largest share of any country in the world. Five EU countries – Denmark, Spain, Portugal, Ireland, and Germany – have more than 5% of their electricity demand produced by wind energy[8].

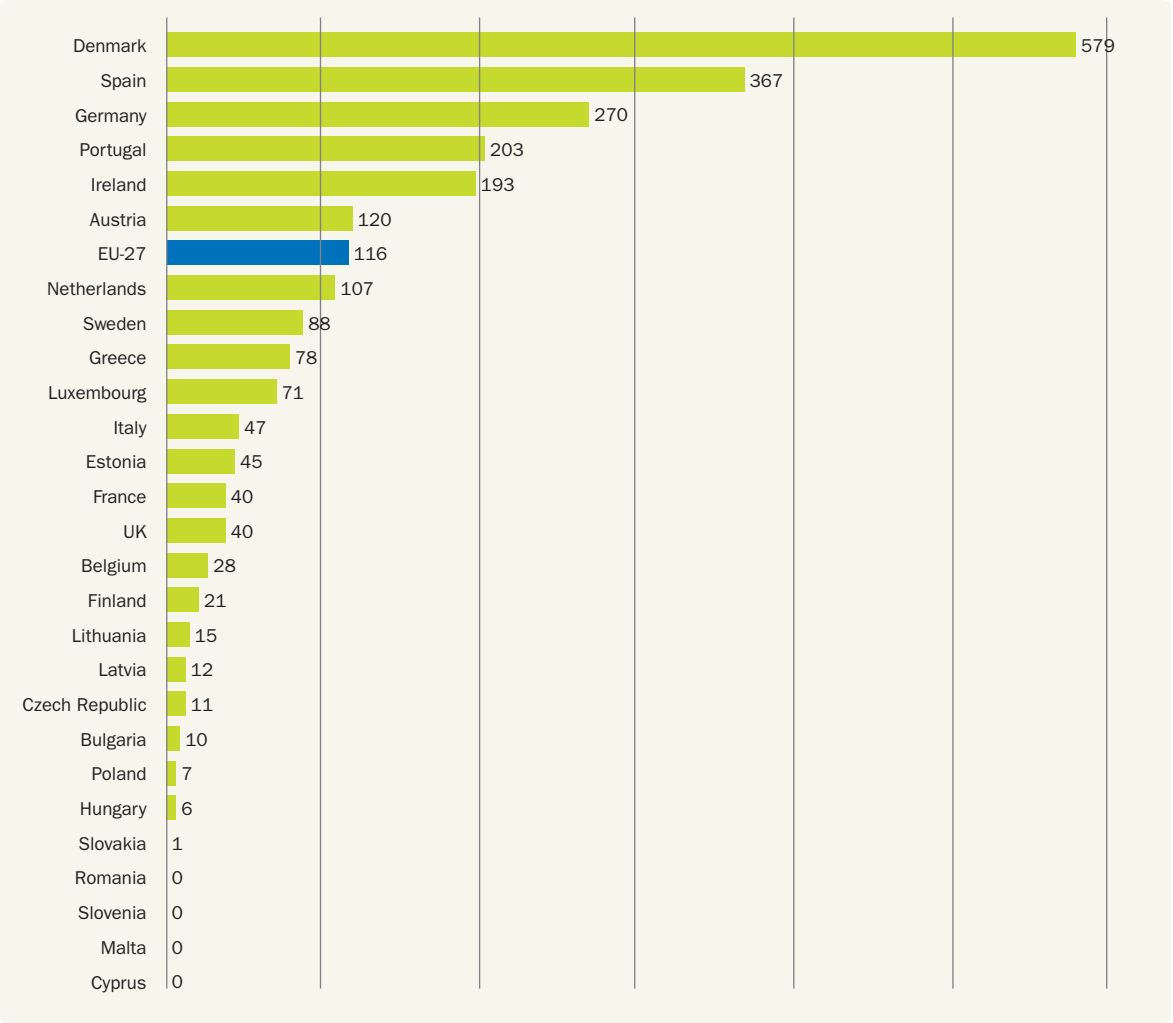
FIG 2.10: **Wind power's share of electricity demand**



By the end of 2007, 116 kW of wind energy capacity was installed for every 1,000 people in the EU. Denmark tops the list with 579 kW/1,000 people followed by Spain (367 kW) and Germany (270 kW). If all EU countries had installed the same amount of wind power capacity per population as Spain, total installation in the EU would be 180,000 MW, equal to EWEA's 2020 target. If all EU countries had the same amount of capacity per capita as Denmark, total EU installations would be 282,000 MW, slightly less than the EWEA's 2030 target.

8 Source: Eurelectric and EWEA
The national wind power shares are calculated by taking the electricity that the capacity installed by the end of 2007 will produce in a normal wind year and dividing it by the actual 2006 electricity demand. The statistical methodology used differs from the methodology otherwise used throughout this report, which explains the difference of 0.1% for the total EU share. The figures may differ from the shares reported by national wind energy associations due to difference in methodology.

FIG 2.11: **Installed wind capacity – kW/1,000 people**



There are 12.2 MW of wind power capacity installed per 1,000 km^2 of land area in the EU (Fig. 2.12). Not surprisingly, being a small country, wind power density is highest in Denmark but Germany is a close second. It is interesting that Spain's wind power density is less than half that of Germany, indicating a large remaining potential – at least from a visual perspective. The Netherlands, Portugal and Luxembourg are also above the EU average.

Many geographically large Member States, e.g. France, Sweden, Finland, Poland and Italy, still have very low density relative to the first-mover countries. If Sweden had the same wind power density as Germany, there would be more than 28 GW of wind power capacity installed in Sweden (0.8 GW was operating by end 2007) and France would have more than 34 GW of wind power capacity (compared to 2.5 GW in December 2007).

The total installed capacity of wind power by the end of 2007 will, in an average wind year, avoid the emission of 91 Mt of CO_2. Figure 2.13 shows the CO_2 avoided due to turbines installed by end 2007 as percentages of the Member States' 1990 greenhouse gas (GHG) emissions (the base-year of the Kyoto Protocol). It assumes that wind power displaces the average EU amount of CO_2 per kWh.

However, caution must be applied when interpreting the results, since one kWh of wind power avoids far more CO_2 in for example Poland, where the share of coal power production is much higher than the EU average, and avoids far less in for example France, where wind power mainly replaces gas at the intermediate load.

Overall, the wind power capacity installed by the end of 2007 avoids the emission of 91.3 Mt of CO_2, of which 90.1 is avoided in the EU-15 which has a common obligation under the Kyoto protocol of cutting GHG emissions by -8% compared to 1990 levels. The new Member States have individual targets (excluding Malta and Cyprus which have no obligation). The wind power installed in the EU-15 by the end of 2007 reduces CO_2 emissions by 2.1% of 1990 GHG emissions, equal to 26% of the bloc's Kyoto obligation.

FIG 2.12: **Wind installation MW/1,000 km²**

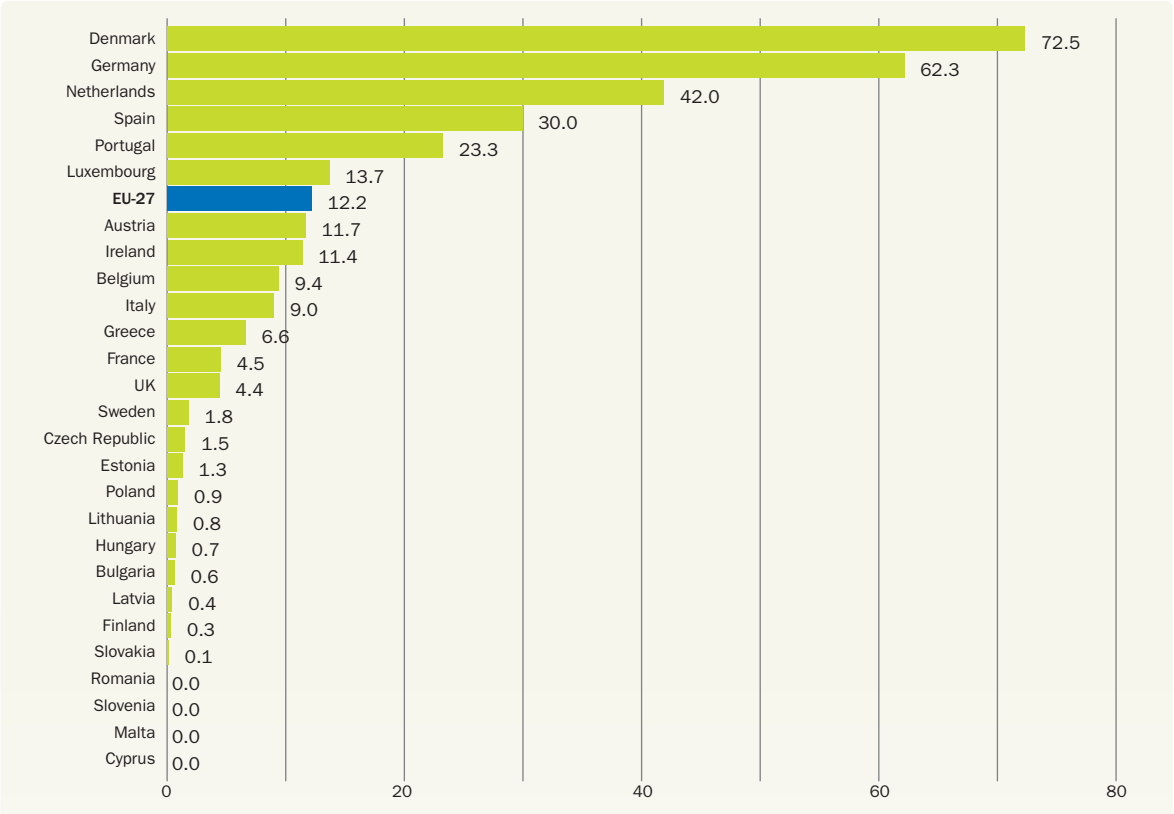


FIG 2.13: **CO_2 reduction from wind in 2007 – % of 1990 GHG emission (CO_2 eq)**

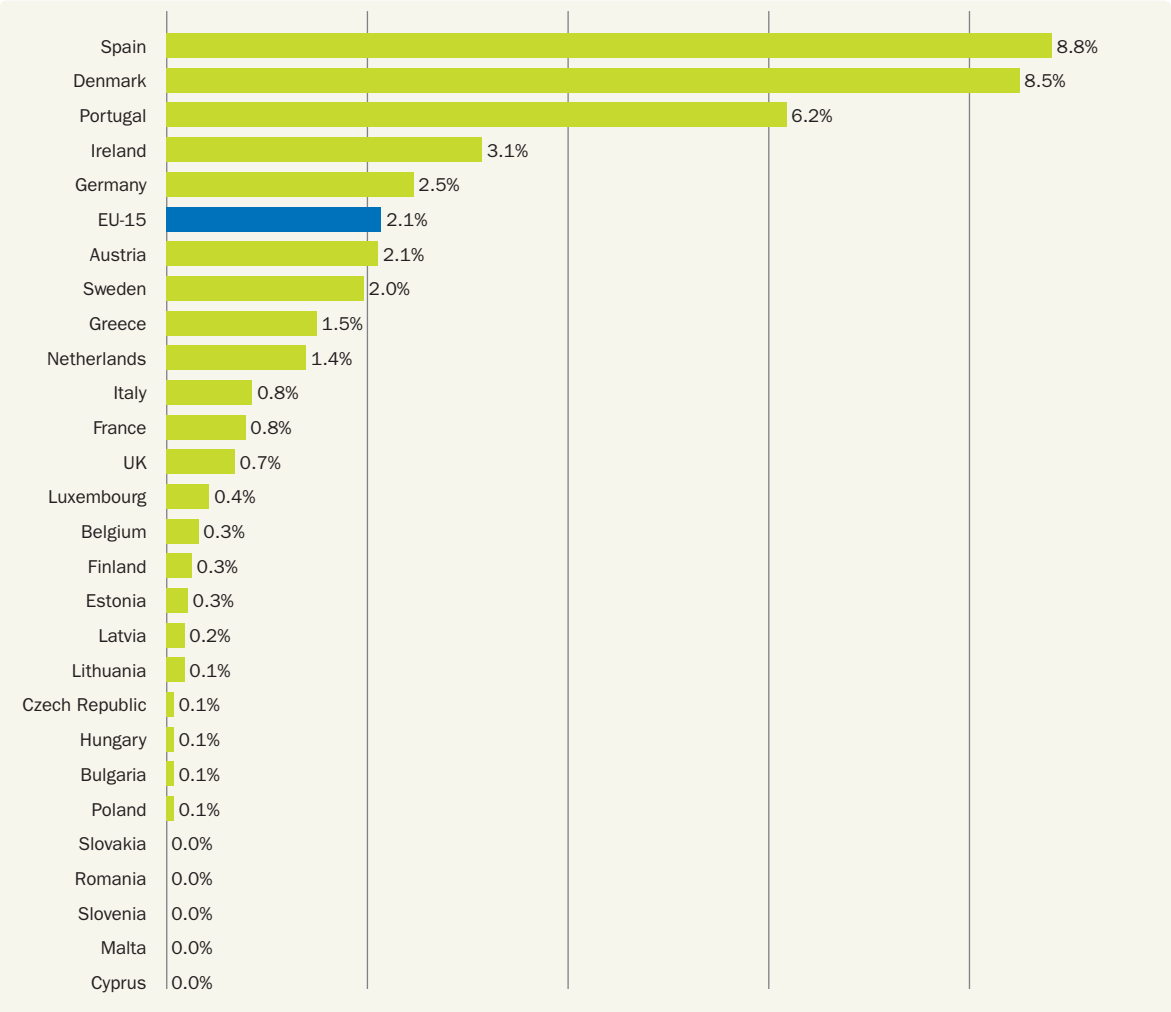
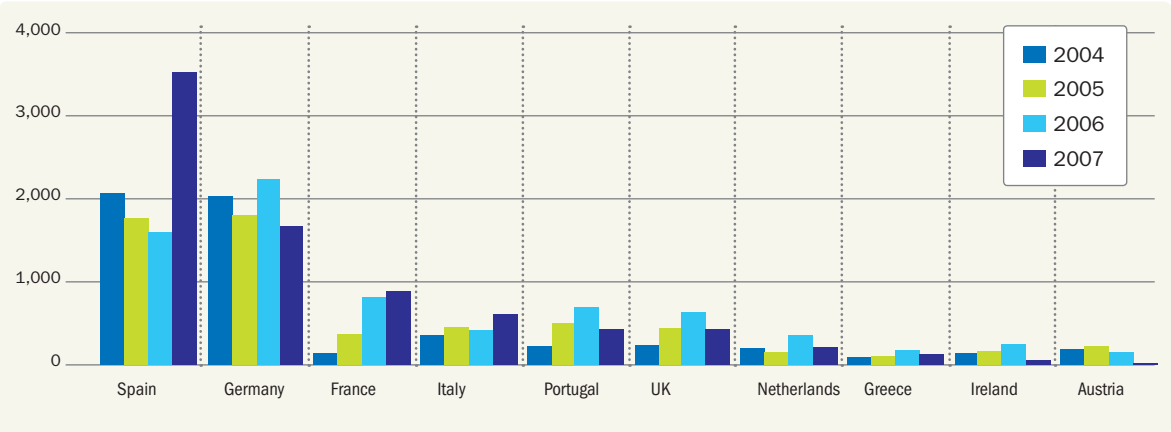


FIG 2.14: **Top 10 annual markets in EU (MW)**



Summary of the wind energy market in the EU-27 in 2007

- 56 GW installed capacity, including 1.08 GW offshore
- Annual installations of 8.5 GW, including 0.2 GW offshore
- Electricity production of 119 TWh, including 4 TWh offshore
- Meeting 3.7% of total EU electricity demand
- 40.3% of the annual new electricity generating capacity
- 55% of annual net increase in installed electricity generating capacity
- 7.3% of total installed electricity generating capacity
- Providing power equivalent to the needs of 30 million average EU households (15% of EU households)
- Avoiding 91 Mt of CO_2 – equivalent to taking 46 million cars off the road (21% of the EU car fleet) and equal to 26% of the EU-15's Kyoto obligation
- Annual avoided fuel cost of €3.9 billion
- Annual avoided CO_2 costs of approximately €2 billion
- Annual investments in wind turbines of €11.3 bn
- Total life-time avoided fuel costs of wind power capacity installed in 2007 of €16 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2007 of €6.6 billion (assuming CO_2 price of €25/t)
- European manufacturers have a 75% share of the global market for wind turbines (2006)[1]

1 BTM World Market Update 2006, March 2007

3. Evolution of targets

The European Commission White Paper of 1997 on Renewable Sources of Energy set the goal of doubling the share of renewable energy in the EU's energy mix from 6% to 12% by 2010. It included a target of 40,000 MW for wind power in EU by 2010, producing 80 TWh and saving 72 million tonnes of CO_2. The 40,000 MW target was reached in 2005. Another target of the White Paper was to increase the share of electricity from renewable energy sources (RES-E) from 337 TWh in 1995 to 675 TWh in 2010. By the end of 2007, there was 56,535 MW of wind power capacity installed in the EU, producing 119 TWh of electricity and saving approx. 90 tonnes of CO_2 annually.

The European Commission's White Paper was followed by Directive 2001/77/EC on the Promotion of Electricity from Renewable Energy Sources. It is the most important piece of legislation ever introduced for renewables, and has led the 27 Member States to develop frameworks for investment in renewables, including financial instruments and ways of overcoming administrative barriers and grid access barriers.

The Directive sets national indicative targets for the contribution of electricity from renewables as a percentage of gross electricity consumption. The overall goal set out in the directive is to increase the share of electricity coming from renewable from 14% in 1997 to 22% in 2010. With the enlargement, the overall EU target was adjusted to 21% of electricity consumption.

The 40,000 MW goal from the European Commission's White Paper naturally formed EWEA's target in 1997, but three years later, due to the strong developments in the German, Spanish and Danish markets for wind turbines, EWEA increased its target by 50% to 60,000 MW by 2010 and 150,000 MW by 2020. In 2003, EWEA once again increased its target, this time by 25% to 75,000 MW by 2010 and 180,000 MW in 2020. Due to the expansion of the EU with ten new Member States, EWEA is now increasing its prediction for 2010 to 80,000 MW, maintaining its 2020 target of 180,000 MW and setting a target of 300,000 MW by 2030.

Baseline Scenarios

Both the European Commission and the International Energy Agency publish baseline scenarios for the development of various electricity generation technologies, including wind energy. In 1996, one year before adopting its White Paper target of 40 GW of wind power by 2010, the European Commission estimated that 8 GW would be installed by 2010 in the EU. The 8 GW was reached in 1999. The Commission's target for 2020 was set at 12.3 GW and was reached, two decades ahead of schedule, in 2000.

Since 1996, European Commission has changed its baseline four times. Over the ten year period, targets for wind energy in 2010 and 2020 have been increased tenfold from 8 GW to 78 GW (2010) and from 12 GW to 128 GW (2020) in its latest baseline scenario from 2006. EWEA's 2010 target for wind energy doubled from 40 GW (in 1997) to 80 GW (in 2006).

While there seems to be consistency between the EWEA and the European Commission forecasts for 2010, the EWEA baseline, or 'reference' scenario for 2020 is 70 GW higher than the Commission's baseline. For 2030, the Commission assumes 185 GW while EWEA assumes 300 GW.

The International Energy Agency (IEA) is also making baseline scenarios for the development of wind power. In 2002 the Agency estimated that 33 GW would be installed in Europe in 2010, 57 GW by 2020 and 71 GW by 2030. Two years later, in 2004, it doubled its forecast for wind energy to 66 GW in 2010 and more than doubled its 2020 and 2030 Business as Usual scenario for wind in the EU to 131 GW in 2020 and 170 GW in 2030. In 2006, the IEA again increased its 2030 target for wind power in the EU to 217 GW (its alterna-

tive policy scenario assumes 227 GW). IEA's reference scenario assumes 68 GW in 2010, 106 GW in 2015, 150 GW in 2020 and 217 GW in 2030. EWEA's reference scenario assumes 80 GW in 2010, 125 GW in 2015, 180 GW in 2020 and 300 GW in 2030.

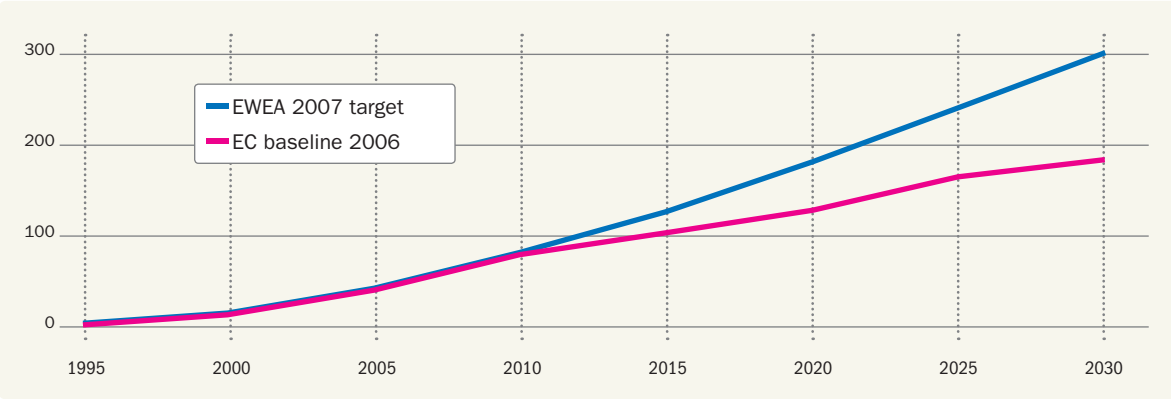
The European Commission's baseline scenario claims to "take into account the high energy import price environment", by assuming an oil price in 2005 of $55/barrel and $44.6/barrel in 2010. In its 2006 scenario, the IEA assumes an oil price of $47 in 2015 reaching $55 in 2030. In November 2007, financial firm UBS raised its 2008 oil price forecast to $74 and forecasted a 2012 oil price of $82. In March 2008, crude oil prices[9] reached an all-time high of $105 a barrel.

European Commission scenarios compared with actual market/EWEA 2007 target

	1995	2000	2005	2010	2015	2020	2025	2030
EC 1996		4.4	6.1	8.0	10.1	12.34		
EC 1999			15.3	22.6		47.2		
EC 2003				69.9		94.8		120.2
EC 2004	2.5	12.8		72.7		103.5		134.9
EC 2006 – baseline		12.8		78.8	104.1	129.0	165.8	184.5
Actual market/EWEA 2007 target	2.5	12.9	40.5	80.0	124.5	180.0	239.3	300.0

The table shows the European Commission's various scenarios for wind energy installations up to 2030, compared with the actual market up to 2007 followed by EWEA's 2007 scenario up to 2030.

FIG 3.1: **European Commission's 2006 baseline scenario compared with the EWEA target up to 2030**



The graph shows the European Commission's 2006 baseline scenario compared with the EWEA target up to 2030.

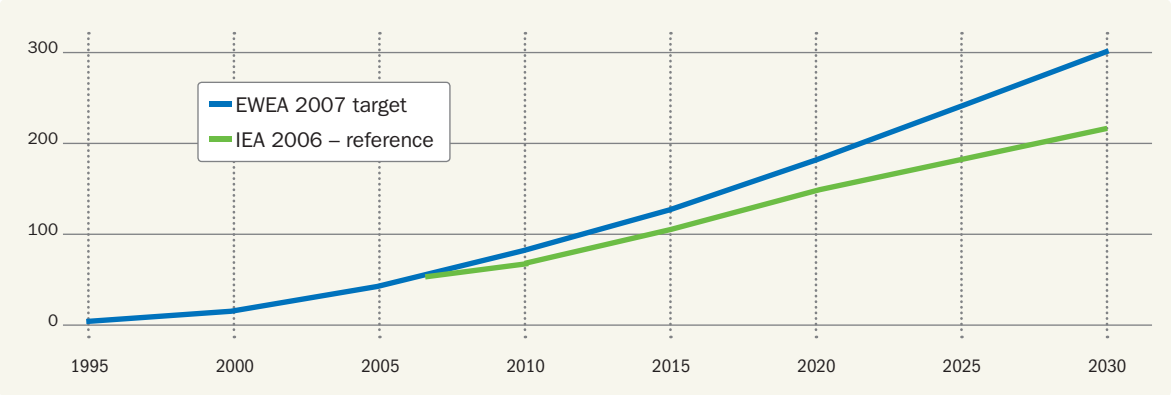
9 West Texas Intermediate

IEA's scenarios for wind energy installations up to 2030, compared with the actual market/EWEA 2007 scenario								
	1995	2000	2005	2010	2015	2020	2025	2030
IEA 2002				33.0		57.0		71.0
IEA 2004				66.0		131.0		170.0
IEA 2006 – reference				68.0	106.0	150.0		217.0
IEA 2006 – APS*				71.0	108.0	151.0		223.0
Actual market/EWEA 2007 target	2.5	12.9	40.5	80.0	124.5	180.0	239.3	300.0

*Alternative Policy Scenario

The table shows the IEA's various scenarios for wind energy installations up to 2030, compared with the actual market up to 2007 followed by EWEA's 2007 scenario up to 2030.

FIG 3.2: **IEA's 2006 reference scenario compared with the EWEA target up to 2030 (in GW)**



The graph shows the IEA's 2006 reference scenario compared with the EWEA target up to 2030.

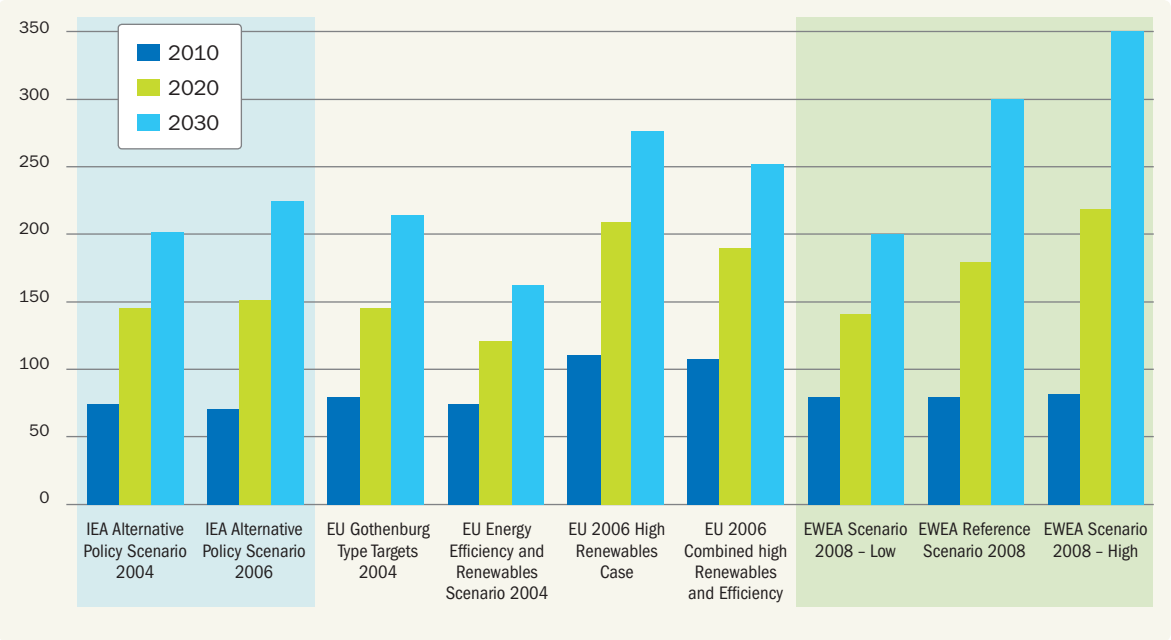
	1995	2000	2005	2010	2015	2020	2025	2030
EWEA 1997				40				
EWEA 2000				60		150		
EWEA 2003				75		180		
Actual market/EWEA 2007 target	2.5	12.9	40.5	80	125	180	165	300

The table shows EWEA's various scenarios for wind energy installations up to 2030, compared with the actual market up to 2007.

In addition to the baseline / business as usual scenarios, the European Commission and IEA have in recent years published more advanced scenarios with less static assumptions. The European Commission's new scenarios on energy efficiency and renewables from 2006 assume that "agreed policies will be vigorously implemented in the Member States and that certain new targets on the overall share of renewables in 2020 will be broadly achieved". However the underlying estimates of fuel and carbon prices are no different from the baseline scenario.

Both the European Commission's and IEA's advanced scenarios from 2004 are in line with the 80 GW target in 2010 from EWEA. However, the 2020 and 2030 targets from IEA and the European Commission are significantly below EWEA's targets. The 2006 IEA Alternative Policy Scenario for the EU (151 GW in 2020) is, somewhat surprisingly, only 1 GW higher than its reference scenario. Its 2030 alternative policy scenario is a mere 6 GW higher than its Reference Scenario (217 GW). The European Commission's advanced 2006 scenarios are more in line with the EWEA targets, and even exceed EWEA's targets for 2020.

FIG 3.3: **Advanced Scenarios for 2010, 2020 and 2030 (in GW)**

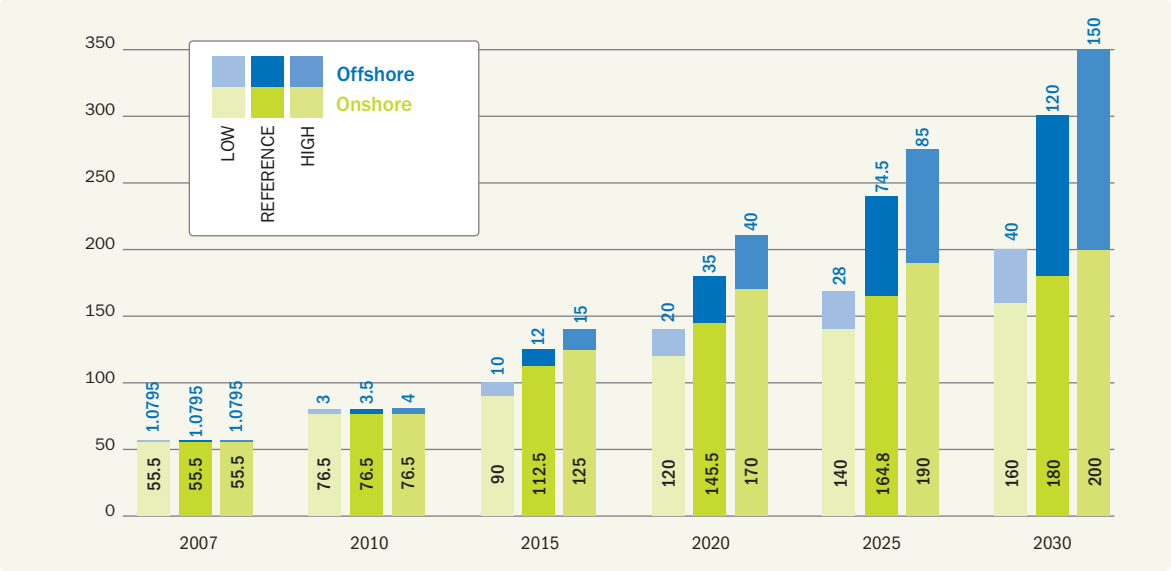


4. Three wind power scenarios to 2030

While EWEA is fairly confident about the projections of wind power in the EU to 2010, there is uncertainty about the targets for 2020 and 2030. The prospects for a significant market for offshore wind power has been pushed beyond the 2010 timeframe, predominantly as a result of strong onshore wind market growth in USA, China and India in recent years. Much also depends on the future EU regulatory framework for the period after 2010.

Consequently, this report introduces three scenarios – low, reference and high – for the development of wind energy up to 2030. The offshore scenarios up to 2020 are based on scenarios established by EWEA in December 2007[10].

FIG 4.1: **EWEA's three wind power scenarios (in GW)**



Much of the development over the coming two decades depends on the evolution of the offshore market, over which there is currently some uncertainty. In December 2007, the European Commission announced an EU Action Plan for Offshore Wind Energy, which is expected to be published in the second half of 2008. As mentioned, EWEA's reference scenario assumes 180 GW in 2020 and 300 GW in 2030. The EU will have 350 GW (including 150 GW offshore) in the high scenario and 200 GW (including 40 GW offshore) in the low scenario.

The 56.5 GW of installed capacity in the EU-27 by the end of 2007 will, in a normal wind year, produce 119 TWh of electricity, enough to meet 3.7% of EU electricity demand.

In terms of wind power's electricity production and its share of total EU power demand, there are large differences between the three scenarios. Much also depends on whether total electricity demand in the EU increases according to the European Commission's business as usual (BAU) scenario or stabilises according to its energy efficiency and high renewables scenario (EFF).

10 See EWEA offshore report, 'Delivering Offshore Wind Power in Europe', EWEA, December 2007

As can be seen from table below, wind power will produce between 176 TWh (low case) and 179 TWh (high case) in 2010, between 361 TWh and 556 TWh in 2020, and between 571 TWh and 1,104 TWh in 2030.

The bottom table shows that in EWEA's reference scenario, wind energy meets between 5% (BAU) and 5.2% (EFF) of EU electricity demand in 2010, between 11.6% and 14.3% in 2020, and between 20.8% and 28.2% in 2030, depending on how overall electricity consumption develops in the EU between now and 2030.

The calculations in the following chapters of this report are based on EWEA's reference scenario and the European Commission's business as usual scenario for electricity consumption.

Electricity production (TWh)

	LOW			REFERENCE			HIGH		
	Onshore	**Offshore**	**Total**	**Onshore**	**Offshore**	**Total**	**Onshore**	**Offshore**	**Total**
2007	115	4	119	115	4	119	115	4	119
2010	165	11	176	165	13	177	165	15	179
2015	204	37	241	255	45	299	283	56	339
2020	285	76	361	344	133	477	403	152	556
2025	350	109	459	412	289	701	475	330	805
2030	415	156	571	467	469	935	519	586	1,104

	LOW			REFERENCE			HIGH		
	Onshore	**Offshore**	**Total**	**Onshore**	**Offshore**	**Total**	**Onshore**	**Offshore**	**Total**
2007 share EFF				3.5%	0.1%	3.7%			
2007 share BAU				3.5%	0.1%	3.7%			
2010 share EFF	4.9%	0.3%	5.2%	4.9%	0.4%	5.2%	4.9%	0.4%	5.3%
2010 share BAU	4.6%	0.3%	4.9%	4.6%	0.4%	5.0%	4.6%	0.4%	5.0%
2020 share EFF	8.5%	2.3%	10.8%	10.3%	4.0%	14.3%	12.1%	4.6%	16.6%
2020 share BAU	6.9%	1.9%	8.8%	8.4%	3.2%	11.6%	9.8%	3.7%	13.5%
2030 share EFF	12.5%	4.7%	17.2%	14.1%	14.1%	28.2%	15.6%	17.6%	33.2%
2030 share BAU	9.2%	3.5%	12.7%	10.4%	10.4%	20.8%	11.5%	13.0%	24.5%

It is assumed that the average capacity factor of all wind turbines in the EU will increase from 24% in 2007 to 25.3% in 2010 and 30.3% in 2020. The increase will be due to better design, exploiting the resources in more windy areas of Europe, technology improvements and a larger share of offshore wind. In Germany, average capacity factors will only start increasing if older turbines start being replaced, and offshore wind power takes off. It should be noted that for a technology that makes use of a free resource, high capacity factors are not a goal in itself. It is not technically problematic to increase capacity factors, but doing so affects grid integration, modelling and generation costs.

5. Prediction for 2010

EWEA's prediction for 2010 has been adjusted from 75 GW (set in 2003) to 80 GW to take account of the new Member States. It assumes approx. 23.5 GW of wind installations in the years 2008-2010.

The Danish wind energy consultancy BTM Consult foresees a cumulative installed capacity of 92 GW by the end of 2010. The main growth markets it highlights are Portugal, France and the UK.

By end 2007, 1.9% of wind capacity in EU was offshore, producing 3.4% of total wind power in Europe. In 2010, EWEA expects 4.4% of total capacity and 16% of the annual market to be offshore wind. Offshore wind power's share of total EU wind energy production will increase to 7% by 2010.

The 56.5 GW of installed capacity in the EU-27 by the end of 2007 will, in a normal wind year, produce 119 TWh of electricity, enough to meet 3.7% of EU electricity demand. The capacity installed by the end of 2010 will produce 177 TWh in a normal wind year, equal to 5.0% of demand in 2010 (5.7% of 2006 demand). With efficiency measures, wind power's share would be 5.2% of electricity demand in 2010.

Germany is projected to reach 25 GW and Spain 20 GW of wind capacity in 2010. France, the UK, Italy, Portugal and the Netherlands constitute a second wave of stable markets and will install 42% of EU capacity over the period.

For 2008, the EU market is expected to fall back to its 2006 level and increase slightly up to 2010 when it should reach 8,200 MW. The forecast assumes that the negotiations on the new EU Renewable Energy Directive and the subsequent development of national action plans in the Member States could cause some legal uncertainty until implemented.

FIG 5.1: **Annual capacity EU 1991-2010 (in MW)**

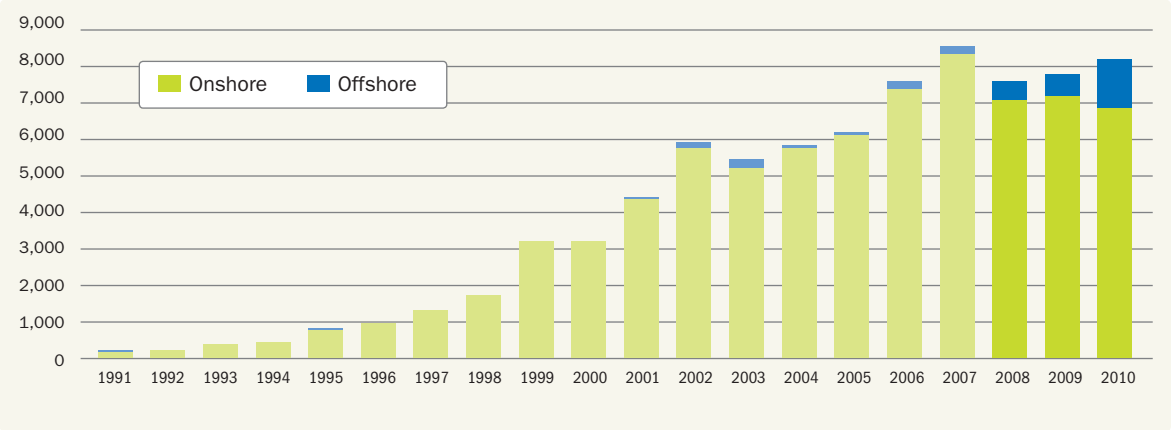
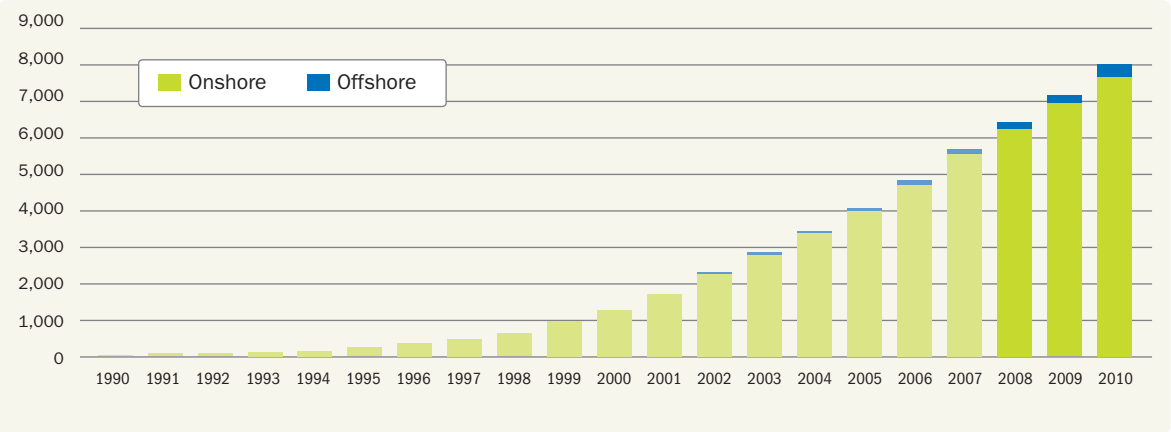


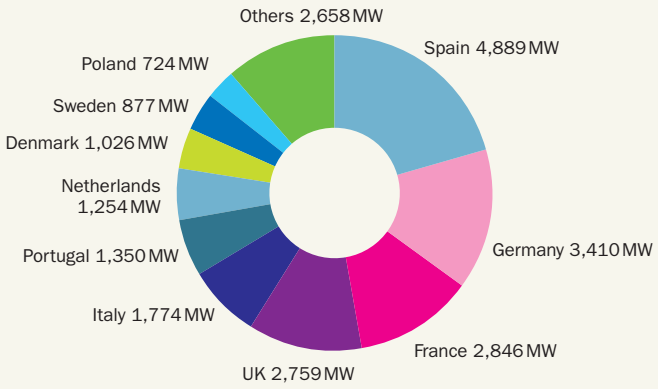
FIG 5.2: **Cumulative capacity EU 1990-2010 (in MW)**



In the three-year period 2007-2010, EWEA forecasts that 23.5 GW of wind energy capacity, including 2.4 GW offshore, will be installed, equal to total investments of €31 billion.

Germany and Spain's share of the European annual market will be 34%, compared to 60% in 2007 and 80% in 2002, confirming the healthy trend towards less reliance on the first-mover markets. The largest markets in the period are expected to be Spain (20.7%), Germany (14.4%), France (12.1%), UK (11.6%), and Italy (7.6%). The total includes an additional, 102 MW of capacity assumed to be build as a result of replacement of turbines installed prior to 1991.

FIG 5.3: **Wind power capacity EU 2008-2010 (total 23,567 MW)**

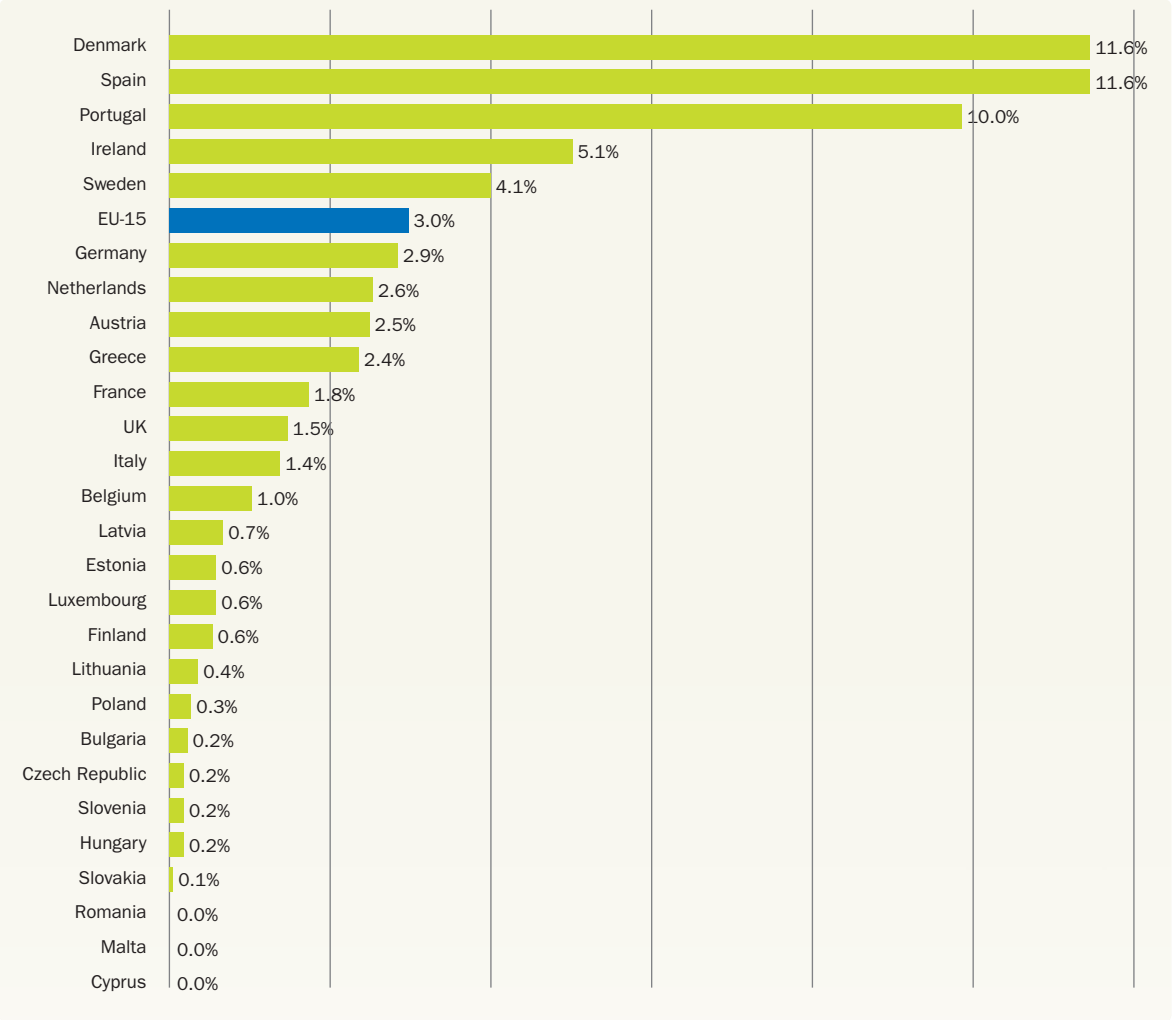


Others	
Greece	629 MW
Ireland	521 MW
Belgium	513 MW
Austria	218 MW
Czech Republic	134 MW
Bulgaria	130 MW
Finland	110 MW
Estonia	92 MW
Hungary	85 MW
Latvia	73 MW
Lithuania	50 MW
Romania	42 MW
Slovenia	25 MW
Slovakia	20 MW
Luxembourg	15 MW
Malta	0 MW
Cyprus	0 MW

The total installed capacity of wind power by end 2010 will, in an average wind year, avoid the emission of 133 Mt of CO_2. Fig. 5.4 shows the avoided CO_2 of turbines installed by end 2010 as percentages of the Member States' 1990 GHG emissions. Further, it assumes that wind power displaces the average EU amount of CO_2 per kWh.

Of the 133 Mt CO_2 avoided by wind energy, 130 Mt CO_2 is avoided in the EU-15 which has a separate obligation under the Kyoto protocol (-8% compared to 1990 GHG emissions) from the rest of the EU (the new Member States – excluding Malta and Cyprus which have no obligation – all have a reduction target of -8% compared to 1990). The wind power installed in the EU-15 by end 2010 reduces CO_2 emissions by 3% of 1990 GHG emissions, equal to 38% of the bloc's Kyoto obligation.

FIG 5.4: **CO_2 reduction from wind in 2010 as % of 1990 GHG emission (Mt CO_2 eq)**



In 2007, the European Environment Agency (EEA) projected that the EU-15 would miss its Kyoto target with 172 Mt CO_2 equivalents. The avoided CO_2 emissions of 133 Mt from wind power in 2010 will fill 77% of that gap (see table in Annex 3).

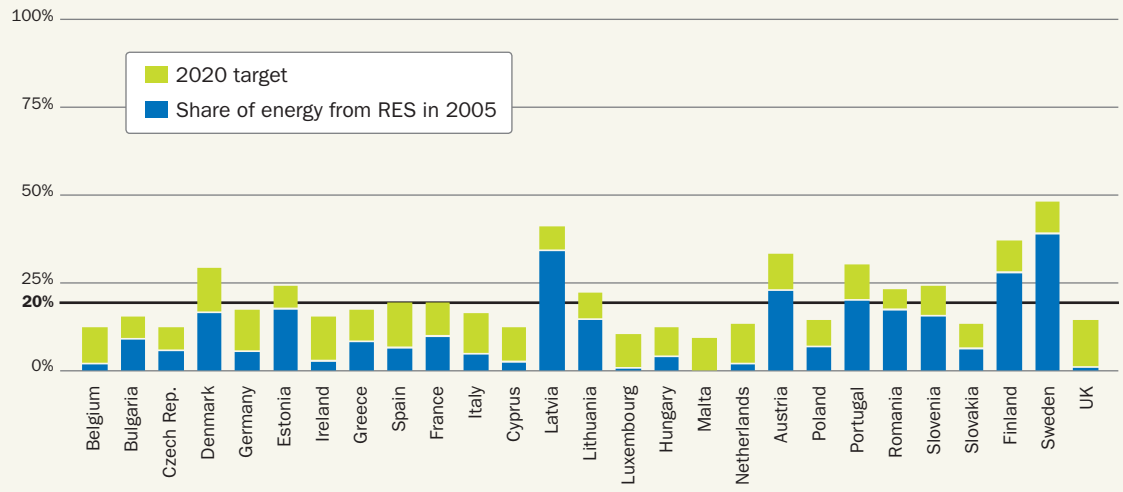
Summary of the wind industry prediction for the EU-27 in 2010

- 80 GW installed capacity, including 3.5 GW offshore
- Annual installations of 8.2 GW, including 1.3 GW offshore
- Electricity production of 177 TWh, including 13 TWh offshore
- Meeting between 5% and 5.2% of total EU electricity demand (depending on 2010 demand)
- 9.9% of total installed electricity generating capacity
- 39% of total new electricity generating capacity installed (2005-2010)
- Providing power equivalent to the needs of 43 million average EU households (21% of EU households)
- Avoiding 133 Mt of CO_2 – equivalent to taking 65 million cars off the road (30% of the EU car fleet in 2004) and equal to 38% of the EU-15's Kyoto obligation
- Annual avoided fuel cost of €8.3 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Annual avoided CO_2 costs of €3.3 billion (€25/t CO_2)
- Annual investments in wind power capacity of €11 billion
- Total wind power investments of €31 billion (2008-2010)
- Total life-time avoided fuel costs of wind power capacity installed in 2008-2010 of €51 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2008-2010 of €21 billion (assuming €25/t CO_2)

6. Projections up to 2020

On 9 March 2007, the European Heads of State unanimously agreed on a binding target of 20% renewable energy by 2020. The 2005 share of renewable energy is approx. 7% of primary energy and 8.5% of final consumption. In January 2008, the European Commission proposed a new legal framework for renewables in the EU, including a distribution of the 20% target between Member States and National Action Plans, containing sectoral targets for electricity; heating/cooling and biofuels.

FIG 6.1: **National overall targets for the share of energy from RES in final consumption of energy 2020**



Source: European Commission draft proposal for a Directive on the promotion of the use of energy from renewable sources

To meet the 20% target for renewable energy, the European Commission expects 34%[11] of electricity to come from renewable energy sources by 2020 (43% of electricity under a "least cost" scenario[12]) and believes that "wind could contribute 12% of EU electricity by 2020".

In 2007, approx. 15% of EU electricity demand is covered by renewables, including approx. 10% large hydro and app. 3.5% wind energy. Excluding large hydropower, for which the realisable European potential has already been reached, the share of renewable electricity in the EU will need to grow fivefold, assuming that electricity demand does not increase, from approx. 5% to 25% to reach the electricity target. With increased demand, non-large hydropower renewable electricity will need to grow even more.

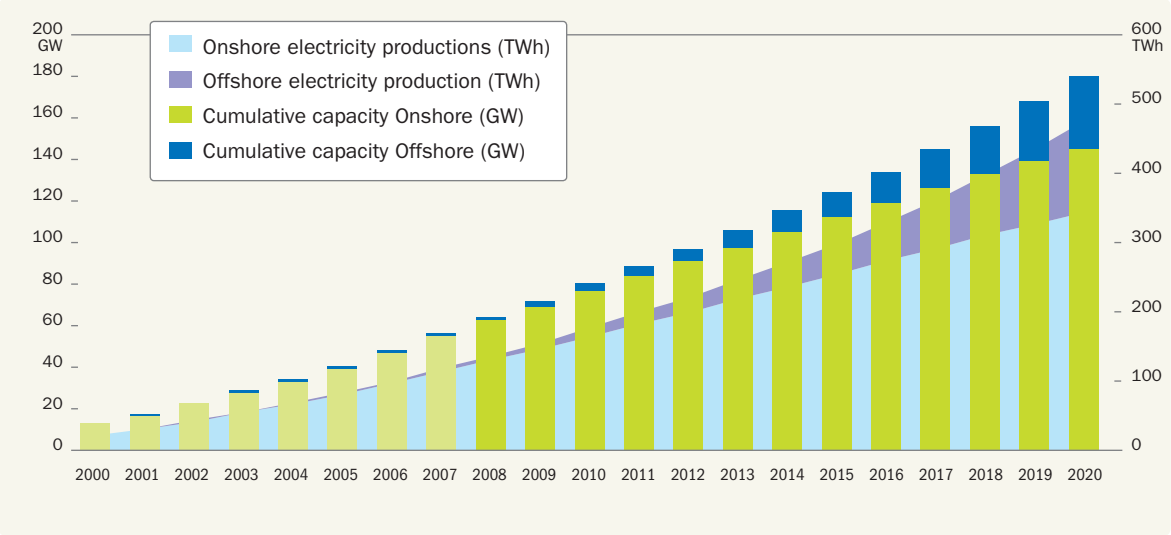
	Today	2020
RES	8.5%	20%
Electricity	15%	34%
Wind Energy	3%	12-14%
Of which offshore	0%	3.2-4%

11 Renewable Energy Roadmap, COM(2006)848 final, European Commission
12 Renewable Energy Roadmap – Impact Assessment; SEC(2006)1720, European Commission

EWEA maintains the target it set in 2003 of 180 GW by 2020, including 35 GW offshore in its reference scenario. That would require the installation of 140 GW wind power capacity, including 34 GW offshore, in the 13-year period 2008-2020. 16.4 GW of capacity is expected to be replaced in the period.

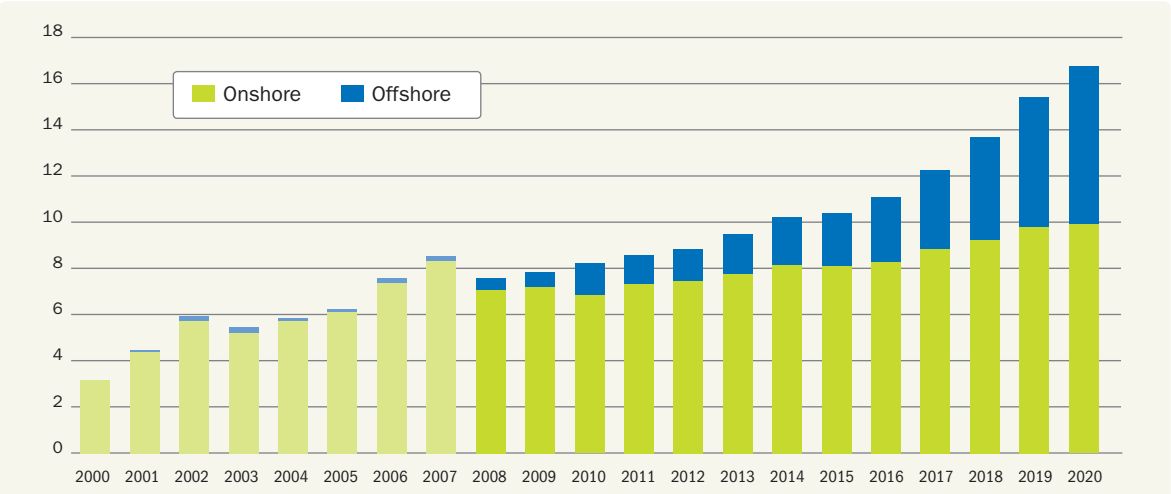
The 180 GW would produce 477 TWh of electricity in 2020, equal to between 11.6% and 14.3% of EU electricity consumption, depending on the development in demand for power. 28% of the wind energy would be produced offshore in 2020.

FIG 6.2: **Electricity from wind up to 2020**



Between 2011 and 2020, the annual onshore market for wind turbines will grow steadily from app. 7 GW per year to app. 10 GW per year. The offshore market will increase from 1.2 GW in 2011 to reach 6.8 GW in 2020. Throughout the period of the reference scenario, the market for onshore wind power exceeds the offshore market in the EU.

FIG 6.3: **Wind energy annual installation 2000-2020 (in GW)**



A precondition for reaching the EWEA target of 180 GW is that the upcoming Directive on Renewable Energy establishes stable and predictable frameworks in the Member States for investors. Much also depends on the European Commission's Action Plan on Offshore Wind Energy (scheduled for the second half of 2008) and a subsequent adoption of a European policy for offshore wind power in the EU.

The 180 GW wind power capacity by end 2020 will avoid the emissions of 328 Mt of CO_2. According to the European Commission's proposed reduction targets for greenhouse gas emissions in 2020, the 27 Member States need to reduce emissions not covered by the Emissions Trading Scheme (ETS) by 10% to 2,668 Mt CO_2 equivalents in 2020. The target implies a reduction in total emissions for the EU-27 of 296 Mt CO_2 equivalents. Consequently, by 2020 wind power will avoid emissions equal to 110% of the reduction required by Member States for emissions outside the ETS.

According to the European Commission's proposed reduction targets for greenhouse gas emissions in 2020, the sectors covered by the ETS must reduce emissions by 21% compared to the 2005 level to 1,720 Mt CO_2 equivalents in 2020. The target implies a reduction in total emissions for the sectors covered by the ETS of 457 Mt CO_2 equivalents. Wind energy will avoid emissions equivalent to 71% of the ETS target.

In total, EU Member States and the sectors covered by the ETS must reduce their emissions by 753 Mt CO_2 equivalents between 2005 and 2020. In 2020, wind power will avoid emissions equal to 44% of the combined target.

Summary of the wind industry target for the EU-27 in 2020

- 180 GW installed capacity, including 35 GW offshore
- Annual installations of 16.8 GW, including 6.8 GW offshore
- Electricity production of 477 TWh, including 133 TWh offshore
- Meeting between 11.6% and 14.3% of total EU electricity demand (depending on 2020 demand).
- 18.1% of total installed electricity generating capacity in the EU
- 32% of total new electricity generating capacity installed (2011-2020)
- Providing power equivalent to the needs of 107 million average EU households (49% of EU households)
- Avoiding 328 Mt of CO_2 – equivalent to taking 165 million cars off the road (76% of the EU 2004 car fleet) and equal to 44% of the EU's GHG reduction target (20%)
- Annual avoided fuel cost of €20.5 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Annual avoided CO_2 costs of €8.2 billion (€25/t CO_2)
- Annual investments in wind power capacity of €16.9 billion
- Total wind power investments of €120 billion (2011-2020)
- Total life-time avoided fuel costs of wind power capacity installed in 2011-2020 of €277 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2011-2020 of €114 billion (assuming €25/t CO_2)

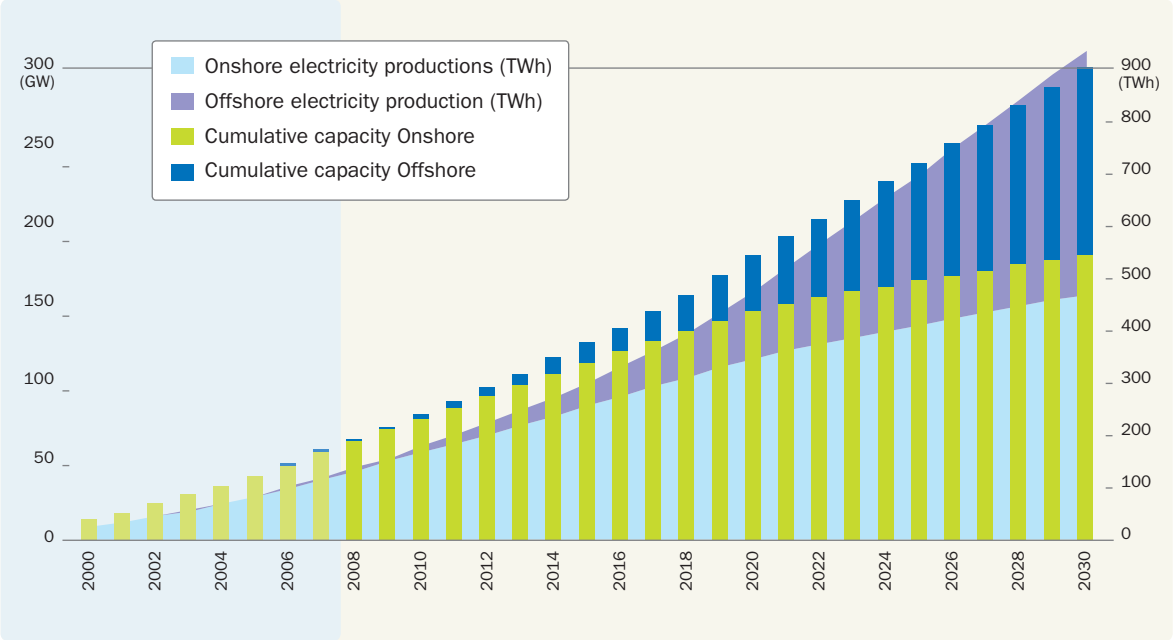
7. Projections up to 2030

In the EWEA reference scenario, 300 GW of wind power will be operating in the EU in 2030, including 120 GW (40%) offshore wind power. 187 GW will be installed in the decade from 2021 to 2030. Of this, 67 GW will be needed to replace decommissioned capacity, predominantly onshore. Onshore represents 54% (101 GW) of the installed capacity in the decade and the onshore market remains larger than the offshore market throughout the period, although the gap narrows towards the end of the period. By 2030, the annual onshore market will be 9.9 GW and the offshore market 9.6 GW, representing investments of €19 billion. In 2025, the offshore market is expected to reach the size of the 2008 onshore market (8.5 GW).

Total installations in the period 2008 to 2030 will be 327 GW, made up of 207 GW onshore and 120 GW offshore. Of this, 83 GW will come from the replacement of decommissioned onshore capacity. Total investments between 2008 and 2030 will be €339 billion.

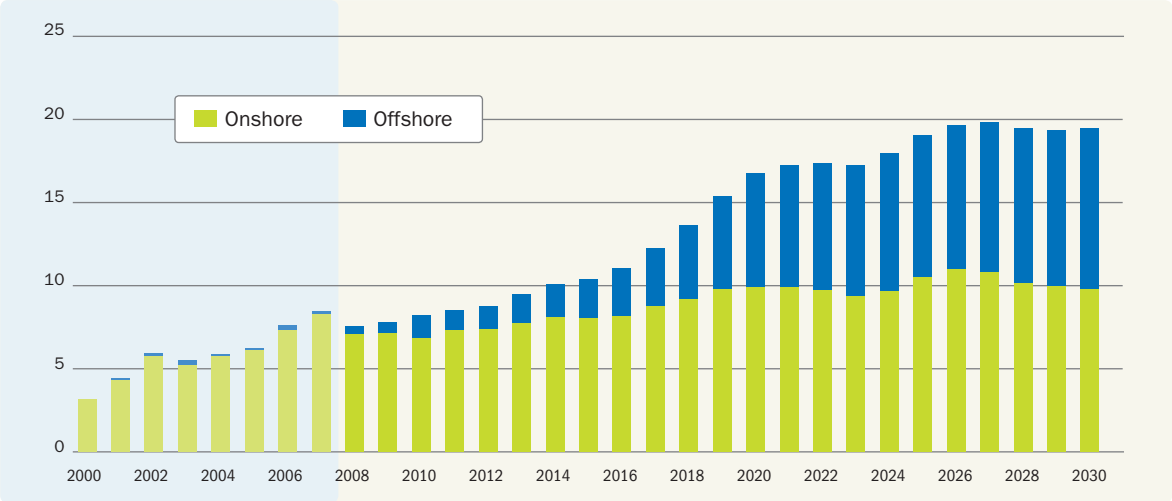
By 2030, wind energy will produce 935 TWh of electricity, half of it from offshore wind power, and cover between 21% and 28% of EU electricity demand, depending on future power consumption.

FIG 7.1: **Electricity from wind up to 2030**



The onshore market stabilises at approx. 10 GW throughout the decade 2020-2030 and 72% of the onshore market will be made up of replacement of older wind turbines. The offshore segment increases from annual installation of 7.3 GW in 2021 to 9.5 GW in 2030.

FIG 7.2: **Wind energy annual installation 2000-2030 (in GW)**



The wind power production in 2030 will avoid the emission of 575 Mt CO_2, equivalent to taking more than 280 million cars off the roads. In 2004 there were 216 million cars in the EU-25.

The following sections (8-13) go into more detail on the impacts that the EWEA's reference scenario would have. Sections 8-10 examine the effect on electricity and generating capacity, section 11 deals with CO_2 emissions, section 12 with avoided fuel costs, and 13 with wind energy investments.

Summary of the wind industry target in EU-27 in 2030

- 300 GW installed capacity, including 120 GW offshore
- Annual installations of 19.5 GW, including 9.6 GW offshore
- Electricity production of 935 TWh, including 469 TWh offshore
- Meeting between 20.8% and 28.2% of total EU electricity demand (depending on 2020 demand).
- 25.5% of total installed electricity generating capacity in the EU
- 46% of total new electricity generating capacity installed (2021-2030)
- Providing power equivalent to the needs of 195 million average EU households (84% of EU households)
- Avoiding 575 Mt of CO_2 – equivalent to taking 285 million cars off the road (132% of the EU 2004 car fleet)
- Annual avoided fuel cost of €34.6 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Annual avoided CO_2 costs of €14.4 billion (€25/t CO_2)
- Annual investments in wind power capacity of €19.4 billion
- Total wind power investments of €187 billion (2021-2030)
- Total life-time avoided fuel costs of wind power capacity installed in 2021-2030 of €455 billion (assuming fuel prices equivalent to $90 a barrel of oil)
- Total life-time avoided CO_2 cost of wind power capacity installed in 2021-2030 of €187 billion (assuming €25/t CO_2)

8. Scenario for wind power's share of household electricity demand

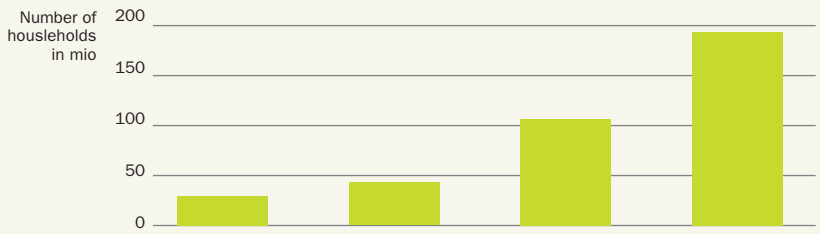
The wind power production derived from the EWEA scenarios can be expressed in relation to household electricity consumption. Household consumption is expected to increase from 790 TWh in 2006 to 1,114 TWh in 2030[13].

By 2030 some 25% of total electricity demand will be consumed by households. Other sectors that consume electricity include industry, agriculture, public and private services.

While the total EU population is estimated to remain relatively stable, the number of households will increase by 35 million, or 18%, indicating a reduction in the average household size. The average household consumption, nevertheless, will increase by 20% over the next 25 years, from 3,995 kWh per year in 2006 to 4,787 kWh in 2030.

The wind power capacity installed by the end of 2007 will produce 119 TWh in an average wind year, equivalent to the electricity needs of 25 million average EU households. If the EWEA reference scenario is reached, wind power will produce electricity equivalent to the needs of 43 million households in 2010; 107 million households in 2020; and 195 million EU households in 2030. Wind power will produce electricity equivalent to the consumption of 84% of the EU's 233 million households in 2030 (see table below).

FIG 8.1: **Equivalent electricity needs met by wind power 2001-2020 (million households)**



	2007	2010	2020	2030
Average household consumption (kWh)	3,995	4,079	4,441	4,787
Wind power production (TWh)	119	177	477	935
Equivalent electricity demand met by wind power (mio households)	**29.8**	**43.4**	**107.4**	**195.3**
Equivalent electricity demand met by wind power (% of households)	15%	21%	49%	84%

13 Source: Eurelectric and European Commission, 2005

9. Contribution of wind power to electricity generation

European electricity generation is projected to increase at an average annual rate of 1.9% between 2000 and 2010, 1.5% in the decade 2010-2020 and 0.9% in the decade up to 2030[14].

The 56.5 GW of installed wind power capacity in the EU-27 by the end of 2007 will, in an average wind year, produce 119 TWh of electricity equal to 3.7% of EU electricity demand (3,243 TWh[15]). If the reference scenario is reached, wind power production will increase to 177 TWh in 2010, 477 TWh in 2020 and 935 TWh in 2030. The European Commission's baseline scenario[16] assumes an increase in electricity demand of 31% between 2005 and 2030 (4,367 TWh). Assuming that EU electricity demand develops as projected by the European Commission, wind power's share of EU electricity consumption will reach 5% in 2010, 11.6% in 2020 and 20.8% in 2030.

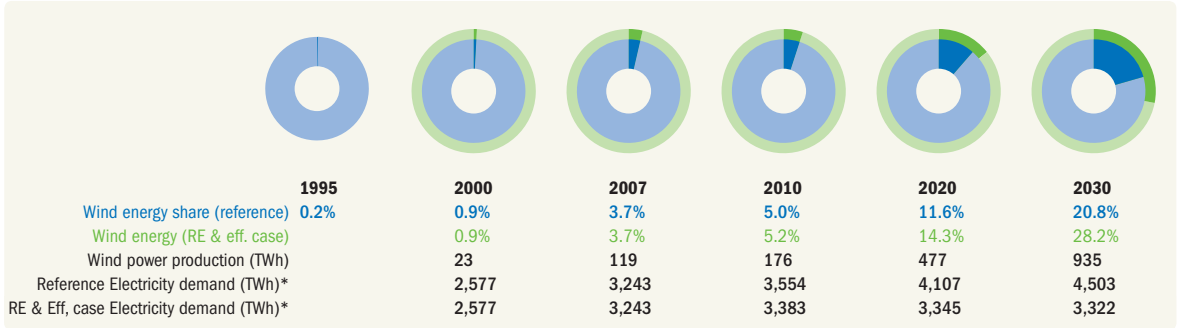
If political ambitions to increase energy efficiency are fulfilled, wind power's share of future electricity demand will be greater than the baseline scenario. In 2006, the European Commission released new scenarios to 2030 on energy efficiency and renewables[17]. If EU electricity demand develops as projected in the European Commission's "Combined high renewables and efficiency case", wind energy's share of electricity demand will reach 5.3% in 2010, 14.3% in 2020 and 28.2% in 2030.

	Wind power's share of EU electricity demand				
	2000	**2007**	**2010**	**2020**	**2030**
Wind power production (TWh)	23	119	176	477	935
Reference Electricity demand (TWh)*	2,577	3,243	3,554	4,107	4,503
RE & Eff. case Electricity demand (TWh)***	2,577	3,243	3,383	3,345	3,322
Wind energy share (reference)	0.9%	3.7%	5.0%	11.6%	20.8%
Wind energy (RE & Eff. case)	0.9%	3.7%	5.2%	14.3%	28.2%
Equivalent electricity demand met by wind power (% of households)		15%	21%	49%	84%

* Sources: Eurelectric, EWEA and European Commission

** European Commission, 2006: Combined High Renewables and Energy Efficiency Case

FIG 9.1: **Wind power's share of EU electricity demand**



14 European Energy and Transport; Trends to 2030 – update 2005; European Commission, 2006.
15 Source: Eurelectric, 2006; European Commission, 2006; EWEA.
16 European Energy and Transport. Trends to 2030 – update 2005; European Commission, 2006.
17 European Energy and Transport. Scenarios on energy efficiency and renewables; European Commission, 2006.

10. Contribution of wind power to electricity generation capacity

The IEA[18] expects 5,087 GW of electricity generating capacity to be installed worldwide in the period 2005-2030, requiring investments of $5.2 trillion in generation, $1.8 trillion in transmission grids and $4.2 trillion in distribution grids. For the European Union, the IEA expects 862 GW to be built, requiring investments of $925 billion in new generation, $137 billion in transmission and $429 billion in distribution grids.

As already mentioned, wind power's contribution to new power capacity in the EU has been exceeded only by gas in the last decade. 30% of all installed capacity was wind power in the period 2000 to 2007. 55% was natural gas and 6% was based on coal.

Spare electricity generating capacity is at a historic low and phase-out policies in the EU Member States require 27 GW of nuclear plants to be retired. Europe has to invest in new capacity to replace ageing plant and meet future demand. Between 2005 and 2030, a total of 862 GW of new generating capacity needs to be built, according to the IEA – 414 GW to replace aging power plants and an additional 448 GW to meet the growing power demand. The capacity required exceeds the total capacity operating in Europe in 2005 (744 GW).

As previously stated, the IEA is less optimistic about the development of wind energy than EWEA. Hence, it is necessary to adjust the IEA figures for total generating capacity and new capacity to take account of the fact that wind energy's capacity factor is lower than that of the average coal, gas or oil plant. Adjusting for the capacity factor adds 18 GW to total generating capacity in 2030 for a total of 1,176 GW and 26 GW to the figure for new generating capacity between 2005 and 2030 for a total of 889 GW over the period.

In 2005, 5.4% of all capacity in the EU was wind energy. That share is forecasted to increase to 9.9% in 2010, 18.1% in 2020 and 25.5% in 2030. Wind power's share of new generating capacity is forecasted to be 34% in the period 2005-2020 and 46% in the decade leading up to 2030. Wind power's share of new capacity in Europe in the 25-year period 2005-2030 is 39%.

	2005	2010	2020	2030
Total installed capacity (GW)	744	811	997	1,176
Total installed wind capacity (GW)	40	80	180	300
Wind power's share of installed capacity	5.4%	9.9%	18.1%	25.5%

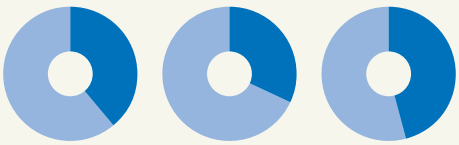
FIG 10.1: **Wind power's share of installed capacity**

	1995	2000	2005	2010	2020	2030
Wind power's share of installed capacity	0.46%	2.1%	5.4%	9.9%	18.1%	25.5%
Total installed capacity (GW)	538.8	580.7	744	811	997	1,176
Total installed wind capacity (GW)	2.5	12.3	40	80	180	300

18 IEA World Energy Outlook, 2006.

	2005-2010	2011-2020	2021-2030
New generating capacity (GW)	117	368	404
New wind generating capacity (GW)	46	117	187
Wind power's share of new capacity	39%	32%	46%

FIG 10.2: **Wind power's share of new capacity**



	2005-2010	2011-2020	2021-2030
Wind power's share of new capacity	39%	32%	46%
New generating capacity (GW)	117	368	404
New wind generating capacity (GW)	46	117	187

11. Greenhouse gas emissions in Europe

In 1997 in Kyoto the EU-15 made a commitment to reduce its emissions of greenhouse gases (GHG) by 8% by 2008-2012 compared to its 1990 level of emissions. The most important GHG by far is CO_2, accounting for 83% of total EU-25 emissions in 2004. A 'burden sharing' approach sets targets for each of the 15 Member States. The new Member States have individual reduction targets of 8% except Hungary and Poland who must reduce by 6%. Cyprus and Malta have no obligation. The overall Kyoto reduction target for EU-25 (excluding Malta and Cyprus) is 7.8%, or 450 Mt of CO_2 equivalents. The EU-15 obligation is a reduction of 342 Mt CO_2 equivalents.

In 2005, total GHG emissions in the EU-27 were 7.9% below 1990. In December 2007, the European Environment Agency (EEA) projected that the EU-27 would remain approximately at 2005 levels in 2010.

There is a noticeable difference between the EU-15 and the new Member States in terms of meeting their targets. While GHG emissions in the new Member States are expected to be 37% below 1990 levels by 2010, it is estimated that the EU-15 will have reduced its emissions by a mere 2% by 2010, assuming existing policies and measures. In other words, the new Member States are making up for the poor performance of the EU-15.

CO_2 reductions from wind power

There are different ways of calculating wind energy's CO_2 avoidance and the results depends on the assumptions made about which fuels are displaced when wind electricity is produced. The energy mix and base load differs between Member States, so ideally wind power's avoided CO_2 emissions should be based on the energy mix at the intermediate load in each member state. Here, it is assumed that wind energy avoids CO_2 at the intermediate load but at the average EU-27 generation.

Operating nuclear power is rather inflexible and can not easily be regulated up and down. Hence, wind power does not displace operating nuclear production, except during scheduled and unscheduled nuclear shutdowns and if nuclear capacity is decommissioned. Neither does wind energy replace hydropower because hydropower resembles a storage technology for electricity. Electricity from hydro that is displaced when wind power is operating will be saved for production later but total production from hydro is constant over time.

For the EU as a whole it is assumed that each kWh of wind power displaces a kWh defined by the energy mix of coal, oil and gas at the time of production. This approach underestimates wind energy's CO_2 avoidance because wind energy in reality avoids the most expensive and CO_2 intense production rather than the average production mix.

Naturally, the EU energy mix will change during the period up to 2030. According to 2006 IEA data, oil, gas and coal power stations produced 1,804 TWh in 2005 and emitted 1,408 Mt of CO_2. Consequently, one TWh produced by wind energy saved 0.78 Mt CO_2/TWh. The same approach is applied to IEA's data for 2010, 2015 and 2030 and a linear variation is assumed in the intermediate years. Using this approach it is assumed that wind energy in 2030, will avoid 0.72 Mt CO_2/TWh. In 2007, wind energy avoided 91 Mt of CO_2. In EWEA's reference scenario, annual CO_2 avoided from wind energy will increase to 133 Mt in 2010, 328 Mt in 2020 and 576 Mt in 2030.

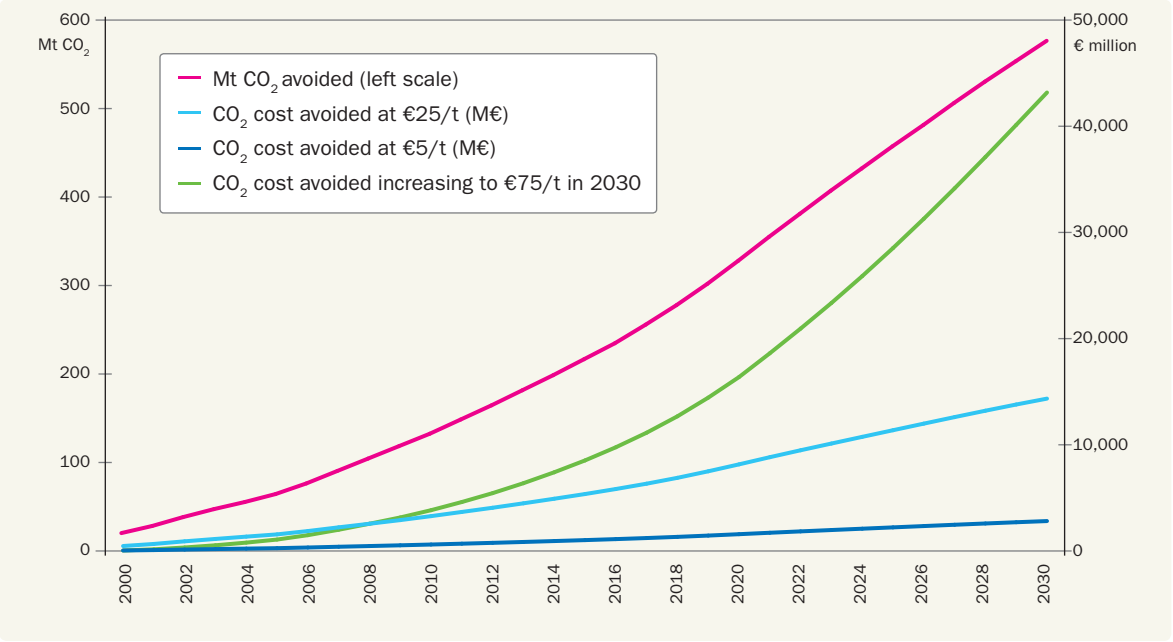
The European Commission's 2006 reference scenario, as well as its energy efficiency and renewables scenarios assumes an emissions permit price of €5/t CO_2. Carbon has been trading up to €30/t in 2006 and was trading at €20/t in February 2008. UBS forecasts a 2008 EU Allowance price of €25/mt CO_2[19].

Fig. 11.1 shows the total annual CO_2 emissions avoided by wind energy for the years 2000 to 2030 and the value of the CO_2 allowances for different scenarios of future CO_2 allowance prices:

- €5/t CO_2 throughout the period (European Commission's assumption, 2006)
- €25/t CO_2 throughout the period (UBS forecasted 2008 allowance price)
- €25/t in 2008, increasing linearly to €50/t in 2020 and €75/t in 2030.

Assuming the linear development in CO_2 allowance prices from €25/t in 2008 to €50/t in 2020, CO_2 costs avoided due to wind energy will increase from €2 billion in 2007 to 16 billion in 2020 and €43 billion in 2030. It is important to note that the total CO_2 reductions from the 327 GW of wind power investments needed to reach EWEA's 2030 reference scenario greatly exceed the figures for the annual reductions illustrated in Fig 11.1 because the turbines installed will deliver CO_2 reductions far beyond 2030. This topic will be dealt with in chapter 13.

FIG 11.1: **Wind energy CO_2 savings and cost avoided for different CO_2 prices in the EU-27 (2000-2030)**



19 UBS Research note, 12 September 2007.

12. Avoided fuel costs

Fuel is not required to produce wind power. When wind energy is produced, it saves significant amounts of fuel costs in the form of coal, gas and oil that would otherwise have been needed for power production. In addition to these avoided costs, the production of wind energy reduces demand for imported fuel (and thereby the cost of fuel) while reducing the rate of depletion of Europe's remaining fossil fuel reserves.

Naturally, the avoided fuel costs of wind energy depend on the assumptions made about future fuel prices. Oil and gas prices are very closely linked, and coal also follows – to a lesser extent – the price of oil. Both the IEA and the European Commission have for many years made predictions on future coal, gas and oil prices, and most governments base their energy policies on the IEA's fuel price scenarios. Historically, the IEA and European Commission scenarios have been similar, and both institutions have been very consistent in underestimating the future fuel prices.

2008 started with the price of oil reaching a record $100 a barrel. The International Energy Agency (IEA), predicts that the oil price will fall to $57 in 2010. In 2004, the IEA predicted that oil would cost $22 a barrel in 2010, $26 in 2020 and $29 in 2030 (in year-2000 dollars).

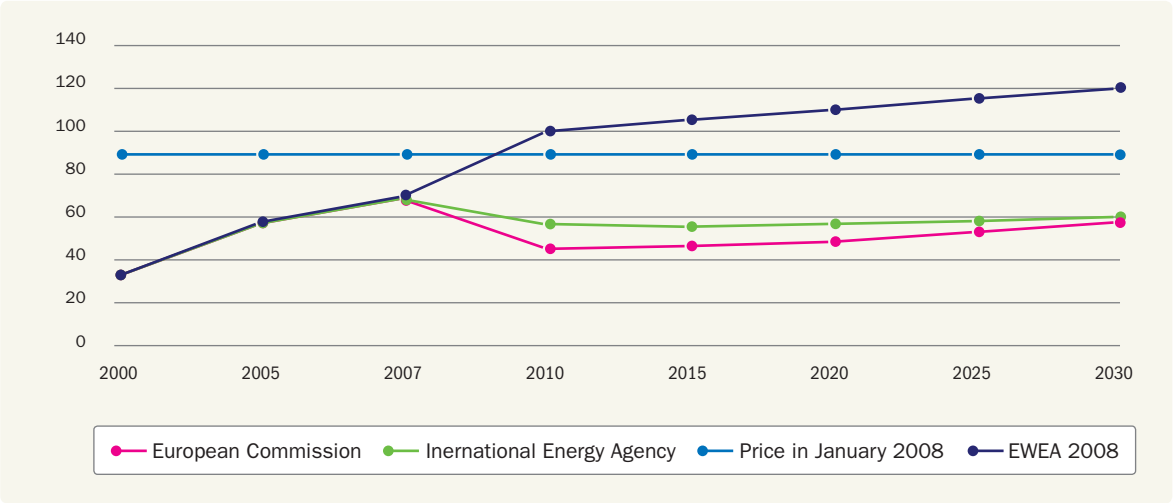
Fig. 12.1 shows the latest oil price estimates from the European Commission (2006) and the IEA (2007), and an alternative oil price scenario from EWEA. As the figure shows, the European Commission believes that the price of oil in 2010 will be approx. 50% lower than today (app. $90 in January 2008) while the IEA estimates a drop in the price of oil to $55 three years from now., Both institutions believe that the price of oil in 2030 will be approx. $60 a barrel – 33% lower than today.

Nobody can predict oil prices, but it should be a minimum requirement that the European Commission and the IEA include fuel price sensitivity analysis in their scenarios for the future development of the energy markets.

Oil price assumptions (in $05)*	2000	2005	2007	2010	2015	2020	2025	2030
European Commission, 2005	31.3	57.1	68.9	44.6	46.4	48.1	52.9	57.6
International Energy Agency, 2007	31.5	57.1	68.9	57.2	55.5	57.0	58.5	60.1
EWEA 2008	31.3	57.1	68.9	100.0	105.0	110.0	115.0	120.0

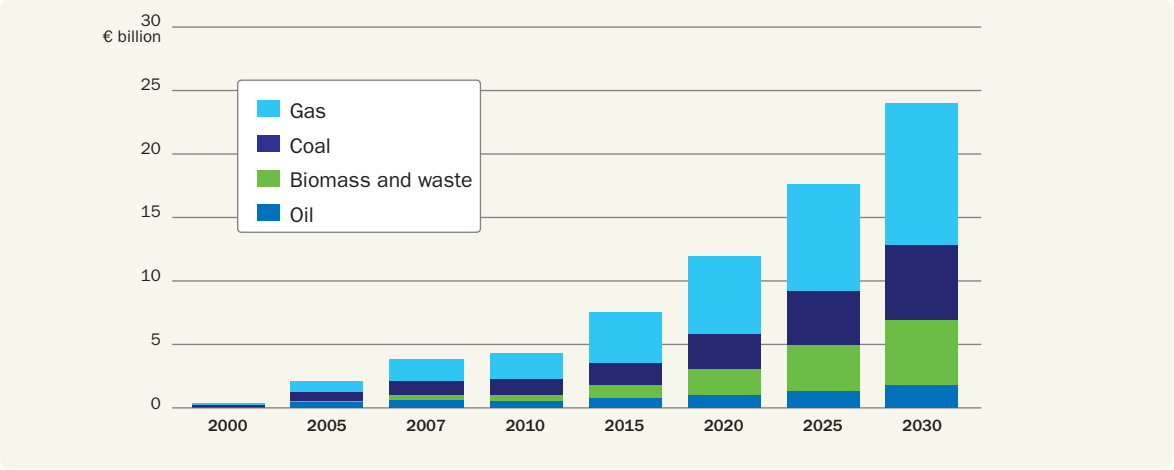
* Adjusted to 2005 prices / actual prices up to 2007.

FIG 12.1: **CH-13 Oil price assumptions (in $2005/barrel)**



The fuel costs avoided due to wind energy production can be calculated on the basis of the European Commission's fuel price assumptions for coal, oil and gas up to 2030. As Fig. 12.2 shows, wind energy avoided €3.9 billion of fuel costs in 2007: €1.7 billion worth of gas; €1.2 billion worth of coal; €0.7 billion worth of oil and €0.3 billion worth of biomass/waste. In EWEA's reference scenario, wind energy will avoid costs of €4.4 billion in 2010; €12 billion in 2020; and €24 billion in 2030, based on the European Commission's fuel price assumptions (Fig. 12.2). Similar results emerge from using the IEA fuel price assumptions (Fig. 12.3).

FIG 12.2: **Avoided fuel cost from wind energy 2000-2030 (European Commission fuel price assumption)**



Assuming fuel prices equivalent to $90 per barrel of oil, rather than the European Commission's assumptions fuel costs avoided due to wind would be €5 billion in 2007; €8.3 billion in 2010; €20.5 billion in 2020; and €34.6 billion in 2030 (see Fig. 12.4).

The calculations here are based on an €/$ exchange rate of 0.6838 (February 2008). Fluctuations in exchange rates can have a profound effect on the avoided fuel cost. Had the €/$ exchange rate been 1, wind energy's avoided fuel cost would have been €50.5 billion in 2030 instead of €34.6 billion. However, it could reasonably be argued that the price of oil would be lower if the US$ was stronger.

FIG 12.3: **Avoided fuel cost from wind energy 2000-2030 (IEA fuel price assumption)**

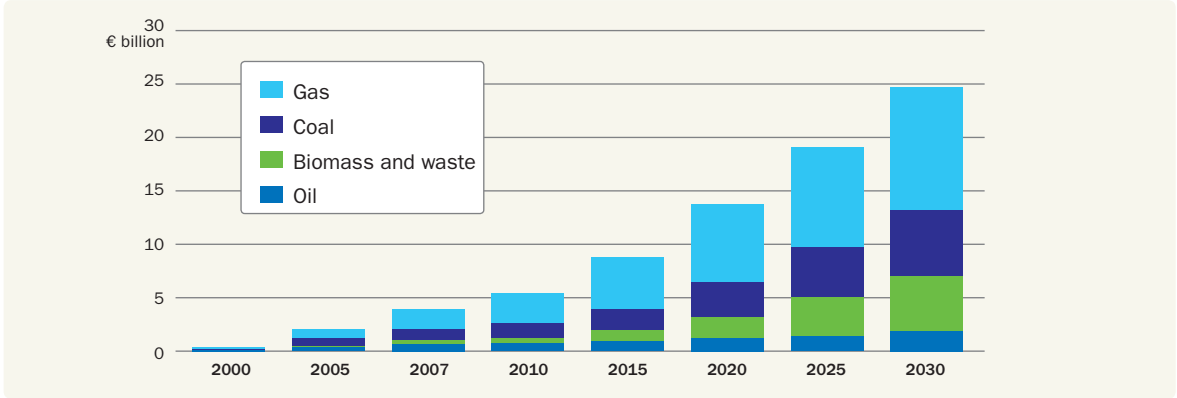
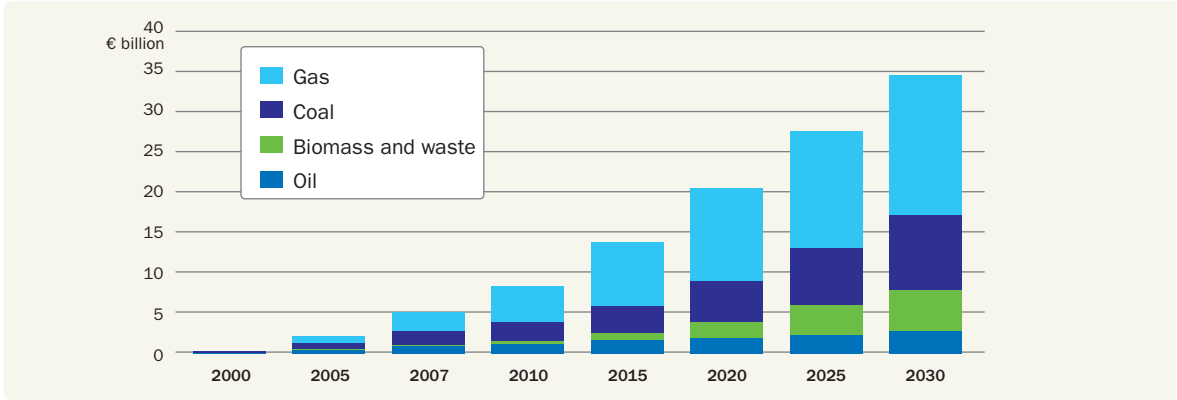
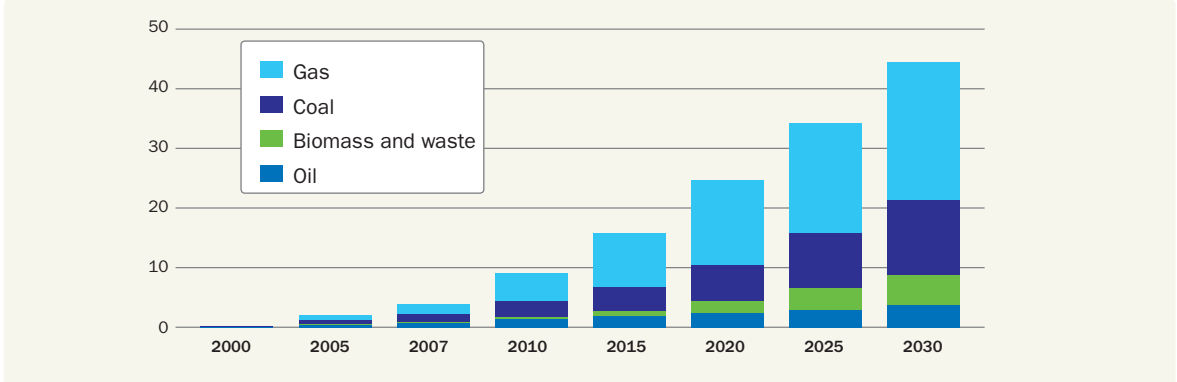


FIG 12.4: **Avoided fuel cost from wind energy 2000-2030 (Fuel price equivalent to Jan. 2008 – $90/barrel – until 2030)**



In EWEA's fuel price scenario – the oil price increases gradually to $120 in 2030, and the relationship between oil, gas and coal remains unchanged from the Commission's scenario – wind energy would avoid fuel costs worth €9.2 billion in 2010; €24.6 billion in 2020; and €44.4 billion in 2030 (see Fig. 12.5.)

FIG 12.5: **Avoided fuel costs from wind energy 2000-2030 (Fuel price increase to $100 in 2010; $110 in 2020; $120 in 2030)**



13. Wind energy investments up to 2030

One of the significant benefits of wind power is that the fuel is free. Therefore, the total cost of producing wind energy throughout the 20 to 25-year lifetime of a wind turbine can be predicted with great certainty. Neither the future prices of coal, oil or gas, nor the price of carbon, will significantly affect the cost of wind power production.

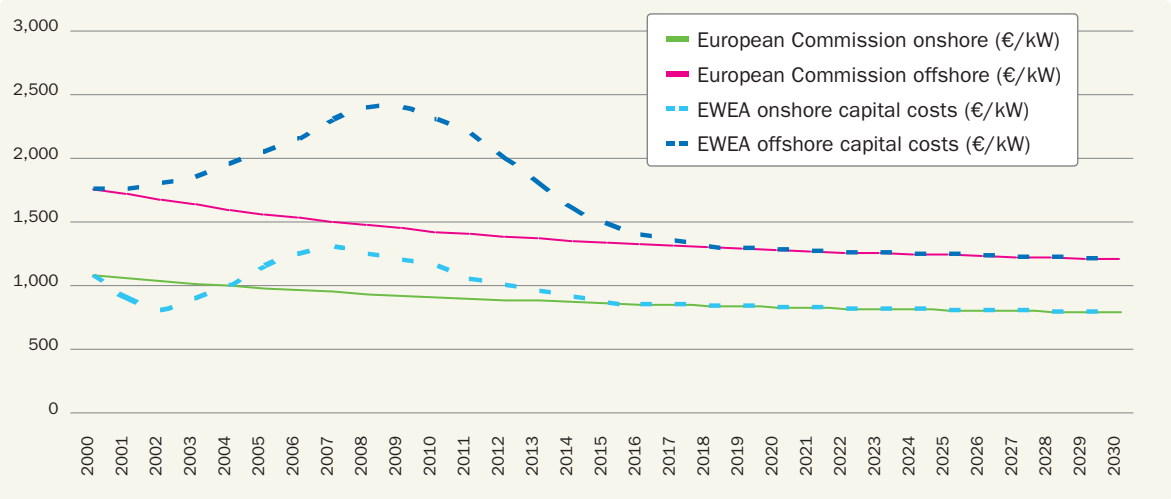
In order to calculate the wind power investments needed to reach EWEA's reference scenario, it is necessary to make assumptions on the future development of the cost of installed wind power capacity. For some years, it has been assumed as a rule of thumb that installed wind power capacity cost approx. €1,000/kW. That is probably still a valid rule of thumb. However, since 2000 there have been quite large variations in the price (not necessarily the cost) of installing wind power capacity.

In the period 2001 to 2004, the global market for wind power capacity grew less than expected (see page 15) and created a surplus in wind turbine production capacity. Consequently, the price of wind power capacity went down dramatically – for some projects €700-800/kW. In the past three years – 2005 to 2007 – the global market for wind energy has increased by 30-40% annually, and demand for wind turbines has surged, leading to increases in prices.

The European Commission, in its renewable energy roadmap[20], assumes that onshore wind energy cost €948/kW in 2007 (in $€_{2005}$). It assumes that costs will drop to €826/kW in 2020 and €788/kW in 2030. That long term cost curve may still apply for a situation where there is a better balance between demand and supply for wind turbines than at the present time.

Fig. 13.1 shows the European Commission's assumptions on the development of onshore and offshore wind power capacity costs up to 2030. In addition, there are two curves that reflect the effect of the demand/supply on wind turbine prices in recent years. EWEA assumes onshore wind energy prices of €1,300/kW in 2007 (€2005 prices) and offshore prices of €2,300/kW. The steep increase in offshore cost reflects the limited number of manufacturers in the offshore market, the current absence of economies of scale due to low market deployment and bottlenecks in the supply chain.

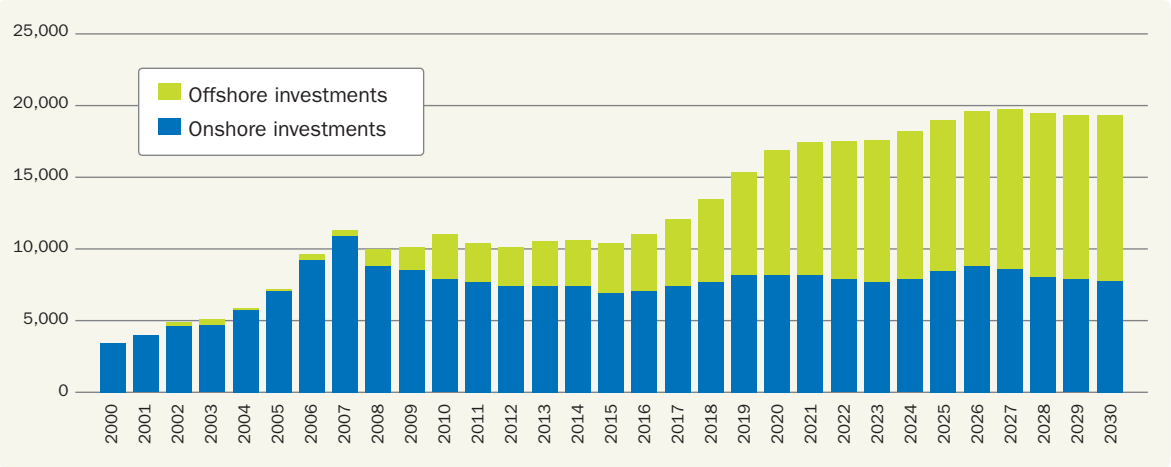
FIG 13.1: **Cost/price of onshore and offshore wind (€/kW) – European Commission / EWEA assumptions**



20 http://ec.europa.eu/energy/energy_policy/doc/03_renewable_energy_roadmap_en.pdf

Based on the EWEA reference scenario for installed capacity up to 2030 and the EWEA wind power capacity prices above, Figure 13.2 shows the expected annual wind power investments from 2000 to 2030. The market is expected to be stable at around €10 billion/year up to 2015, with a gradually increasing share of investments going to offshore. By 2020, the annual market for wind power capacity will have grown to €17 billion annually with approximately half of investments going to offshore. By 2030, annual wind energy investments in EU-27 will reach almost €20 billion with 60% of investments offshore.

FIG 13.2: **Wind energy investments 2000-2030 (€ mio)**



Cumulative investments in wind energy over the three decades 2000 to 2030 will total €390 billion. Between 2008 and 2030 in EWEA's reference scenario, approx. €340 billion will be invested in wind energy in the EU-27 – €31 billion in 2008-2010; €120 billion in the decade 2011-2020; and €188 billion in the decade 2021-2030.

The IEA (2006) expects that €925 billion of investment in electricity generating capacity will be needed for the period 2005 to 2030 in the EU. According to the EWEA reference scenario, €367 billion – or 40% – of that would be wind power investments.

14. Wind energy investments and total avoided lifetime cost

So far, this report has looked at wind energy's contribution to electricity, CO_2 reductions, avoided fuel cost, etc. from a perspective of total installed capacity by the end of each individual year. In this chapter a life-time approach is used, in order to determine how much CO_2 and fuel cost are avoided from wind power investments made in a given year over the entire life-time of the capacity. For example, chapter 12 demonstrated that the 300 GW of wind power capacity installed in the EU in 2030 will avoid the emission of 576 Mt/CO_2 in 2030. What has not been taken into account so far in this report is that the wind energy capacity installed, e.g. the 19.5 GW that will be installed during the year 2030, will continue to produce electricity, avoid CO_2 and fuel costs beyond 2030 – some CO_2 and fuel costs will be avoided right up to 2055.

Fig. 14.1 shows the total CO_2 costs and fuel costs avoided during the lifetime of the wind energy capacity installed for each of the years 2008-2030, assuming a technical lifetime for onshore wind turbines of 20 years and for offshore wind turbines of 25 years. Furthermore, it is assumed that wind energy avoids an average of 690 g CO_2/kWh produced; that the average price of a CO_2 allowance is €25/t and that €42 million worth of fuel is avoided for each TWh of wind power produced, equivalent to an oil price throughout the period of $90 per barrel.

For example, the 8,554 MW of wind power capacity that was installed in the EU in 2007 had an investment value of €11.3 billion, will avoid CO_2 emissions worth €6.6 billion throughout its lifetime and fuel costs of €16 billion throughout its lifetime, assuming an average CO_2 price of €25/t and average fuel prices (gas, coal and oil) based on $90/barrel of oil.

Similarly, the €152 billion of investments in wind power between 2008 and 2020 will avoid €135 billion worth of CO_2 and €328 billion in fuel cost under the same assumptions. For the period up to 2030, wind power investments of €339 billion will avoid €322 billion in CO_2 cost and €783 billion worth of fuel.

FIG 14.1: **Wind investments compared with life time avoided fuel and CO_2 costs (Oil – $90/barrel; CO_2 – €25/t)**

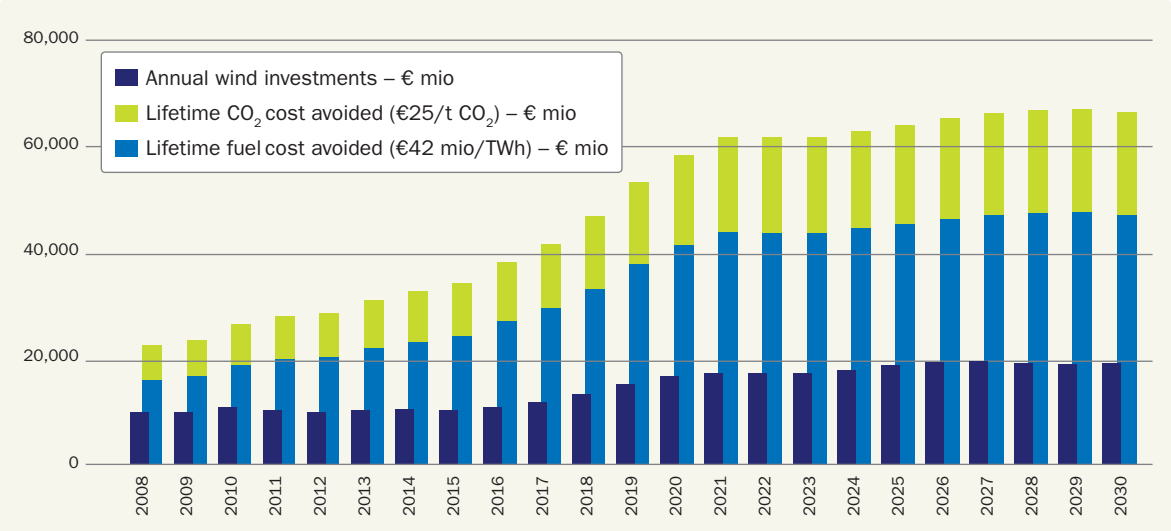


FIG 14.2: **Wind investments compared with life time avoided fuel and CO_2 costs (Oil – $50/barrel; CO_2 – €10/t)**

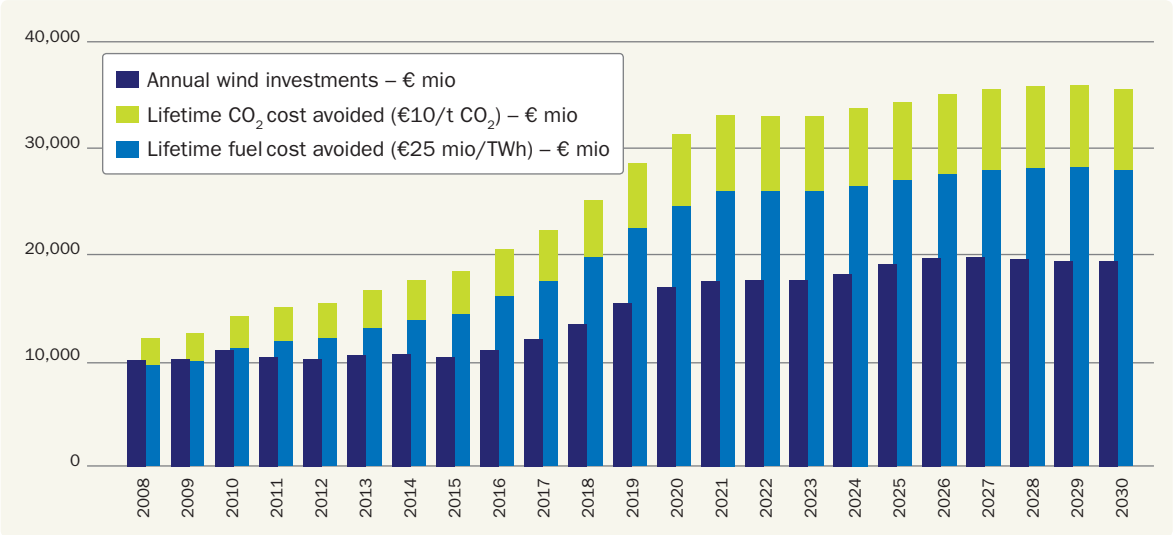
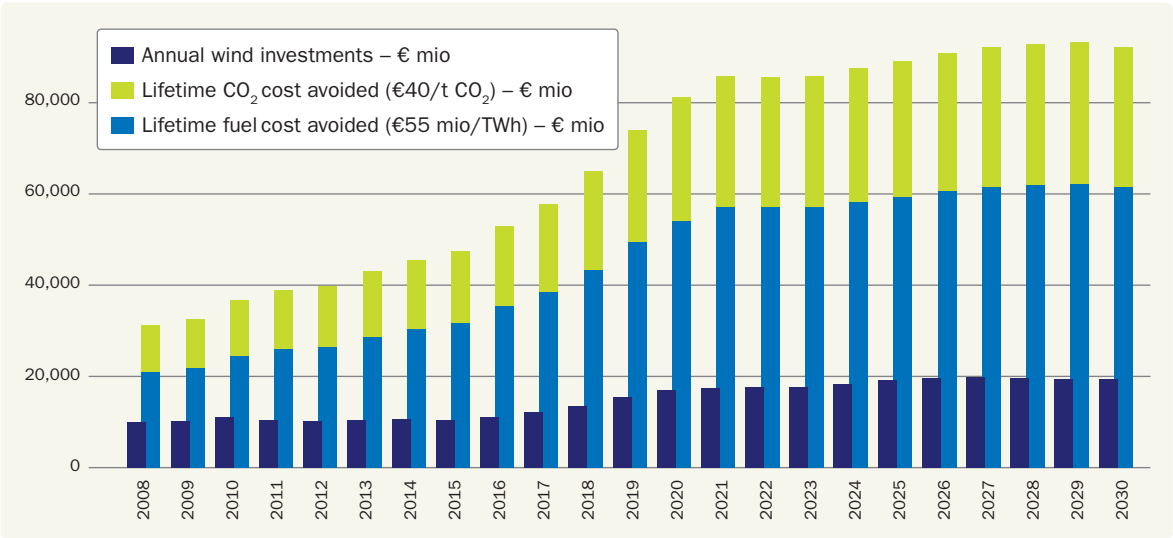


FIG 14.3: **Wind investments compared with life time avoided fuel and CO_2 costs (Oil – $120/barrel; CO_2 – €40/t)**



It is important to note that these calculations only compare the capital cost of wind energy to avoided CO_2 and fuel cost. The operation and maintenance cost (low because the fuel is free) has not been taken into account. In addition, it would be reasonable to assume that some components of the wind turbine would need replacing during their technical lifetime. This has not been taken into account either. The purpose is to compare the investment value in an individual year with the avoided fuel and CO_2 cost over the lifetime of the wind turbines.

As can be seen from Fig. 14.2, Fig. 14.3 and the table below, changing the CO_2 and fuel price assumptions has a dramatic impact on the result. With low CO_2 prices (€10/t) and fuel prices (equivalent of $50/barrel of oil) throughout the period, the wind power investments over the next 23 years avoid €466 billion instead of €783 billion. With high prices for CO_2 (€40/t) and fuel (equivalent to $120/barrel of oil) wind power would avoid fuel and CO_2 costs equal to more than €1 trillion over the three decades from 2000 to 2030.

The following table shows the different savings made depending on the price of oil (per barrel) and CO_2 (per tonne).

Totals (oil $90; CO_2 €25)	**2008-2010**	**2011-2020**	**2021-2030**	**2008-2020**	**2008-2030**
Investment	31,062	120,529	187,308	151,591	338,899
Avoided CO_2 cost	21,014	113,890	186,882	134,904	321,786
Avoided fuel cost	51,165	277,296	455,017	328,462	783,479
Totals (oil $50; CO_2 €10)	2008-2010	2011-2020	2021-2030	2008-2020	2008-2030
Investment	31,062	120,529	187,308	151,591	338,899
Avoided CO_2 cost	8,406	45,556	74,753	53,962	128,714
Avoided fuel cost	30,456	165,057	270,843	195,513	466,356
Totals (oil $120; CO_2 €40)	2008-2010	2011-2020	2021-2030	2008-2020	2008-2030
Investment	31,062	120,529	187,308	151,591	338,899
Avoided CO_2 cost	33,623	182,223	299,011	215,846	514,857
Avoided fuel cost	67,002	363,126	595,856	430,128	1,025,984

ANNEX 1: Wind energy installations 2007-2030

	Cumulative capacity onshore (GW)	Cumulative capacity offshore (GW)	Annual decommissioning (GW)	Total cumulative capacity	Wind energy production (TWh)	Wind Energy's share of electricity demand (BAU)	Wind Energy's share of electricity demand (High RE&Efficiency)	Mt CO_2 avaoided	Annual wind power investments (€ mio)	Annual avoided fuel cost – € billions (assuming $90 oil price)	Annual avoided CO_2 cost – € billions (assuming €25/t CO_2)
2007	55.5	1.1	0.1	56.5	119	3.7%	3.7%	91	11,330	5.018	2,283
2008	62.5	1.6	0.0	64.1	137	4.1%	4.2%	105	10,017		2,619
2009	69.7	2.2	0.0	71.8	156	4.5%	4.7%	119	10,079		2,963
2010	76.5	3.5	0.0	80.0	177	5.0%	5.2%	133	10,966	8.328	3,336
2011	83.8	4.7	0.0	88.5	200	5.5%	5.9%	149	10,341		3,730
2012	91.1	6.0	0.2	97.1	223	6.1%	6.6%	165	10,082		4,124
2013	98.3	7.7	0.6	106.0	247	6.6%	7.3%	182	10,476		4,541
2014	105.4	9.7	1.0	115.1	273	7.2%	8.1%	199	10,590		4,972
2015	112.5	12.0	1.0	124.5	299	7.7%	8.9%	217	10,338	13.770	5,414
2016	119.5	14.8	1.3	134.3	329	8.3%	9.8%	235	10,970		5,886
2017	126.4	18.2	1.9	144.6	360	9.0%	10.7%	256	12,042		6,388
2018	133.0	22.6	2.6	155.6	395	9.8%	11.8%	278	13,439		6,939
2019	139.3	28.2	3.5	167.5	435	10.7%	13.0%	302	15,364		7,552
2020	145.0	35.0	4.3	180.0	477	11.6%	14.3%	328	16,887	20.512	8,205
2021	149.9	42.3	5.1	192.2	522	12.5%	15.6%	355	17,441		8,880
2022	154.1	49.9	5.6	204.0	567	13.4%	17.0%	381	17,567		9,532
2023	157.9	57.8	5.6	215.7	611	14.3%	18.3%	407	17,583		10,164
2024	161.4	66.0	6.3	227.4	655	15.1%	19.6%	432	18,161		10,792
2025	164.8	74.5	7.1	239.3	701	16.0%	21.0%	457	19,034	27.501	11,416
2026	168.1	83.2	7.7	251.3	747	16.9%	22.4%	481	19,597		12,037
2027	171.3	92.1	7.8	263.4	794	17.9%	23.9%	506	19,756		12,651
2028	174.4	101.2	7.3	275.6	842	18.9%	25.3%	530	19,504		13,251
2029	177.3	110.5	7.2	287.8	889	19.8%	26.7%	553	19,312		13,834
2030	180.0	120.0	7.3	300.0	935	20.8%	28.2%	576	19,353	34.566	14,389

ANNEX 2: Annual avoided fuel cost from total wind power capacity installed

EUROPEAN COMMISSION FUEL PRICES

Avoided fuel cost (€ mio)	2000	2005	2007	2010	2015	2020	2025	2030
Coal	120	660	1,186	1,146	1,703	2,673	4,220	5,969
Oil	86	418	697	606	848	1,025	1,364	1,792
Gas	117	806	1,744	2,144	4,052	6,158	8,413	11,074
Biomass and waste	44	180	283	466	949	2,069	3,666	5,136
Total (€05)	366	2,064	3,909	4,362	7,552	11,926	17,663	23,971

IEA FUEL PRICES (WEO 2007)

Avoided fuel cost (€ mio)	2000	2005	2007	2010	2015	2020	2025	2030
Coal	120	660	1,186	1,470	2,039	3,169	4,674	6,224
Oil	86	418	697	777	1,016	1,216	1,511	1,869
Gas	117	806	1,744	2,749	4,853	7,301	9,319	11,546
Biomass and waste	44	180	283	466	949	2,069	3,666	5,136
Total (€05)	366	2,064	3,909	5,462	8,857	13,755	19,170	24,775

AT CURRENT FUEL PRICE ($90/BARREL)

Avoided fuel cost (€ mio)	2000	2005	2007	2010	2015	2020	2025	2030
Coal	120	660	1,548	2,313	3,306	5,002	7,186	9,327
Oil	86	418	910	1,222	1,647	1,919	2,322	2,800
Gas	117	806	2,277	4,326	7,868	11,522	14,326	17,302
Biomass and waste	44	180	283	466	949	2,069	3,666	5,136
Total (€05)	366	2,064	5,018	8,328	13,770	20,512	27,501	34,566

FUEL PRICE INCREASE TO $100 IN '10; 110 IN '20; 120 IN '30

Avoided fuel cost (€ mio)	2000	2005	2007	2010	2015	2020	2025	2030
Coal	120	660	1,186	2,570	3,858	6,113	9,182	12,436
Oil	86	418	697	1,358	1,921	2,345	2,967	3,734
Gas	117	806	1,744	4,807	9,179	14,083	18,306	23,070
Biomass and waste	44	180	283	466	949	2,069	3,666	5,136
Total (€05)	366	2,064	3,909	9,201	15,907	24,610	34,122	44,376

OIL PRICE ASSUMPTIONS (IN $05)*

	2000	2005	2007	2010	2015	2020	2025	2030
European Commission	31.3	57.1	68.9	44.6	46.4	48.1	52.9	57.6
International Energy Agency	31.5	57.1	68.9	57.2	55.5	57.0	58.5	60.1
Price in January 2008	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
EWEA 2008	31.3	57.1	68.9	100.0	105.0	110.0	115.0	120.0

* Adjusted to 2005 prices/actual prices until 2007

ANNEX 3: GHG emissions in CO_2 equivalents

	Base-year emissions Mt CO_2-eq	2005 Mt CO_2-eq	EU burden sharing or Kyoto commitment	EU burden sharing or Kyoto commitment	Projections 2010 MT CO_2-eq	Projections 2010 MT CO_2-eq compared to base-year %	Commitment implied by burden sharing Mt CO_2-eq	CO2-eq increase projection 2010	Gap	Change 1990-2005 Mt CO_2-eq	Change 1990-2005 %
Austria	78.9	93.3	-13.0%	68.6	92.5	17%	-10.3	13.6	23.9	14.4	18%
Belgium	146.9	143.8	-7.5%	135.9	141.6	-4%	-11.0	-5.3	5.7	-3.1	-2%
Bulgaria	138.3	69.8	-8.0%	127.2	87.1	-37%	-11.1	-51.2	-40.1	-68.5	-50%
Cyprus	6	9.9		6.0	12.2	103%		6.2		3.9	65%
Czech Republic	196.3	145.6	-8.0%	180.6	145.7	-26%	-15.7	-50.6	-34.9	-50.7	-26%
Denmark	69.3	63.9	-21.0%	54.7	62.6	-10%	-14.6	-6.7	7.9	-5.4	-8%
Estonia	43.5	20.7	-8.0%	40.0	18.9	-57%	-3.5	-24.6	-21.1	-22.8	-52%
Finland	71.1	69.3	0.0%	71.1	85.0	20%	0.0	13.9	13.9	-1.8	-3%
France	564	553.4	0.0%	564.0	569.0	1%	0.0	5.0	5.0	-10.6	-2%
Germany	1231.5	1001.5	-21.0%	972.9	955.4	-22%	-258.6	-276.1	-17.5	-230.0	-19%
Greece	111.7	139.2	25.0%	139.6	150.4	35%	27.9	38.7	10.8	27.5	25%
Hungary	122.2	80.5	-6.0%	114.9	87.4	-28%	-7.3	-34.8	-27.5	-41.7	-34%
Ireland	55.8	69.9	13.0%	63.1	68.4	23%	7.3	12.6	5.3	14.1	25%
Italy	519.5	582.2	-6.5%	485.7	587.3	13%	-33.8	67.8	101.6	62.7	12%
Latvia	25.3	10.9	-8.0%	23.3	13.6	-46%	-2.0	-11.7	-9.7	-14.4	-57%
Lithuania	48	22.6	-8.0%	44.2	33.5	-30%	-3.8	-14.5	-10.7	-25.4	-53%
Luxemburg	12.7	12.7	-28.0%	9.1	14.2	12%	-3.6	1.5	5.1	0.0	0%
Malta	1	3.4	-		2.2	120%		1.2		2.4	240%
Netherlands	213.2	212.1	-6.0%	200.4	211.8	-1%	-12.8	-1.4	11.4	-1.1	-1%
Poland	586.9	399	-6.0%	551.7	420.0	-28%	-35.2	-166.9	-131.7	-187.9	-32%
Portugal	60.9	85.5	27.0%	77.3	88.0	44%	16.4	27.1	10.7	24.6	40%
Romania	282.5	153.7	-8.0%	259.9	192.5	-32%	-22.6	-90.0	-67.4	-128.8	-46%
Slovakia	73	48.7	-8.0%	67.2	58.3	-20%	-5.8	-14.7	-8.9	-24.3	-33%
Slovenia	20.2	20.3	-8.0%	18.6	21.6	7%	-1.6	1.4	3.0	0.1	0%
Spain	288.4	440.6	15.0%	331.7	410.2	42%	43.3	121.8	78.5	152.2	53%
Sweden	72.2	67	4.0%	75.1	69.8	-3%	2.9	-2.4	-5.3	-5.2	-7%
UK	775.2	657.4	-12.5%	678.3	595.6	-23%	-96.9	-179.6	-82.7	-117.8	-15%
EU-15	4271.4	4192	-8.0%	3,929.7	4101.8	-4%	-341.7	-169.6	172.2	-79.4	-2%
EU-25*	5807.6	5163.8	-7.8%	5357.174	5180.4	-11%	-450.4	-627.2	-176.8	-643.8	-11%
New MS	1536.2	971.8	-7.1%	1427.5	1078.6	-30%	-108.7	-457.6	-349.0	-564.4	-37%

*Malta and Cyprus have no obligation

Source: EEA GHG trends and projections 2007, p.100 (table 16.2)

EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

About EWEA

EWEA is the voice of the wind industry, actively promoting the utilisation of wind power in Europe and worldwide. It now has 400 members from 45 countries including manufacturers with more than a 90% share of the global wind power market, plus component suppliers, research institutes, national wind and renewables associations, developers, contractors, electricity providers, finance and insurance companies and consultants. This combined strength makes EWEA the world's largest and most powerful wind energy network.

The EWEA Secretariat is located in Brussels at the Renewable Energy House. The Secretariat co-ordinates European policy, communications, research, and analysis. It manages various European projects, hosts events and supports the needs of its members.

Tel: +32 2 546 1940 – Fax: +32 2 546 1944
E-mail: ewea@ewea.org – Web: www.ewea.org

Printed on FSC certified paper / Design & production by www.inextremis.be