

## Ten Year Review of the International Wind Power Industry 1995-2004

### Forecast for 2015 & Long Term Scenario to 2025

*BTM Consult ApS - September 2005*

The latest report from BTM Consult ApS is a review of progress in the international wind power industry over the past ten years. With comprehensive highlights from the previous decade, the report also includes new analysis of trends and important developments. In addition, two special topics are covered - the requirement for large wind farms to integrate with today's utility systems and a review of technological developments and trends in the design of modern wind turbines.

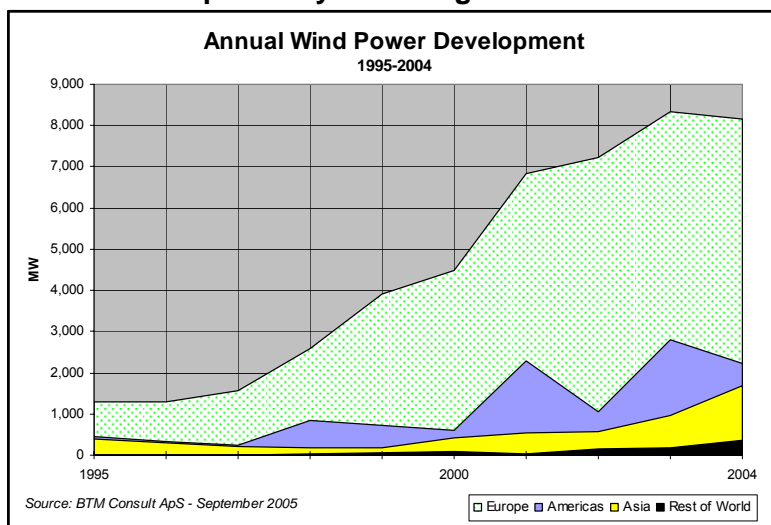
The period from 1995 to 2004 represents the maturing era of the modern wind power industry, and the aim of this publication is to give an overview of the last decade. Against this background, the likely prospects for the future are also presented in the form of a ten year forecast up to 2015 and a long-term scenario up to 2025. The findings and highlights of the report are:

#### Market development

Worldwide installed wind power capacity has increased from 3,500 MW at the end of 1994 to nearly 48,000 MW by the end of 2004, a growth factor of 13.5. More detailed figures for the decade are:

- Annual new installed capacity has increased by an average rate of 27.3% p.a. since 1995. During 2004, 8,154 MW of new capacity was installed.
- Cumulative wind power has increased by an average rate of 29.1% p.a. By the end of 2004, 47,912 MW of capacity was recorded in operation worldwide.

#### Installed wind power by world region 1995 to 2004



#### Increase in wind turbine size

In 1995 the average size of wind turbine delivered to the market had an installed capacity of 400 kW. By the end of 2004 this figure had increased to 1,248 kW. The report lists total deliveries to the market by size segment. The table below shows development in these size segments over the past five years.

#### Distribution of total MW by size segment 2000 to 2004

Year	2000	2001	2002	2003	2004
Total MW supplied	3,961	7,056	7,416	8,304	8,508
<b>Product (Size range)</b>	<b>% of total MW</b>				
"Small WTGs" <750 kW	49.3%	32.3%	13.7%	7.4%	5.4%
"Mainstream" 750-1500 kW	37.7%	50.8%	55.7%	56.4%	50.9%
"MW-class" 1501-2500 kW	13.0%	16.9%	30.0%	35.3%	42.8%
"Multi-MW Class" >2500 kW	0.0%	0.0%	0.6%	0.9%	0.9%
<b>Total</b>	<b>100.0%</b>	<b>100.0%</b>	<b>100.0%</b>	<b>100.0%</b>	<b>100.0%</b>

Source: BTM Consult ApS – September 2005

### High penetration of wind power in Europe

The penetration of wind power in Europe has reached a level at which 2.3% of total electricity consumption in Europe is now satisfied by wind energy. A few countries have reached a remarkably high level of penetration, including Denmark with 19.7%, Spain with 7.7% and Germany with 5.4%.

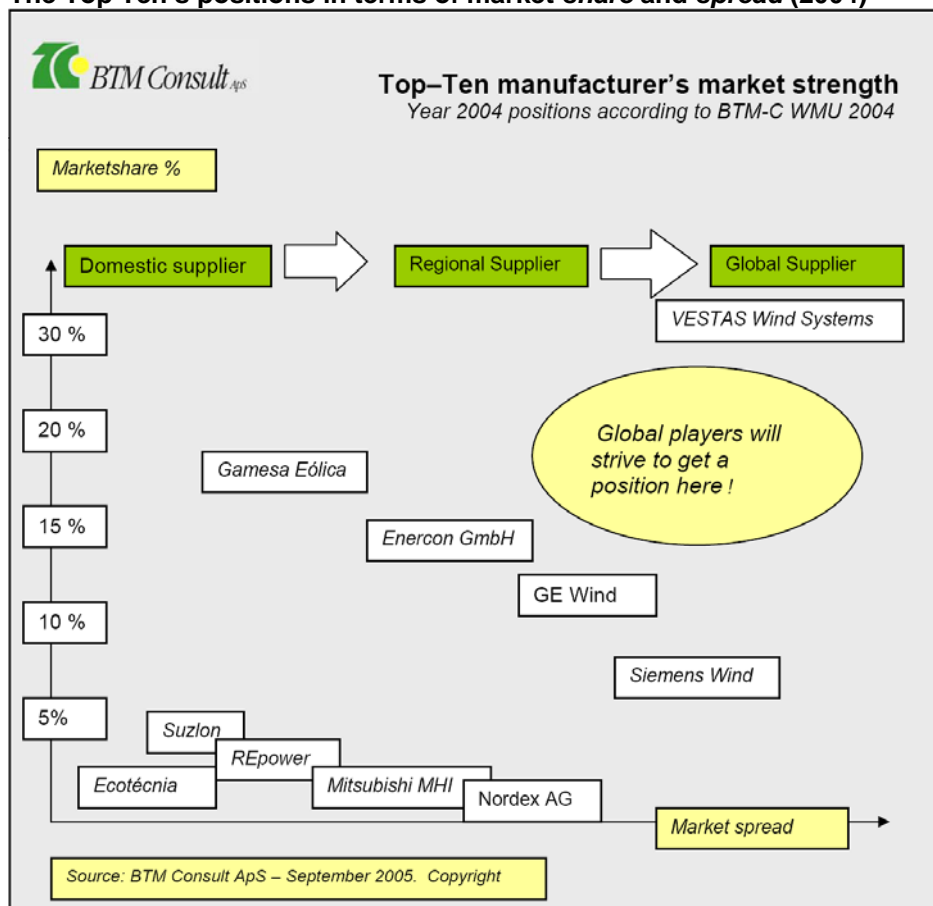
### Developments on the supply side

The overall supply of wind turbines to the markets has been shared among a group of some 25 companies, of which the ten leading ones are ranked as the “Top Ten” suppliers. Over the decade this Top Ten has typically accounted for 90-96% of supply. The top five to six suppliers have remained the same over the whole period, even though some have changed name as a result of mergers and/or acquisition. Further down the list, there have been changes from time to time. The six leading manufacturers during the ten year period have been Vestas, Gamesa, NEG Micon (now part of Vestas), Enercon, GE Wind (formerly Enron Wind) and Siemens (formerly Bonus Energy). The highest market share for a single company has been Vestas, with 34.3% in 2004 after it acquired NEG Micon.

### Consolidation in the industry

The report traces consolidation in the industry, with the most remarkable mergers/acquisitions described. A brief review of the period up to 1995 is included. The assessment concludes by grouping the major players into three categories based on the present situation and past track records. A group of minor players are also identified, since they might be candidates for future entry into the Top Ten. In the following figure, the market positions of the Top Ten companies are illustrated in terms of market share and geographical spread. This is based on the position in 2004.

**The Top Ten’s positions in terms of market share and spread (2004)**



Even though there are four companies in the central “emerging global players” group, all candidates to move upwards, there will obviously not be room for five global players with a 25% market share each! A more likely scenario in the medium term is that there will be a group of 3-4 companies at the top sharing 80% of the market.

## Development of wind turbine technology

Developments over the past decade are reviewed from both a market and R&D perspective. The most spectacular progress has been in the size of wind turbines. In 1980 the typical turbine was a 50 kW machine with a rotor diameter of 15 metres. By 1995, where this review starts, the average size had increased to 500-600 kW and with a 40-50 metre rotor diameter. In 2004 commercial turbines had reached 2-3 MW with 90 – 100 metre rotor diameters. The “invisible” improvements behind these bald statistics are better design codes, optimised use of materials and control strategies and devices which reduce loads and improve the quality of the electrical output. The review also analyses the records of turbine deliveries in the market to show which have been the most successful models from the major manufacturers. The biggest selling turbines over the past decade are listed in the report, with the three best sellers being the Vestas V47, Gamesa G52 and GE Wind’s 1.5 MW range.

Along with the basic design and up-scaling, the evolution of concepts in terms of power conversion from rotor to the grid are also assessed comprehensively. Topics covered in the report include power control capability and methodology, reflecting the shift from stall regulated fixed pitch to variable speed with full span pitch.

A review of the offshore market lists operational projects in the world and the candidate-products for future offshore projects, with the latest turbines in the size range 3 – 5 MW identified. Most of these are currently in operation as prototypes on land.

## Wind power joins the mainstream

Ten years and more of product development and improvements have moved the wind industry forward from the stage of manufacturing a single turbine which can export electricity to a stiff grid to the supply of a complete wind power plant. The latter must comply with the requirements of both utilities and Transmission System Operators, especially their desire for an increasing level of system compatibility. This is no longer a matter of 50 to 100 kW of capacity coming on and off at a low voltage level. Instead, wind farms with several hundreds of MW are being required to actively contribute to the stability of the whole system – a huge challenge to be met.

## Forecasting – an exercise in uncertainty

BTM Consult has made an evaluation of previous forecasts presented in the annual World Market Update publication, published since 1995. In fact, our first “five year forecast” has already been overtaken. The basic conclusion is that the dynamics of the wind turbine industry have been far stronger than expected by us (and other analysts) ten years ago. However, there now seems to be a broader consensus about the short term expectations for the industry. This is because wind power has become mainstream technology and therefore more predictable. The table below shows previous BTM-C forecasts set against actual development:

### Predicted cumulative installation five years ahead from BTM Consult ApS

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
<b>Forecast's from previous BTM-C World Market Updates (Cum. MW by end of the year):</b>									
Summary by 1995	6,125	7,625	9,520	11,615	13,710				
WMU '96		7,724	9,739	12,044	14,524	17,514			
WMU '97			9,583	11,563	13,763	16,713	20,283		
WMU '98				13,358	17,028	21,163	26,243	31,833	
WMU '99					18,817	24,642	30,737	38,337	47,512
WMU '00						24,704	31,589	39,604	48,084
WMU '01							32,447	42,352	52,757
WMU '02								41,002	50,262
WMU '03									48,336
<b>Actual cumulative installation, as recorded by BTM-C (MW capacity):</b>									
<b>Cum. Installed MW</b>	<b>6,104</b>	<b>7,638</b>	<b>10,153</b>	<b>13,932</b>	<b>18,449</b>	<b>24,927</b>	<b>32,037</b>	<b>40,301</b>	<b>48,394</b>

Source: BTM Consult ApS – World Market Update 1996-2003

This section of the report also includes a review of past estimates and/or projections from bodies such as the IEA (IEA’s World Energy Outlook), EWEA (European Wind Energy Association) and WEC (World Energy Council). These organisations have equally been surprised by the actual pace of development in the wind power industry. Even though the IEA has been more conservative in its view

of the future role of wind power, the series of WEO reports have become an important reference point for BTM-C when looking forward at the energy industry as a whole.

## Long term development of wind power – two scenarios

This report includes two scenarios for wind power development, a different approach from that in BTM-C's World Market Update. This is the first time that BTM-C has produced a long-term scenario (to 2025), whilst the short-term scenario is effectively a forecast with a time horizon five years longer than usual. This forecast for 2015 is broken down by continent and by country and the figures are shown year by year. The forecast and scenario are respectively described as:

1. **Business as Usual**
2. **Environment and Security of Supply focused Policy**

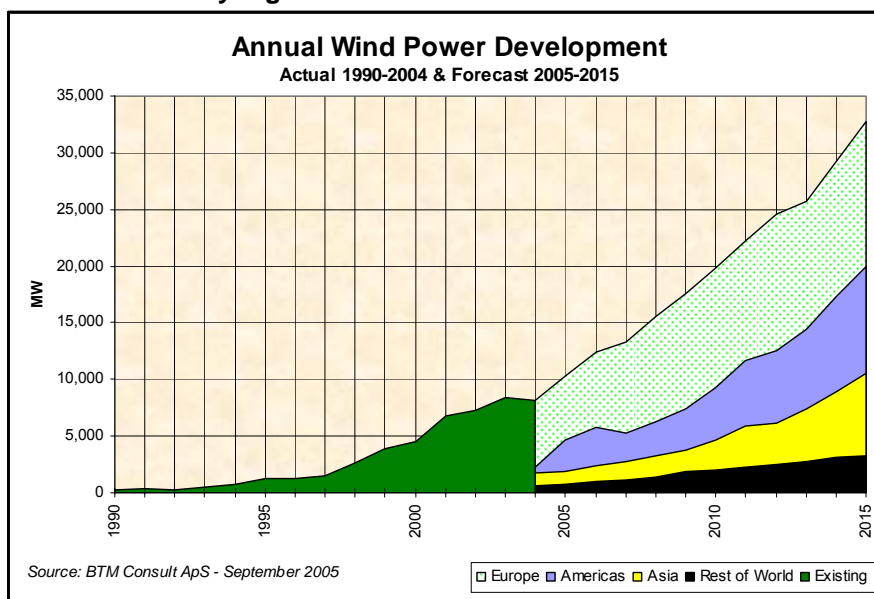
An important part of the task has been to estimate the expected share to be taken by wind power compared to other generation technologies. This has involved an assessment of the competition in terms of cost-effectiveness, reliability and the environmental impacts, whether positive or negative. Included in the process has been an evaluation of wind power technology and its potential for further improvements, along with progress among competing technologies. It is assumed that the higher oil prices seen recently will be maintained at a level of US\$ 40 – 50 for a long time.

## Forecast to 2015

### Overall figures:

- Annual installation will increase from the 2004 figure of 8,152 MW to **32,720 MW in 2015**
- Cumulative capacity will increase from 48,000 MW in 2004 to **271,512 MW in 2015**
- The average growth in **annual installation** for the whole period is **13.5% p.a.**
- The average growth in **cumulative installation** for the whole period is **17.1% p.a.**
- The fastest growing regions will be America and Asia
- Europe will show more moderate growth than in the past. However, even with an 8.4% average increase in annual installation, Europe will maintain its position as the largest regional market for wind power up to 2015
- Wind power plants are expected to produce **620 TWh** per year in 2015, equal to a **penetration rate of 2.7%** in the world's electricity supply
- **Europe's share** of the cumulative installation in 2015 **will drop** from today's 72.5% to 53%. The **Americas share will grow** from today's 15.4% to 23.6%.

## Global forecast by region to 2015



This Executive Summary reflects the main findings of the BTM Consult ApS report, *Ten Year Review of the International Wind Power Industry – Sept. ISBN 87-987788-7-0*. Results, figures, tables may not be reproduced without permission from BTM-Consult ApS

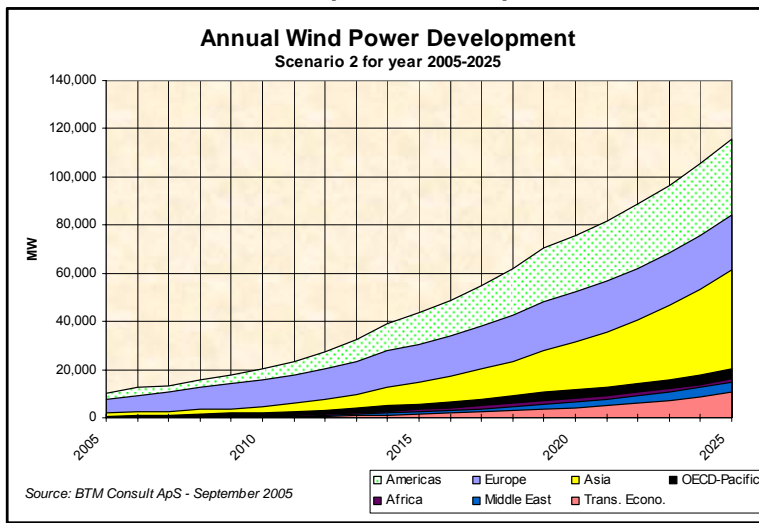
**Cost estimate for the forecast to 2015:**

The additional **224,000 MW** to be installed over the next eleven years, according to the forecast, represents a **total investment of around US\$ 224 billion**, based on today's prices of approximately US\$ 1,000 per kW of wind power capacity. Note that future price development has not been assessed as part of this forecast study.

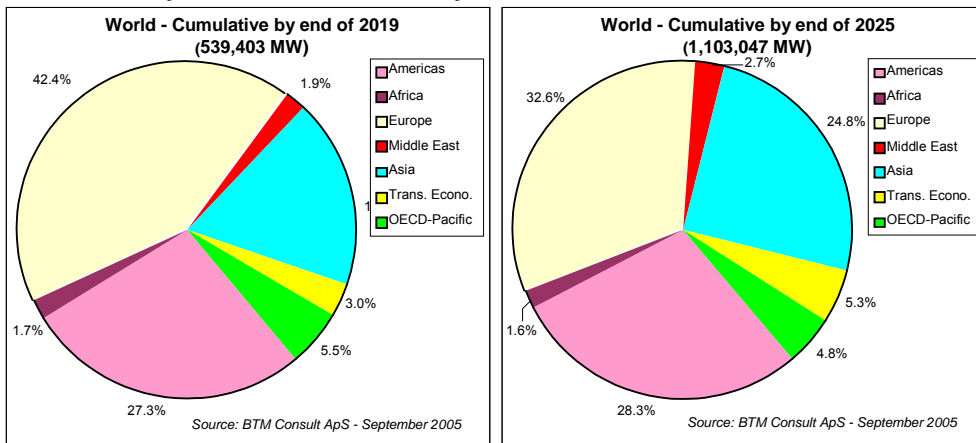
**Scenario to 2025**

This longer term scenario is built on a set of assumptions about global progress on the issues of climate change and security of supply. Based on these considerations, along with development patterns likely to be replicated in the future and the capacity of both physical resources and the grid, the scenario is quantified by region and annually to 2025. The cumulative installed capacity will reach 1,000,000 MW (1,000 GW) by the end of the period, 20 times more than today's level. The annual demand for new wind power capacity will grow to some 70,000 MW in 2020, and 118,000 MW by 2025. Europe will end up a saturated market, with a wind power penetration close to 20%. Other regions of the world have still some way to go to reach that level. The development of Scenario 2 is shown in the following graphs.

**Scenario 2 – Global wind power development to 2025**



**Scenario 2 by 2019      Scenario 2 by 2025**



The impact of the scenario is calculated in terms of penetration in the electricity supply with reference to the IEA's global projection for 2030 (adjusted to 2025 through interpretation of the WEO 2004 data).

The main findings are:

- *By 2025 the global penetration of wind power will have reached 8.6%.*
- *The highest penetration will be in Europe, reaching almost 20% and a fully saturated market. From then on Europe will need to install some 18 GW each year just to maintain its installed capacity.*
- *All the remaining world regions still have a potential for further expansion, as they are some way from the "20% penetration" limit. Most countries belonging to the Transition Economies are not likely to take off before the end of the scenario and do not have a huge potential.*