ENERGYWATCHGROUP

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Wind Power in Context –
A clean Revolution in the Energy Sector

December 2008

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About Energy Watch Group

Energy policy needs objective information.

The Energy Watch Group is an international network of scientists and parliamentarians. The supporting organization is the Ludwig-Bölkow-Foundation. In this project scientists are working on studies independently of government and company interests concerning:

- the shortage of fossil and nuclear energy resources,
- development scenarios for regenerative energy sources,

  as well as,
- strategic deriving from these for a long-term secure energy supply at affordable prices.

The scientists are therefore collecting and analysing not only ecological but above all economical and technological connections. The results of these studies are to be presented not only to experts but also to the politically interested public.

Objective information needs independent financing.

A bigger part of the work in the network is done unsalaried. Furthermore the Energy Watch Group is financed by donations, which go to the Ludwig-Boelkow-Foundation for this purpose.

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Content

Abbreviations

CAGR	Compound Annual Growth Rate
CF	capacity factor
CF-100	capacity factor of 100% - a theoretical capacity able to deliver base-load with a 100% availability over 8760 hours per year
CHP	combined heat and power
EWEA	European Wind Energy Association
EWEC	European Wind Energy Conference
GWEC	Global Wind Energy Council
HVDC	High voltage direct current (connection)
IEA	International Energy Agency
MW	Megawatt (1,000,000 W)
NFFO	Non Fossil Fuel Obligation
NGCC	Natural Gas Combined Cycle plant
O&M	operation and maintenance (costs)
PPA	Power purchase agreement
PTC	Production Tax credit (a tax deduction of some 1.8-2.1 US-Cents)
US	United States of America
WWEA	World Wind Energy Association

Cover Pictures

Vestas V90-3,0 MW Bockinghalde / Germany, courtesy of Vestas
Q7/ Princess Amalia wind farm, off the Netherlands, by Jerome Guillet

Abstract

This study is about growth, past forecasts and the future prospects of wind energy.

Wind power net capacity additions over the last ten years (1998-2007) have showed a mean growth rate of 30.4 percent per year, corresponding to a doubling of net additions every 2½ years.

In 2007, net capacity additions reached 19553 Megawatts, a level that most energy pundits failed to anticipate. Net additions, in 2007, were 417 percent bigger than the mean estimate published by the International Energy Agency (IEA), in its World Energy Outlook 1995-2004 editions.

In the IEA's most recent World Energy Outlook (2008) scenario, it again predicts a low growth "reference scenario" for wind power with only a 2.2 percent increase of annual wind capacity additions over the 2010-2030 period. The IEA acknowledges that the "risk of a supply crunch" for oil after 2010 could be "driving up oil prices – possibly to new record highs", but then fails to revise its forecasts for renewable energies. Not surprisingly, the IEA forecasts have historically proven to be empirically unsound.

This study takes a different view, developing four global scenarios for the future of wind power, after scrutinizing some of the most established forecasts for the wind sector. It assumes a continuous growth of global wind power additions over the next decades. The driving force for this growth is not ecological or moral motivations but the demonstrable economic advantages of wind power, including the abundant and cost free primary energy source (wind) which never runs out, easy technology access, short time to market, stable life-cycle-costs and continuous cost reductions due to progress on the learning curve.

In scenario A, the observed mean annual growth rate of wind power additions, 30.4 percent, from 1998 to 2007, is used as a proxy for further expansion. As a result, wind energy will have conquered a 50 percent market share of global new power plant installations by 2019 and a close to 100 percent market share by 2022, alongside with solar and other renewables such as hydro and biomass. Global non-renewable power generation would peak in 2018 and could be phased out completely by 2037.

The scenarios B, C and D, with half the annual growth rates for wind power or/and electricity consumption growth, show similar results: Market conquest of the wind sector (together with other renewables) is expected in 2019 (scenario C), 2031 (scenario D) or 2039 (scenario B). Non-renewable power generation will peak between 2014 and 2032 and could be phased out within the following two decades.

The study concludes that roadblocks against wind power growth, such as fluctuations of wind, lack of grid connections and lack of reserve capacities, will be overcome through: planning, growing price incentives derived from the observed increase of oil prices and the restructuring of electricity markets (unbundling). Technical improvements will further propel the wind industry to deliver ever more affordable, secure and clean electricity at a very high speed that will be unattainable by more traditional technologies such as nuclear, natural gas or coal. Wind and solar, accompanied by hydro power, biomass and geothermal energy will pave the way to a 100 percent renewable power generation, very probably within the first half of this century.

1. Executive Summary

From 2005-2008, prices for oil, gas, coal and uranium were subject to price increases of several hundred percent. The oil price reached a peak at $147 per barrel in July 2008 and then collapsed. By December 2008, hovering between $40 and $50 per barrel, the oil price still is more than 100 percent higher than the mean price over the 1990s, and the same accounts for natural gas.

In the wake of this price shift, new wind power installations turn out to be a competitive and cost-secure technology, compared with other new power technologies. Despite the mentioned price reductions for oil and natural gas, the low-cost character of wind power is upheld for the future, considering the structural shortage of fossil fuels with marginal costs for new fields in OECD nations well beyond $70 per barrel – and on the rise.

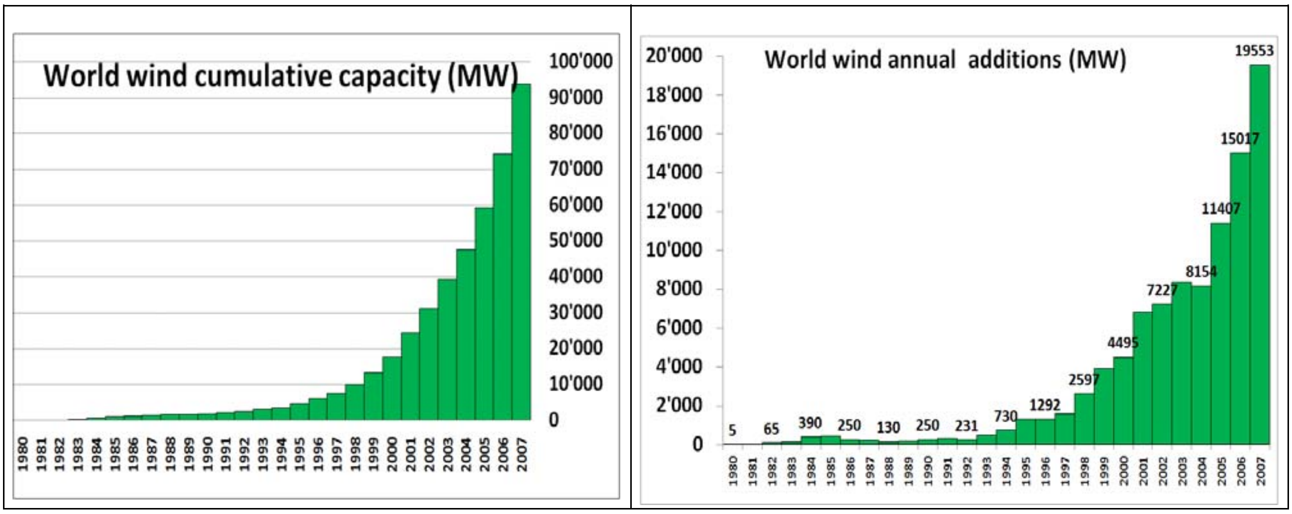

Figure 1 world wind power capacity and annual additions

Since the early 1990s, the wind power industry shows exponential growth with mean growth rate of annual MW-additions exceeding 30 percent over the past ten years. This relentless expansion, so far barely touched by any sign of recession or financial crisis, is a sign of a new era that wind industry experts call a “historically unique growth path, a positive trend that is expected to continue for years.”

Over the last 25 years, the productivity of wind turbines grew one hundred fold and average capacity per turbine grew by more than 1000 percent. Transnational companies, such as General Electric, Siemens, Areva, Alstom, Suzlon have entered the booming industry and, by 2008, all have established divisions for wind power. Additionally, numerous Chinese companies are entering the sector.

2^n-serial milestones of exponential growth	Milestone passed/expected	Number of years until next GW doubling	Cumulative capacity worldwide at milestone's year's end
1000 MW	1985	6	1020 MW
2000 MW	1991	6	2170 MW
4000 MW	1995	4	4778 MW
8000 MW	1998	3	10153 MW
16000 MW	2000	2	17706 MW
32000 MW	2003	3	39434 MW
64000 MW	2006	3	74328 MW
128000 MW	2009exp.	3?	
264000 MW	2012?	3?	

Figure 2 2^n milestones in cumulative wind power capacities

It took six years (1980-85) for world wind capacity to reach the first 1000 MW of cumulative capacity and another six years (1985-1991) to double this milestone. Since 1998, the frequency of capacity-doubling has been reduced to 2-3 years and the prospects for growth have never been better.

Peak oil and peak natural gas – the decline of oil and natural gas production in an ever-growing number of nations – puts wind power on the forefront of competitiveness. But the reason for its success goes far beyond pure cost considerations. It is a combination of more than one dozen specific attributes that give wind power an advantage over other power technologies:

1. The primary energy (wind) is cost-free;
2. The primary energy is renewable and never runs out;
3. There is an abundant resource, nobody can cut access/supply;
4. Stable life-cycle-cost of its use can be guaranteed;
5. Wind power is competitive with other new power sources;
6. Operating wind turbines cause no carbon emissions, no air pollution and no hazardous waste;
7. No water for cooling is needed;
8. Wind has a short energy payback of energy invested, normally less than one year;
9. There is a global, easy access to wind technology, compared to nuclear and others;
10. Time to market is very short, erection of entire wind farms within one year possible;
11. Fast innovation cycles prevail, based on maturing know-how;
12. Wind is still a young technology, allowing progress on the learning curve and cost reductions;
13. Wind is decentralized power; it allows small organizations or groups in various places to become a part of the power generation business and to sell it for a profit – very different from the exclusive structure of the oil, gas or nuclear business;
14. Distances from good wind sites to consumers in general are moderate (1-1000 miles) compared to other energy sources (oil, gas, uranium, coal)
15. Wind energy has positive side benefits for various stakeholders such as job creation, taxes, income options for farmers, infrastructure for remote areas, investment opportunities for local communities etc.
16. Wind energy replaces expenses for (often imported) fuels by technology, creating energy, know-how and human labor in a decentralized way.

High worldwide growth rates for wind power will continue, and wind power will conquer a large part of the energy market in the next foreseeable future (10-15 years).

Misleading predictions and the role of IEA (International Energy Agency)

By comparing historic forecasts on wind power with reality for Germany, for Europe and for the World, we find that all official forecasts were miles away from reality – they were much too low – with the exception of the forecasts done by Greenpeace who supposed exponential growth over time. Greenpeace was wrong by just 1 percent of reality due to its simple method, assuming non-erosion of growth rates.

The worst forecasts on wind regularly came and still do come from the International Energy Agency (IEA). For example the IEA's World Energy Outlook 1998 predicted cumulative installations of 47.4 GW wind power by 2020. This 2020-prediction was exceeded in real terms of cumulative installations in December 2004. The IEA's 2002 forecast predicting 104 GW wind power by 2020 was exceeded in real terms in summer 2008. The "best" IEA forecast on wind so far was the 2004 World Energy Outlook alternative energy approach, which was surpassed three years later in real additions by an amount of "only" 68 percent.

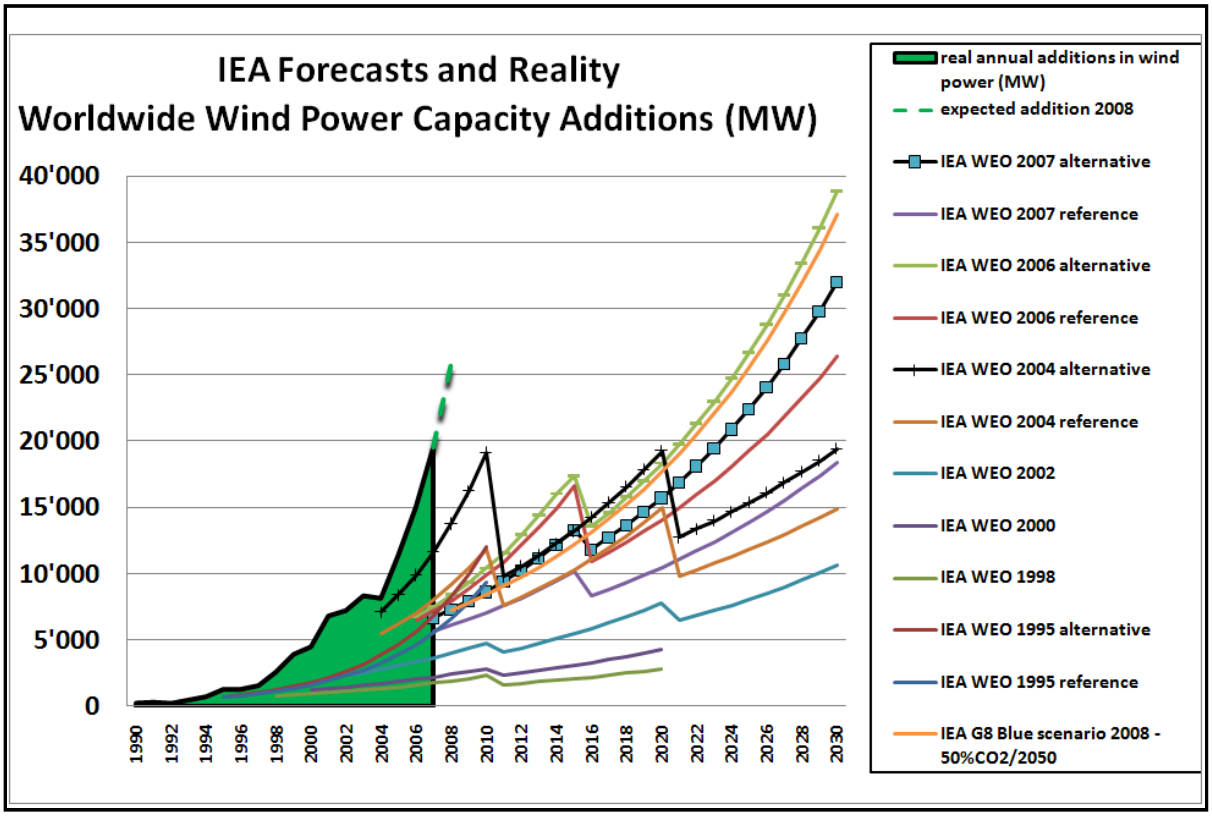

Figure 3 IEA long-term forecasts of annual additions: World

Despite all wind industry indicators pointing at an acceleration of capacities, the IEA in its 1995-2007 forecasts has predicted continuous stagnation of annual wind capacity additions for at least the next ten years, independent of scenario names such as 'reference' or 'alternative'.

The IEA numbers were neither empirically nor theoretically based. A doubling of wind power additions from 10,000 to 20,000 MW was observed in a 2½ year period between the end of 2005 and start of 2008 worldwide. So why should it take 22 years going forward for another doubling of wind additions while the prices of fossil and nuclear fuels were exploding?

Is there not enough wind resource?

Are there doubts about the commercial viability of the technology?

Is there a lack of grid technology or extensions?

Is there a reduction of wind turbine manufacturing?

If so – then why would the IEA stay tacit on these issues instead of resolving bottlenecks and of advancing energy security?

The 2008 World Energy Outlook

The 2008 World Energy Outlook for the first time took a slightly different view. Global wind output has been projected to grow fivefold from 130 TWh in 2006 to 660 TWh in 2015. But after 2015, cumulative wind power capacity is forecasted to rise to 1,490 TWh in 2030 only. This translates into sharp reductions of annual capacity additions – from 57 GW per year in 2015 down to an average of 32 GW for the 2016-2030 period, a virtual stagnation compared to the 25-26 GW addition expected for 2008. No arguments are given why the wind sector should suffer such a crisis by 2015 and after.

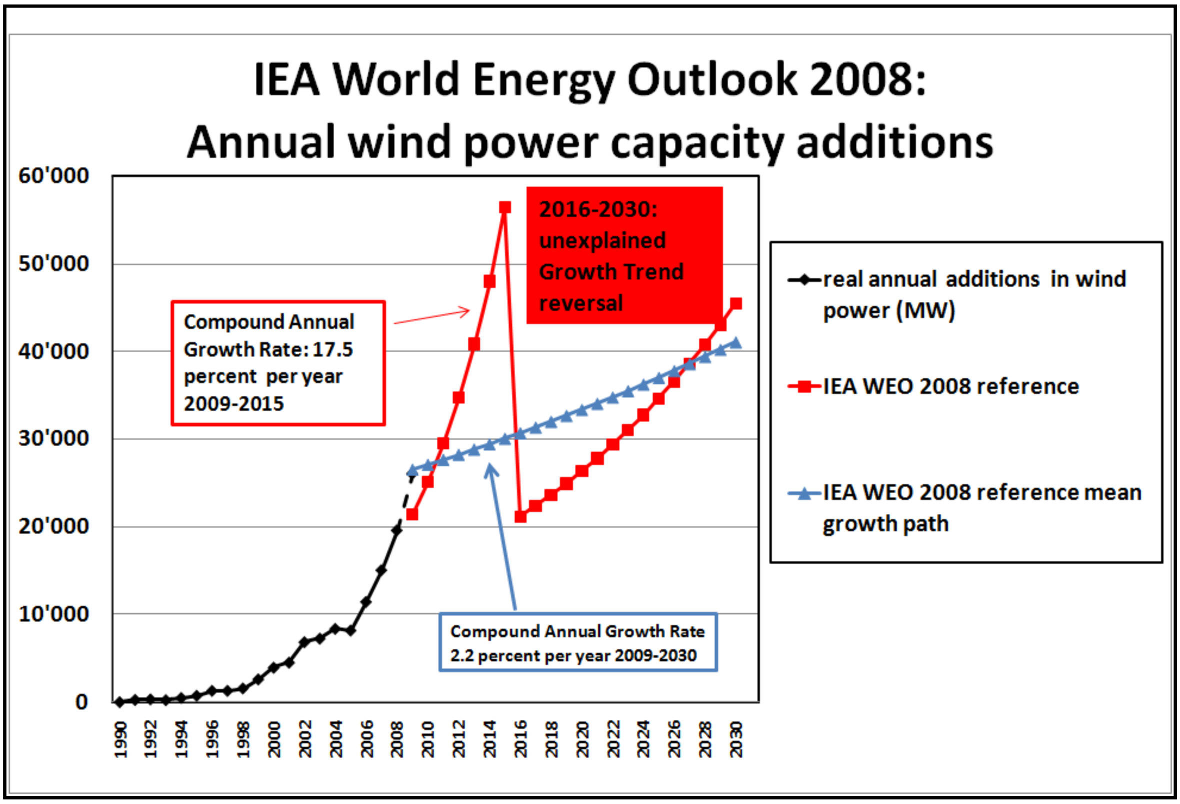

Figure 4 IEA projection of annual wind capacity additions 2010-2030, from World Energy Outlook 2008

While for the short-term the IEA acknowledges a healthier growth perspective for the wind sector, the growth of annual additions over the whole 2010-2030 period remains at only 2.2 percent per year, which is a very low projection compared with the mean growth of 30.4 percent per year over the 1998-2007 period.

We conclude by saying that the IEA Outlook remains attached to oil, gas, coal and nuclear, and renewables seem to have no chance to reverse this trend. This organization, whose constitutional task would be to protect consumers from price hikes and to deliver energy security, has been and is deploying misleading data on renewables for many years. This is also true vice versa: As recently as 2002, IEA predicted an oil price of $29 per barrel by 2030, and in 2007 its forecast for 2030 stood at $60 per barrel. By summer 2008, we found out that a price of $50-$150 per barrel is more realistic – for 2008, let alone 2030!

In its 2008 World Energy Outlook, the agency suddenly has doubled its oil price forecast. While in 2007, it said the cost of crude would fall in the long term to less than $60 per barrel, it now predicts an average of $100 per barrel until 2015, despite a deepening recession, and rising to $120 in real terms by 2030.[1] It concludes that the era of cheap oil is over and that the recent extreme price volatility will continue. And it acknowledges that the "*risk of a supply crunch*" for oil after 2010 could be "*driving up oil prices – possibly to new record highs*".[2]

But then it fails to give a structurally revised perspective of affordable renewables and their potentials for replacing fossil energy sources on a large scale and on solid economical grounds. Instead it views wind power and other new renewable energies delivering only a 4% share of global electricity by 2030. Its faith in nuclear, a technology in decline, and its great expectations of carbon capture and storage, a technology with a highly uncertain future beyond the certainty that it will be expensive, remains unbroken.

One has to ask if the ignorance and contempt of IEA toward wind power and renewables in general is done within a structure of intent. Renewables tend to look ever expensive and close to irrelevant while oil, coal and nuclear look irreplaceable in the IEA World Energy Outlook reference scenarios. Is it this message that big companies and US presidents need to fight a war for oil, subsidies and profits, disguised as a "war on terrorism"?

The real significance of wind power: four scenarios

In this study we try to show why wind power will make a key contribution to the global supply of energy. It would be arrogant though to construct a "wind exclusive" model for future growth. Solar and other technologies of course will grow over the next decades, and they will complement the wind sector as well as hydro and some biomass. We therefore assume that wind power will be accompanied or substituted in parts by a non-specified volume of solar power deliveries.

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[1] IEA: World Energy Outlook 2008, p.79

[2] IEA: World Energy Outlook 2008, p.92

Model assumptions

There are two model assumptions for both annual power consumption growth and annual wind additions growth (accompanied by solar):

High growth	**mean annual growth of 1998-2007 continuing over next decades**
Moderate growth	**only half of mean annual growth 1998-2007 over next decades**

Growth rates for electricity consumption are derived from the widely used annual BP Statistical Review. The growth rate for the wind sector (accompanied by solar) is derived from Windpower Monthly Magazine data.

Scenario	Power consumption growth	Wind sector growth
A	High	High
B	High	Moderate
C	Moderate	High
D	Moderate	Moderate

Scenario	Power consumption growth	Wind sector growth
A	3.6%	30.4%
B	3.6%	15.2%
C	1.8%	30.4%
D	1.8%	15.2%

Figure 5 the scenario A-D Parameters

World electricity generation grew at an average rate of 3.6 percent over the ten-year period 1998-2007 and is assumed to continue at this rate annually in scenarios A, B. Starting at 11,855 TWh in 1990, passing at 19,895 TWh in 2007, this voracious demand growth will account for 63,927 TWh in 2040, a threefold increase compared to 2007.

Growth rates for electricity consumption in scenarios C, D are supposed to be only half of A, B scenarios: 1.8 percent per year, bringing power consumption to 35,847 TWh by 2040 which is 80 percent more than in 2007, but only about half the A, B scenarios.

The wind sector's net additions are assumed to further increase by 30.4 percent annually in scenarios A and C (as they did in the past ten years), or by 15.2 percent annually in scenarios B and D. The High-high Scenario A ends at 26,354 GW cumulated nameplate capacity (CF-25)[1]; moderate-moderate scenario D will achieve 10,406 GW cumulated nameplate capacity (CF-25) of the wind power sector (accompanied by solar) in 2040.

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[1] CF = capacity factor, share of full load hours during one year

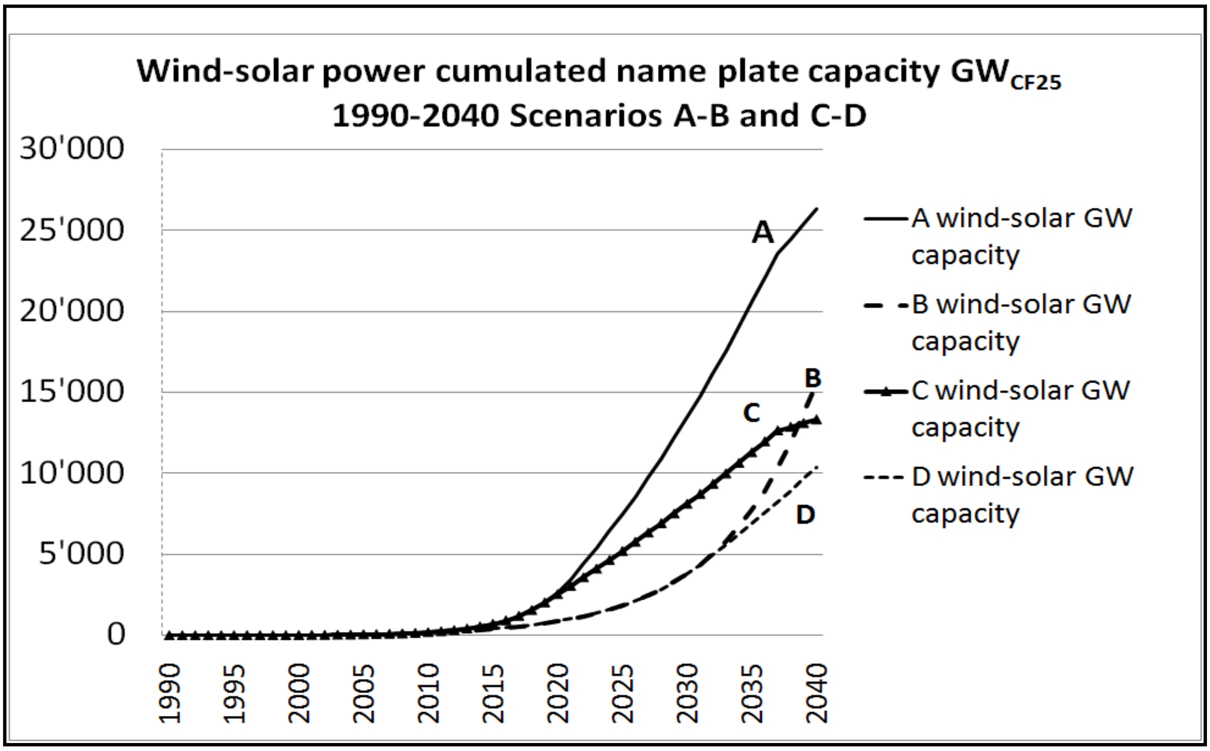


Figure 6 cumulative wind power capacity (accompanied by solar)

Due to the massive amount of old power plants, a full substitution of the conventional power generation before 2040 will only be achieved in the A and C growth Scenarios with a fast wind penetration (accompanied by solar) while in the other cases a conventional power will persist at various degrees.

2025	Wind (incl. solar)	other renew-ables	Conventional (fossil/ nuclear)
scenario A	**44%**	**12.2%**	**44%**
scenario B	**11%**	**12.2%**	**77%**
scenario C	**42%**	**16.8%**	**42%**
scenario D	**15%**	**16.8%**	**69%**

2040	Wind (incl. solar)	other renew-ables	Conventional (fossil/ nucl.)
scenario A	**90%**	**9.9%**	**0%**
scenario B	**53%**	**9.9%**	**37%**
scenario C	**82%**	**17.7%**	**0%**
scenario D	**64%**	**17.7%**	**19%**

Figure 7 power generation market shares 2025 and 2040

Wind power generation will be of the same volume as conventional generation as soon as 2025 if historical growth of the wind sector continues (A, C-scenarios). In that case, high market shares of wind will dominate the power plant industry over the next 15 years (accompanied by solar expansion). Or expressed in a different way: construction of new coal and nuclear installations will come to an end soon, and natural gas will be used for peak power only, and might find a more rewarding demand in the car sector – an idea that the so-called Pickens-plan is asking for in the US in the face of dwindling oil deliveries. The plan is convincing in terms of relative power generation costs – which have exploded over the 2005-2008 period in the case of oil and natural gas.

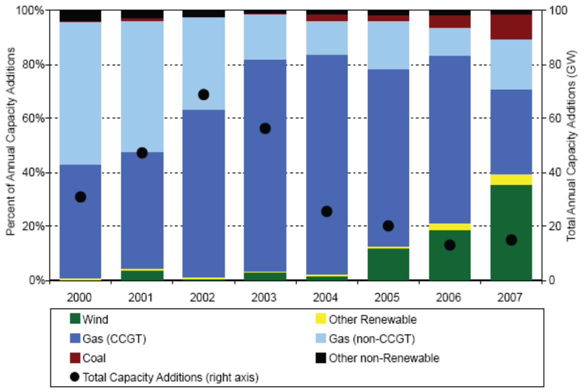
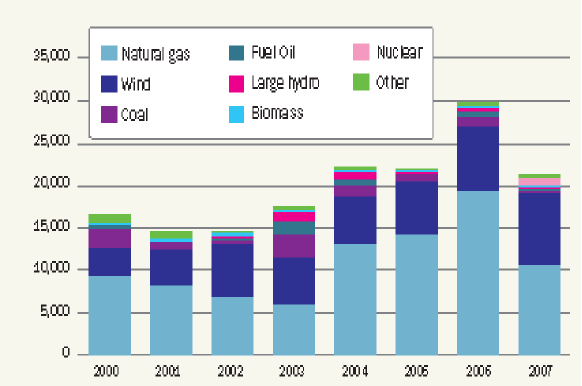
United States 2000-2007	**Europe 2000-2007**
	

Figure 8 Power Mix of Capacity Additions in the US and in Europe 2000-2007[1]

Over the past 8 years, wind has represented around 40 percent of new installed capacity in Europe (which, it is true, represents a smaller fraction a new production, in kWh, which is probably closer to 25 percent). In 2007, wind accounted for a market share of close to 40 percent of new power plant installations in the US, after a much steeper ramp-up than in Europe. There are strong indicators for this growth trend to continue all in terms of a high number of new wind equipment manufacturers entering the market all over the world. Over the next five years no other power source will outdo wind power in terms of both capacity and market share additions. In terms of volume this means that at first *additional* demand will be conquered by wind, then *replacements* of old coal and nuclear will be substituted by wind (accompanied by solar) and finally the power sector will find a steady state where regular replacements of wind, solar and some hydro will dominate the market, expanding in parallel with overall power demand.

	Scenario A	Scenario B	Scenario C	Scenario D
Power plant additions and replacements covered by wind (accompanied by solar)	2022	2038	2019	2031
Wind additions in that year (CF-25)	958 GW	1765 GW	506 GW	625GW
Repowering market in that year	510 GW	930 GW	378 GW	468 GW

Figure 9 overall market conquest by the wind sector (accompanied by solar)

In all scenarios a *market conquest of renewables* in terms of *new* capacity installations can be expected before 2040 – meaning that all new installations of power plants will come from the wind, solar or the "other renewables sector" (hydro and else). In terms of wind power: between one and five million wind turbines in the 5-MW range or two to ten million turbines in the 2.5 MW range will be needed – the exact number depending on location, capacity factors and consumption growth.

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[1] Sources US: Ryan Wiser, Mark Bolinger: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, May 2008 ed. US Department of Energy p. 5, source Europe: EWEA: Pure Power, Wind Energy Scenarios up to 2030, March 2008 p. 14

The huge capacity additions growth of renewables does not mean that conventional power generation will disappear overnight. There may well be resistance against closing coal and gas plants, but the cost advantages of coal and gas will have disappeared and the ecological pressure will favor wind energy and other renewables.

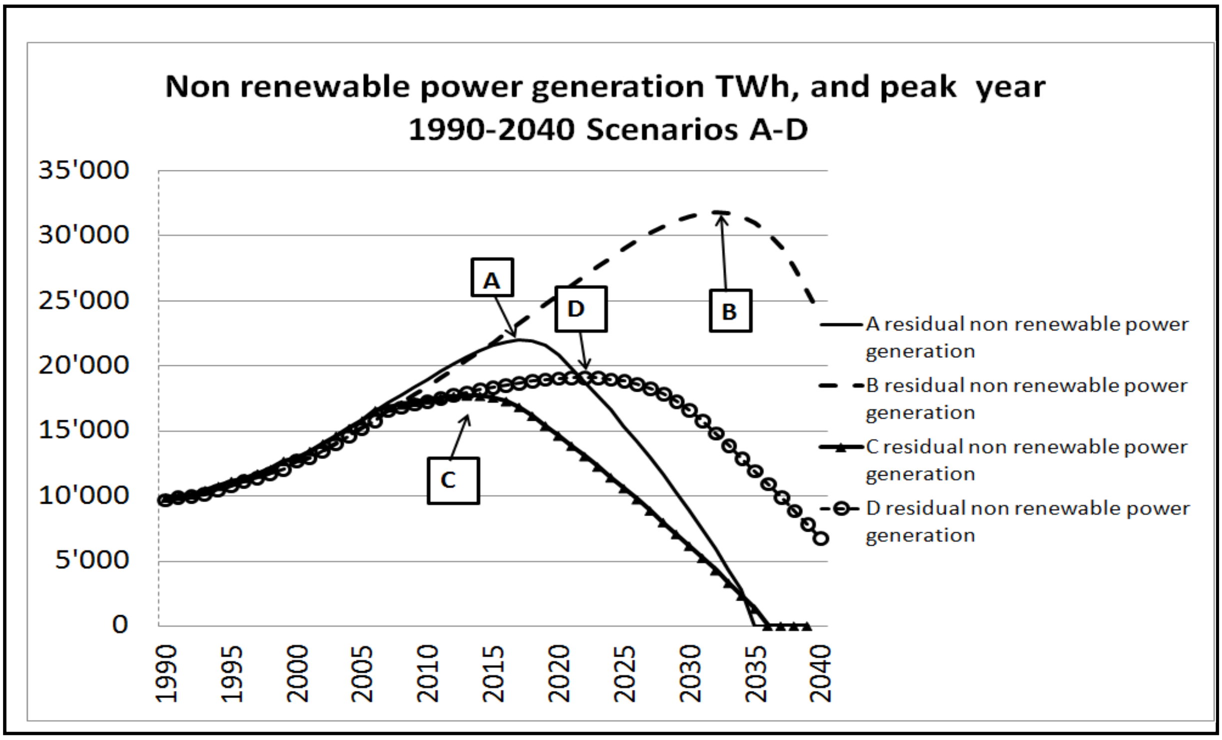


Figure 10 non-renewable power generation 1990-2040

Not surprisingly, the best scenario in terms of CO2-reductions is scenario C with high wind growth and moderate electricity demand expansion. Non-renewable power generation comes in at 576,000 TWh over the 1990-2040 period. Second best scenario A with high wind and high consumption growth shows 672,000 TWh remaining power generation from non-renewables. This scenario might be the most probable in case of electricity substituting fossil fuels in the traffic sector with battery-driven hybrid cars. By no means should the electricity sector be analyzed just on its own.

The worst scenario in terms of CO_2 (and radioactive risks) is scenario B, with moderate renewables expansion and high consumption growth. In this scenario CO_2-emissions from power generation will stay higher than in the 1990 Kyoto reference year beyond 2040.

Model findings

	Scenario A	Scenario B	Scenario C	Scenario D
World electricity generation growth rate 2007-2040	3.60%	3.60%	1.8%	1.8%
growth of annual additions of wind power	30.4%	15.2%	30.4%	15.2%
Moment of renewable generation surpassing annual consumption growth (TWh)	2019	2034	2015	2023
when will wind power cross a 50% market share of all new installed power plants (CF100-equivalents) [new installed = additions + replacements]	2019	2033	2017	2026
Market conquest: All power plant additions and replacements covered by wind (accompanied by solar and other renewables)	2022	2038	2019	2031
how much GW wind power capacity would there be in 2030? (GW-CF25)	13457	3782	8126	3782
how much wind power would be produced in 2030 (TWh)?	29471	8283	17796	8283
how much other renewable [hydro, biomass, geothermal] power would be produced in 2030 (TWh)?	5120	5120	5120	5120
how much non-renewable power would be produced in 2030 (TWh)?	10290	31475	7070	16583
how much non-renewable power would be produced in 2040 (TWh)?	0	23780	0	6714
peak year of non-renewable power generation TWh (and CO2-peak)	2018	2032	2014	2022
peak TWh of nonrenewable power generation	21969	31794	17703	19091
total nonrenewable electricity generation 2008-2040 (TWh)	432,978	860,192	354,091	531,543
when will CO2-emissions for the first time be lowered compared to 1990 (Kyoto-benchmark)?	2031	after 2040	2028	2038

Figure 11 survey of model findings

The most decisive factor for climate and environment protection is a high growth rate for wind and solar. Most importantly, it is the period *up to 2020* where most investment and technology decisions will be taken. After 2020, the scenarios tend to converge, with renewable energies on the rise in every scenario, but with a huge difference in CO_2 and hazardous (radioactive) waste.

Underlying Innovations

A consequence of the rapidly growing wind power industry is a virtuous cycle of technological improvement driving wind-generated electricity to be a cheaper-than-coal solution. Better blades, higher and cheaper towers, turbines of a bigger size, new technical designs and higher reliability have reduced and will reduce specific costs per kWh. With every increase of turbine efficiency, more areas become economically accessible which before were considered “no-wind zones”. In the offshore sector, new foundation types and floating turbines are being developed, and a growing number of companies is entering this new market.

Social Innovation

For the first time in decades, the energy supply has seen a de-centralization and de-monopolization caused by thousands of individuals and many small and medium enterprises investing in wind energy. Community power (such as Bürgerwindparks, cooperative and municipality owned wind farms etc) has become a social innovation and a driver of a more sustainable energy system in technical, environmental, institutional and economic terms.

Far-off Gigawatt clusters for wind

Some off-grid-locations are so attractive in terms of wind speed that wind farmers or governments are willing to build high-voltage-connections to load centers themselves, provided bureaucratic hurdles for new lines are removed. Advancing peripheral wind resources, complementary to grid embedded sites, have a number of positive implications. Turbine sites over-the-horizon have no neighbors involved. Offshore, connected by undersea transmission lines, they can eliminate aesthetic concerns and bird issues. Since many large load centers are located at coasts, turbines at a distance of some 30-50 kilometers can be installed quite close to load, decreasing transmission costs.

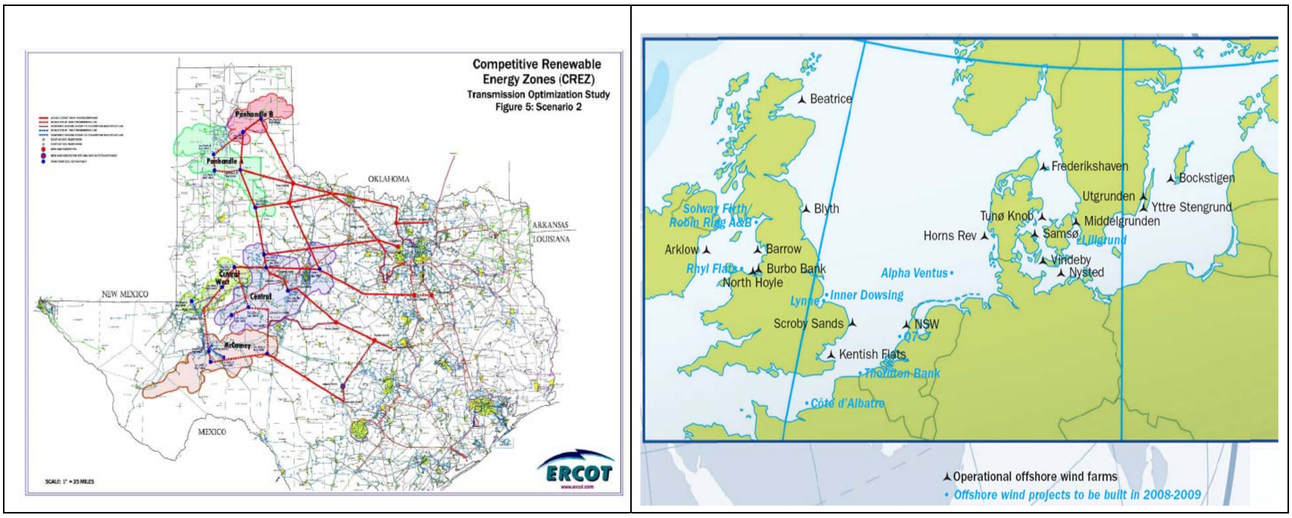


Figure 12 Texas wind integration plan adopted by the Texas PUC (left) and offshore developments 2009/2010 in European waters (right)

Over the next few years many far-off wind clusters will start production in rural areas, deserts and the sea, and they will more than pay for the additional costs in transmission, construction and maintenance due to better wind speeds and higher capacity factors. Regions with best wind resources close to city populations include the US Midwest and Southern Canada, Brazil's North-East, Patagonia, Morocco, Egypt and the Red Sea region, Norway, North Sea and Atlantic Ocean coasts, North-West Russia and the Baltic States, Southern Russia, Ukraine, Turkey, Iran and India, Inner Mongolia, South China, Central Vietnam, South Australia, New Zealand and South Africa. All these regions have potentially large customers within a 1000-mile range, accessible with proven HVDC grid technology, or AC connections for smaller distances.

Financial benefits for these regions, for the owners of windy areas and for the owners of wind farms can be substantial. Local communities investing in wind farms or selling licenses for land lease can earn money. Between $2000 and $20,000 per turbine or MW are cited as a normal benefit for the land owners in the US. Corn or wheat farmers signing contracts for installations get more income from wind turbines than from agriculture, without being forced to abandon the latter. In some municipalities in Northern Germany or Texas, the wind industry has become the biggest taxpayer.

Breakthrough in regulations

New and better regulations can bring breakthroughs in terms of economics and availability of clean power. In 2005, eight so-called Competitive Renewable Energy Zones (CREZ) were created in Texas paving the way for thousands of turbines. Companies in the wind business get the acknowledgment that if they build within a CREZ, transmission lines will be promptly available. Best sites are designated in a competitive way, bringing substantial cost reductions.

In July 2008, the Public Utility Commission (PUC) of Texas selected a transmission scenario that will give access to a total of 18,456 MW of wind power from these CREZ zones in West Texas and the Texas Panhandle to metropolitan areas. The selected Scenario is estimated to cost US$4.93 billion, or around US$4/month per residential customer, once grid constructions are completed and costs are reflected in rates. The benefits, however, are much higher than the 4.93 billion invested in transmission: The new wind brought online will save $1.7 billion *per year* in fuel costs, repaying the $4.9 billion cost of the investment in 2.9 years because the "*average system fuel-cost savings for each megawatt-hour of wind in this scenario was $38/MWh* [=3.8 US-Cents per kWh]."

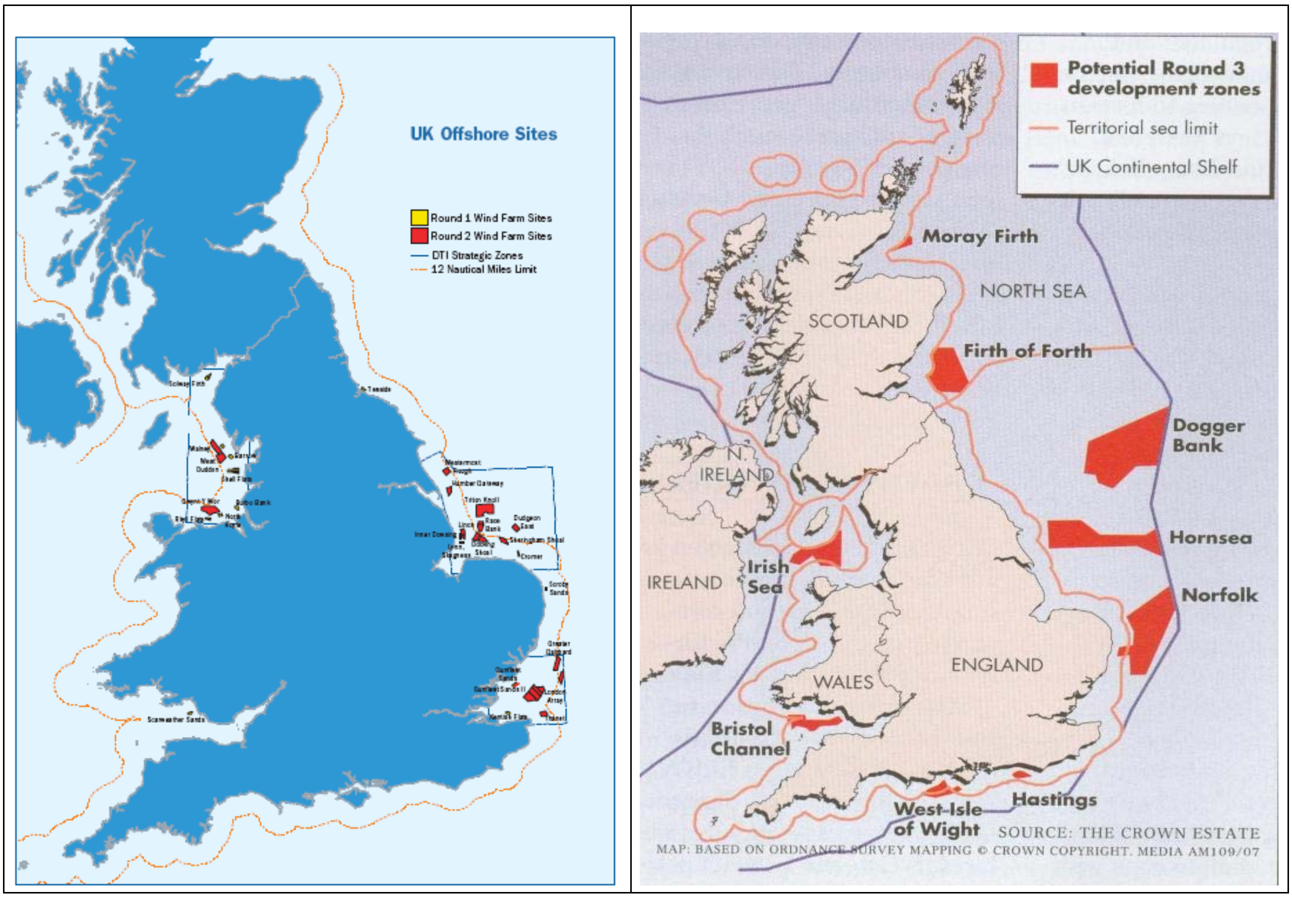


Figure 13 British offshore wind areas Round 1, 2 (left) and Round 3 (right)

Germany, the UK, France, Spain and others now are preparing comprehensive planning approaches for wind zones and interconnection, too. Coupled with concerns on energy security and climate change the idea is more and more accepted that grid costs and security of supply are an issue for all consumers and not just for a specific wind farmer who would have to pay for resource developments and connections on his own.

Centrally planned interconnection between hundreds of decentralized wind farms with new grids – some are talking of "supergrids" – has multi-functional advantages: It will (1) bring electric power to the customers, connecting them with new, prolific wind resources, (2) smooth fluctuations in the energy profile over various sites, (3) give way to new or existing reserve capacities such as stored hydro that before were out of reach and (4) accelerate competition between the best and cheapest clean power resources and therefore lower prices for consumers.

Today thousands of citizens, investing in wind power, and thousands of companies have become the innovative and powerful drivers of the wind business, developing new technologies and business models. Utilities and oil companies are entering the wind business too. They have deep pockets, bring expertise and are recognized as creditworthy by secondary lenders. Therefore they pay lower interest rates compared to small wind funds or private owners who get their money from banks, and their long term plans will persist even within an environment of financial turmoil. In a business where more than 70 percent of costs is financing, a reduction of interest rates by 1 percent can bring overall cost reductions of more than 10 percent. However, small local investors can play an equally important role. They are better in dealing with social acceptance issues, and many governments are paving new ways for local communities and farmers to get invested into wind power on an equal ground with big companies.

With utility and oil company demand, the size of wind projects has changed in some places. Multi-year agreements of thousands of turbines are registered, thanks to more stable policy frameworks for wind power world-wide, implying a more stable demand for manufacturers. With the boom and bust cycles reduced, risk premiums shrink, production can be optimized and costs are reduced for all partners involved.

The manufacturing of wind turbines is expanding very fast from Europe to Asia and the US, coupled with reduced transport costs. China is creating a huge wind sector, with more than 70 new manufacturers of wind turbine components involved. Once exports begin on a large scale, their additional supply will put pressure on wind turbine prices in Europe and the US, deepening the comparative economic advantages of wind energy.

The problems of non-renewables

One reason for wind power's success is the fact that non-renewable technologies have their own problems: Resource quality and resource availability for oil, natural gas, coal and uranium is declining. Natural gas can be used in the transport sector, thereby driving natural gas prices upwards to levels paid for gasoline. Nuclear power has its own risks with its market share continuously shrinking, and big capacity additions are not to be expected before 2020 – if ever – due to cost overruns, planning procedures, eroding knowledge and a shortage of components such as large vessels. A scarcity of uranium is looming, reflected in a price surge since 2000, and radioactive waste issues are unresolved as ever. The increase of oil and gas prices and the fierce competition for wind turbines today is a key driver for many countries to have revised and optimized their incentive structure for renewable energies.

Political opponents

Based on past growth rates we can say with some confidence that the fossil and nuclear power sector could virtually disappear over the next two decades, provided wind and solar power are no more blocked politically as has been the case in so many nations with a “nuclear power culture”. In many places the idea of high penetration of wind power is not common and deep-rooted misconceptions prevail in conventional wisdom of public, media and elected officials.

Intermittency and interconnection

The frequently stated claim of wind power requiring an equal amount of reserve power for back-up is not correct. A substantial adjustment tolerance is already built into our power networks, and the impacts of wind power fluctuations can be balanced through a variety of measures. These include better interconnection, geographic diversification of sources and diversification of supply from different technologies. More flexibility can be achieved by connection and enlargement of existing stored hydro power capacities. Stored hydro capacities in Europe have a combined capacity of some 100 GW but only a part of these capacities is interlinked with wind power and managed in a comprehensive way. Additional steps for the integration of huge shares of wind energy include construction of new hydro turbine capacities within existing storage dams, market oriented power exchanges, erection of AC and HVDC super grids extending over several weather zones, demand-side-management, real time tariffs, smart meters, ripple control for consumption and new storage technologies including ultra-capacitors, superconducting magnetic systems, conventional batteries and new types of flow batteries such as vanadium redox systems.

Older natural gas plants as back-up

With natural gas prices on the rise, a large number of natural gas power plants – among them the older and least efficient ones – can be taken out of service in favor of wind, with reasonable savings for consumers. In practice these older conventional plants can be mothballed or put on stand-by (but will hardly be ever used) for emergencies. Capacity costs of such reserve units are minuscule and can offer the necessary backup until more hydro capacities or other storages are connected to the grid.

A bargain for consumers

Due to rising fuel costs for non-renewables we expect that interconnection, balancing and storage issues can and will be resolved within reasonable terms and at reasonable costs. The main driver of this movement is market economics. Incentives for wind integration are given by cost savings. Incentives for storage facilities are given by excess wind power which is and will be available in huge volumes at very cheap prices in times of low demand. These additional supplies will drive access to and construction of new, affordable back-up storages.

Wind and solar as a primary energy are free. The long-term trend for turbine costs is falling. In the US, existing wind power capacities today deliver electricity at a price of 5.0-6.5 US-Cent/kWh (mean full costs) and at 4.0-4.5 US-Cents/kWh with the Production Tax Credit deducted. Where wind power is used, consumers will save money and can rely on a clean, secure resource with fixed costs – even if turbine prices have gone up for some time, due to excessive demand (and meanwhile seem to be in decline again). Last but not least, additional wind power brings additional savings by driving more expensive marginal supply – mostly gas – out of the market.

Wind power is better than coal in terms of fuel costs, carbon emissions and pollution. Overall electricity from *new* coal plants comes in at a par or slightly higher costs compared with new wind power on good sites, but coal has its risks in the future: increasing emission taxes and fuel cost insecurity.

Even without taking into account externalities, wind power is definitely cheaper than nuclear because onshore, it is cheaper in terms of capital expenses, and offshore, it comes at a par with cost reductions to be expected within a few years. In all other cost aspects – fuel costs, operation and maintenance, waste treatment costs and technical risks – wind is cheaper and less risky than nuclear.

Natural gas prices have been rising step by step since 2000. An oil price level of $120 per barrel, as projected by the IEA for the 2015-2030 period, translates into natural gas fuel costs of some 13 US-Cent for each kWh of electricity – or more, depending on the efficiency of each individual plant. Any power producer with natural gas plants will therefore be happy to switch to wind power for base load – and then sell excessive gas and excessive wind power at the spot market with a profit.

Globalization of wind turbine manufacturing, liberalization of power generation and the unbundling of production and transmission in the electricity sector has transformed the wind power industry from a local into an internationally connected business. This relates to the use of wind resources, too: with an expected acceleration of transmission, a diversification of geographic origins of wind energy is in sight, improving capacity factors and competitiveness even more.

Wind power and wind power components therefore will be one of the most traded international commodities, conquering a high market share in the energy sector within a very short period. It will emerge as a backbone of the power business. And it will expand into new sectors such as traffic, heating and industry demand for energy – markets which for decades were dominated by fossil fuels.

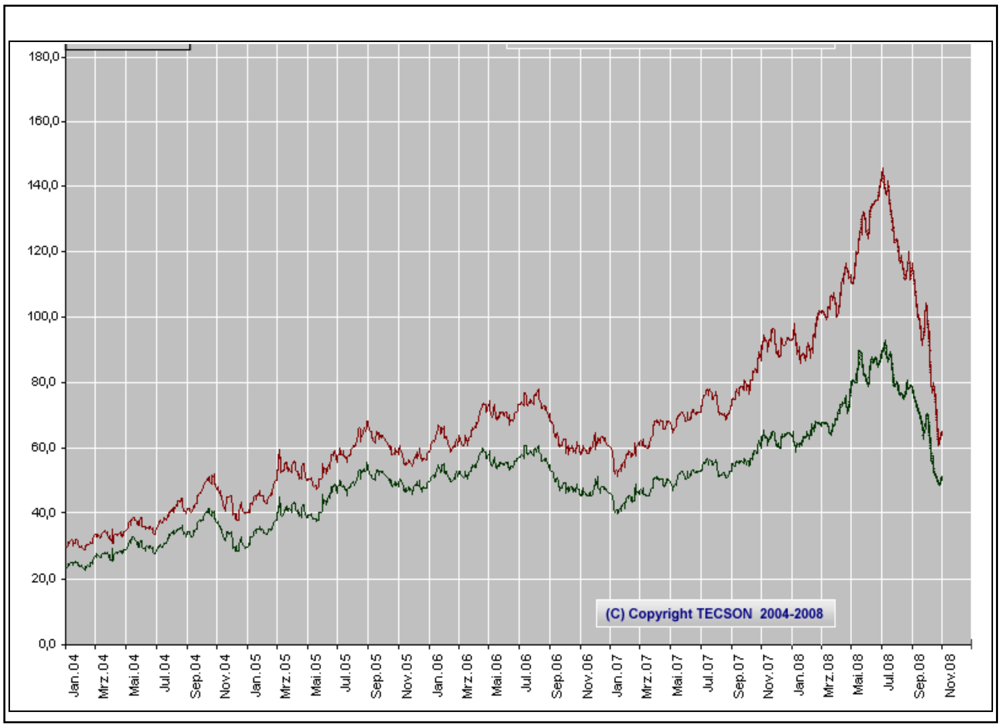
And, well, it is noteworthy that this is good for the environment.

2. Oil peak and the power sector

By 2007, a general, persisting shortage of wind turbines and main components was deplored within the wind sector. The most important factor driving this shortage was the new found competitiveness of wind power on the back of the price escalation for fossil fuels and nuclear.

In 2005, oil prices crossed the $40 mark per barrel and by July 2008 the mark of $145/barrel was noted for the first time in history. The reasons for this can mainly be found in the peak oil phenomenon, described by many experts[1], which is not subject of this report.

Crude oil as a lead energy was a driver for natural gas, coal and uranium prices too. For natural gas similar capacity constraints as for oil are expected, with a production peak within reach over the next decade or so, and with a lack of pipelines and a slow buildup of liquid natural gas (LNG) infrastructure already visible now.



Oil price 2004-2008 in US-$ (red) and in Euro per barrel (green)

Figure 14 Development of oil spot prices source: Tecson[2]

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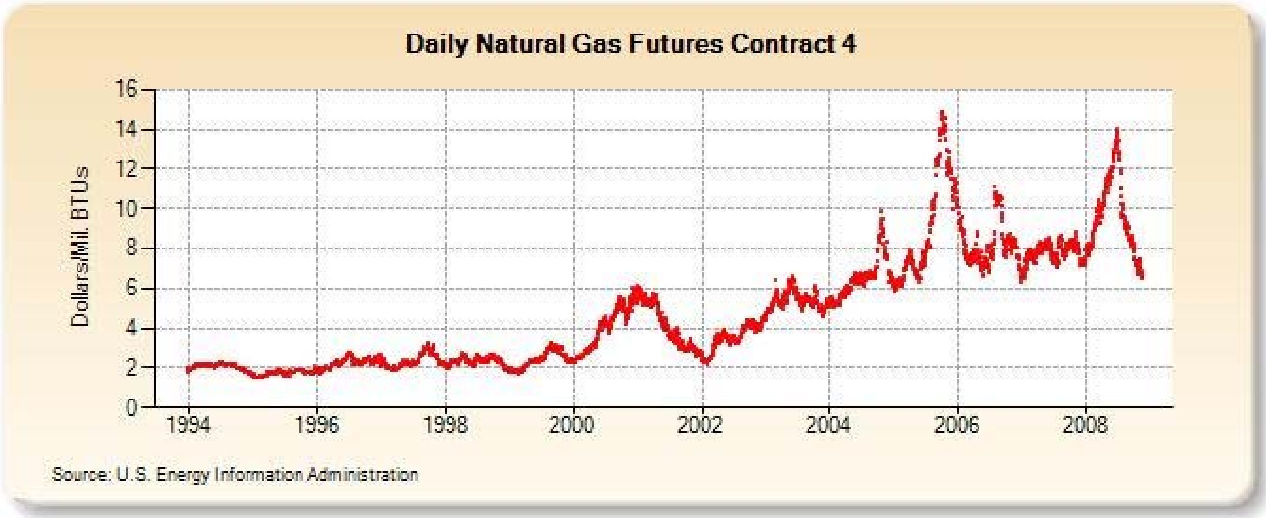
[1] see the publications of the Energy Watch Group: Crude Oil – the Supply Outlook, Ottobrunn 2007 http://www.energywatchgroup.org/fileadmin/global/pdf/EWG_Oilreport_10-2007.pdf or (in German) Rudolf Rechsteiner: "Grün gewinnt – die letzte Ölkrise und danach, Zürich, Orell Füssli, 2003 http://www.rechsteiner-basel.ch/uploads/media/gruen_gewinnt_gesamtes_buch_01.pdf

[2] http://www.tecson.de/poelhist.htm#chart_$_€ ;



Natural Gas price $/MMBTU, New York Nymex

Figure 15 development of oil and natural gas spot prices source: EIA[1]

Combined cycle natural gas plants have been the favored choice for new power plants during the last decade. Oil prices and the electricity generation costs are interconnected by the price for natural gas.

A barrel of conventional oil is priced traditionally about six-fold the price of natural gas, on a barrel/MBTU scale. With oil prices at the $120/barrel a gas price of some $20/MBTU is expected and for a long time gas prices followed this price parity, based on the energy content. This was no longer the case during the steep rise of the oil price 2005-2008 due to the more mid- and long-term character of gas contracts and due to imperfect competition.

With a more fluid natural gas market, based on LNG-trade, and wider use of natural gas in the automotive sector, oil price parity for gas is anticipated to return within a couple of years. This could mean another doubling of natural gas prices for the electricity sector.

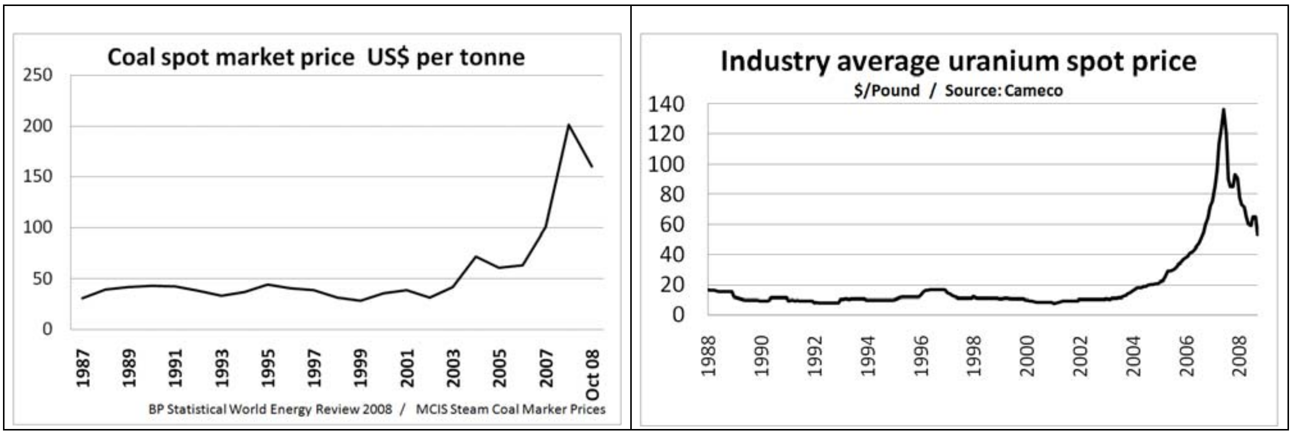


Figure 16 and Figure 17: Coal prices and uranium spot prices 1987-2008
Source: BP Statistical World Energy Review/MCIS; Cameco[2]

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[1] http://tonto.eia.doe.gov/dnav/ng/hist/rngc4d.htm

[2] http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622; http://www.cameco.com/investor_relations/ux_history

Prices for coal and uranium were subject to high price rises too, partly because their deliveries relied on oil and gas (for mining, transport, steel) and partly for scarcity reasons on their own due to resource depletion, described by the Energy Watch Group and many others.[1]

In the wake of this price shift for all non-renewable energies, the competitiveness and development of renewable energies is of an entirely new character. New wind power installations (and in some places: concentrated solar) turned out to be the most competitive and cost-secure technology, compared with any other new power plants.

Since 2005, the wind industry shows accelerated growth rates, with annual capacity additions growth exceeding 30 percent each single year. This relentless growth, so far untouched by any sign of recession, is a sign of a new era. Eize de Vries, a renowned wind technology expert, calls it a "historically unique growth path, a positive trend that is expected to continue for years".[2]

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[1] Energy Watch Group: Coal: Resources and Future Production
http://www.energywatchgroup.org/fileadmin/global/pdf/EWG_Report_Coal_10-07-2007ms.pdf
Energy Watch Group: Uranium Resources and Nuclear Energy, Ottobrunn/Aachen 2006
http://www.energywatchgroup.org/fileadmin/global/pdf/EWG_Report_Uranium_3-12-2006ms.pdf

[2] Eize de Vries: The Challenge of Growth, supply chain and wind turbine up scaling challenges, Renewable Energy World, May-June 2008, p.24-31

3. Wind power: Global market status

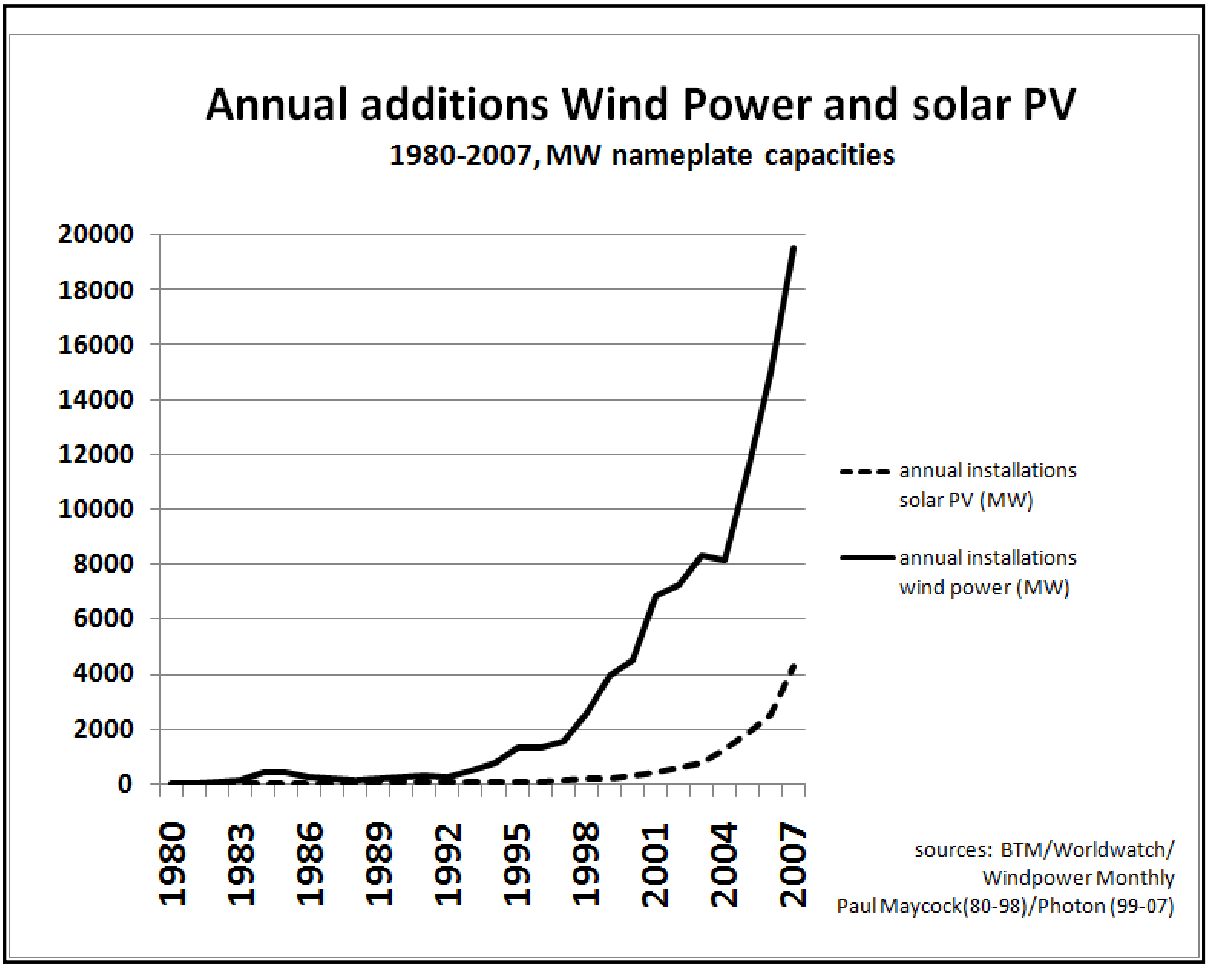

Figure 18 Annual installations of solar photovoltaic and wind power[1]

Since the early 1990s, new renewable technologies have been entering the power market on an industrial scale with an average growth rate of 34.9 percent per annum for global wind power and 31.3 percent for solar PV. Over the last ten years (1998-2007) mean growth rate of annual additions was 30.4 percent for wind power and 42.9 percent for solar PV. In 2007 annual solar PV shipments were estimated at 4279 MW_{peak}[2] (+69 percent) and net wind power additions numbered 19,553 MW[3] (with an additional estimated 2000 MW of new turbines who replaced older models).

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[1] Data for solar PV 2008: Photon international 3/2008; data 1990-2006 from Paul Maycock: PV market update, cit. in: Renewable Energy world, July-August 2007, 60-74, older data from Paul Maycock: PV news, var. Editions;
Data for wind power: 1980-1990 from Worldwatch Institute, Vital Signs 2001 (New York: W.W. Norton & Co.), 2001, pp. 44-45, Updated by Earth Policy Institute from BTM Consult, AWEA, EWEA, Windpower Monthly, 1999-1997: BTM Consult, Ten Year Review 2005 p. 3, Windpower Monthly , May, 2006:72 and Windpower Monthly May, 2007:78. Some small data discrepancy might arise from the fact that some authors publish data for new installed wind power when others such as the Wind Power Monthly Windicator count net additions (new capacity minus capacity taken out of service).

[2] Source: Paul Maycock: PV market update, cit. in: Renewable Energy world, July-August 2007, 60-74

[3] Source Windpower Monthly Magazine April 2008

Solar

Grid connected solar power is still dependent on state or utility financial support: feed-in tariffs, tax credits or voluntary green power trading. It will remain dependent for a while in most areas, though in some markets grid parity now can be reached during periods of high demand. Grid parity means that the cost per kWh of solar power for certain consumers is competitive with kWh-prices from the grid.

Hydro

For decades hydropower technology was the only accepted renewable power source, covering a production of 3134 TWh (+1,7%) or 15.8 percent of world electricity generation in 2007[1]. Despite hydropower generation having matured in many regions (such as the US or the European Union), its worldwide output rose by 18.8% over the last ten years (1998-2007), mostly in emerging economies such as China where hydro capacities have doubled since 1997.

Nuclear

Since the 1950s, nuclear power has been touted as an energy source able to resolve any energy problem ("too cheap to meter"). However, the number of nuclear reactors has been stagnant at around 440 units since 1986. Nuclear power delivered 2748.9 TWh in 2007 (-2,0%[2]), which corresponded to 13.8 percent of world electricity generation. A production growth of 13.0 percent over the last ten years (1998-2007) has been registered, but many nuclear installations are old and due for replacement. Just to keep the actual market share of 13.8 percent would require a strong acceleration in buildups of new installations – which is not a reality so far.

Wind

For wind power, no official statistics are published by the International Energy Institutions. The data from the renown Windpower Monthly Magazine and BTM Consult and World Wind Energy Association (WWEA) show a cumulative capacity of 93.8 GW which – at an annual specific yield of 2190 kWh/kW (=capacity factor of 0.25) corresponds to an electricity output of some 205 TWh. This equals an amount of 1.03 percent of worldwide electricity consumption in 2007.[3] To understand the significance of wind power today, a short look back is useful.

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[1] BP Statistical Review of World Energy June 2008

[2] In 2006 nuclear power delivered 2805.9 TWh; the number fell to 2748.9 TWh in 2007 due to various shortfalls. See BP Statistical Review of World Energy June 2008, chart Nuclear Consumption in Terawatt-hours

[3] Wind energy expert Paul Gipe believes that these values might be a bit too optimistic, proposing 2000 kWh/kW a year. Which would result in an average capacity factor of 23%. 25% as a percentage might be expected when more peripheral high-wind sites will be developed. So as a prospective it might get its validity in the mid-term future.

Why is the situation in the wind market so different today from what it was before?

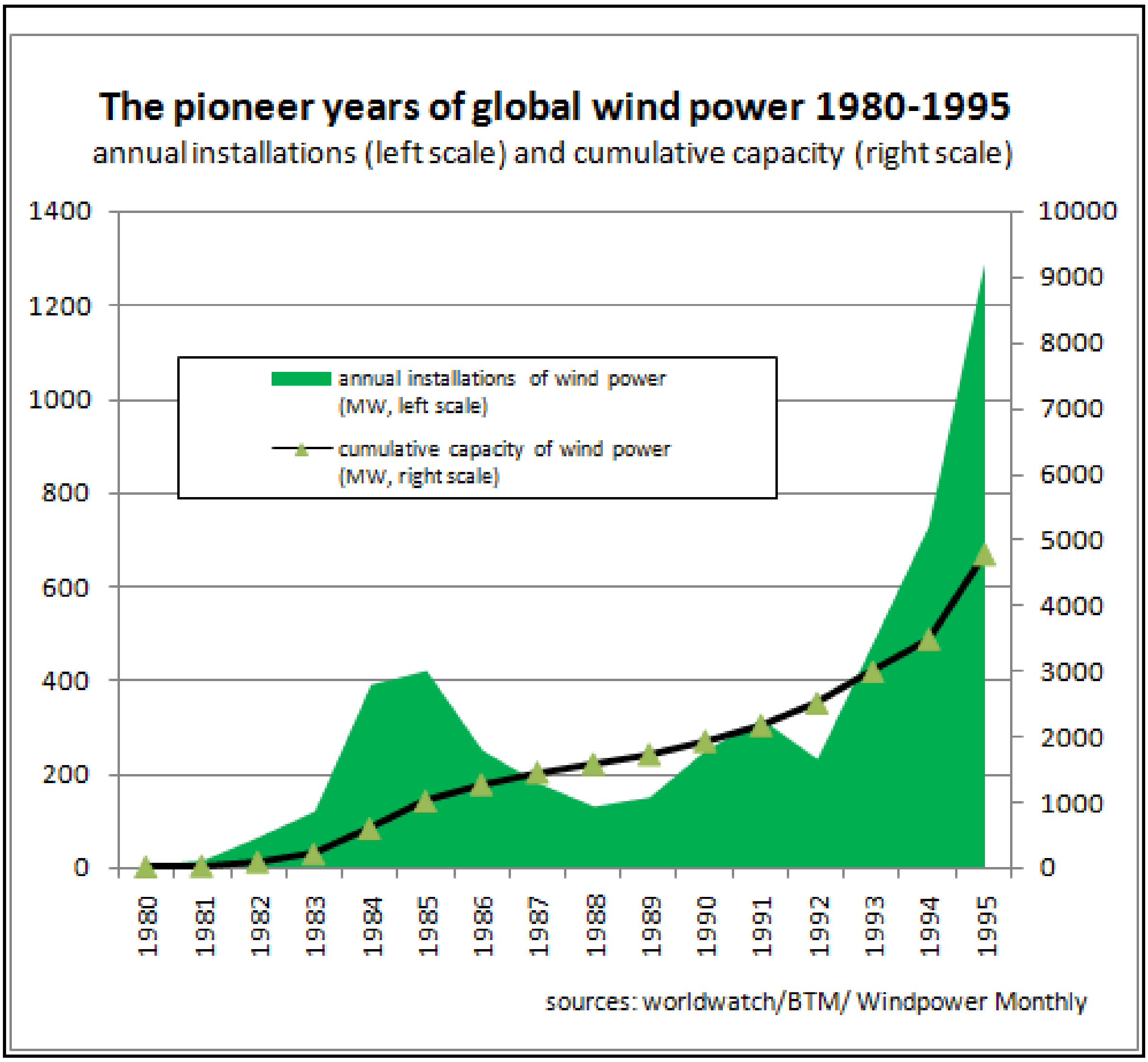

Figure 19 Annual additions and cumulative capacity of wind power, 1980-1995
Sources: Worldwatch/BTM/Windpower Monthly Magazine

The emergence of wind power did not follow a linear path.[1] Industry-scale wind turbines were introduced during the first oil crisis (1973-1985), led by Danish R&D efforts. Despite earlier failures on the part of some of the world's largest engineering firms, small Danish manufacturers of agricultural machinery succeeded in the construction of viable wind power generators.[2]

The early 1980s witnessed wind energy's first boom when thousands of wind turbines were put up in the "California wind rush", promoted by State and Federal Tax Credits. More than 17,000 small wind turbines with an output from 30-300 kW were erected. The first 1000-MW-milestone was reached in 1985. New installations from 1980-85 averaged some 170 MW per year. Year-over-year growth rates in this first period exceeded 100 percent.

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[1] Main pioneers of wind power before 1980 were Danish Poul la Cour, German Hermann Honnef and Ulrich Hütter; cf. Matthias Heymann, Die Geschichte der Windenergienutzung 1890-1990; Frankfurt 1995

[2] BTM: Ten Year Review 2005, 23

In the early 1980s, the US market held more than 70 percent of the world market. However, wind power was not yet competitive, depending entirely on a favorable tax scheme provided by the State and Federal governments.

In 1985, the US wind market came to an abrupt halt when State and Federal tax credits were slashed, after oil prices had dropped to pre-1979 levels. From 1985 to 1990, the wind power market experienced a period of decline. The low level of new installations (130-250 MW per year) drove many suppliers into bankruptcy. In the US, not a single producer of industry scale turbines survived. For some 15 years (1988-2003), no industrial scale wind turbine production took place in the US - the industrial take-off shifted to Europe and Asia (India).

Struggling for take-off (1996-2005)

Starting in the early 1990s and influenced by the Chernobyl nuclear accident, European nations took over the lead in wind power technology and market structure. The wind industry's slump ended in 1993. The introduction of feed-in laws in Denmark, Germany (1990) and Spain (1995) put wind power systems in high demand. In 1995, new German installations numbered 487 MW. For the first time, they outnumbered the US installation record of 399 MW (1984). Average kW-capacity of newly installed turbines in Germany passed 500 kW in 1995. By the end of 1997, a tenfold increase in new installations was recorded compared to ten years before, with Denmark and Germany accounting for more than two-thirds of the 4500 MW installed.

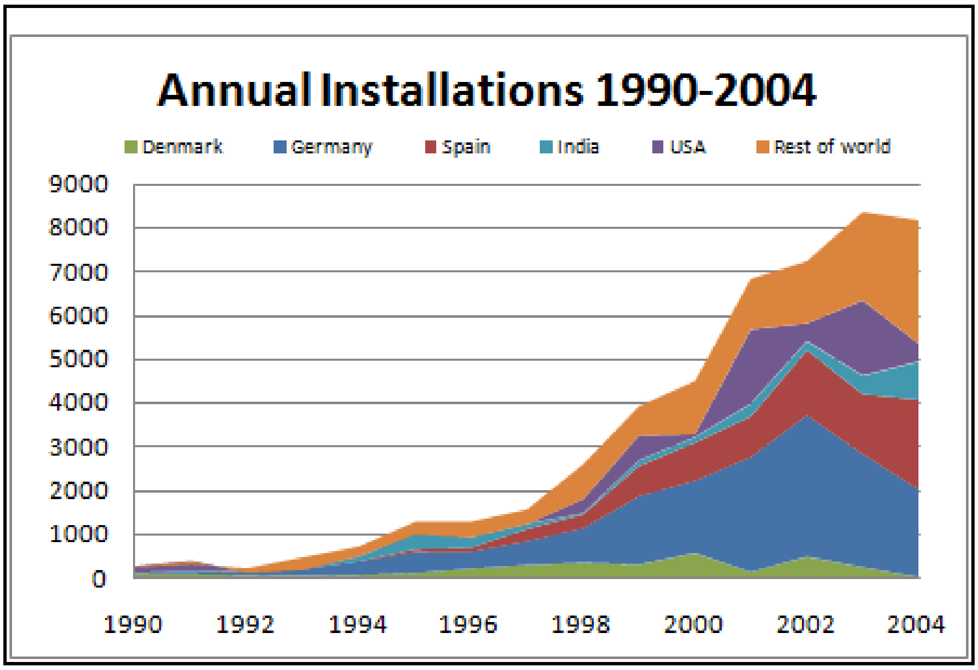


Figure 20 development of wind markets 1990-2004

From 1996 to 2003, annual installations grew by a factor of six from 1292 MW to more than 8344 MW. In 2002, the dominant German market peaked at 3250 MW, followed by a significant reduction of annual installations. Around the same time an environmentally hostile new right-wing government in Denmark abolished the Danish feed-in-law. Wind turbine installations in this pioneer nation for wind energy came to halt in 2004 – at a time when wind power delivered close to 20 percent of electricity consumption in Denmark.

Feed-in tariffs versus tax credits and certificates

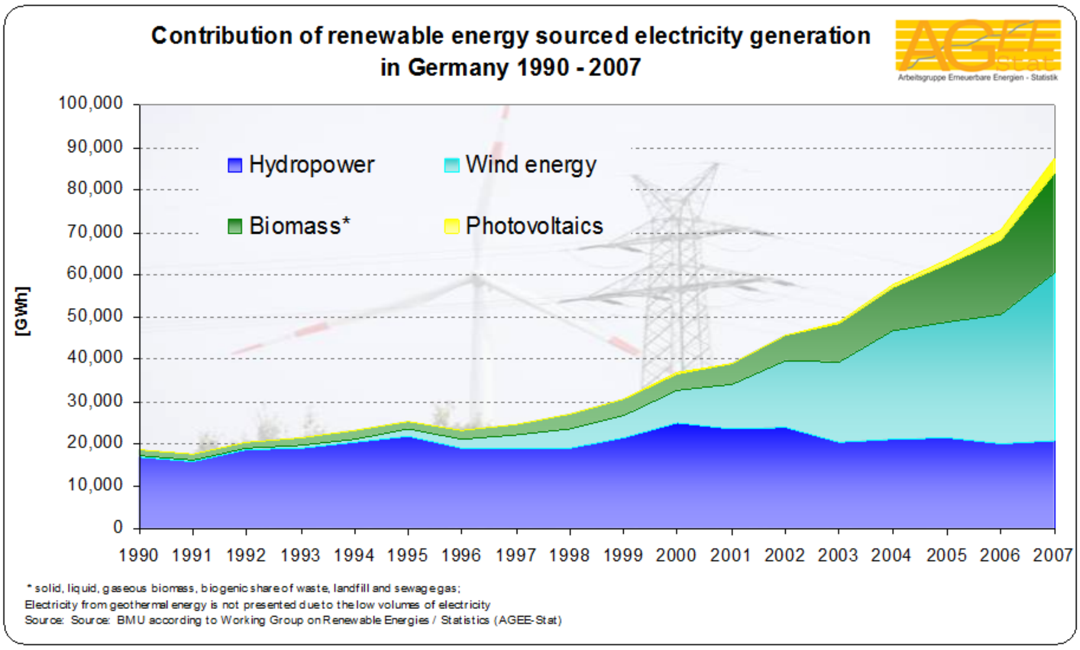
During the 1990-2005 era, feed-in tariffs were crucial for the wind industry. Legal continuity combined with strong R&D efforts delivered the stability for technical advancements.

Feed-in tariffs are a legally based minimum price that utilities were obliged to pay per kWh to any wind power producer. With this fair financial treatment for a clean resource of electricity, wind projects became "bankable". Wind investors, planners and producers proceeded with a long-term approach: measuring wind speed, getting permissions, ordering turbines and constructing them, expanding grids and delivering wind power – all this went hand-in-hand with the expansion of turbine manufacturing within a small number of countries, mainly Denmark, Germany, Spain and India.

Wherever feed-in tariffs were put into law, small and big investors found a chance to grow and to bring their technologies to perfection. While big utilities hesitated to invest in new technologies and battled their propaganda war against new renewable energies, small investors, local cooperatives and independent wind funds took a lead and created thousands of individual investments in decentralized power generation.

Early on, feed-in tariffs were decisively higher than market prices. But year after year, they were reduced by law by some 1- 4 percent in nominal terms – or by an additional 2 - 5 percent in real terms (inflation adjusted). Production costs of wind turbines were assessed periodically by government agencies in Germany, Denmark and Spain. The annual minimum price reductions followed the learning curve of the industry.

Feed-in tariffs specifically matched site-specific wind conditions for each individual wind turbine. And in Germany and France, on good wind sites, indicated by the number of full-load-hours refunded, feed-in tariffs were reduced gradually beginning after an initial five-year term. This prevented wind-fall profits. Combined with the annual reduction of the minimum price for new installations, feed-in tariffs became politically accepted in many nations, and, beyond wind, other technologies such as biomass, geothermal, hydro and solar power were scheduled the same way.



Contribution of renewable energy sourced electricity generation in Germany 1990 - 2007

* solid, liquid, gaseous biomass, biogenic share of waste, landfill and sewage gas;
Electricity from geothermal energy is not presented due to the low volumes of electricity
Source: Source: BMU according to Working Group on Renewable Energies / Statistics (AGEE-Stat)

Figure 21 Contribution of Renewable Energy in the German power sector 1990-2007

In Germany feed-in tariffs introduced in 1990 were sufficient to drive wind and hydro developments. Then in 1998, geothermal and biomass power received additional tariffs, followed by solar power, fully included in 2004. Renewable power generation in Germany grew more than fourfold from some 19 TWh in 1990, mainly from hydro, to 88 TWh in 2007. Equally important was the export growth of renewable energy systems for the German economy.

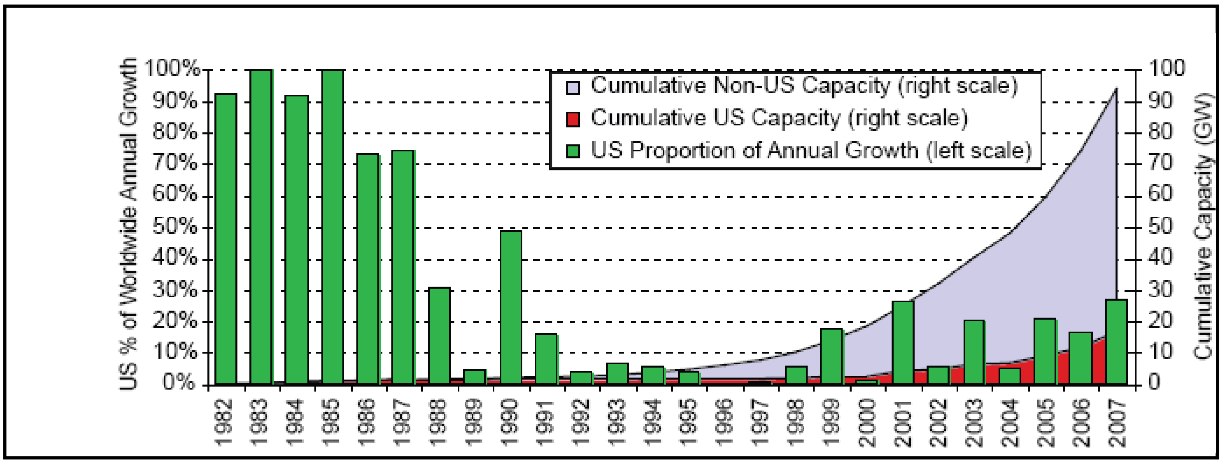


Figure 22 US market share of world wind power installations 1982-2006
Source: Wyser & Bollinger 2008[1]

In the US, the wind power market started a comeback after 1998. But the unstable on-off cycles of the Production Tax Credit (PTC) created boom and bust situations with installations close to a standstill in 2000, 2002 and 2004 (when the PTC had expired). For many years no industry scale US manufacturer found conditions for growth. The situation changed when General Electric took over the German Tacke Wind company in 2004 (after being acquired by Enron in 2002). GE Wind was the first US company to introduce modern, European, state-of-the-art manufacturing of turbines on an industrial scale.

In Britain – notably the nation with the best wind resource in Europe – a defective market structuring lead to a similar or even worse situation than in the US. In the 1990s, the conservative government started to auction so-called Non-fossil-fuel obligations (NFFO). In the freshly liberalized electricity market, some lowest-cost renewable energy projects received a Power-Purchase-Agreement (PPA) for an auctioned number of MW capacity to be built.

Despite some minor capacity additions, the NFFO scheme failed in many aspects. The most productive offers for new wind power installations often intended to cover scenic places at the coastline with excellent wind conditions, close to power lines within areas of dense populations. Opposition against this type of wind power project was strong. Second class sites with longer distances to the grid and less than excellent wind speeds failed to receive contracts because of their slightly higher generation costs. The succeeding PPAs rarely came to completion because they were brought to courts with lengthy administrative procedures. Advocates of wind power faced delays and additional development costs. Many projects were abandoned then for lack of funding. No serious wind manufacturer survived in Britain in this environment, based on contracts for a supply of only one or two years.

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[1] Ryan Wiser, Mark Bolinger: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, May 2008 ed. US Department of Energy, p. 6

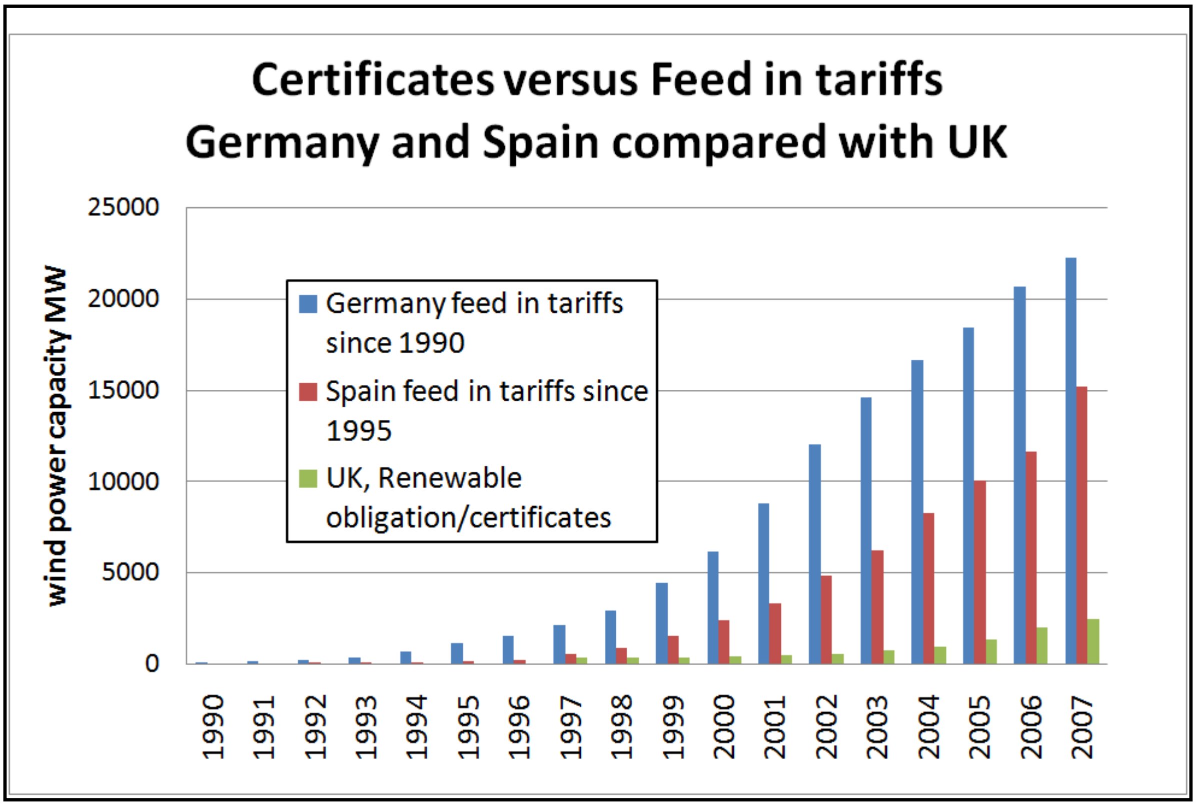

Figure 23 comparison of three nations with feed in schemes and certificates

The situation in the UK barely changed when the Labour government introduced a new legal framework of renewable obligation certificates (ROCs). Despite the high prices of ROCs and a more continuous growth perspective, the system did not work as planned. The British Renewables Obligation (RO) had a target of 10.4 percent of electricity sales from renewable sources by 2010, but "performance has been hampered by the emphasis within the mechanism on encouraging the cheapest forms of generation" and due to the "government's lukewarm endorsement" of renewable energy, investors could never be sure of a continuous value of their ROC-income over the life time of a turbine. [1]

Indeed ROCs created an extra payment, additional to market prices, but only as long as not enough wind power was delivered to the grid. Once the obligation was accomplished and exceeded, investors faced a drop in the ROCs value toward zero – a situation well known from carbon trading – when more certificates were on the market than asked for by the state. For these reasons, wind investors in Britain had to ask for much higher risk premiums than investors counting on feed-in tariffs on the European Continent.

The ROC's "failure to deliver renewable energy as cheaply as it should" and its "inability to bring forward more expensive technologies"[2] was recognized by the government in 2007. A new system was announced. A new, so-called banding-system would allow less commercial renewables – offshore wind, purpose-built biomass – to receive more than one RO-certificate per megawatt hour, while cheaper technologies, such as co-firing of biomass in conventional power stations, would receive less than one ROC/kWh.

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[1] Bridget Woodman and Catherine Mitchell: TOO LITTLE TOO LATE? http://users.wbs.ac.uk/group/cmur/people/catherine_mitchell

[2] Windpower Monthly, March, 2007 p. 59

Under a new name, the British government silently approached the economic logic of the abhorred German system it tried to avoid for so long, introducing incentives along specific generation technologies and abolished the worst windfall profits.

At wind energy conferences, UK ministers repeatedly spoke out in favor of wind power. Behind the scenes and in private industry association conferences however, they repeatedly showed their strong, pro-nuclear sympathies. If wind power proved to be too successful, wouldn’t new nuclear plants lose their necessity, and wouldn’t old ones face a fadeout? The same questions were raised in many other nuclear-oriented nations such as France, Finland, Japan or Southeastern US where nuclear never faced the same hurdles in terms of permission or finance as did the promoters of wind energy projects.

In the UK, along with financial instability, wind developers had no preferred treatment for grid access or construction permissions such as existed in Germany. By the end of 2006, some 5000 MW of application requests were stuck just in the Scottish government’s bureaucracy, and more so in England, Wales and Northern Ireland. In the first quarter of 2008, the British administrations approved 726 MW of new projects, but rejected 880 MW others. Requests for permission were delayed for years or blocked by the Ministry of Defense on “interference with radar protection”. The resistance toward wind drove Britain into a growing dependence on Russian natural gas. And the British energy industry so far completely failed to create a homegrown renewable energy industry within the fast-growing global market, despite excellent wind resources right at home.

On a legal ground, small investors, such as British farmers, local villagers or small independent “green funds,” had few or no chance to receive a reasonable income from ROCs income, and the same impact resulted from the PTC-scheme in the US, a scheme that favored big business with deep pockets. Meanwhile in Denmark, Germany and Spain, independent investors successfully organized billions of Euros for grass-root investments into new wind farms of an industrial scale. With “people’s wind-parks” (Bürgerwindparks, community power approaches), local people participated in the benefits of wind energy and gave support to local developments while in Britain, the absence of small, local investors or cooperatives lead to more resistance against “ugly” wind farms.

This weak legal situation for renewable power was a political battleground in the legislative bodies of Britain. It came as a surprise when, on November 26 2008, the Queen gave her "royal assent" to Britain's long-debated Energy Bill which contained provisions calling on Gordon Brown's Labour government to implement a system of feed-in tariffs for small renewable energy producers by 2010. The innovation followed a political upheaval within the Labour Party and was supported also by Conservative and Liberal Party members. Conservative Party leaders put the ruling Labour Party on notice that if the feed-in tariff provisions didn't pass, they would support the policy in a subsequent Conservative Government.

Previously, Gordon Brown suffered an embarrassing back-bench revolt over the issue from his own party members. The move by the British government has far reaching ramifications. The English speaking world has been more resistant to feed-in tariffs than non-English speaking countries, sometimes on ideological grounds, sometimes simply out of ignorance. Many North Americans, for example, attribute continental Europe's success with renewable energy to renewable portfolio standards, which is not the case.[1]

However, the feed-in tariff provisions are modest in comparison to those in other countries. In contrast to continental European policies, projects are limited to no more than 5 MW.

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[1] Paul Gipe: British Feed-in Tariff Policy Becomes Law--Was Once Unthinkable, (emailed press report, November 28, 2008)

One interpretation of the decade-long delays in Britain is that ministries were intransigently determined to “prove” nuclear power’s irreplaceability.

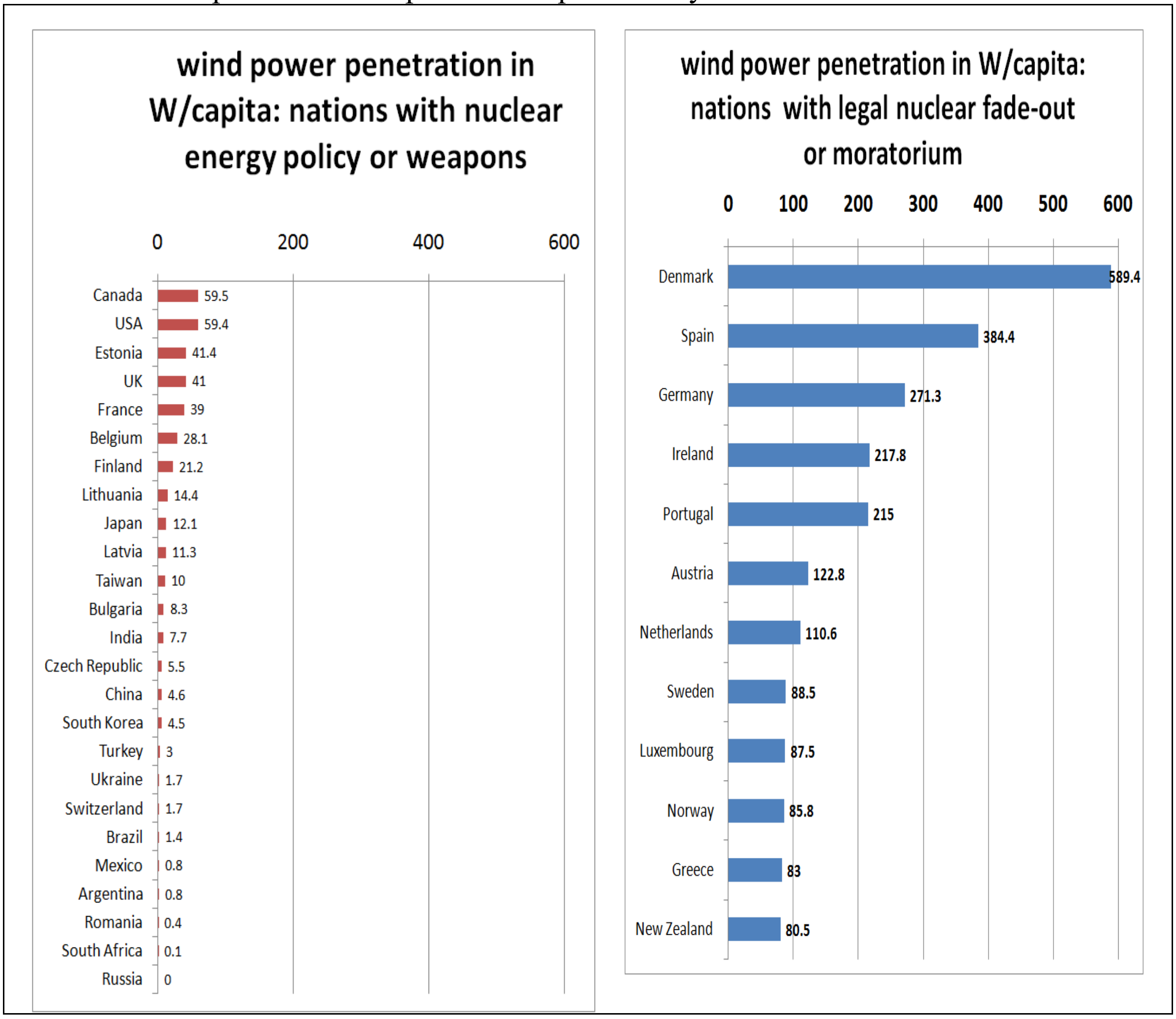

Figure 24 Wind penetrations per capita in nations with and without nuclear ambitions

Empirically there is a significant difference in wind penetration between nations with no nuclear or with a nuclear fade-out/moratorium-decision versus those nations which consider nuclear power as a technology of the future.

The twelve nations with highest wind penetration per capita are exactly those which said good-by to nuclear energy or which never started it; in nations dominated by nuclear lobbies and academia, wind power so far faces many obstacles such as discriminatory grid access, legal and permission hurdles, unfair price practices, etc.

In real terms, nuclear never has delivered as expected; its world market share is steadily declining. But its contribution in blocking wind and solar has been significant.

Nations with some of the very best wind resources, such as Britain and France, for decades created minuscule wind capacity, compared with Germany or Spain where nuclear power is under moratorium or fade-out. Meanwhile Germany, with rather modest winds, has earned billions from wind technology and exports worldwide.

Technical innovations

The wind industry, in the 1990-2005 period, saw many improvements in technology such as variable speed generators, pitch regulated rotor blades and larger and more productive turbines. System related qualities improved too: site-specific wind speed analysis and higher turbine towers opened new areas of production. Better grid convenience and computer-aided weather analysis led to improvements in production forecasts and increased acceptance of wind power within the utility sector.

After a difficult start, wind power turned out to be a reliable technology for worldwide, cheap and clean power, with many improvements still ahead. Most important: the increased generator and rotor sizes and the higher hub heights significantly reduced the cost per kilowatt hour.

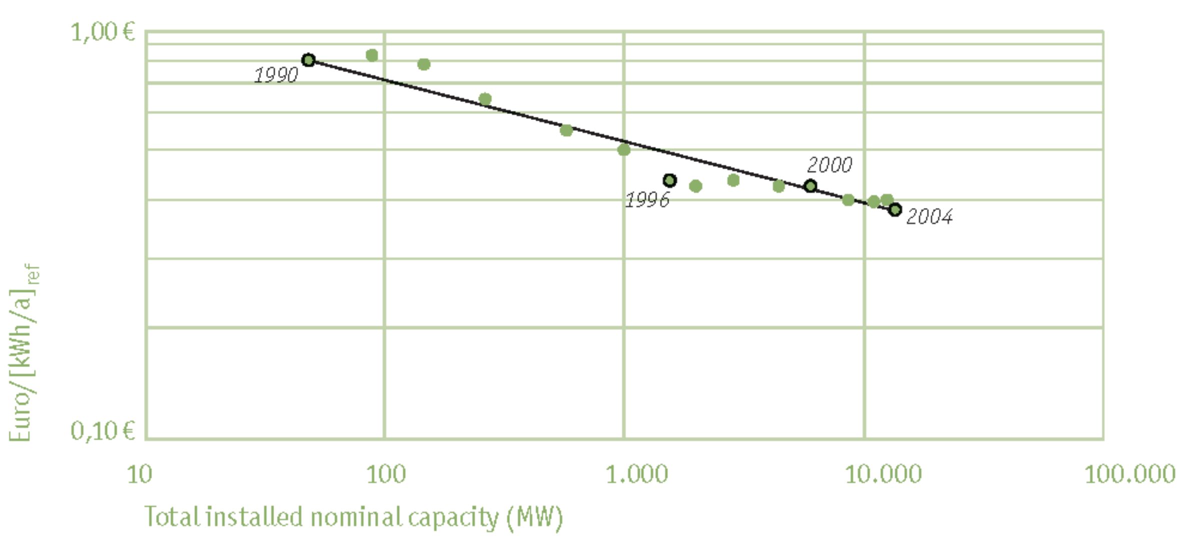
Fig. 1: Wind power learning curve, wind turbine price per kWh, annual energy yield (reference site)

Figure 25 cost reduction for the amount of capital needed for the production of 1 kWh annually by wind power (horizontal axis: globally installed nameplate capacity, vertical axis Euro/[kWh/a$_{ref}$], source: ISET/Reisi[1]

Between 1990 and 2004, the German ISET (Institut für Solare Energieversorgungstechnik) reported a mean annual cost reduction of 4.8 percent. The investment costs to produce one kWh per year dropped from 0.80 to 0.38 Euro-Cent. (0.38 Cents is *not* the cost of energy but the cost of installation divided by the annual generation).

The reasons for this positive development are many-fold, namely larger rotors and turbine sizes, up scaling of production numbers, optimizing of manufacturing, better technology and higher reliability of wind turbines. The price of a new turbine dropped from 1260 Euros per kWh to 890 Euros per kWh in 2004 in real terms.[2] Since 2005, turbine prices increased due to the price increases of raw materials such as copper and steel and due to the strong position of

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[1] Wind energy efficiency – An excerpt from the 2005 German wind energy report compiled by the Institute for Solar Energy Supply Systems (Institut für Solare Energieversorgungstechnik, ISET), on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Reworked and amended special reprint by the German Wind Energy Association (Bundesverband WindEnergie e.V.), Berlin 2006; **http://www.wind-energie.de/fileadmin/dokumente/English/Broschueren/060515_BWE_ISET_broschuere_en.pdf**

[2] BWE: Effizienz der Windenergie; Auszug aus: Windenergie Report Deutschland 2005 des ISET (Institut für Solare Energieversorgungstechnik)

turbine manufacturers, both a result of high demand, but in relative terms – compared with new gas, coal or nuclear power plants – wind power stayed ahead of its competitors.

Significant cost reductions are testified by many sources. A survey of the US Department of Energy declared: "Based on our limited sample of 7 projects built in 1998 or 1999 and totaling 450 MW, the weighted-average price of wind in 1999 was just under 6.1US-Cents/ kWh (in 2006 dollars). By 2006, in contrast, our cumulative sample of projects built from 1998 through 2006 had grown to 85 projects totaling 5,678 MW, with an average price of $36/MWh [3.6 US-Cents/kWh]."[1]

(These numbers contain subsidies to a certain degree – namely the US Production Tax Credit of some 1.8-2.1 US-Cents/kWh – and might therefore be a bit too low to reflect the full cost of US wind power installations, but the trend is significant despite higher turbine prices in the more recent past. Full costs in the range of 6-8 US-Cents/kWh for *new* installations can be seen as competitive compared to conventional *new* installations (gas, coal, nuclear) where risky fuel price volatility is a cause of continuous financial uncertainty).

Over only 25 years, the productivity of individual wind turbines grew 100-fold. The early turbines of the 1980s were small machines with significant noise emissions. Modern wind turbines are characterized by slow motion, higher hub heights (70-130 m) and rather insignificant noise.

Capacity (MW)	0.5	1.5	4.5
Relative capacity	1	3	9
Rotor speed (turns per minute)[a]	40	20	10
Relative rotor speed	1	0.5	0.25
Relative rotor torque (Nm)	1	6	36

Figure 26 Changes in rotor speed and rotor torque resulting from up-scaling[2]

Relative rotor speed slowed while relative capacity grew by a factor of five to nine for turbines of 2.5 to 4.5 MW size, compared to 500 kW turbines produced in the early 1990s.

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[1] US-DOE: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2006, Washington, May 2007, p. 10

[2] Eize de Vries: The Challenge of Growth, supply chain and wind turbine up scaling challenges, Renewable Energy World, May-June 2008, p.24-31

New turbines typical in	Rated capacity kW	Diameter m	Typical Energy production kWh/ y
1980	30	15	35,000
1985	80	20	95,000
1990	250	30	400,000
1995	600	46	1,250,000
2000	1500	66	3,500,000
2005	2000	80	4,400,000
2008	2500-3000	80-100	5,400,000-6,500,000
Turbines in early serial production (2008)	6000	126	20,000,000

Figure 27 Wind turbine rated capacity, rotor diameter and expected annual energy production in kWh annual yield in kWh of state of the art wind turbines

There is an exponential relation between power production and rotor radius. By a rule of thumb, you had to increase rotor radius by one third to receive a doubling of kWh earned, as shown in the figure below.

The exponential relation between larger rotor blades and kWh production created strong R&D incentives for the advancement of turbine size. This can best be seen in the growth of nameplate capacity of newly installed turbines in Germany. From 1990 to 2007, mean-rated capacity of new turbines grew from 164 kW to 1924 kW – a growth of 1173 percent.

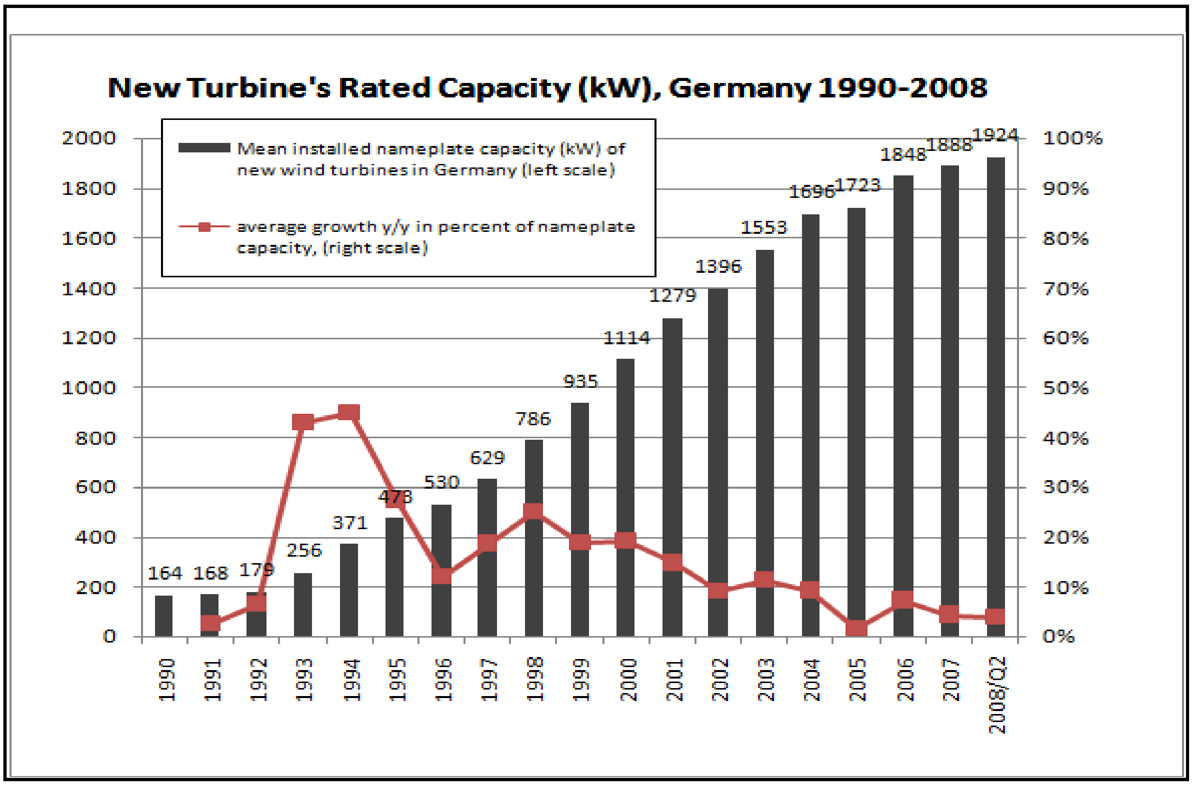

Figure 28 Nameplate capacity of new wind turbines installed in Germany, 1990-2008 (Source: DEWI (2006/2007/2008)[1]

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[1] Deutsches Windenergie-Institut, Status Report 31.12.2006, 2007, 2008

These improvements within less than two decades were revolutionary and crucial for the success of a technology, which until 1980 was in a pre-industrial start position and never enjoyed huge technology funding as did other technologies. Decisive for the fast innovation cycles was the short time-to-market, compared to other energy technologies, and the long-term, productivity-based support by feed-in tariffs.

“Teething problems”

Not everything went well though. In 2002, Danish industry leader Vestas constructed its first “utility-size” offshore wind farm, Horns Rev, on the West Coast of Denmark. 80 turbines of its 2-MW-size were erected in waters of 6-14 meters of depth.[1] The investment was a turnkey contract that suffered some serious failures which Vestas-boss Svend Sigaard called "teething problems".

With the introduction of new models, the wind power industry faced a number of serial failures of components such as bearings, hydraulic pitch regulation, gearings or rotor blades. These risks were especially high with offshore technologies. Vestas had to tear down all of its Horn Rev’s wind turbines for repair on land – a costly and painful operation.

The on-off cycles of the US Production Tax Credit put the industry under additional stress because turbines had to be delivered within very short time frames – and small delays meant that a whole new wind farm worth hundreds of million dollars could fail financially. Companies like Vestas, Nordex and NEG Micon ran into losses by running too fast with multi-megawatt-machines. These factors combined with a general slump of the wind business in 2004 were at the root of financial difficulties across the industry at the time.

Market leader Vestas, in its 2004 full year report, declared that “eight low margin orders for North America to be completed before year-end have led to significant opportunity costs from taking up production resources and components that were originally assigned to other projects”. This led to “significant direct cost overruns related to shipping and installation“. Vestas then deplored “domino effects”: “Delayed component deliveries have reduced capacity utilization, slowing down or even stopping production…Offshore: Due to delayed nacelle completion, towers and nacelles have been shipped to site separately” and delays were “costly to sea transport in general: A ship is costing 20,000 US Dollars per lay day, ships have been dispatched with incomplete cargos…afterwards, delayed components have been flown in and installed on site”, and then “delayed components have caused late commissioning, leading to additional penalties”.[2]

Another challenge was currency exposure, especially in the US. Between January 2002 and December 2005, the Vestas Company expressed no less than eight profit warnings,[3] and by the end of 2005, reduced profit expectations for the fourth year. Failures with multi-Megawatt offshore machines persisted through 2007 when Vestas had to take its V90-3,0 MW-offshore-version temporarily out of the market.

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[1] Elsam: Horns Rev Offshore-Windpark: Ein bahnbrechendes Windkraftwerk in der Nordsee

[2] Vestas Annual Report 2005, fact sheets p. 6, 7

[3] Windpower Monthly, December 2005, p. 30

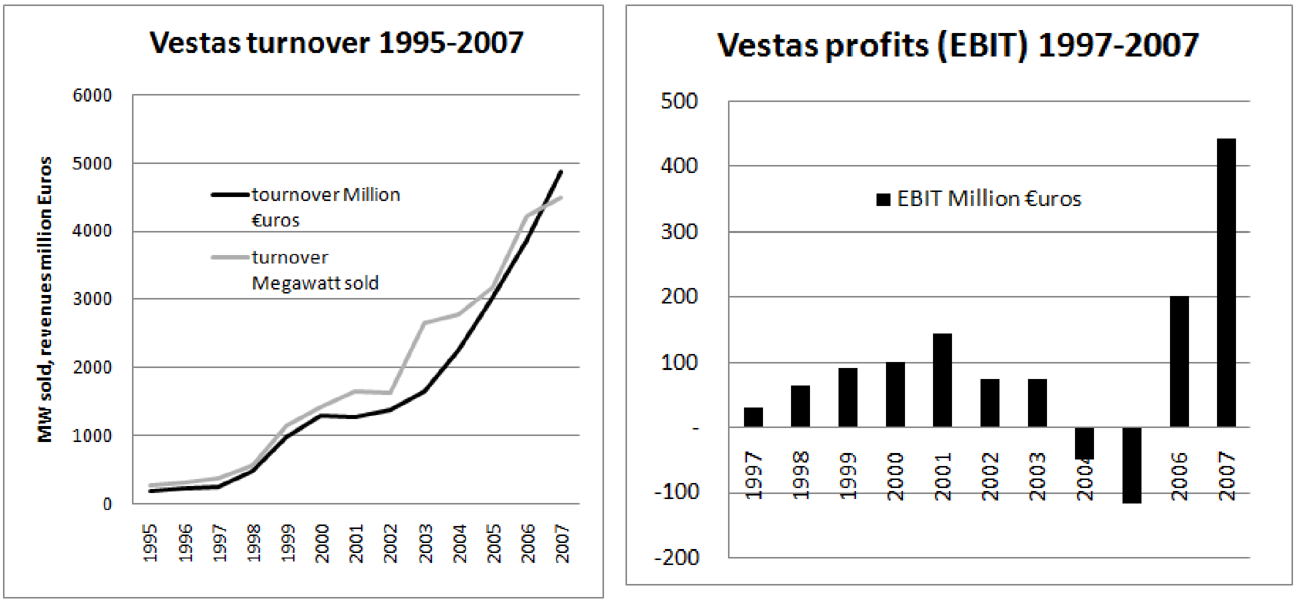

Figure 29 Development of Vestas turnover and profits

Vestas was not alone with its up and downs. Some of its problems stemmed from the merger with Danish company NEG Micon – the world's second largest manufacturer in 2003 which ran into financial problems after serial failures. Other companies such as German Nordex and Tacke went bankrupt and later were re-capitalized, finding new investors.

There was good news with offshore wind farms, too. By 2005, the former problem-shaken Horns Rev installation reached one of the highest capacity factors of all wind farms worldwide, with 45 percent annual production of name-plate capacity.[1] The 160-MW-offshore construction at an original cost of 270 Million Euro[2] then produced more than 629,000 MWh [629 million kWh]. At a market value of some 5 €-Cents/kWh, it created revenues worth 31.5 million Euros, proving the viability of the offshore technology as such.

In 2005, one other crucial change happened in the US when for the first time a *three-year* extension of the Production Tax Credit (PTC) passed legal hurdles. It gave way for many industry leaders to finally enter the wind business and set up production facilities within the US.

Combined with the sharp price rise of fossil fuels, wind power suddenly was in much higher demand, and the political will for a reform of market schemes in favor of renewables strengthened on the back of ever more pressing climate change issues.

By no coincidence, the new Vestas boss, Ditliv Engel, put product quality and profitability at the core of a new strategy – the "will to win" – and he steadily raised the prices for new turbines. Other companies followed.

Before 2005, a strong focus went into the development of offshore technology with much bigger machines. This changed in 2005. Vestas and General Electric delayed their plans for higher sized turbines in the 4-5 MW range. Small companies, like Bonus and Gamesa, had shown solid profits with less ambitious sizes for their standard models.

This subtle change of technological strategy had a solid background in terms of demand. New buyers from nations with vast territories mainly were interested in onshore installations. The

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[1] Windpower Monthly, July 2006 p. 59

[2] Elsam **http://www.hornsrev.dk/nyheder/brochurer/Horns_Rev_TY.pdf**

feed-in tariffs for offshore deployment were not attractive enough yet to cope with the high risks involved. General Electric's proven 1.5 MW-machine fitted well with the US market, where wide-open land was not scarce as in Germany or Denmark and where profitability counted first. There was enough to be done to bring older models to perfection before investing large amounts into new models. In the 2006-2008 period, Vestas still was plagued by high warranty provisions of some 5 percent of its total revenues – a fact which Vestas CEO Engel called "highly unsatisfactory". Defective gearboxes, in particular, were calling in a lot of warranties.

The Globalization of wind power: 2005 and beyond

Since 2005, in Denmark, Germany, Spain, India, the US and China, formerly small and medium turbine manufacturers expanded markedly. European companies were the undisputed industry leaders in terms of volume, technology and innovation. But the picture changed quickly. Old energy giants were eager to conquer a place in the booming wind industry. By 2008, General Electric, Siemens, Areva and Alstom all had created their own wind equipment business by acquiring smaller companies experienced in the field.

Buying company	located	Takeover of	Origin	Year
Enron Wind	USA	Zond Systems	USA	1997
Enron Wind	USA	Tacke Wind	Germany	1997
General Electric	USA	Enron Wind	USA	2002
Vestas	Denmark	NEG Micon	Denmark	2003
Gamesa	Spain	Made	Spain	2003
Siemens	Germany	Bonus	Denmark	2004
Acciona	Spain	Ingetur	Spain	2005
Areva	France	Multibrid	Germany	2007
Suzlon	India	Repower	Germany	2007
Alstom	France	Ecotecnia	Spain	2008
Goldwind	China	Vensys	Germany	2008

Figure 30 Mergers and acquisitions of wind turbine manufacturers since 2002[1]

The consolidation did not only take place on the manufacturer's level but also among wind power developers. Most utilities entered the wind market by acquiring small companies with experts active in the field for many years. The next figure gives an impression of just the US merger activity, which grew steadily over time. In a period of turbine shortages it was a logical step for independent developers to look for utility cooperation. Deep pockets were necessary to get contracts at reasonable prices.

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[1] On the history of Zond and Tacke the source is: Koen Rijnsent: Wind turbines: manufacturing and location, Utrecht University 2002 http://www.energie.demon.nl/windenergy/location%20of%20wind%20turbine%20production.pdf

Table 6. Acquisition and Investment Activity Among Wind Developers*

Investor	Transaction Type	Developer	Announced
EDF (SIIF Energies)	Acquisition	enXco	May-02
Gamesa	Investment	Navitas	Oct-02
AES	Investment	US Wind Force	Sep-04
PPM (Scottish Power)	Acquisition	Atlantic Renewable Energy Corp.	Dec-04
AES	Acquisition	SeaWest	Jan-05
Goldman Sachs	Acquisition	Zilkha (Horizon)	Mar-05
JP Morgan Partners	Investment	Noble Power	Mar-05
Arclight Capital	Investment	CPV Wind	Jul-05
Diamond Castle	Acquisition	Catamount	Oct-05
Pacific Hydro	Investment	Western Wind Energy	Oct-05
EIF U.S. Power Fund II	Investment	Tierra Energy, LLC	Dec-05
Airtricity	Acquisition	Renewable Generation Inc.	Dec-05
Babcock & Brown	Acquisition	G3 Energy LLC	Jan-06
Iberdrola	Acquisition	Community Energy Inc.	Apr-06
Shaw/Madison Dearborn	Investment	UPC Wind	May-06
NRG	Acquisition	Padoma	Jun-06
CPV Wind	Acquisition	Disgen	Jul-06
BP	Investment	Clipper	Jul-06
BP	Acquisition	Greenlight	Aug-06
Babcock & Brown	Acquisition	Superior	Aug-06
Enel	Investment	TradeWind	Sep-06
Iberdrola	Acquisition	Midwest Renewable Energy Corp.	Oct-06
Iberdrola	Acquisition	PPM (Scottish Power)	Dec-06
BP	Acquisition	Orion Energy	Dec-06
Naturener	Acquisition	Great Plains Wind & Energy, LLC	Feb-07
HSH Nordbank	Investment	Ridgeline Energy	Feb-07
Energias de Portugal	Acquisition	Horizon	Mar-07
Iberdrola	Acquisition	CPV Wind	Apr-07
Duke Energy	Acquisition	Tierra Energy, LLC	May-07
Acciona	Acquisition	EcoEnergy, LLC	Jun-07
Babcock & Brown	Acquisition	Bluewater Wind	Sep-07
Good Energies	Investment	EverPower	Sep-07
E.ON AG	Acquisition	Airtricity North America	Oct-07
Wind Energy America	Acquisition	Boreal	Oct-07
Marubeni	Investment	Oak Creek Energy Systems	Dec-07

* Select list of announced transactions; excludes joint development activity.
Source: Berkeley Lab.

Figure 31 Acquisitions and investments in the US wind developer business
source: Wiser & Bolinger 2008[1]

Emergence of new markets

"Up until just four or five years ago there were only a handful of countries that could be considered significant wind markets. And there were only a couple of – mainly European – suppliers that dominated global wind turbine development and supply. That picture is now changing." [2] The geographical expansion of wind power is driving manufacturers to start production closer to the new markets. Production is emerging in countries that on a wind power map barely existed before: China, Canada, Portugal, Turkey, Brazil, Vietnam, Egypt, Morocco.

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[1] Ryan Wiser, Mark Bolinger: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, May 2008 ed. US Department of Energy, p. 13

[2] Eize de Vries: The Challenge of Growth, supply chain and wind turbine up scaling challenges, Renewable Energy World, May-June 2008, p.24-31

Year	three biggest markets, market share	New installations per year MW worldwide	Biggest three markets, MW installed	Number of nations installing >100 MW
1980	~100%	~10	California/US (8), Denmark (5)	0
1985	92.6%	420	California/US (292), Denmark (23)	1
1990	~100%	240	US (152), Denmark (81), Germany (35)	1
1995	75.5%	1290	Germany (487), India (391), Denmark (98)	1
2000	69.9%	4495	Germany (1668), Spain (872), Denmark (555)	7
2005	50.9%	11700	US (2390), Germany (1799), Spain (1765)	18
2006	43.8%	15054	US (2556), Germany (2195), India (1836)	17
2007	62.0%	19553	US (5273), Spain (3530), China (3312)	16

Figure 32 Market share of three biggest markets, 1980-2006

Over the first 20 years of industrial wind power (1980-2000) only five nations appear in the "first three" table: Denmark, US, Germany, India and Spain. The number of nations with more than 100 MW of new installations per year reached only seven. The industry at this stage was driven by strong *political will* and not by market forces. The motives for wind power stemmed from its cleanliness (no air pollution or waste), from the idea of local sourcing of energy and manufacturing (energy independence) and from the historic experience of wind as a risk-free resource.

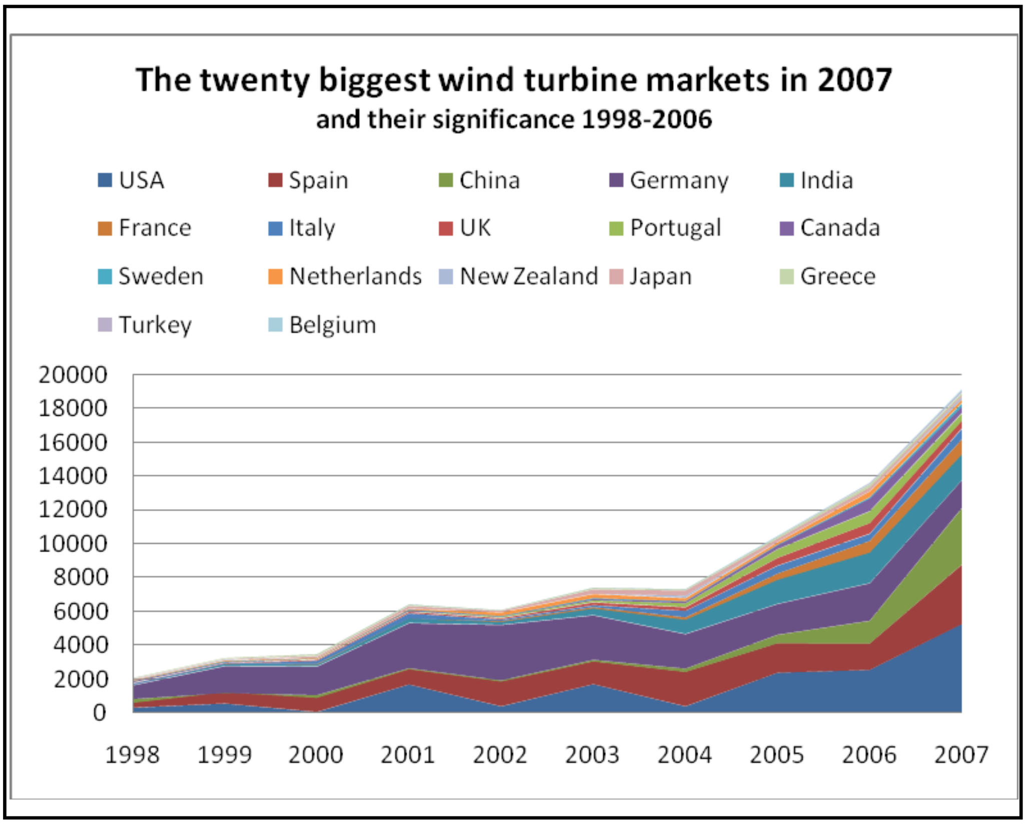

Figure 33 The twenty biggest wind markets in 2007 and their production history since 1998

By 2006, the market share of the "biggest three" had dropped to a low of 44 percent of turbines installed with 16-18 nations installing more than 100 MW a year (2005-2007).

A shift can be observed toward nations with big wind resources, huge populations and with large regions where proponents of nuclear power wield less influence. On that ground, China and the US (Texas, Mid-West and West, not the nuclear oriented East and South-East) emerged as gigantic new markets.

	MW installed in 2007	total capacity by 2007	market share MW sold 2007	market share total wind capacity 2007
USA	**5273**	**16971**	**27.0%**	**18.1%**
Spain	**3530**	**15145**	**18.1%**	**16.1%**
China	**3312**	**5906**	**16.9%**	**6.3%**
Germany	**1625**	**22247**	**8.3%**	**23.7%**
India	**1574**	**7844**	**8.0%**	**8.4%**
France	**901**	**2370**	**4.6%**	**2.5%**
Italy	**603**	**2726**	**3.1%**	**2.9%**
UK	**467**	**2425**	**2.4%**	**2.6%**
Portugal	**434**	**2150**	**2.2%**	**2.3%**
Canada	**395**	**1846**	**2.0%**	**2.0%**
Sweden	**216**	**788**	**1.1%**	**0.8%**
Netherlands	**188**	**1747**	**1.0%**	**1.9%**
New Zealand	**151**	**322**	**0.8%**	**0.3%**
Japan	**144**	**1538**	**0.7%**	**1.6%**
Greece	**125**	**871**	**0.6%**	**0.9%**
Turkey	**108**	**192**	**0.6%**	**0.2%**

Figure 34 market shares 2007, nations installing more than 100 MW in 2007

Other nations containing a huge wind resource, such as Russia and Japan, still lag strongly behind, their central governments favoring nuclear and, as a result, holding back necessary permissions and market structuring for wind.

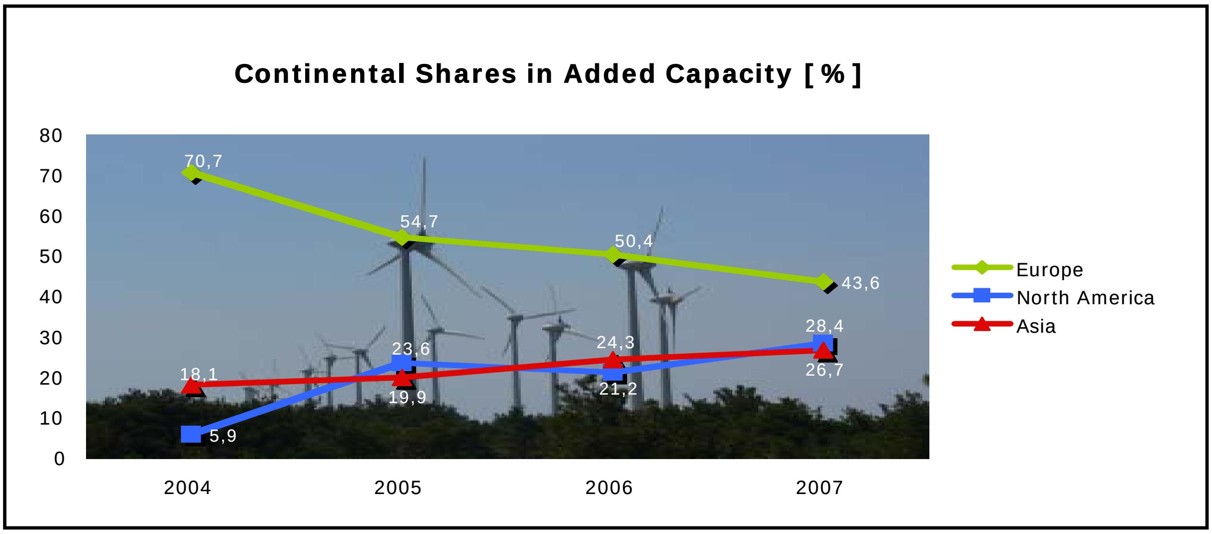

Figure 35 Market shares of capacity additions, source: WWEA

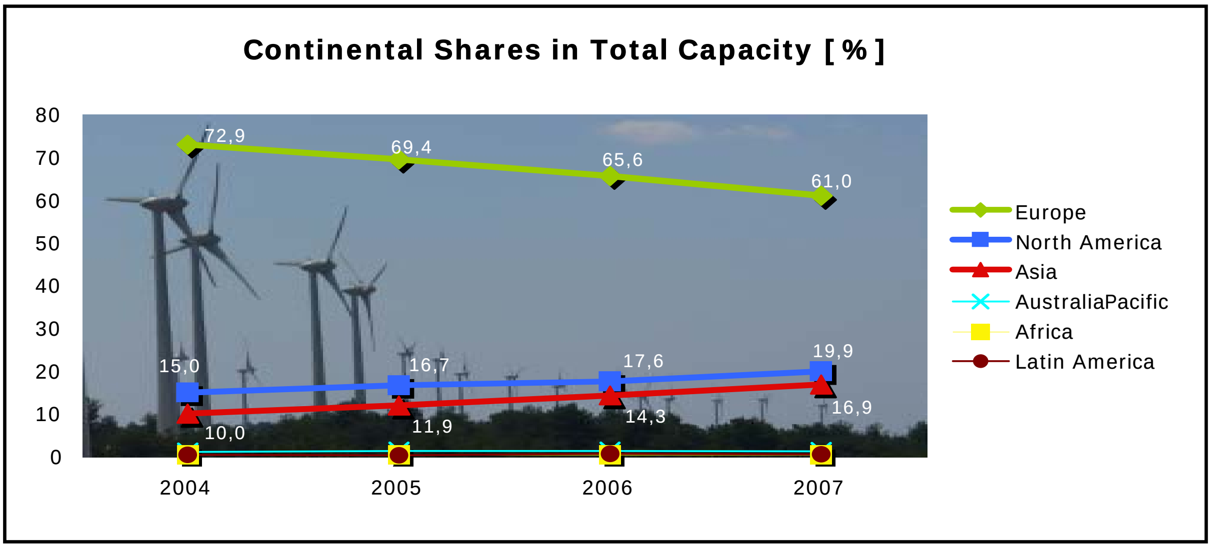

Figure 36 Market shares, total capacities, source: WWEA

The situation today

World cumulative capacity growth rates 1980-2007

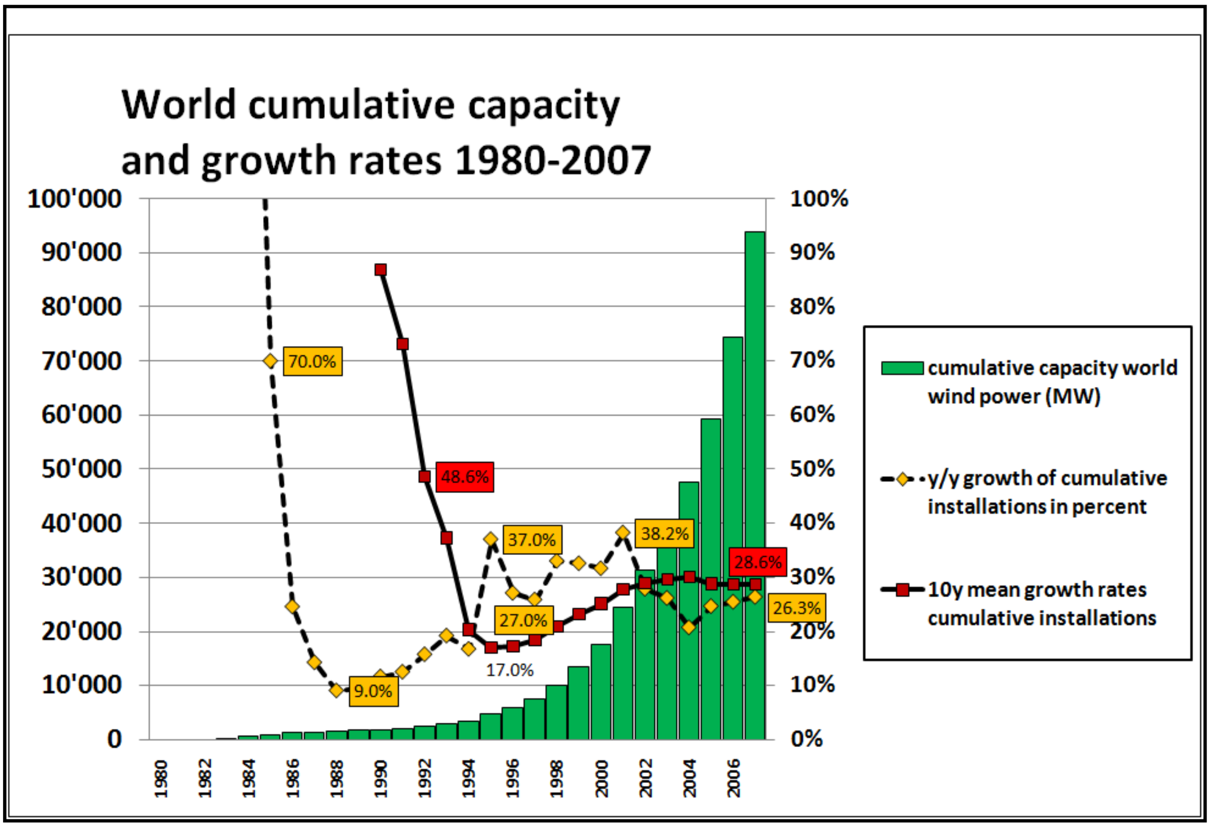

Figure 37 cumulative installations of wind power 1980-2006

Over the last 27 years cumulative wind capacity rose from 10 MW to 93,881 MW by the end of 2007. The highest growth rate after ending the pioneer period in 1985 occurred in 2001 at

38 percent, the lowest rate was observed in 1988 at 9 percent per year. In 2007 year-over-year growth rose to 26 percent again, after a low of 21 percent in 2004. The ten-year mean growth rate from 1998 to 2007 stands at 28.6 percent per year.

2^n-serial milestones of exponential growth	Milestone passed/expected	Number of years until next GW doubling	Cumulative capacity worldwide at milestone's year's end
~0 MW	1979		
1000 MW	1985	6	1020 MW
2000 MW	1991	6	2170 MW
4000 MW	1995	4	4778 MW
8000 MW	1998	3	10153 MW
16000 MW	2000	2	17706 MW
32000 MW	2003	3	39434 MW
64000 MW	2006	3	74328 MW
128000 MW	2009 exp. (?)	3?	
264000 MW	2012 exp.(?)	3?	

Figure 38 milestones of wind power growth worldwide

It took six years (1980-85) for cumulative world wind capacity to reach 1000 MW and another six years (1985-1991) to double world wind capacity and to reach the 2000-MW-milestone. Since 1998 the frequency of capacity doubling has been reduced to 2-3 years and it seems highly likely that this trend will continue until at least 2012.

World annual installations Growth Rates

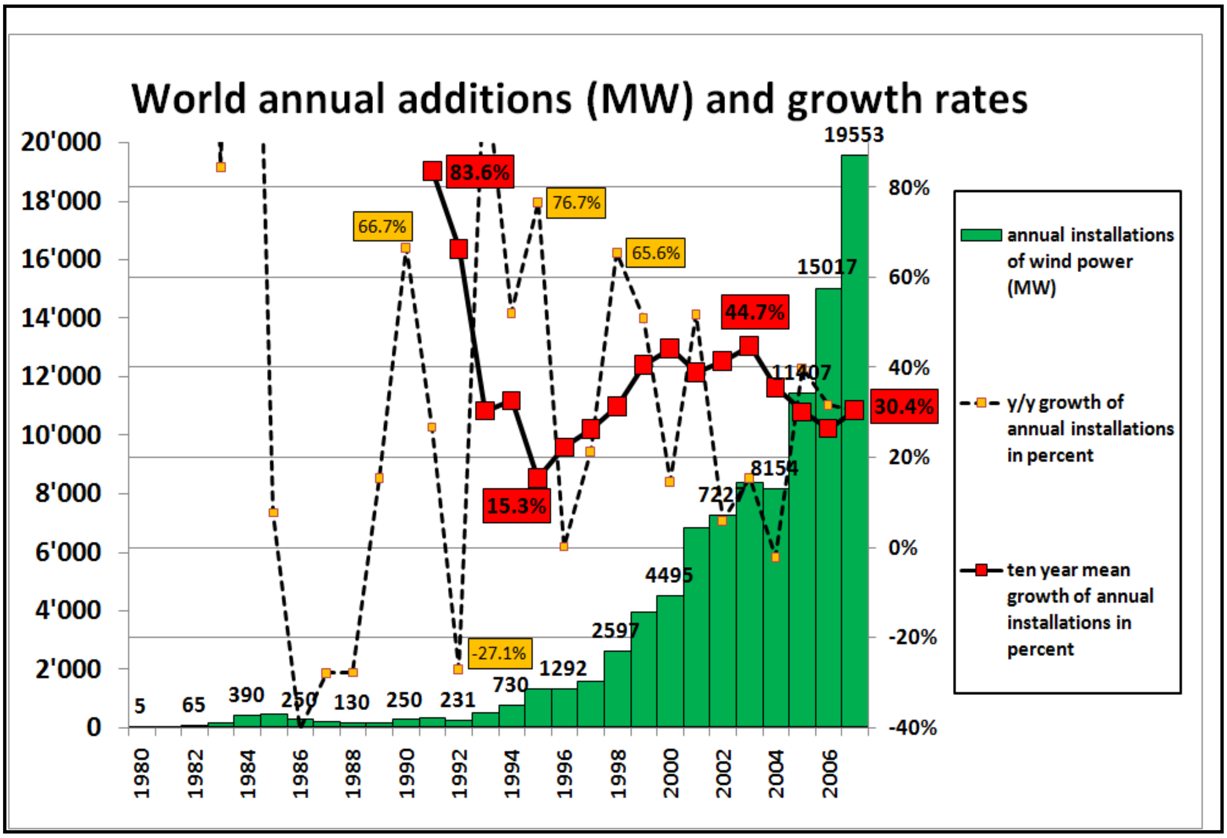

Figure 39 Growth of annual net installations of wind power, MW, 1980-2006

Annual net additions of new wind power installations increased from 5 MW in 1980 to 19'553 MW in 2007. Gross new installations were a little higher due to replacements.

The ten-year mean growth rate of annual additions in 2007 stands at 30.4 percent per year. This means that a doubling of annual additions happened within less than every 2½ years. The ten-year mean growth rate had its low in 1995 at 15.3 percent and recorded a peak of 44.7 percent in 2003. After a drop to 26.4 percent in 2006 it rose to 30.4 percent again in 2007.

Changes in growth rates of annual additions show a high volatility: 1986, 1987, 1988 and 1992 were crash years for the industry with year-over-year reductions of more than 20 percent. 1996 and 2004 showed near zero-growth. On the other side 1993/94/95 recorded a 108/52/76 percent high-growth period in annual additions. In 2002/2003/2004 the market then slowed down to only 6/15/-2 percent annual growth in additions. With 40/32/30 percent growth in new installations another boom period was observed 2005/2006/2007. The Megawatt-addition of this latter boom in real terms was some twenty times bigger than the 1993-1995 boom! And this boom is likely to continue. Market leader Vestas – to give just one industry example – announced a capacity increase of its annual output of new turbines from 4500 (2007) to at least 10,000 MW by Q1/2010.[1]

For future estimates it is important to memorize some important findings on the past:

- Over the medium term, growth in wind power additions showed a remarkable stability on a high level.
- Year-over-year growth of new installations can be volatile.
- A reduced growth in annual additions does not mean that overall capacity is shrinking.
- Since 1990, the mean year-over-year growth of cumulative capacity stands at 25.1 percent per year.
- Since 1991, the ten-year-mean-growth rate of annual additions exceeded 30 percent in 13 years out of 17. It dropped below 30 percent only four times (in 1995/96/97 and in 2006).

Component shortages

It is considered a fact that without the tight component supply that continues to put a brake on expanding global wind turbine output, today's industry growth could have been even faster. Along with shortages of materials, such as steel, one of the major challenges has been scaling up manufacturing capacities to support successfully running models and new generations of larger machines. Manufacturing capacity is increasing, but the component supply chain is stretched to its limits. "Wind turbine demand continues to outstrip the world's cumulative supply capacity".[2]

Shortages of components are not a new phenomenon for the wind industry. "In 1999 most manufacturers cited organizational constraints and bottlenecks in the supply chain as the major impediments to further growth", market analyst BTM Consult reminded in 2005.[3] Bottlenecks are neither a transparent nor a static phenomenon. Staff, transport, installation equipment (such as cranes) – the sector has growth challenges on all sides. Component shortages occurred in a number of supply chain areas including single main bearings, gearboxes, generators, main shafts, control cabinets, and complex castings such as hubs and

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[1] Vestas presentation Full Year 2007, chart 55 **http://www.vestas.com/Admin/Public/DWSDownload.aspx?File=%2fFiles%2fFiler%2fEN%2fInvestor%2fFinancial_presentations%2f2007%2f2007-AR-PRES-UK.pdf**

[2] Eize de Vries: The Challenge of Growth, supply chain and wind turbine up scaling challenges, Renewable Energy World, May-June 2008, p.24-31, http://www.renewableenergyworld.com/rea/news/story?id=51446

[3] BTM: Ten Year Review 2005, 23

mainframes. Larger bearings in particular were quoted in short supply and will maybe persist until 2010.

However, many components of the wind industry are applied in multiple industries. With profit margins improving over the 2005-2008 period, a number of new manufacturers have entered the wind industry, in part diversifying away from the floundering transport sector where oil prices by 2008 had caused a recession. Many old suppliers of the wind industry boosted their production considerably as well.

One strategy to cope with bottlenecks by some big manufacturers was scaling up in-house production of scarce components. Market leader Vestas, for example, in 2008 announced the creation of a new foundry in China and had more than a dozen factories in construction over three continents.[1]

Other companies started to acquire their suppliers to boost their output.

- In 2005, Siemens acquired Flender Holding GmbH, Bocholt, one of the world's leading suppliers of electrical and mechanical drive systems, including gearboxes, generators and frequency converters.
- India's market leader Suzlon acquired the renowned Belgian gearbox maker Hansen Transmissions International in 2006, so giving itself access to the latest drive technology and production. In 2007 Suzlon took an 87.1% stake in Germany's REpower, a step to acquire the German know how in on- and offshore wind technology and design.
- Chinese market leader Goldwind bought a majority stake of German Vensys Energiesysteme with whom it had a cooperation agreement before.

These moves herald a trend for ambitious newcomers, especially from Asia, to enter the world market. The trend has been reinforced by a major global wind technology transfer. A number of specialized engineering consultancy firms are involved in the design of new wind turbines for Asian clients based on European technology. German Company Aerodyn worked for a number of Chinese manufacturers, and created models specially adapted to specific local conditions. "An example of design adaptations is dealing with large differences in operating temperature between summer and winter, or mechanically coping with sand storms in harsh desert conditions," Sönke Siegfriedsen from Aerodyn is cited.[2]

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[1] Vestas Annual Report 2007 p. 18

[2] Eize de Vries: A solid foundation: Technological developments from the DEWEK conference
http://www.renewableenergyworld.com/rea/news/story?id=51565

	Up to 1 MW	Up to 1.5 MW	up to 2.5 MW	Up to 2.5-5 MW	5 MW and more
world top ten manufacturers (2007)		Acciona (Spain) Goldwind (China) Sinovel (China)	Gamesa (Spain) General Electric (US) Nordex (Germany) Suzlon (Ind.)	Siemens (Germany/DK) Vestas (DK)	Enercon (Germany)
Other manufacturers (2007)	Conergy (Germany) Unison (Korea) Vergnet (France) Windflow (New Zealand)	Alstom- Ecotécnia (F/E) CKD (Czech) Dongfang (China) Eozen (Spain) Huayi (China) New United (China) Torres (Spain) Vensys (Chi/Ger)	Clipper (US) CTC/Dewind (USA/Germany) Fuhrländer (Germany)	WinWinD (Finland) Mitsubishi Heavy Industries (Japan)	Bard (Germany) Repower (Ger/India) Multibrid/Areva (Germany/France)
Manufacturers in prototype stage or non-specified stage	Hui De (China) Innovative Wind Power (IWP, Germany) Wu Zhong (China) GC-Nordic (China)	CCWE (China) Harbin wind power equipment (China) Leitwind (Italy) Norwin (DK) ReGen Powertech (Ind.) Shanghai Electric (Chin) Tian-Wei (China)	Avantis Energy (China) Beijing Bei Zhong (China) CSR Zhuzhou (China)	Doosan (Korea) ScanWind (Norway)	DarWinD (NL)
New Turbine Companies with no data on specified production available	ACSA (Spain) AAER (Canada), Emergya Wind Technologies (NL) Harokasan (Japan), Norwin (DK) Seewind (Germany), Subaru (Japan), Turbowinds (Belgium), **From China:** Zhejiang Yunda Windey, Mingyang Wind Power Technology Co. Ltd., Galaxy Wind, Xiangtan Electric Manufacturing Co. Ltd. (XEMC), Baoding, Beijing Wandian, Changzhou Railcar Propulsion Engineering Center (CPC, Wind Power Equipment Manufacturing Company, ZheJiang, Envision, Chonqing Haizhuang Wind Power Equipment (CSIC), Guangzhou Enggawind Energy Ltd. Co., Harbin Turbine Company Co. Ltd. (HTC), Nantong Kailian Windpower Equipment Co. Ltd., Shanghai Wande Wind Power Co. Ltd., Shenyang Huachuang Wind Energy Co. Ltd., Wuxi-Baonan Machine Building Co. Ltd., Huayi Goldwind Wind Power Co. Ltd., Guizhou Changzheng Electrical Apparatus Co. Ltd., Jiangxi Zhonghang, Tianjin Eastern Steam Turbine Engineering Co Ltd., Wuzhong Instrument /Meters Co., Ltd., Baoding Huide Wind power engineer Co., Ltd., Hunan Hara XEMC Windpower Co Ltd. (Hara), Guodian, Sufoma				

Figure 40 Companies active in wind turbine manufacturing (status end 2007)[1]

By the end of 2007 the number of turbine manufacturers with existing serial production has grown to more than 50 companies, with just ten of them covering 90 percent of the market. A high number of companies entering the wind industry, some 40 of them from China, are in their infancy of serial production and product development.

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[1] Information derived from Windpower Monthly Magazine (var. ed.), Renewable Energy World (var. ed.), Neue Energie (see specially for Chinese manufacturers edition 9/2007 p. 38

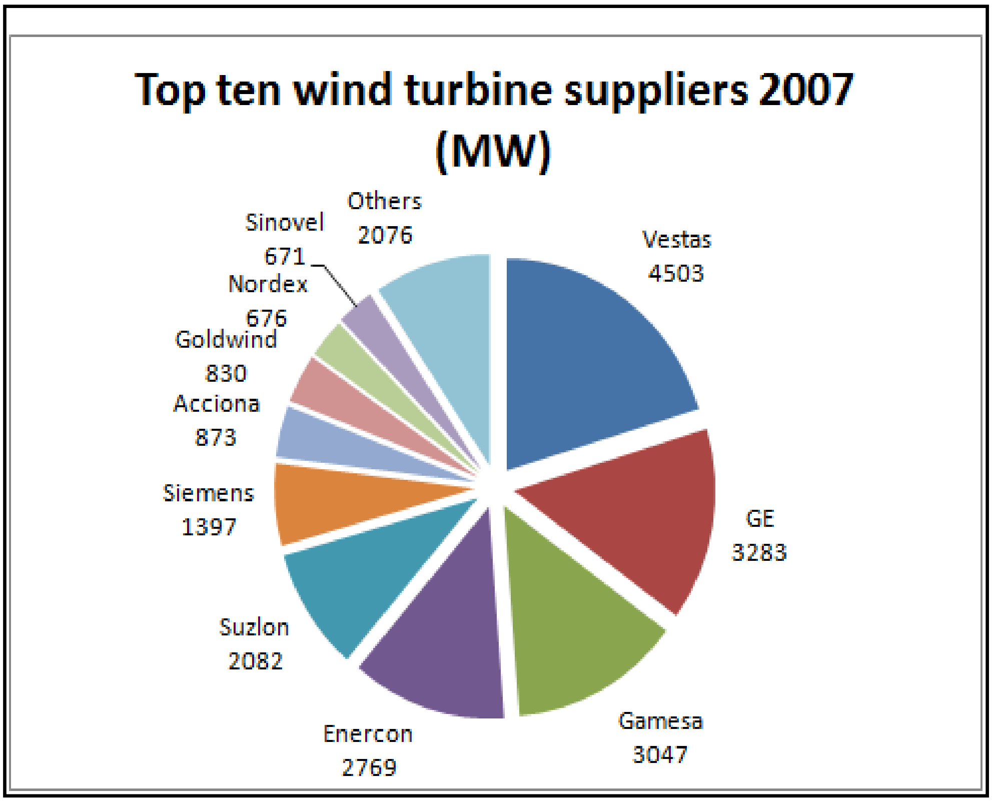

Figure 41 Top ten turbine manufacturers in 2007 source: Windpower Monthly Magazine[1]

Many governments today are eager to create their own wind industry. China, Canada, Portugal and Brazil have implemented strong homemade component standards for access to feed-in tariffs or tax reliefs.

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[1] Windpower Monthly May 2008 p.96 the sum of all turbines delivered amounted to 22207 MW when the net additions registered by Windpower Monthly in 2007 was 19553 MW. The difference is due to replacements and disposal of older turbines; some minor differences might stem from different statistical definitions such as shipments versus newly installed turbines.

The advantages of wind power

The new cost constellation in the power sector put wind power on the forefront of competitiveness and availability. The success of wind power goes far beyond pure cost advantages. It is a combination of more than one dozen specific attributes that give wind power an advantage over other power technologies:

1. The primary energy (wind) is cost-free;
2. The primary energy is renewable and never runs out;
3. There is an abundant resource, nobody can cut access/supply;
4. Stable life-cycle-cost of its use can be guaranteed;
5. Wind power is competitive with other new power sources;
6. Operating wind turbines cause no carbon emissions, no air pollution and no hazardous waste;
7. No water for cooling is needed;
8. Wind has a short energy payback of energy invested, normally less than one year;
9. There is a global, easy access to wind technology, compared to nuclear and others;
10. Time to market is very short, erection of entire wind farms within one year possible;
11. Fast innovation cycles prevail, based on maturing know-how;
12. Wind is still a young technology, allowing progress on the learning curve and cost reductions;
13. Wind is decentralized power; it allows small organizations or groups in various places to become a part of the power generation business and to sell it for a profit – very different from the exclusive structure of the oil, gas or nuclear business;
14. Distances from good wind sites to consumers in general are moderate (1-1000 miles) compared to other energy sources (oil, gas, uranium, coal);
15. Wind energy has positive side benefits for various stakeholders such as job creation, taxes, income options for farmers, infrastructure for remote areas, investment opportunities for local communities etc.;
16. Wind energy replaces expenses for (often imported) fuels by technology, creating energy, know-how and human labor in a decentralized way.

For these reasons we express the central thesis of this essay: *High growth rates of wind power generation worldwide will persist and wind power will conquer a large part of the energy market in the close foreseeable future (10-15 years).*

We now will explore what a continued exponential growth of wind power means for the power sector (chapter 5). Then we will analyze past forecasts for the wind power sector (chapter 6) and take a look at some main future drivers of wind power (chapter 7) and at costs and economic benefits (chapters 7-10) before we reflect some objections frequently put forward against the expansion of wind (chapter 11 and 12) in the power sector.

4. Four World Scenarios for the Wind Sector

Preliminary remark

The following model focuses on wind energy. Wind power is seen as the most competitive renewable energy source, following solid exponential growth rates over the past fifteen years. For a number of reasons we think that this trend will continue in the future.

An extensive analysis is given in chapter 5 of past forecasts by international institutions such as the International Energy Agency (IEA) and the European Wind Association (EWEA). There can be no doubt that the growth of wind power has been underestimated continuously. The main thesis of this essay is that high growth rates of wind power additions will persist. Wind power will conquer a high market share in the business of new power plants over the close foreseeable future (10-15 years).

Some uncertainty exists regarding the amount of wind expansion compared with other renewable energies. To successfully compete with wind power, other new renewable energy sources need to be as cost effective as wind power, based on high growth rates and solid innovation cycles. This might be the case for solar energy. Or they must have other attributes such as storage quality, as for hydro and biomass, to become part of the booming market for renewable energies.

For electricity generation, solar is more expensive than wind power so far. This will gradually change over the next decade or so. It would be arrogant therefore to construct a “wind exclusive” model for future replacements of non-renewable power generation. Solar will play an important part, and more renewable technologies might complement the wind sector, with hydro and biomass playing an important role for power management.

Wind power growth prospects therefore are modeled within a so-called *wind-solar sector*. There-in wind power will play the more important role over the next decade or so, but gradually can and will be substituted, accompanied or exceeded by solar, depending on cost reductions and availability of feed-in tariffs for photovoltaic and solar thermal power generation.

Relative growth of solar in recent years exceeded that of wind power. Future growth is difficult to estimate, however, because solar electricity is not (yet) competitive under legal current energy market conditions, except for off-grid applications. Demand for solar panels for some time and to a significant extent is dependent on, and limited by, local policy support. Someone other than the producer has to pay a part of the generation costs. Such an environment is not considered as a framework which would allow extrapolation of growth rates over the long-term. This may change of course as soon as grid parity for solar becomes reality which is possible for some markets very soon.

While the graphs speak of a wind-solar, they do not specify the solar share. Overall growth rates for this sector are solely derived from data for wind power over the last ten years, and the sector as such could also be perceived as a pure wind scenario (which, in our view, is less probable than a mix of wind and solar). We will not specify the solar share within this sector because there is too much uncertainty about the speed and extent of solar cost reductions.

Continuous growth of the wind sector projected

We describe in this chapter what will happen if wind power continues a steady expansion over the next decades. Wind power is considered to be self-reliant. Self-reliance means that no public financial support is needed that would exceed the extent of support that non-renewables such as oil or gas, so-called "clean coal" or nuclear receive**.** Ditliv Engel, CEO of Vestas, the world's biggest wind power manufacturer described it this way:

"*Wind power will be able to make a key contribution to the global rise in energy supply because wind power is competitive with conventional power plants in terms of costs; because the price of wind is known for all eternity; because wind is a local source of power that reduces dependency on imported energy; because wind power can be installed quickly and, finally, because wind power is good for the environment, which is not harmed by any hazardous emissions and CO2.*"[1]

Oil, gas, coal or nuclear all receive massive gifts from governments or the military sector: tax credits or subsidies for exploration, pipelines, research, military protection and colonial theft, state financed radioactive waste disposal and liability exemptions. Despite this long-standing support, they are losing competitiveness in terms of cost, cost stability, availability and in environmental terms.

During the past ten years, wind power showed that it is able to grow fast within an environment that was anything than benign. Therefore and due to the enormous and cost-free renewable resource of wind, it seems basically reasonable to extrapolate tentatively former growth rates of this new technology over the next decades.

Model assumptions

Model assumptions: four scenarios

Four scenarios A-D for power consumption and for the wind sector are outlined. They turn around two parameters: world electricity demand growth and world wind sector growth (accompanied by solar) . Non-renewable power generation is treated as a residual; the "other renewables sector" (mainly hydro and some biomass/geothermal) is assumed to grow at an independent rate derived from empirical data.

There are two models for power consumption and wind expansion (accompanied by solar) each:

High growth means	**mean annual growth observed from 1998-2007 will continue**
Moderate growth means	**only half of mean annual growth rates 1998-2007 will happen after 2008**

Growth rates for electricity consumption are derived from the widely used annual BP Statistical Review of World Energy[2]. The growth rate for the wind sector (comprising also some solar) is derived from data for wind power only. In doing that, the spectacular growth of the solar power sector over the past couple of years is excluded from exponential

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[1] Vestas Interim financial report, second quarter 2007, p.5

[2] BP Statistical Review of World Energy 2008, **http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622**

extrapolation. This is done in recognition of a) the small scale of solar MW-contributions in the early years and b) the still prevailing dependence of political support such as feed-in tariffs or tax credits.

The extrapolation of wind power is based on the mean annual growth rates over the 1998-2007 period as described in the statistical data base of Windpower Monthly Magazine[1] which is a reputed source in its field. The two parameters describe growth assumptions as follows:

Scenario	Power consumption growth	Wind-sector growth
A	High	High
B	High	Moderate
C	Moderate	High
D	Moderate	Moderate

Scenario	Power consumption growth	Wind sector growth
A	3.6%	30.4%
B	3.6%	15.2%
C	1.8%	30.4%
D	1.8%	15.2%

Figure 42 the scenario A-D Parameters

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[1] Windpower Monthly Magazine, 1990-2007, **http://www.windpower-monthly.com/WPM:WINDICATOR:621760127** ; older numbers (before 1997) are from Earth Policy Institute, cited in: Worldwatch Institute, Vital Signs 2001 (New York: W.W. Norton & Co.), 2001, pp. 44-45

World electricity generation and consumption

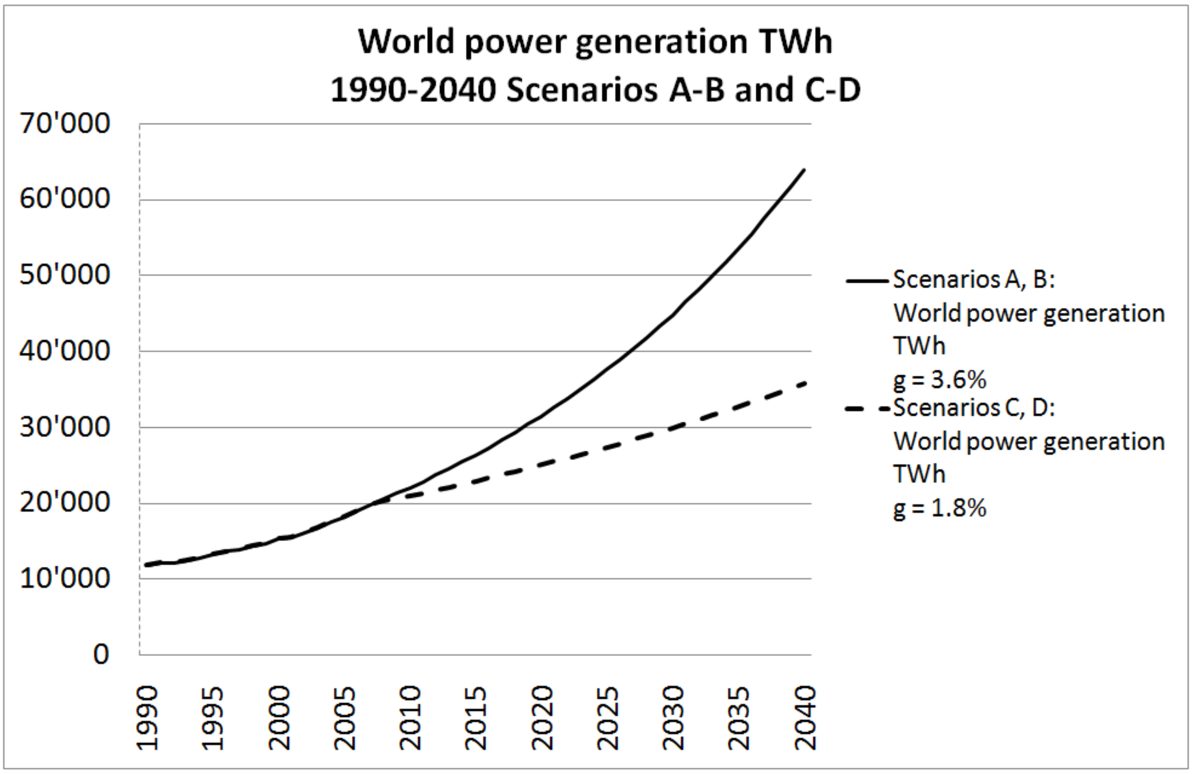

Figure 43 World electricity generation/consumption

World electricity generation grew at an average rate of 3.6 percent over the ten-year period 1998-2007.

We suppose in Scenarios A and B that growth will continue at this rate annually. Starting at 11,855 TWh in 1990, passing at 19,895 TWh in 2007 it will reach 63,927 TWh in 2040, a threefold increase compared to 2007. The extrapolation of this high growth level in the A,B scenarios can be interpreted as a demand shift from higher priced fossil fuels to electricity and a substitution of gasoline and diesel in the traffic sector where electricity and battery-driven plug-in-hybrid-vehicles PHEV would dominate. Another driver of growth is demand by newly industrialized nations in the world's South.

Growth rates for electricity consumption in scenarios C,D are supposed to be only half of the A,B cases: 1.8 percent per year. This brings power consumption to 35,847 TWh in 2040 which is 80 percent more than in 2007 but only about half the 2040-consumption of the A,B scenarios. The demand reduction in the C,D cases can be understood as a reaction to generally rising energy and raw material prices, a gradual saturation of demand and a result of efficiency policies to mitigate climate change.

No indication is given here which one of these demand projections is more probable or less. The scenarios just show a bandwidth of possibilities, and some readers might combine these scenarios by switching from one to another over time.

The "effective power capacity" Concept

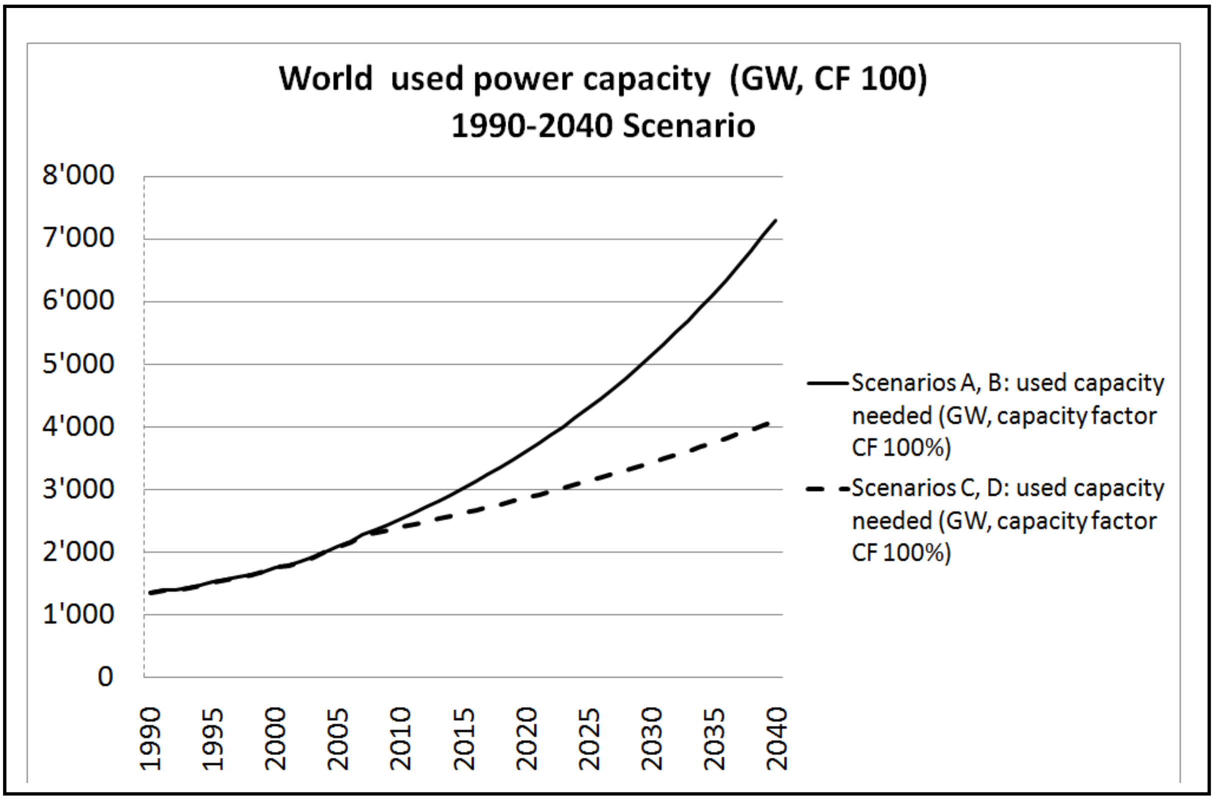

Figure 44 The "effective power capacity" concept

To produce the described amounts of electricity, a certain power capacity in terms of running plants is needed. We introduce the "effective capacity concept" which translates the annual power consumption into "effective capacity at a 100% capacity factor" (CF-100).

"Effective capacity" measures a *fictitious necessary capacity* that exactly is needed to produce the indicated amount of electricity during a year's full time, 365 days, 24 hours. It is pure *running capacity* and it by definition ignores the demand for power reserves, for peak power or idle capacity for maintenance. Effective capacity as such is a purely calculative tool.

Through the division of power generation (a certain amount of TWh, shown in the former graph) by the 8760 hours of a year we arrive at a effective capacity of 1353 GW in 1990, 2271 GW in 2007 and, for 2040, at 7298 GW (scenarios A, B) or 4092 GW (scenarios C, D) respectively.

If we wanted to cover effective capacity of 2007 purely by wind power at a mean capacity factor of 25 percent, we would have needed 9084 (2272/0.25) GW nameplate capacity, which would translate into some 3 million turbines at 3 MW onshore or into some 1 million turbines of 5 MW capacity offshore at a capacity factor of 45%. The *effective capacity concept* allows us to translate *running capacity* into *real* capacity of various technologies at different locations.

In reality however, no power station is running at 100 percent nameplate capacity all the time; all power stations lie idle or have to work on partial load for some time of a day or year for various reasons, including maintenance, low-wind-speed (for wind), low rainfall periods (for hydro), at night (for solar) or due to interruption or decline of gas, coal or nuclear fuel deliveries.

On the consumption side, every unit of electrical power has to be produced and delivered just in time. It means that reserve capacity has to be in place, following the load curve, and necessary interconnection between power generation and consumption is needed too.

Three types of supply are to be distinguished:

(1) **Base load power** with few variations over 24-hours, such as coal, nuclear, running hydro or geothermal power, with additional complementary capacities necessary to follow the load curve. Contrary to common knowledge, we consider a big share of wind power from interconnected farms "as reliable, base load electric power", in the words of wind researchers Archer and Jacobson.[1]

(2) **Fluctuating power**, following natural variations by day, by season or by weather, such as solar power, wind power from non-interconnected, single wind farms or running hydro in areas of highly irregular rain falls.

(3) **Dispatchable power** which is running precisely to fill the gaps when the sum of all fluctuating or base load capacities are not sufficient to satisfy load requirements. Dispatchable power is derived from stored or pumped hydro, biomass, natural gas or other fossil fuels.

Managing power reserves and interconnection

The significance of the "effective capacity concept" is derived from the idea that an open, interconnected market balance of effective and uneffective capacity is managed on its own terms – by markets or by system operator's assignments.

Individual power plants in an open market are managed along the so called merit order: plants with low variable costs run first; more expensive units are added when additional load is asking for more power.

In traditional monopolistic systems, hydro, coal and nuclear, in general, run for base load. Their vertically integrated owners did largely ignore power deliveries from independent sources, often putting hurdles to independent power deliveries. Not so in an open power market.

With various new power supplies such as wind and solar emerging, traditional power suppliers have to scale down their base-load units in situations of excessive supply. This has implications for traditional base-load units: Lower capacity factors and financial burdens for owners of coal and natural gas plants for example. In many markets, wind power significantly reduces the demand for natural gas and – at today's natural gas prices – this is welcomed by consumers and power producers because it brings price reductions and a competitive advantage on wholesale electricity markets as has been shown in the US[2], in Germany and elsewhere.

Lower capacity factors – higher capital costs – lower fuel costs

A de-centralized system with a high penetration of wind, solar, hydro and biomass will show lower capacity factors than a system dominated by non-renewables. This translates into higher overall nameplate capacities and a higher level of interconnection needed. Such a system might bear higher capital costs, but it will stay untouched by rising fuel costs and will be rather immune toward accidents or fuel delivery interruptions.

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[1] CRISTINA L. ARCHER AND MARK Z. JACOBSON: Supplying Baseload Power and Reducing Transmission Requirements by Interconnecting Wind Farms, JOURNAL OF APPLIED METEOROLOGY AND CLIMATOLOGY NOVEMBER 2007, **http://www.stanford.edu/group/efmh/winds/aj07_jamc.pdf**

[2] See Wiser & Bolinger 2008 p. 17

A more centralized system with mainly fossil or nuclear fuels will show lower overall nameplate capacities, but it is exposed to price risks of fuels, to accidents which can disturb the centrally dispatched supply-demand balance and to political interruptions of fuel supply.

Both systems – the wind/hydro/solar/biomass prone or the fossil/nuclear – will need *the same* amount of *effective capacity.* And the cost of each system has to be measured in the final price for consumers. It is not a single element such as interconnection, nameplate or reserve capacity, or fuel costs that decides on the overall cost, but the sum of it all.

Gas and nuclear might need less interconnection than wind, but the high capital costs for pipelines, exploration and the risky character of both fuels and emissions or waste bear costs on its own. Therefore the renewable system with reserve capacities and interconnection might not be as expensive as some people would like us to believe.

The costs of interregional connection of wind power amounts to some 10 percent of overall generation costs.[1] Therefore interconnection and power management are definitely not decisive obstacles for the expansion of wind power. Resistance against interconnection lines may be overcome with new technical solutions, including high voltage direct current (HVDC) lines and a change toward earth cables in sensitive areas. More flexibility from grid companies has to be asked for in this respect.

As a general trend with fuel costs on the rise, any renewable system with no fuel costs becomes economically more attractive. *The trend predicted here is that reserve capacity and interconnection costs within a diversified renewable power sector will play a minor role in an environment of increasing fuel and emission costs facing conventional power plants.* These issues are further discussed in depth in chapter 8 and 9.

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[1] "[Connection] is comparatively inexpensive: 30,000 km of new line will cost roughly $60 billion, says Brian Parsons, compared to between $450 billion and $600 billion for the 300 GW of new wind generating capacity needed under the [US] 20 per cent [wind]plan." Vestas Win[d] No.13, Year 05, 15 August 2008, p. 9

The "other renewables" sector

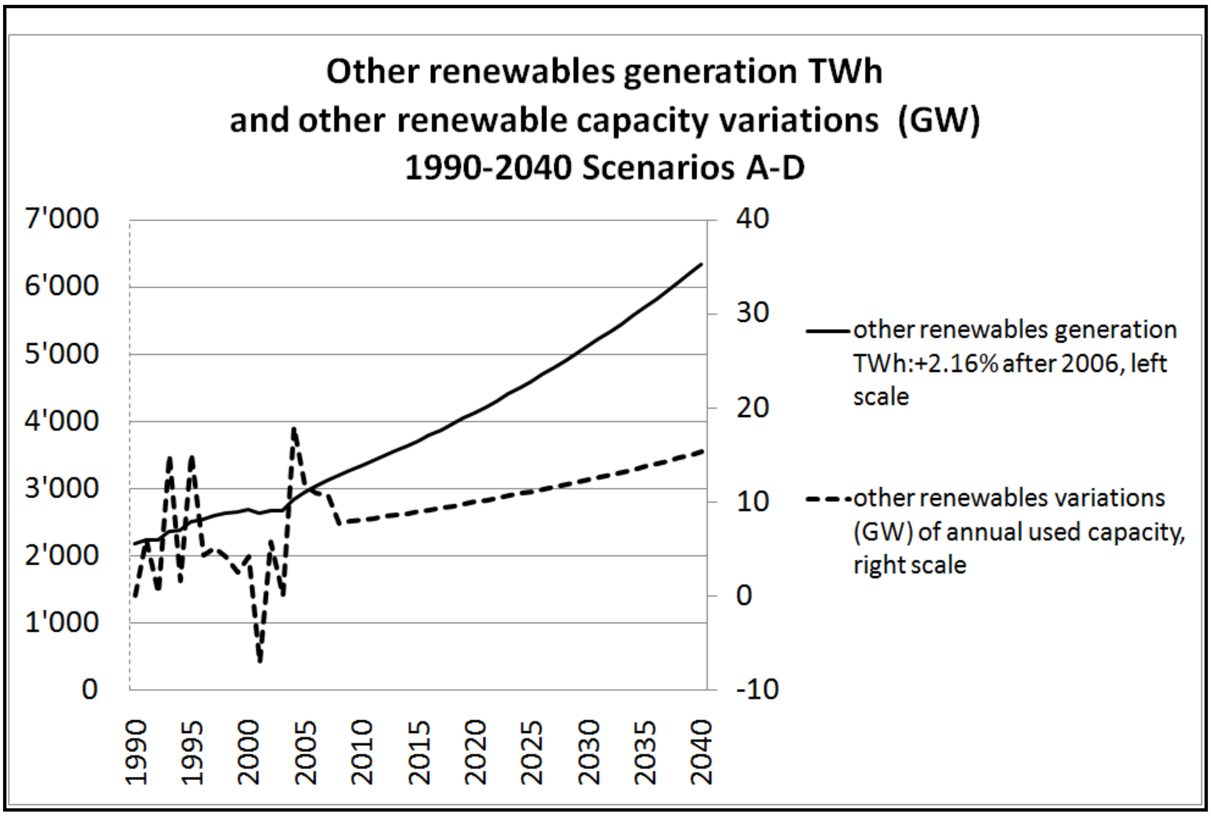

Figure 45 Other renewables power generation and capacities 1990-2040 (data 1990-2007 for hydro, source BP world energy statistics

The "other renewable sector" includes hydro, geothermal and biomass. Hydro is a fairly mature technology however and we suppose that geothermal and biomass power generation will show a higher growth than hydro.

Hydro power so far is the only renewable energy source statistically described in the BP World Energy Statistics. With 3134 TWh, it delivered 15.8 percent of world power consumption and the lion's share of renewable electricity in 2007.

We assume here that mean annual production growth of 2.16 percent over the 1991-2007 period will continue from 2008 to 2040. Derived from the effective capacity concept, this translates into a supposed annual capacity addition of 7.7 GW (CF-100) in 2008, growing to an annual addition of 15.3 GW (CF-100) in 2040. Power production of this sector is supposed to grow from 3134 TWh in 2007 to 6344 TWh by 2040. These numbers are assumed to be identical for all scenarios A-D.

Compared to the additions of wind (and solar), the other renewables sector will play a minor role in scenarios A and B with a market share of 9.9 percent in 2040 and a stable role in scenarios C and D with a 17.7 percent market share in 2040. For grid management and reserve capacity reasons the "other renewable sector" and its storage options for power reserve play an essential part for the wind expansion (accompanied by solar).

Development of the wind sector and market shares (accompanied by solar)

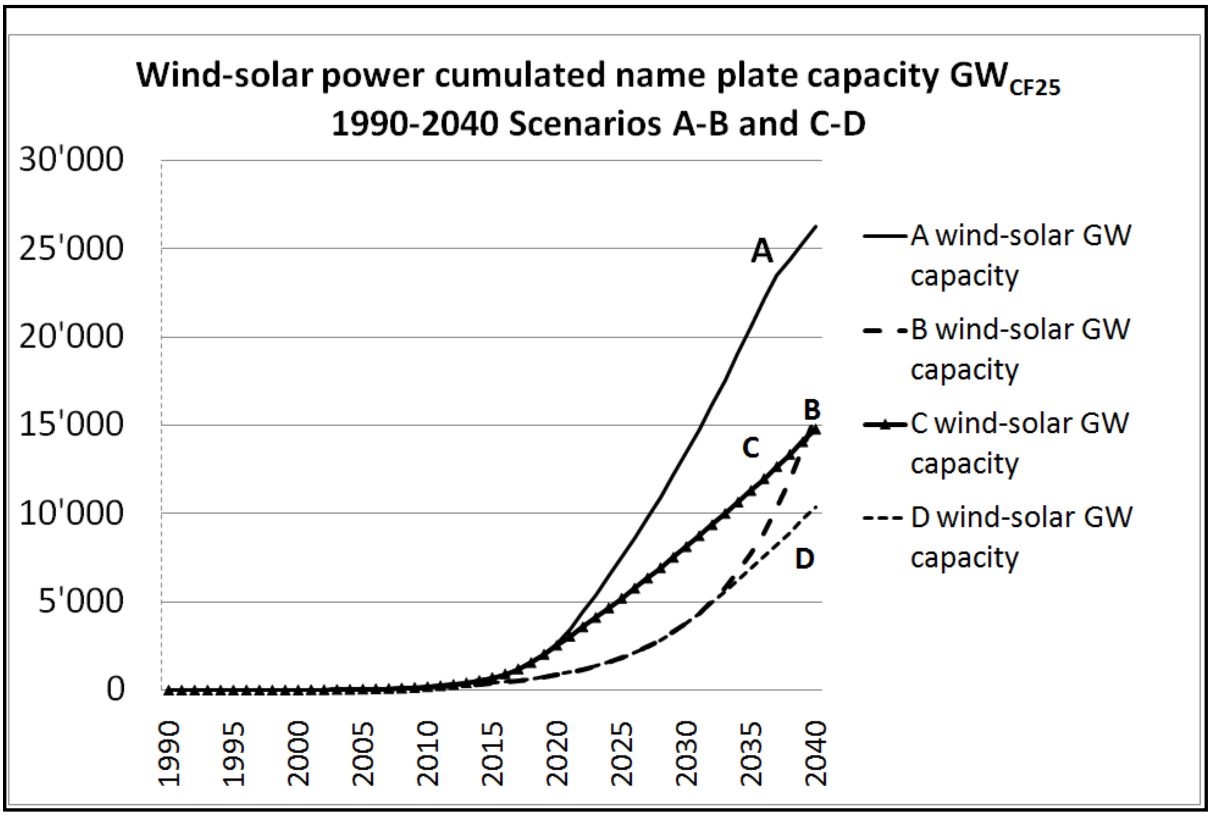

Figure 46 cumulative wind power capacity (accompanied by solar)

The wind sector's net additions are assumed to increase by 30.4 percent annually in scenarios A and C, and by 15.2 percent annually in scenarios B and D.

The High-high Scenario A ends at 26,256 GW cumulated nameplate capacity (CF-25); moderate-moderate scenario D will achieve 10,406 GW cumulated nameplate capacity (CF-25) of the wind power sector in 2040. In both cases, a market conquest of renewables in terms of *new installations* can be observed – meaning that all new installations of power plants come from the wind (and solar) or the "other renewables" sector.

Due to the massive amount of old power plants, a full substitution of the conventional power generation can only be observed in the A and C scenarios with a fast wind penetration (accompanied by solar), while in the other cases a fossil fuel power industry will persist at various degrees.

2025	Wind (and some solar)	other renewables	conventional (fossil/nuclear)
scenario A	44%	12.2%	44%
scenario B	11%	12.2%	77%
scenario C	42%	16.8%	42%
scenario D	15%	16.8%	69%

2040	wind (and some solar)	other renewables	conventional (fossil/nuclear)
scenario A	90%	9.9%	0%
scenario B	53%	9.9%	37%
scenario C	82%	17.7%	0%
scenario D	64%	17.7%	19%

Figure 47 power generation – market shares in 2025 and 2040 scenarios A-D

Interestingly wind generated electricity ((accompanied by solar) will have the same volume as fossil generation as soon as 2025 if historical 30.4 percent growth can continue. High growth rates for wind (and solar) will therefore completely change the power generation industry in the next 15 years alone! The situation is less significant in the B, D scenarios with a slow-down of renewables installations: only by 2030/2040 will renewables gain the same size or more than non-renewables!

Wind annual capacity additions

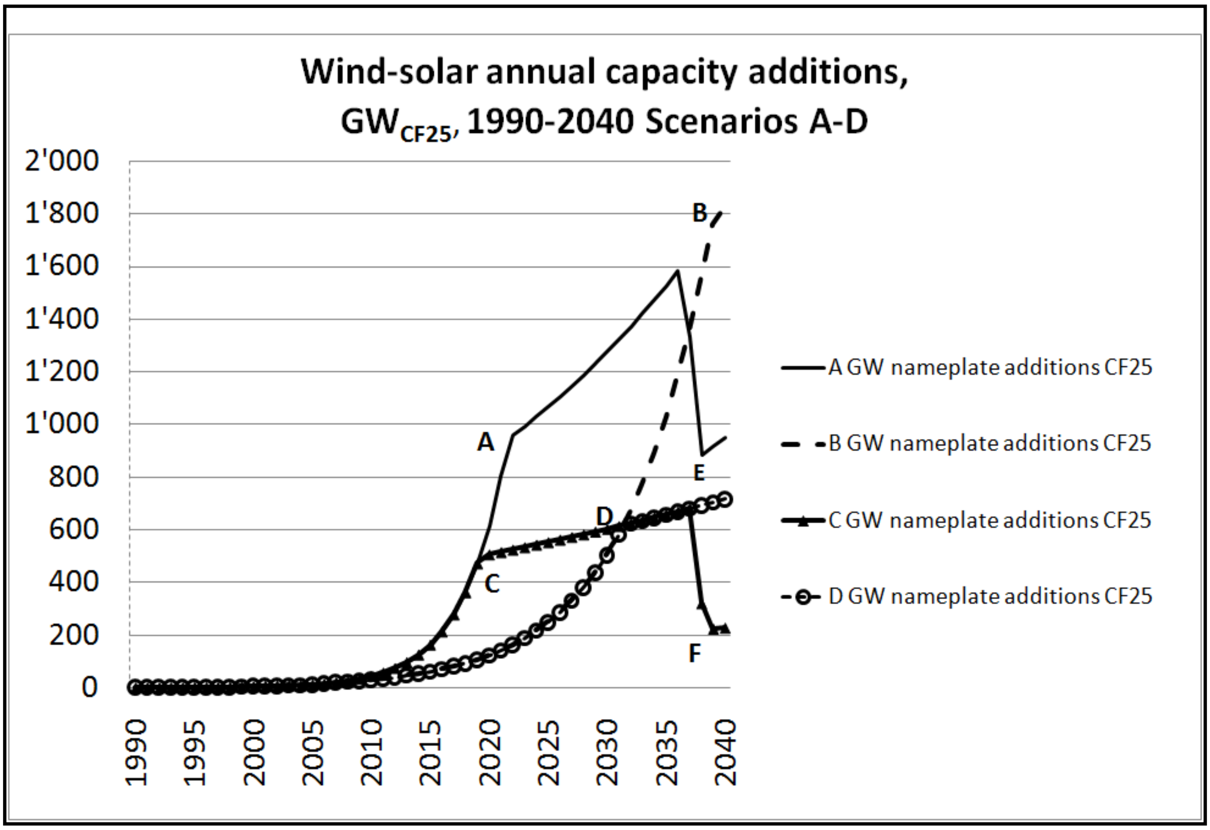

Figure 48 wind capacity additions (excluding replacements) and market saturation

What we see next is of some interest for analysts of power markets. By definition, we extrapolated the wind sector along the growth observed for wind power for the last ten years (A, C scenarios), or half of it (B, D scenarios) respectively.

With such a continuing growth over the next dozen years or so, world total power plant **net additions** would be 100 percent covered by renewables in a **2019-2023 time frame in the scenarios A, C and D**. Only in the low-growth B-case it would take until **2033** to cover the power **additions** market.

Once the power additions market is covered, the wind sector (accompanied by solar) will bite into the **replacement-market** of non-renewables.

Once the replacements market is also conquered, the wind additions will shrink toward a steady-state level. This is shown by the points E and F in the chart above, while in the B and D scenarios the low-growth of the wind-solar sector will be absorbed to deliver power additions and conventional power replacements up to 2040.

We assumed a replacement rate of 3 percent for existing capacities, meaning that every 33 years (average), a power plant will be disposed or mothballed for power reserve, adding to the non-running capacity. No proper statistical data of replacements is available on a global scale.

An early retirement of non-renewable capacities could include power stations which would be transferred from running capacity into reserve capacity (natural gas plants).[1]

Overall market conquest by renewables

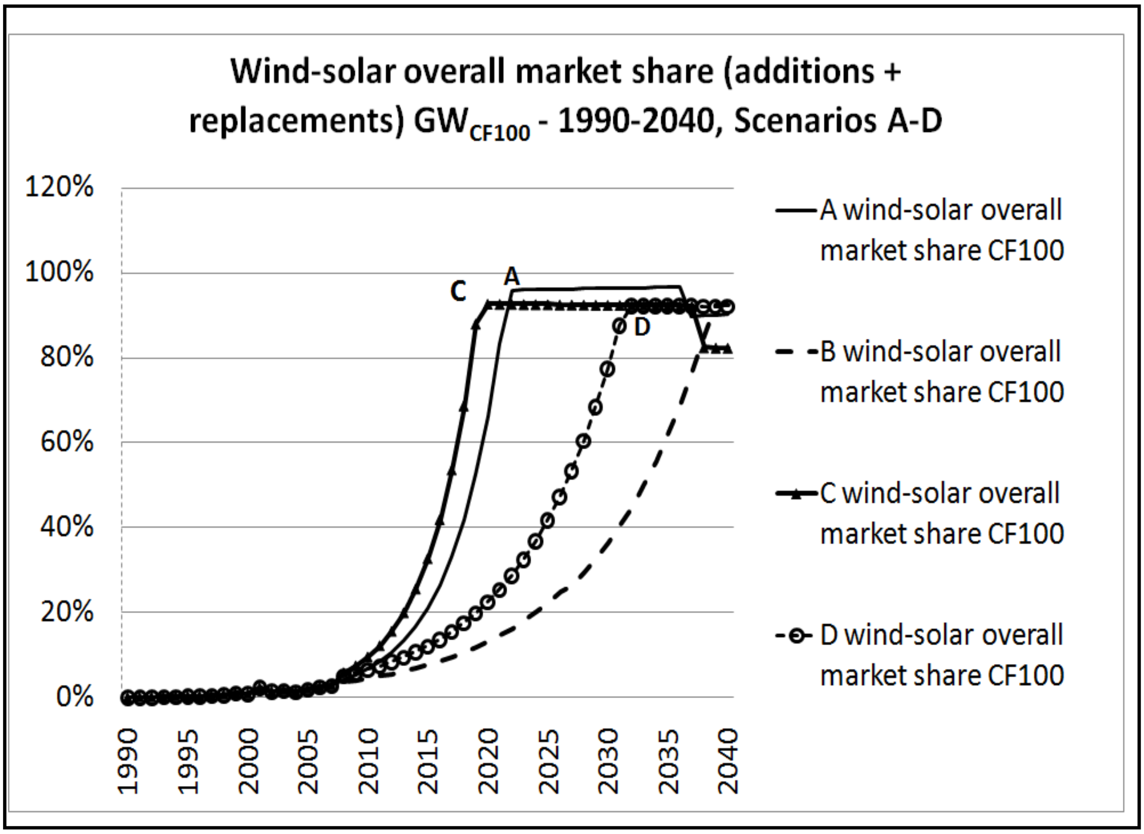

Figure 49 overall market share of the wind sector (accompanied by solar)

Market saturation by the wind-solar sector is achieved

- when all *additional demand* is satisfied by wind and solar (accompanied by "other renewables")
- when all *replacements* of coal, gas and nuclear plants are achieved by the wind sector (accompanied by solar).

The earliest point in time for market saturation to be achieved is 2020 in the **moderate-high-scenario C** (steady 1.8 percent annual power consumption growth and a steady 30.4 percent wind growth). After this point, non-renewable installations would be zero – no more new coal, gas, nuclear or fuel oil plants worldwide! To achieve this stage of market penetration the wind sector (accompanied by solar) would have to get some 506 GW (CF-25) new nameplate-capacity added in the year 2020 (**Point C**), a 20-fold increase compared to the some 24 GW installations expected in 2007 (19.5 GW wind and 4.5 GW solar).

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[1] For wind power 33 years might be too high in some cases, for hydro or coal it seems rather low. The 33 years are understood as an average of the overall power plant mix.

Power plant installations wind	Scenario A	Scenario B	Scenario C	Scenario D
Year of market conquest	2022	2039	2020	2032
Wind additions in that year (CF-25) (including some solar)	958 GW	1765 GW	506 GW	625GW
Repowering market in that year (CF-25)	510 GW	930 GW	378 GW	468 GW
total market volume	1468 GW	2695 GW	884 GW	1093 GW
cost per GW (billion Euros)*	1.3	1.3	1.3	1.3
Expected annual investment expenditure (billion Euros)	1908	3503	1149	1421

*2007 price level for installed capacity

Figure 50 overall market conquest by the wind sector (including solar)

In the high-high scenario A, overall market saturation by the wind complex would be achieved only two years later in **2022**, at 958 GW (**Point A**) of newly added wind capacities (CF-25).

The two scenarios, with a more moderate growth of the wind sector, will lead to overall market conquest by renewables as well, but at a slower pace and, therefore, at a higher consumption level. Market saturation in the moderate-moderate scenario D will be achieved by **2032** when annual additions of wind would achieve 625 GW (**Point D**) and at 930 GW in 2039 in the slow growth scenario B with high consumption growth.

The absolute level of new installations is much higher in scenario A than in the scenario C because by definition power consumption grows by a staggering 3.6 percent annually, and annual wind GW-additions would have to rise up to 1585 GW in 2040 – a speculatively high number. However, any power generation technology claiming saturation of such an exponentially growing, voracious demand would be challenged, and one could argue that wind and solar technologies are quickly installed, have few resource constraints on physical grounds and would come at a much cheaper price than oil.

If we compare the expected annual investment expenditures for wind power in the market conquest year for the A, C, D scenarios, the investment expenditure for 884-1468 GW would be in the range of 1.1 to 1.9 trillion Euros, covering the main costs of the whole electricity sector. This power bill for wind would come in much cheaper than oil because oil today – at a price of $120 per barrel – comes at an annual cost of some 3.7 trillion US-Dollars and later on can’t come in but more expensive due to resource exhaustion.

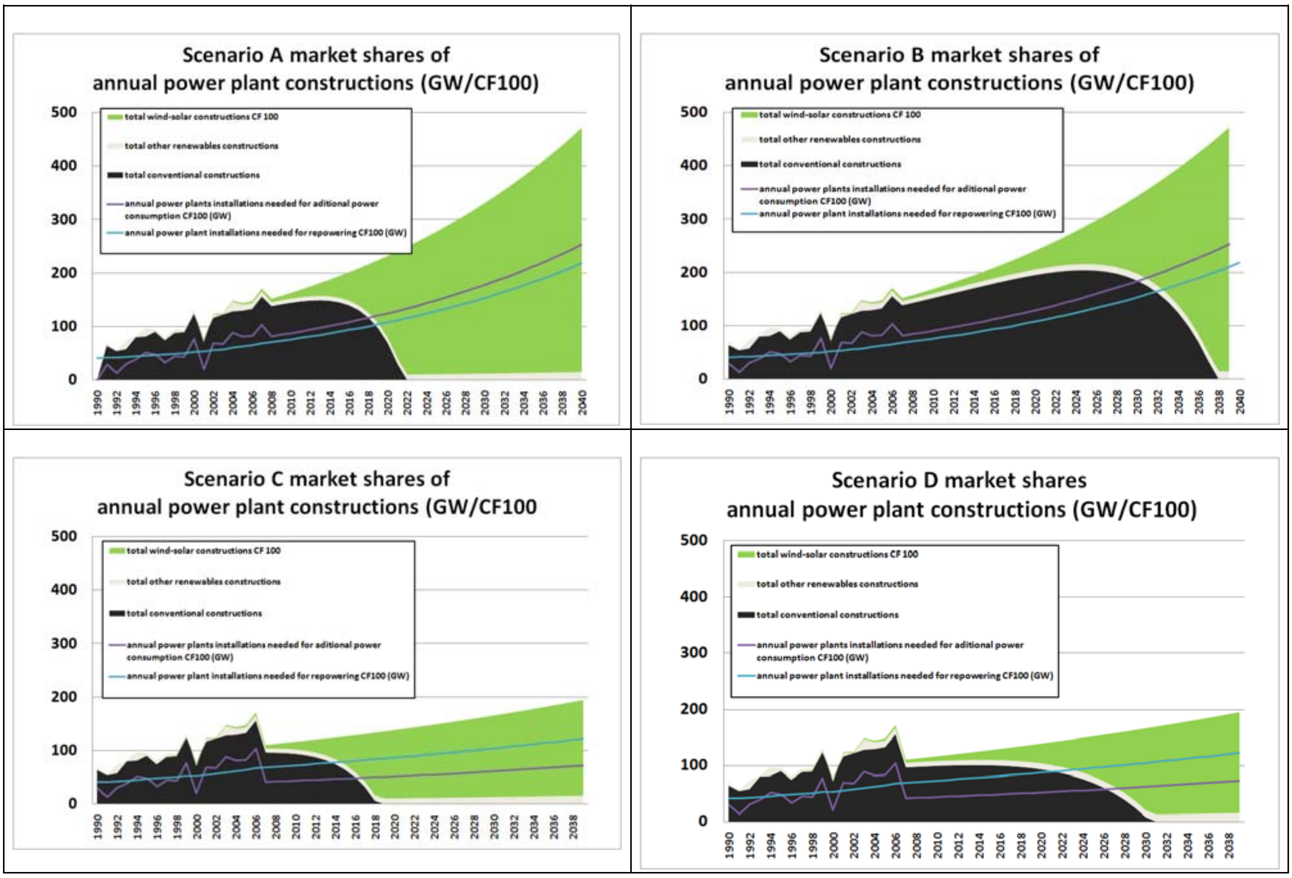

Figure 51 the market for new power plants: market volumes and market shares of conventional (black) wind (green) and other renewables (white). Scenarios A-D (GW CF100): blue line: power plant replacements; grey line: power plant additions per year

The development of market shares in the power plant business can be seen in the next chart. It is important to remember that the A scenario extrapolates existing trends in power consumption and wind sector expansion, it therefore is next to “business as usual”. The A scenario is the most probable one in the short-term if we assume that no structural change happens in demand or supply trends.

The B scenario shows a sudden decline of wind growth while demand would continue at a fast growth level, and therefore has the worst environmental record. The C scenario shows a demand reduction while wind sector growth is continuing at its high growth level. This scenario is the best in environmental terms and would be a probable case if policy would be successful in mitigation of climate change.

The D scenario shows a structural change of both – demand and wind sector growth. This could become a reality in case of a macro-economic slow-down persisting for decades, a rather improbable phenomenon.

Market development of non-renewables and CO_2-emissions

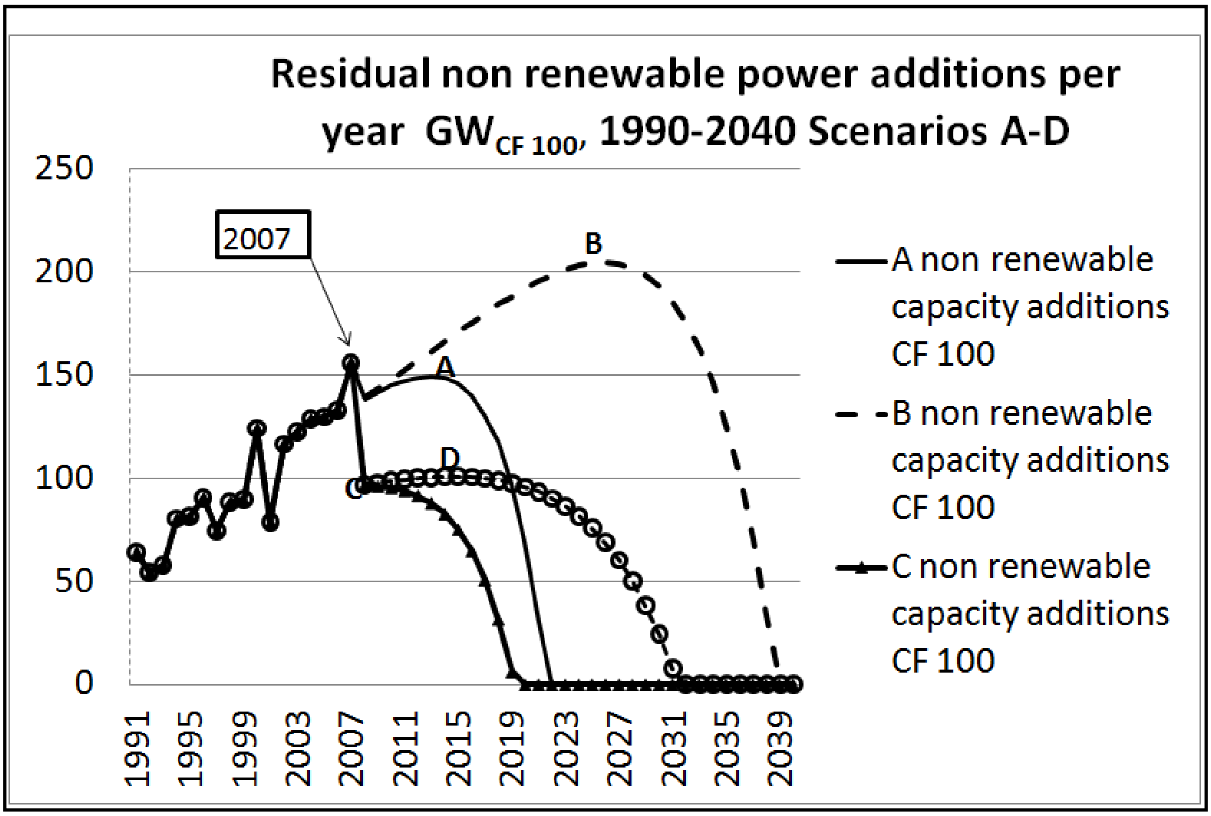

Figure 52 annual non-renewable capacity additions (CF100)

A fast deployment of wind power has its negative side for the non-renewable sector. Depending on speed of transformation, the fossil and nuclear expansion would come to an end.

As has been shown, it is not so much overall consumption growth of electricity which decides on the speed of fossil and nuclear market reductions, rather it is the speed of expansion of the wind sector. Remember that by definition we treat non-renewables as a residual of the expanding renewable sector. This is logical from an economic point of view in open markets because power generation from hydro, wind, solar and geothermal has lower variable costs than gas, coal or nuclear and will feed power to the grid while all other sources are turned off for their higher variable costs.

It is interesting to observe a rather steep decline of installations of fossil and nuclear capacities in *all* models, once wind and solar power have achieved market domination! In real terms this might not come so unexpected, because wind and solar technologies will be ultimately ever cheaper while fossil fuel prices and uranium costs are showing escalations.

In 2007, the non-renewable power sector registered an estimated record addition of 156 GW_{CF-100} effective capacity. But “peak coal” could come in sight over the discussed period, not only due to wind power, but also due to resource erosion within the coal sector itself, while “peak nuclear additions” have been registered more than 20 years ago in 1985.

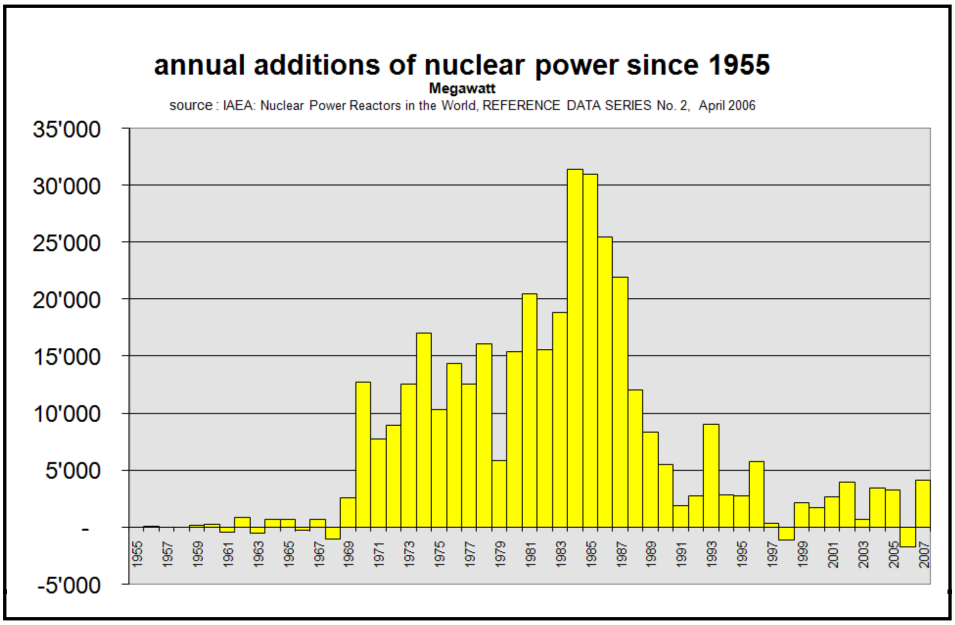

Figure 53 net additions of nuclear power installations 1955-2007

Non-renewable power generation and CO_2-emissions

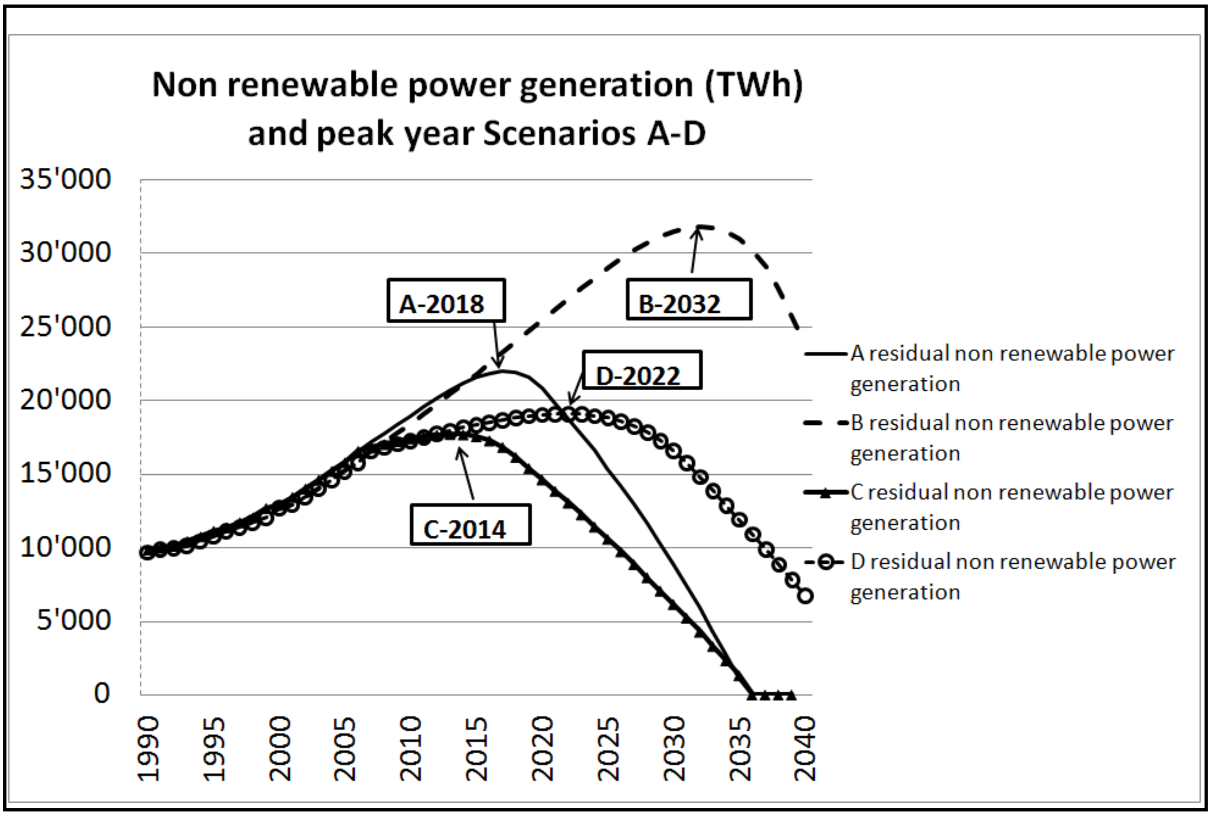

Figure 54 non-renewable power generation 1990-2040

A *capacity additions peak* does not mean that overall conventional power generation will disappear overnight. Lots of new coal power installations have been built recently and there might be some resistance toward closing them.

Not surprisingly, the best scenario in terms of CO_2-reductions is scenario C with high wind growth and moderate power demand expansion. Non-renewable power generation comes in at 576,000 TWh over the 1990-2040 period.

Interestingly, the second best solution turns out to be the high-high scenario A with high wind and high consumption growth. It shows a 672,000 TWh power generation from non-renewables. This scenario might be all the more true in case of electricity substituting fossil fuels in the traffic sector by battery-driven cars (PHEV). By no means should the electricity sector be analyzed on its own.

In third place in terms of CO_2-reductions is the moderate-moderate expansion path (scenario D) at 754,000 TWh from non-renewables until 2040.

The worst scenario in terms of CO_2 (and radioactive risks) is scenario B, with moderate renewables expansion and high consumption growth. In this scenario, CO_2-emissions from power generation will stay much higher than in the 1990 Kyoto reference year until 2040 and beyond.

	Scenario A	**Scenario B**	**Scenario C**	**Scenario D**
World electricity generation growth rate 2007-2040	3.60%	3.60%	1.8%	1.8%
Growth of annual additions of wind power	30.4%	15.2%	30.4%	15.2%
Moment of renewable generation surpassing annual consumption growth (TWh)	2019	2034	2015	2023
When will wind power cross a 50% market share of all new installed power plants (CF100-equivalents) [new installed = additions + replacements]	2019	2033	2017	2026
Market conquest: All power plant additions and replacements covered by wind (accompanied by solar)	2022	2038	2019	2031
How much GW wind power capacity would there be in 2030? (CF25)	13457	3782	8126	3782
How much wind power would be produced in 2030 (TWh)?	29471	8283	17796	8283
How much other renewable [hydro, biomass, geothermal] power would be produced in 2030 (TWh)?	5120	5120	5120	5120
How much non-renewable power would be produced in 2030 (TWh)?	10290	31475	7070	16583
How much non-renewable power would be produced in 2040 (TWh)?	0	23780	0	6714
Peak year of non-renewable power generation TWh (and CO2-peak)	2018	2032	2014	2022
Peak TWh of nonrenewable power generation	21969	31794	17703	19091
Total nonrenewable electricity generation 2008-2040 (TWh)	432,978	860,192	354,091	531,543
When will CO2-emissions for the first time be lowered compared to 1990 (Kyoto-benchmark)?	2031	after 2040	2028	2038

Figure 55 survey of findings

The model gives some insight into what could happen with continuing wind power growth, whereby wind power would be accompanied/substituted in parts by a non-specified volume of solar power deliveries.

The most decisive factor for climate and environment protection is a high growth rate for wind and solar and, most importantly, the short-term *development running up to 2020* when most investment decisions over *new* power plants will be taken. **After 2020,** the scenarios tend to converge, with increasing amounts of renewable energies, but the difference in CO_2 and other hazardous pollution in the various scenarios is huge.

As a rule of thumb, the annual combined net additions of wind and solar should grow by at least 20 percent to significantly change the power generation structure, independent of the extent of consumption growth. This high growth needs good incentives and some planning by states and nations regarding interconnection and reserve management.

The model’s meaning in real terms

For the real extent of wind name-plate capacities, the availability of geographical sites for turbines and solar farms will be decisive: offshore wind has a higher capacity factor than onshore; southern sites for solar farms have a higher yield than installations in the north.

Territories for wind power

In terms of wind power: between one and five million wind turbines in the 5-MW range will be needed to convert the electrical power system toward renewables, the exact number depending on location, capacity factors and overall consumption growth.

As a rule of thumb, up to two turbines (10 MW) can be allocated on one square kilometer. The delivery of this power by “wind onshore only” would cover an area of some one to three million square kilometers on land or sea, corresponding to an area of between double and five-fold territory of the size of Texas/USA (695,621 km^2) or once to twice the area of the Republic of Mongolia (1,564,116 km^2). (Two turbines might be a bit conservative. The distance between turbines should be 5 diameters, some wind farms have only three).

It is important to point out that these areas as such are not “occupied” by wind turbines but only a small fraction of them, for turbine foundations and roads, an estimated 1% of the area used in maximum. Landowners signing contracts for installations get income from wind turbines, without being forced to abandon agriculture or herd keeping.

With “wind offshore only” the demand would be in the range of 1-3 million wind turbines of 5 MW capacity covering 0.5-1.7 million square kilometers at sea which would, at its maximum, be less than one percent of the Pacific Ocean (1.8 Mio. km^2)

Roofs and territories for solar

As a rule of thumb, some 40-80 MW of photovoltaic cells can be allocated to one square kilometer, depending on specific cell efficiency.

The delivery of power “solar farms at Northern sites only” would translate into some 100,000-300,000 km^2 needed. Such installations in populated regions would cover roofs mainly, with some territory of free land of minor agricultural quality combined.

If located in the south, the area for the same production of solar power would be less than half of that: an area in the range of 50,000-150,000 km^2 would be needed, corresponding to less than one percent of the world’s deserts. For all scenarios, including the more moderate ones, the approximations are given in the next figure.

	number of 5-MW machines onshore (CF25)	number of 5-MW machines offshore (CF45)	siting North, solar areas km^2 insolation 1000 kWh/m^2/a)	siting South solar areas km^2 insolation 2000 kWh/m^2/a)
Scenario A	**5,270,706**	**3,247,350**	**320,026**	**160,013**
Scenario B	**3,086,967**	**1,714,982**	**169,011**	**84,506**
Scenario C	**2,668,693**	**1,642,375**	**161,856**	**80,928**
Scenario D	**2,081,167**	**1,156,204**	**113,944**	**56,972**

Figure 56: Wind and solar capacities in 2040 - four variations of possible power plant areas needed

Real market trends of wind power in 2007

In the real world, market shares of wind and solar power indeed developed in a very dynamic way over the last ten years. But overall the market share of wind power on a CF-100-base was still at a modest level in 2007, compared to all other power additions.

The 19.6 GW added in 2007 at CF-25 translate into 4.9 GW effective capacity (CF-100). This corresponds to 4.9 percent of all capacity additions (CF-100) in that year (additional capacity counted in terms of effective power). The solar contribution of 4.3 GW in 2007 at a 12 percent mean capacity factor (CF-12) translates into some 0.5 GW addition (CF-100) which is less than 0.5 percent of total running capacity added.

Together the two renewable segments, in 2007, delivered some 5.5 percent of new power plant additions (with power plant replacements neglected here).

A growth rate of 30.4 percent in new installations (scenarios A and C) means that nameplate additions of the wind sector (including solar) will double every 2½ years. Wind power and solar in these two scenarios would conquer 50 percent of all power additions by 2013 and 2017.

In the moderate wind growth scenarios B and D at 15.2 percent growth of capacity additions, wind power will double its contributions every 4½ years and market share of wind would grow beyond 50 percent of newly added capacity (CF 100) by 2019 (for D) and 2027 (for B) only.

	Scenarios A,C		Scenarios B,D	
Year	**Effective capacity GW (CF-100)**	**Nameplate capacity GW CF-25**	**GW (CF-100)**	**Nameplate GW (CF-25)**
2007	**5.5**	**22**	**5.5**	**22**
2008	**7.2**	**29**	**6.3**	**25**
2009	**9.4**	**37**	**7.3**	**29**
2010	**12.2**	**49**	**8.4**	**34**
2011	**15.9**	**64**	**9.7**	**39**
2012	**20.7**	**83**	**11.2**	**45**
2013	**27.0**	**108**	**12.9**	**51**
2014	**35.3**	**141**	**14.8**	**59**
2015	**46.0**	**184**	**17.1**	**68**
2016	**60.0**	**240**	**19.7**	**79**
2017	**78.2**	**313**	**22.6**	**91**
2018	**102.0**	**408**	**26.1**	**104**

Figure 57 annual effective capacity additions and annual nameplate capacity additions of the wind sector (Scenarios A,B,C,D), including solar

Remember that by assumption the other renewables sector – mainly hydro power with some geothermal and biomass – would grow by 2.16 percent annually. Therefore, wind and solar power never will conquer 100 percent of the market. These “other renewables” will continue to play an important role within power supply and for power management reasons, and more so in scenarios with modest consumption growth.

Comparisons with the real world

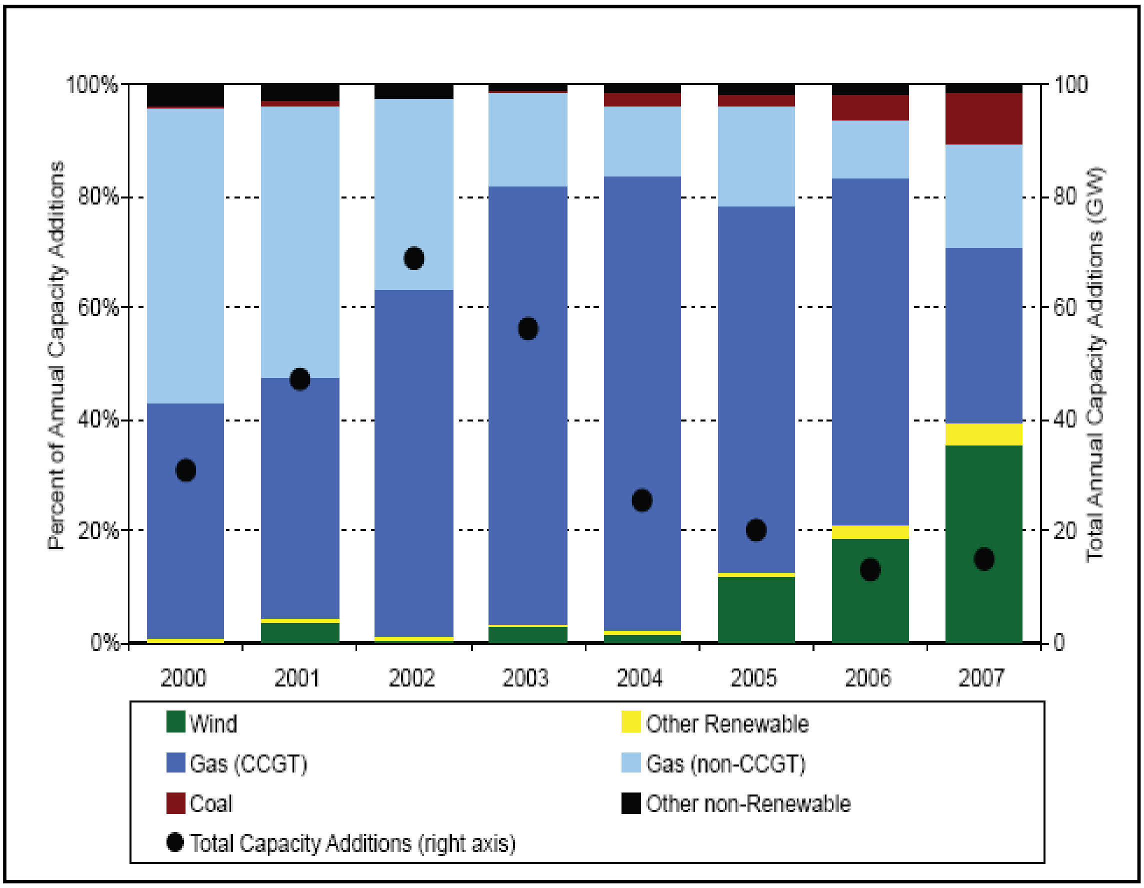

Figure 58 power mix of capacity additions in the US 2000-2007
source: US-DOE[1]

In the real world, a world growth rate of 30.4 percent such as in the A and C scenarios *is real*! In 2007, close to 40 percent of all additions to electric generating capacity additions in the US came from wind power, after ramping up fast from 2000-2006.

This trend is visible worldwide in the high number of new wind manufacturing facilities in construction all over the world. It seems that over the next five years no other power source will outdo wind power in terms of both capacity additions and market share growth.

From a technical perspective, the chance for fast wind (and solar) deployment are very good due to the short construction time of wind turbines and of solar cells and due to their high versatility. We can be confident that wind power (together with solar) will conquer at least a 50 percent market share in terms of new "effective capacity" (capacity factor CF-100) by 2025 at its latest. This indeed is a clean revolution of the power sector.

The fast market penetration will have a huge impact for power management, interconnection and reserve capacity needs, but the requirements are not impossible to fulfill.

These movements in market share can be seen already in the real world: in the US and in Europe wind energy is the most significant contributor of new power capacity and has outgrown coal and natural gas in terms of nameplate-capacity in Europe and will do so over the next few years in the US and, maybe, even in Asia.

One could think that nameplate market share of new wind capacity is much higher than its share in energy production. Not so, points out NRELs Ryan Wiser:

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[1] Ryan Wiser, Mark Bolinger: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, May 2008 ed. US Department of Energy, p. 5

“Given the relatively low capacity factor of wind, one might initially expect that wind’s percentage contribution on an energy basis would be lower than on a capacity basis. This is not necessarily the case, in part because even though combined-cycle gas plants can be operated as base load facilities with high capacity factors, those facilities are often run as intermediate plants with capacity factors that are not dissimilar from that of wind. Combustion turbine facilities run at even lower capacity factors.”[1]

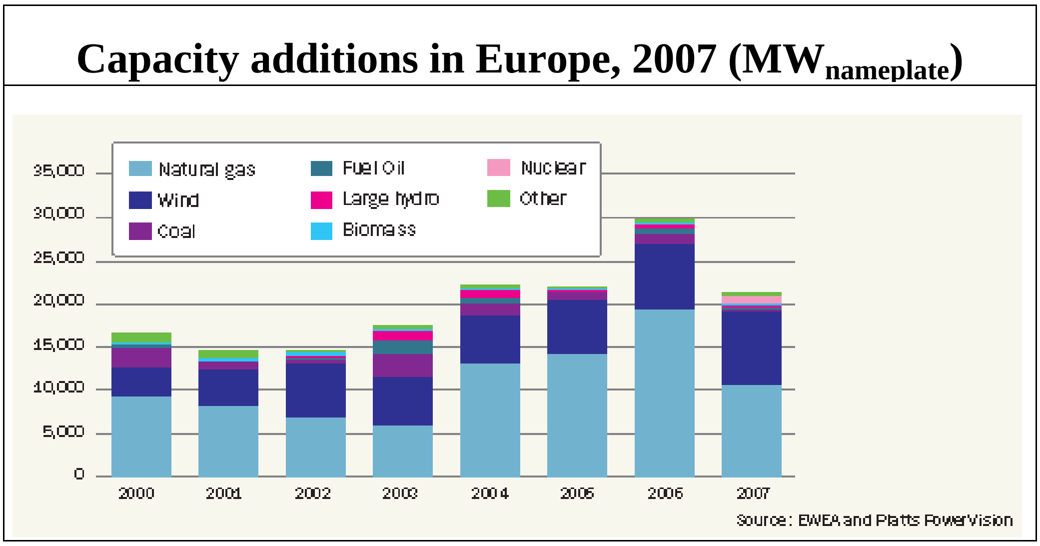

Figure 59 capacity additions in Europe (EU) 2000-2007 Source: EWEA purepower[2]

In Europe wind power’s nameplate capacity in 2007 for the first time exceeded those of all other power generation technologies. But overall growth of European additions stayed rather sluggish compared to the explosive growth in the US and China. One reason for this was the shortage in turbines and turbine components.

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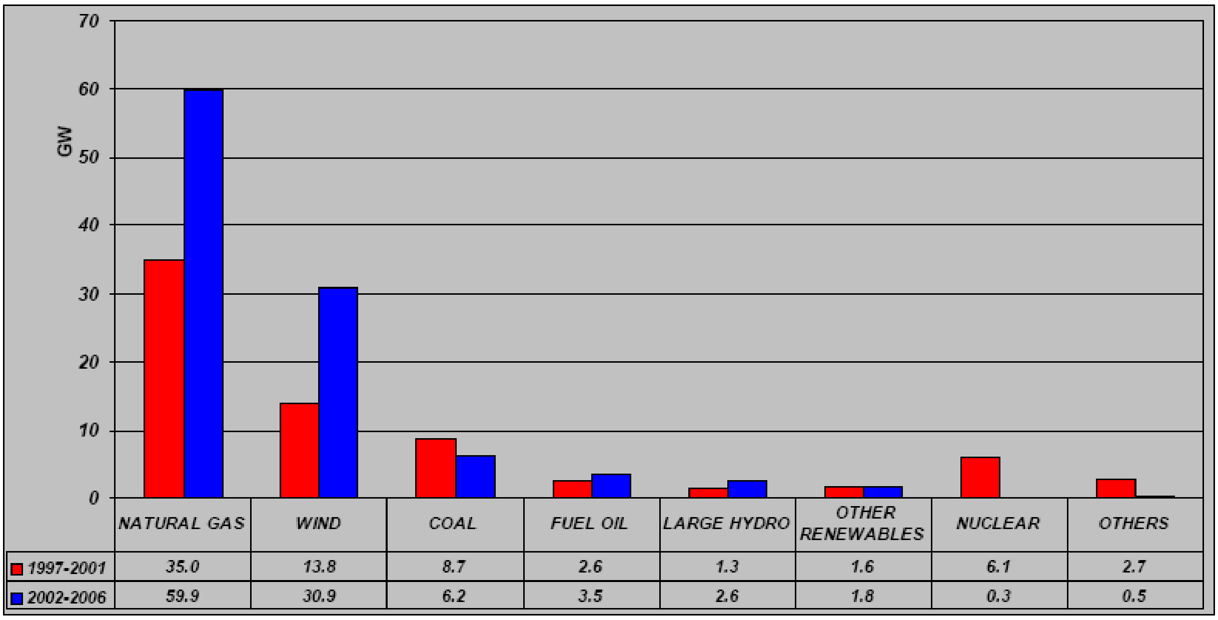
[1] Ryan Wiser, Mark Bolinger: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, May 2008 ed. US Department of Energy, p. 5

[2] EWEA: Pure Power, Wind Energy Scenarios up to 2030, March 2008 p. 14



	NATURAL GAS	WIND	COAL	FUEL OIL	LARGE HYDRO	OTHER RENEWABLES	NUCLEAR	OTHERS
🟥 1997-2001	35.0	13.8	8.7	2.6	1.3	1.6	6.1	2.7
🟦 2002-2006	59.9	30.9	6.2	3.5	2.6	1.8	0.3	0.5

Figure 60 new capacity installations in the European Union 1997-2006
source EWEA/Arturos Zervos

Political will is important too. Wind and solar power need grid access and permissions. Coal prices could recede if wind and solar power win huge market shares. Hence, a strong policy for CO_2-reductions will be needed despite strong wind-solar growth.

China

Excessive growth has been observed in China as well – with more than 100 percent annual additions growth in 2004/2005/2006/2007 each. Chinese National Development and Reform Commission (NDRC) has been discussing the possibility of raising the goal for accumulated wind energy in 2020 from 30 GW to 100 GW.[1] .[2] Instead of the previous (2004) target of 20 GW in 2020, China aims now at achieving 20 GW by 2010. In a report, the consulting company McKinsey has concluded that the Chinese industrial companies generally increase their productivity appreciably more quickly than their overseas counterparts, and that as early as 2005, the privately owned Chinese high-tech manufacturers were operating with productivity levels that were 35 per cent higher than those of their foreign competitors measured in produced value per year per person.[3]

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[1] Shanghai Daily newspaper, 28 April 2008, cited in Vestas Win[d] No. 13 p. 23 (August 2008)

[2] Shanghai Daily newspaper, 28 April 2008, cited in Vestas Win[d] No. 13 p. 23 (August 2008)

[3] Vestas Win[d] No. 13 p. 30 (August 2008)

5. On the accuracy of Wind Power Installation Forecasts

Methodological remark

Many energy think tanks and intergovernmental institutes publish energy industry forecasts. This chapter analyzes the accuracy of their work. We will analyze historic forecasts for wind power and compare them with real growth. This will be done – along the industry's development – each for the German, for the European and for the world market; we also give a survey of forecasts for the time ahead and an interpretation of why past forecasts were right or not.

In general, there are two factors which influence the market share of an energy source:

- The costs and availability of the source itself
- The costs and availability of competing energy sources.

The fact that wind has a price of zero is not yet widely recognized . But with fossil fuel prices on the rise, the costs of primary energy sources today are gaining greater attention. An analysis of wind power's future therefore should not only rely on industry facts (endogenous growth factors) but on overall costs of competing energies and regulative environments (exogenous factors) as well.

Most forecasts and scenarios for wind power give an estimate of a certain amount of cumulative capacity at a certain point in time (MW capacity in year x). To make such cumulative numbers comparable, they have to be translated into annual wind power additions. Where no specific numbers were given by the forecast's author, we suppose a fixed Compound Annual Growth Rate (CAGR) approaching the indicated additions in steady growing steps. In doing so, the original indicated cumulative capacities were respected.

What do past forecasts on Germany tell us?

Germany was the first big wind market to develop steadily on an industrial scale, together with Denmark. In the early 1990s, it was rather difficult to estimate correctly the growth of wind power additions because feed-in tariffs were a new instrument whose impact was as yet unknown.

Cumulative capacity forecasts and reality: Germany

In 1991, cumulative wind installations in Germany stood at 110 MW. By the end of 2007, they had grown by a factor of more than 200 to 22,247 MW.

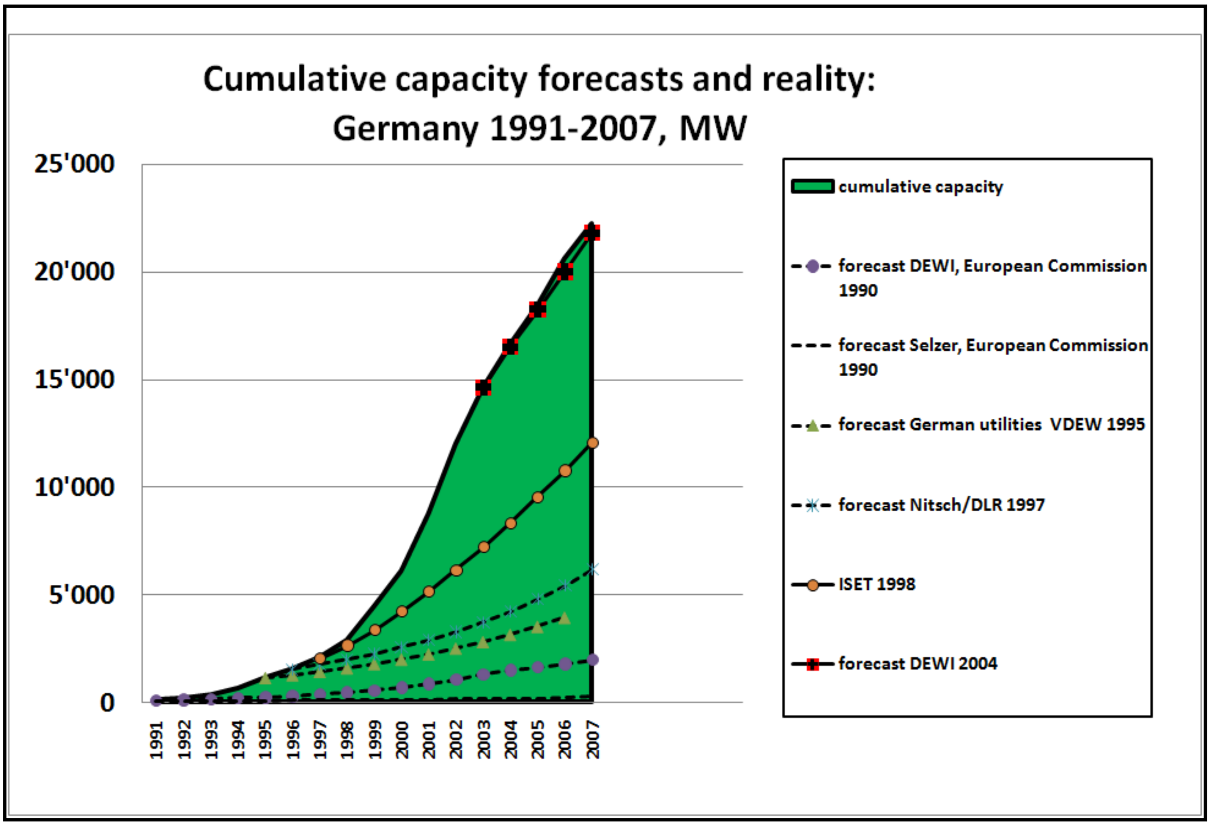

Figure 61 Cumulative capacity and forecasts Germany 1990-2006
Sources: Wind Power Monthly, Zittel 2006, DEWI, BWE[1]

date of forecast	Forecast source	Year of forecast	forecast MW for that year	Real cumulative capacity MW	Wind power reality compared to forecast
1990	forecast Selzer, European Commission 1990	2007	287	22247	+7659%
1990	forecast DEWI, European Commission 1990	2007	1982	22247	+1023%
1995	forecast German utilities VDEW 1995	2005	3531	18428	+422%
1997	forecast Nitsch/DLR 1997	2007	6165	22247	+261%
1998	ISET 1998	2007	12071	22247	+84%
2004	forecast DEWI 2004	2007	21800	22247	+ 2%

Figure 62 reality check for German capacity forecasts 1990-2007

In Germany, wind power reality was much better than all forecasts. Before the year 2000 there was no single expert who came even close to predicting the extent of real developments. Even forecasts, such as the 1997 prognosis by Joachim Nitsch/DLR, written in an era of full wind power growth, gave an estimation for 2007 that was exceeded in real capacity by more than 250percent.

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[1] The forecasts by Selzer, European Commission 1990, VDEW 1995, DEWI/ European Commission 1990 and Nitsch/DLR 1997 are cited by Werner Zittel: Deutsche Energiepolitik: Wie geht Deutschland mit PEAK OIL um? Presentation for the Parlamentarian Peak Oil Group Switzerland, Ludwig Bölkow Systemtechnik GmbH, 12.Dezember 2006 http://www.energiestiftung.ch/files/ses_fachtagung/Fachtagung_2007/praesentation_zittel_ses_07_08_31.pdf ; The BWE forecast of 2020 can be found in Sylvia Pilarsky-Grosch: Renewable Energy and grid structure, 19.November 2007 – Bonn Conference papers; the DEWI prognosis is in Market Prognosis 2008, 2012 and 2030, J. P. Molly, DEWI Wilhelmshaven, DEWI Magazin Nr. 25, August 2004, p.33-38. The ISET-1998 numbers are cited in Andreas Wagner: Germany's New Renewable Energy Law , http://www.climnet.org/news/EEG.htm

The more distant the forecasts, the higher the deviation. Only the forecast by DEWI (Deutsches Wind Institut), from 2004, had just a minimal deviation in a time when German new installations have been in decline. This was due to a very specific market environment where onshore expansion had declined and offshore expansion had not started yet, due to turbine shortages, permit hurdles and continued delays in grid reinforcements. (Meanwhile some of these handicaps are mitigated and it is much more difficult to forecast further German wind developments).

Annual additions forecasts and reality: Germany

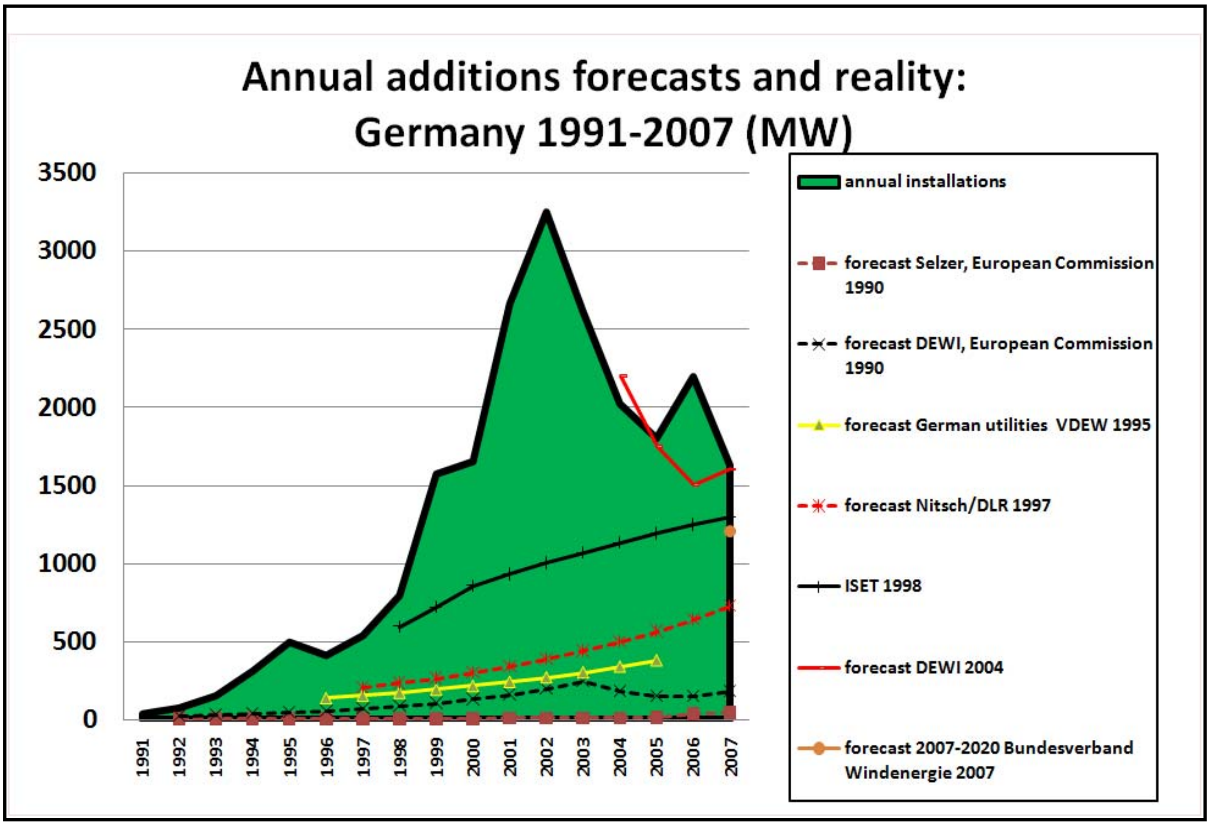

Figure 63 Annual additions forecasts and reality: Germany 1991-2007

Date of forecast	Source	Year of forecast	forecast MW for that year	Real net additions MW	Wind power reality compared to forecast
1990	forecast Selzer, European Commission 1990	2007	47	1625	+3381%
1995	forecast German utilities VDEW 1995	2005	378	1799	+375%
1990	forecast DEWI, European Commission 1990	2007	182	1625	+794%
1997	forecast Nitsch/DLR 1997	2007	729	1625	+123%
1998	ISET 1998	2007	1296	1625	+25%
2004	forecast DEWI 2004	2007	1600	1625	+2%

Figure 64 reality check for German annual additions forecasts 1990-2004

The next chart shows the developments of annual additions. It is remarkable that some forecasts, such as those by VDEW (1995) or Nitsch/DLR (1997), started with annual additions estimates that were substantially lower than the annual installations in the year of publication or of the year before. VDEW for example, in 1995, forecasted annual installations in the 100-200 MW range when, in 1994 and 1995, annual additions stood at 300 and 500 MW each. Nitsch/DLR forecasted annual installations in the 200-300 MW-range in 1997 when, in 1995 and 1996, annual additions of 500 and 400 MW were observed.

These conservative predictions show that midst a boom of wind power, insiders of the electric power sector were hesitating or unwilling to take wind power seriously.

The forecasts of annual additions for Germany turned out to be miles away from real growth. New annual installations in Germany peaked in 2002 at 3247 MW. Despite a reduction of additions afterwards, wind energy in Germany continued to be a success story and annual installations were generally higher than forecast.

German turbines unsold on the home market went to exports. 83 percent of German wind turbine production went to exports by 2007.[1] By end-2007, the German wind capacities were able to cover 7.2 percent of the German electricity consumption[2]. A new offshore wind industry is moving to the start line. Together with an expected doubling of the existing wind capacity just by replacement of older, smaller machines (repowering) on existing sites, and with additional onshore sites, a second giant wind boom in Germany is in preparation.

Outlook beyond 2007: Germany

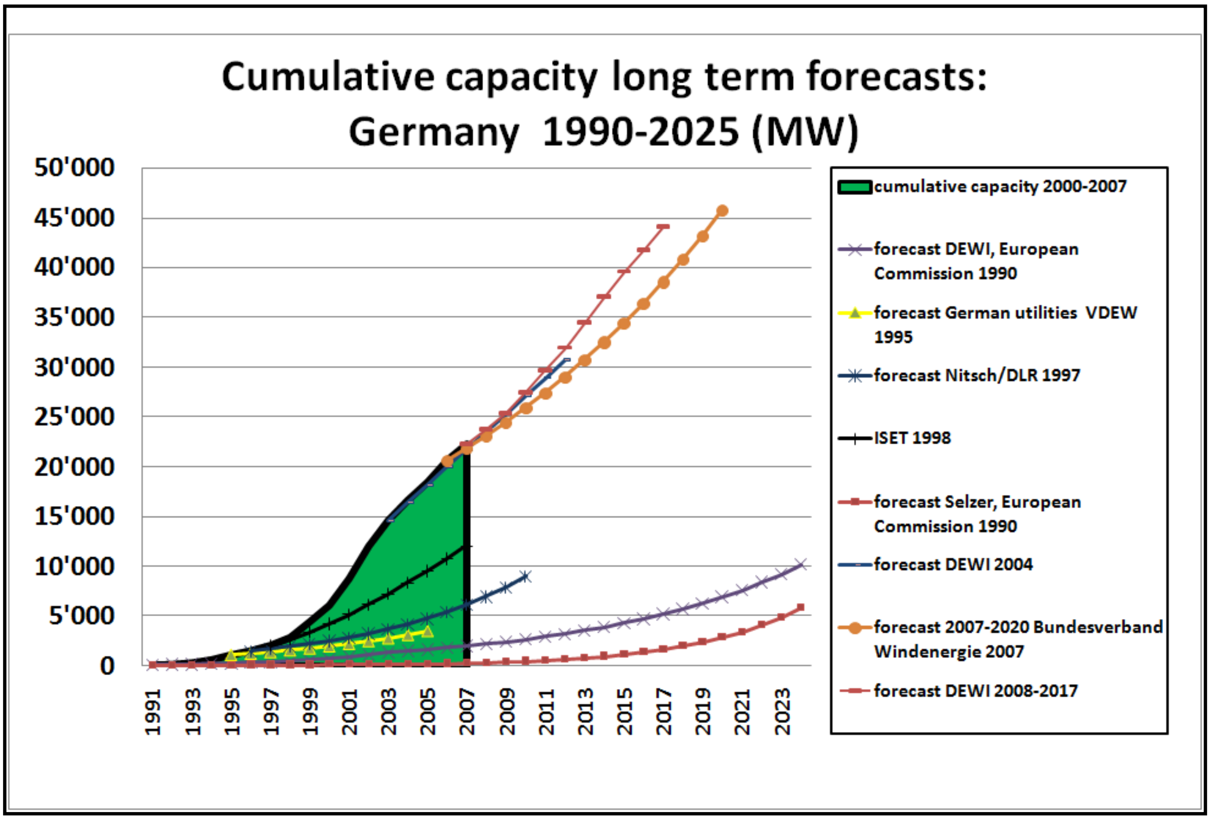

Figure 65 Long-term forecasts for cumulative wind capacity: Germany

The German Wind Energy Association (Bundesverband Windenergie) gives a positive outlook for wind power. It is forecasting a doubling of cumulative capacity at 45 GW in 2020. 10 GW should come from offshore sites. Other capacity additions are achieved by repowering (bigger turbines on existing wind sites) and by expanding existing wind permission zones.

The German Wind-Institute DEWI has beefed up its forecasts since 2004 as well. In its newest forecast, it estimates a capacity of 44 GW already by 2017 which corresponds to a doubling of capacity within the next ten years.

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[1] DEWI / J.P. Molly: Stand der deutschen Windenergienutzung am 30.6.2008
http://www.dewi.de/dewi/fileadmin/pdf/publications/Statistics%20Pressemitteilungen/30.06.08/Statistik_1HJ_2008.pdf

[2] DEWI/ J.P. Molly: Stand der deutschen Windenergienutzung am 30.12.2007
http://www.dewi.de/dewi/index.php?id=66&L=1&tx_ttnews[tt_news]=64&tx_ttnews[backPid]=47&cHash=feae143574

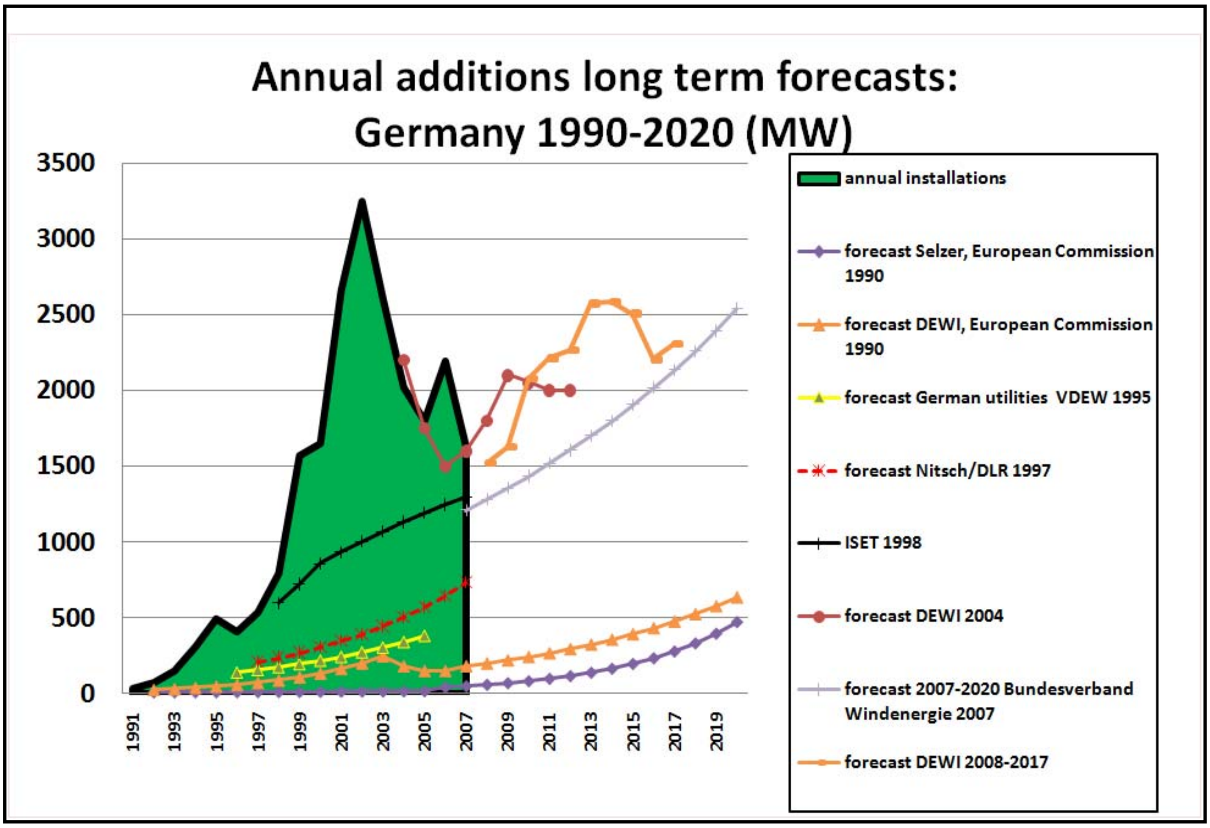

Figure 66 Long-term forecasts for annual additions: Germany

By translating cumulative growth into annual additions we can make these observations:

- All forecasts beyond 2007 stay below the 2002 peak level of 3250 MW additions.
- No indications are given why annual additions should stay so modest, provided offshore wind power, where substantial cost reductions are expected, works as it does in Denmark and Britain so far.
- Repowering of smaller, older wind turbines by bigger machines may lead to a doubling of the existing onshore capacity on existing sites.
- No forecast derives its numbers from the idea of an indicative goal to be achieved, such as a 50 percent market share for wind power.

It is important to note that even in a country such as Germany with a rather moderate wind resource, the size of additional MW wind capacity is not limited by physical constraints. Policy decisions and market factors have been much more decisive:

- The extent of additional onshore sites, permitted by states governments
- The extent of offshore development areas
- The changes of feed-in tariffs for new turbines and, indirectly, the changes in market prices for new electricity
- The extent, speed and planning conditions for repowering of existing sites
- The extent and speed of grid expansion.

Wind energy expert Knud Rehfeldt from German Wind Energy Institute (DEWI) in the year 2000 assessed German offshore wind power as follows:

‚Wind turbine 5 MW, 110 m rotor diameter
- Area per wind turbine: 0,42 km^2
- Output per turbine 18 GWh/a (3600 full-load-hours)
- Output per area: 42 GWh/km^2/a
- 29369 wind turbines rated at 5 MW are able to deliver the entire German power supply with an area of 11883 km^2 needed (a square with a side length of 109 km).’ [1]

The production numbers meanwhile derived from Danish Horns Rev offshore wind farm, with a 45 percent capacity factor of its 160 MW-installation, proves that up to 3942 MWh a year can be derived from 1 MW capacity. The output of a 5 MW turbine then could be expected at 20 GWh a year – some ten percent better than calculated by Rehfeldt in 2000.

So a 100 percent wind powered Germany is possible in physical terms, but such a development would need some additional services regarding interconnection and reserve capacities.

What do past forecasts in Europe tell us?

Cumulative capacity forecasts and reality: Europe

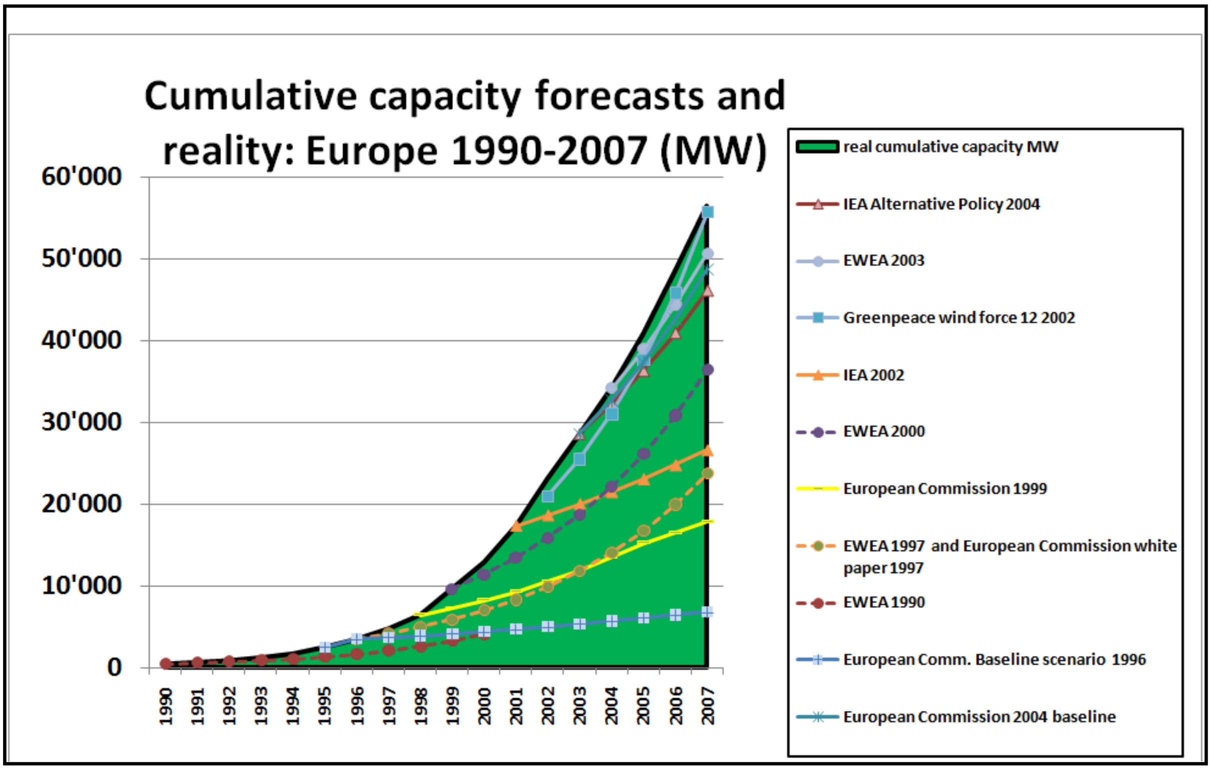

Figure 67 Cumulative Capacity and Forecasts for Europe 1990-2006
Sources: EWEA, EC, IEA,[2]

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[1] Potentiale der Offshore-Windenergienutzung und ihr Beitrag zum Klimaschutz Dr. K. Rehfeldt; DEWI, Deutsches Windenergie- Institut GmbH, Wilhelmshafen, 27 Juni 2000 **http://www.dewi.de/dewi/fileadmin/pdf/publications/Studies/Offshore/Tagungsband/08.pdf**

[2] For EWEA 1990, 1997, 2000 and 2003 see EWEA: Wind energy – the Facts Vol. V p. 239; for European Commission EC 1997 see BTM Consult TYR 2005, p. 65 and EWEA: Wind energy – the Facts Vol. V p. 240; The EC 1999 numbers are cited in EWEA: Pure Power, wind energy scenarios up to 2030 p. 25; All IEA Scenarios are from EWEA: Pure Power, wind energy scenarios up to 2030 p. 27; The Greenpeace Scenario can be found in EWEA/Greenpeace Windstärke 12 p.64.

date of forecast	Forecast source	Year forecasted	forecast MW for that year	Real cumulative capacity MW for that year	Wind power reality compared to forecast
1990	**EWEA 1990**	**2000**	**4089**	**12887**	**+215%**
1996	**European Comm. Baseline scenario 1996**	**2007**	**6799**	**56535**	**+732%**
1997	**EWEA 1997 and European Commission white paper 1997**	**2007**	**23709**	**56535**	**+138%**
1999	**European Commission 1999**	**2007**	**17886**	**56535**	**+216%**
2000	**EWEA 2000**	**2007**	**36378**	**56535**	**+55%**
2002	**Greenpeace wind force 12 2002**	**2007**	**55703**	**56535**	**+1%**
2002	**IEA 2002**	**2007**	**26648**	**56535**	**+112%**
2003	**EWEA 2003**	**2007**	**48286**	**56535**	**+17%**
2004	**European Commission 2004 baseline**	**2007**	**48726**	**56535**	**+16%**
2004	**IEA Alternative Policy 2004**	**2007**	**46087**	**56535**	**+23%**

Figure 68 reality check for European capacity forecasts 1990-2007

EWEA's forecast of 1990 predicted a cumulative capacity of 4089 MW for the year 2000. In reality, the European wind capacity reached 12887 MW in 2000. In 1997, EWEA predicted a capacity of 19,911 MW for 2006 when in reality 48,545 MW turned out to be in line. More recent forecasts were closer to the real outcome, maybe because they are younger and no one surpassed the real capacity growth – any overestimates are not registered.

The European Commission was more on the wrong side: 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.[1]

Real capacity in Europe was between 16 percent and 732 percent better than the capacity forecasted just three to ten years before. The best forecast was done by Greenpeace **which supposed stable exponential growth** over time. It underestimated the real outcome by only 1 percent.

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[1] European Wind Energy Association: Pure Power, Wind Energy Scenarios up to 2030, March 2008 p. 25

Annual additions forecasts and reality: Europe

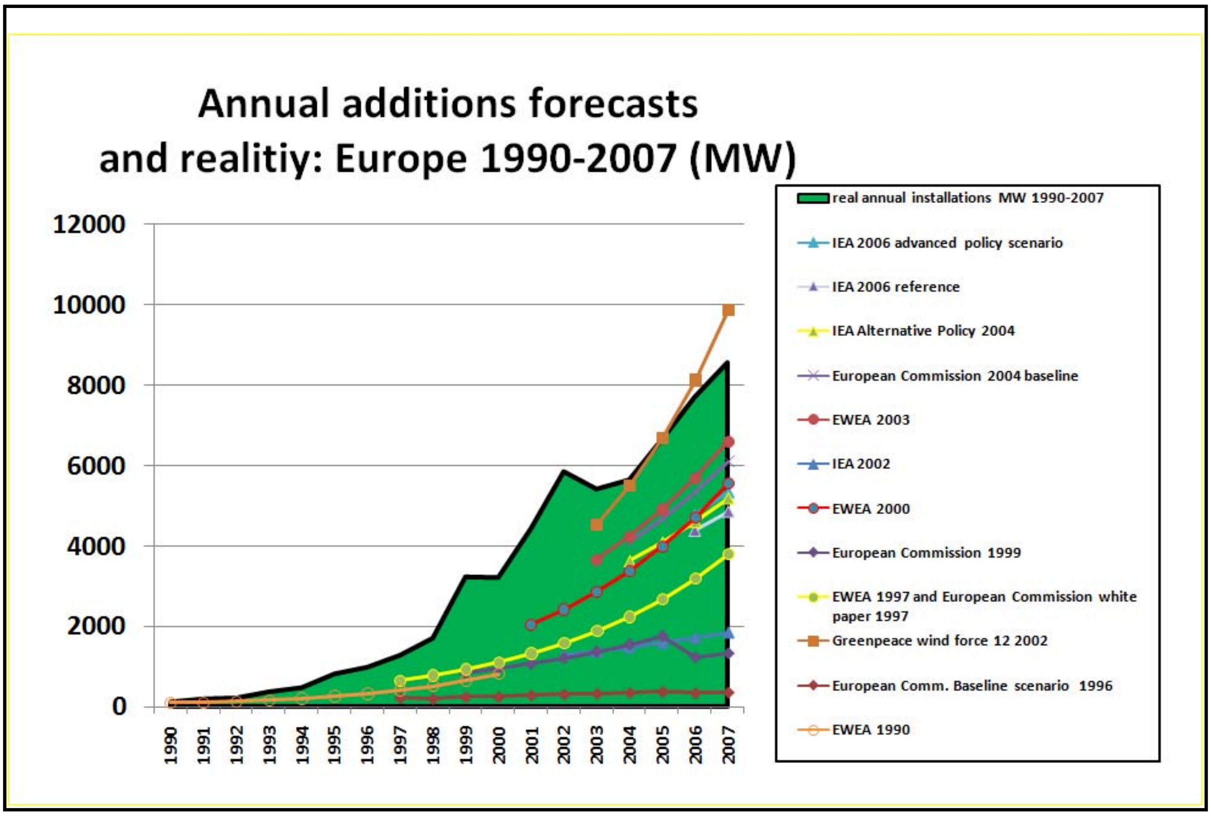

Figure 69 Annual additions forecasts and reality: Europe 1990-2007

date of forecast	Forecast source	Year forecasted	forecast MW	Real annual addition that year	reality better than forecast
1990	EWEA 1990	2000	818	3209	292%
1996	European Comm. Baseline scenario 1996	2007	367	8554	2233%
1997	EWEA 1997 and European Commission white paper 1997	2007	3797	8554	125%
1999	European Commission 1999	2007	1343	8554	537%
2000	EWEA 2000	2007	5549	8554	54%
2002	Greenpeace wind force 12 2002	2007	9857	8554	-13%
2002	IEA 2002	2007	1848	8554	363%
2003	EWEA 2003	2007	6599	8554	30%
2004	European Commission 2004 baseline	2007	6089	8554	40%
2004	IEA Alternative Policy 2004	2007	5193	8554	65%

Figure 70 reality check for European annual additions forecasts 1990-2004 (MW)

Annual additions were more volatile than cumulative growth. They showed a compound average annual growth rate (CAGR) of 23.4 percent for the ten-year period 1998-2007. In 2007, 8554 MW net installations were added on the European market.

All forecasts except one (EWEA/Greenpeace Wind Force 12, 2002) expressed a lower or far lower addition in MW for the year 2007. The worst underestimates of annual growth were published by the European Commission (1996 and 1999) and more recently (2002) by the International Energy Agency.

The estimates for annual additions – even the younger ones – were exceeded by reality by 20-60 percent. Even the forecasts published by the European Wind Energy Association (EWEA), a wind industry organization, were mostly far too low.

BTM, a Danish market research institute which is considered as the "reference as the most cited report in the industry in terms of progress and future perspectives on wind power",[1] noted these trends in 2005:[2] "EWEA has adjusted its target upwards every time, by the successful implementation of wind power in Europe, during the last decade. EWEA has not been overly optimistic in their early prediction; The 4000 MW milestone by 2000 was achieved already in mid 1997…The 40,000 MW milestone by 2020 is likely to be achieved by end of year 2005…"

Outlook beyond 2007: Europe

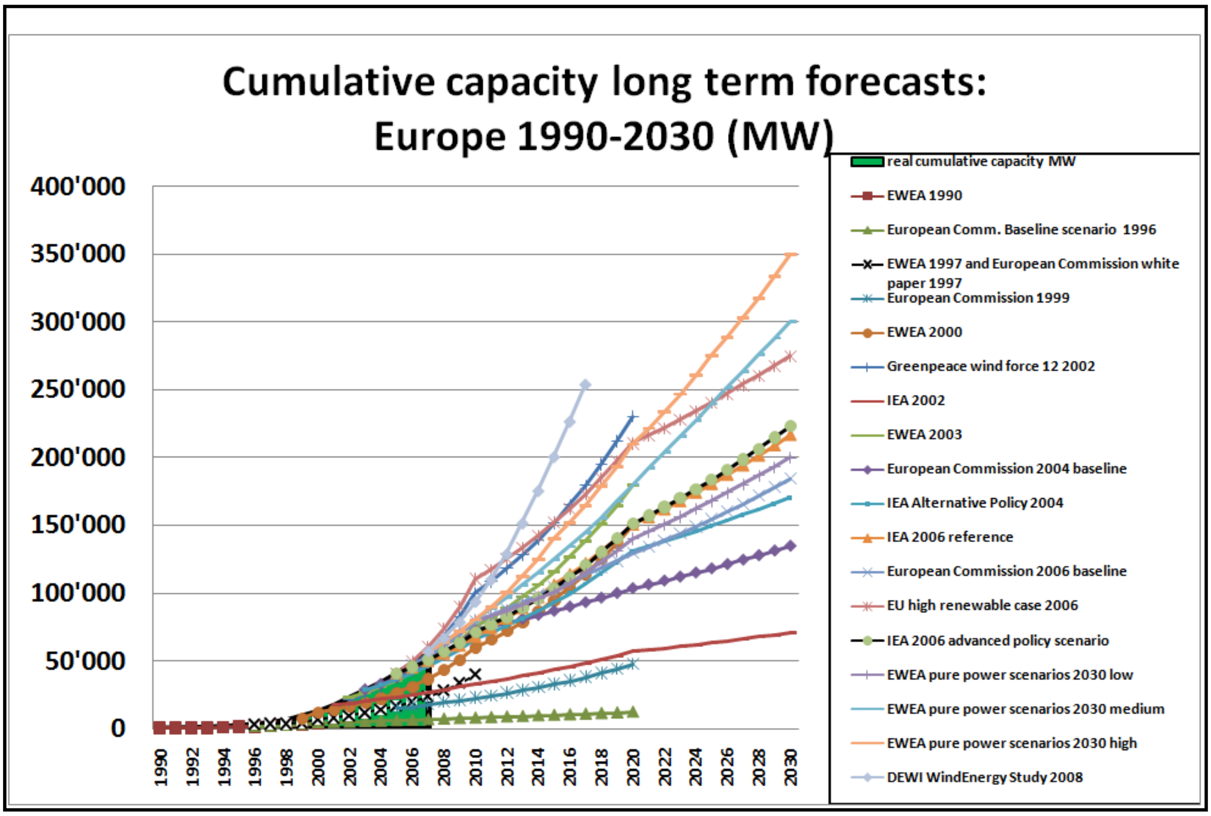

Figure 71 long-term forecasts of cumulative capacity: Europe

Most long-term forecasts deploy a conservative or pessimistic perspective for wind power in terms of overall growth and market share. The more positive forecast "EWEA pure power 2008 high" has a prospect of 350 GW by 2030 which corresponds to 1090 TWh or 24.2 percent market share of European electricity consumption by 2030. Another more positive vision is given by the DEWI's most recently published "DEWI WindEnergy Study 2008" with a slightly better short-term forecast until 2017.

All "official" forecasts deploy a pessimist view of wind power:

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[1] BTM Ten Years review 2005, p. vii

[2] BTM Ten Years review 2005, 65-66

- No exponential growth can be found in these forecasts which would lead to something similar to what the wind sector has experienced in the 1990-2007 period.
- No forecast is discussing a vision of “market conquest” or “market saturation”.
- No forecast gives arguments that would substantially exceed the European Union’s goal of 20 percent renewables by 2020.
- No discussion on the methods of forecasting is going on. Even the most positive forecast (DEWI 2008) seems to rely on interviews of wind market actors rather than developing a conceptual framework for market penetration or non-penetration.
- Very little in-depth analysis is done about wind power’s competitiveness, wind resources and possible wind contributions to overall electricity consumption in a “let’s do it!” attitude. There seems to be no ambition for market conquest either – something that would be a logical goal for a new, clean, available, least-cost, abundant and emission-free power technology.

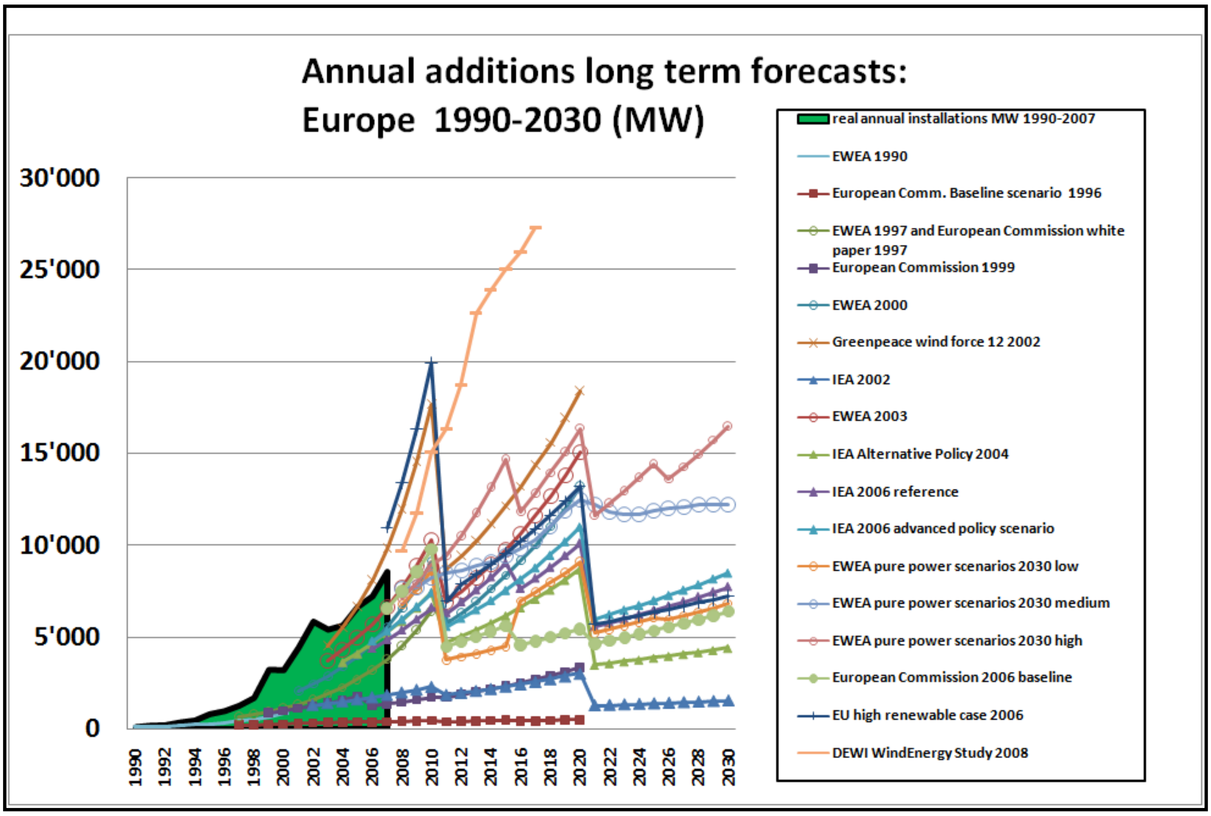

Figure 72 Annual additions derived from cumulative forecasts: Europe 1990-2030

What these modest long-term forecasts mean in terms of annual additions is revealed when we look at year-over-year developments. **Some remarkable trends in most of these forecasts can be found:**

- There is only one forecast exceeding additions of 20,000-MW annually for Europe. It is the recently published DEWI-WindEnergy Study 2008. It substantially exceeds the EWEA “pure power” scenarios.
- The more positive forecasts by EWEA and the EU-high-renewables case show a 10,000-15,000-MW range only for annual additions in Europe, with some short-time exceptions of slightly higher growth.

- The International Energy Agency (IEA) repeatedly has predicted a **stagnation or decline of annual turnover** in the wind power sector**.** It does so again for the next five to ten years or more, compared to 2007 installations. In its most recent projections (IEA 2006, 2004, 2004AP) average yearly additions in Europe are stagnating in a 4000-8000 MW range when in the 2007 reality an annual installation of 7990 MW was reached.
- The IEA 'alternative' forecast goes against the industry growth trend, and more so do 'reference' scenarios. There is just no 'alternative' policy visible in the IEA forecasts, or 'alternative' then would mean a return to nuclear power, which certainly is not what the public expects by this time.

The pessimist view goes beyond IEA. Most projections mean at best that another doubling of additions per year would take place before a stagnation or recession would set in, long before market saturation is observed. But if the European wind sector continues its ten-year mean growth rate of 22.7 percent, the 15000 MW-threshold would be reached by 2010. Is stagnation and decline afterwards a realistic scenario?

Even if onshore ever should start to be an ubiquitous problem – which is not the case so far at all (if ever there is a lack of interconnection and not a lack of sites) – why are there no scientific estimates for specific maximum contributions the offshore sector in Europe could deliver?

Most scenarios speak of Europe in terms of the European Union. No scenario includes the vast areas of Eastern and Northern Europe such as Russia, Ukraine, Norway or Turkey for development of wind power – something that seems a logical step for these countries with huge wind power resources, in an environment of rising fossil fuel prices. There is a strong lack of imagination in these respects.

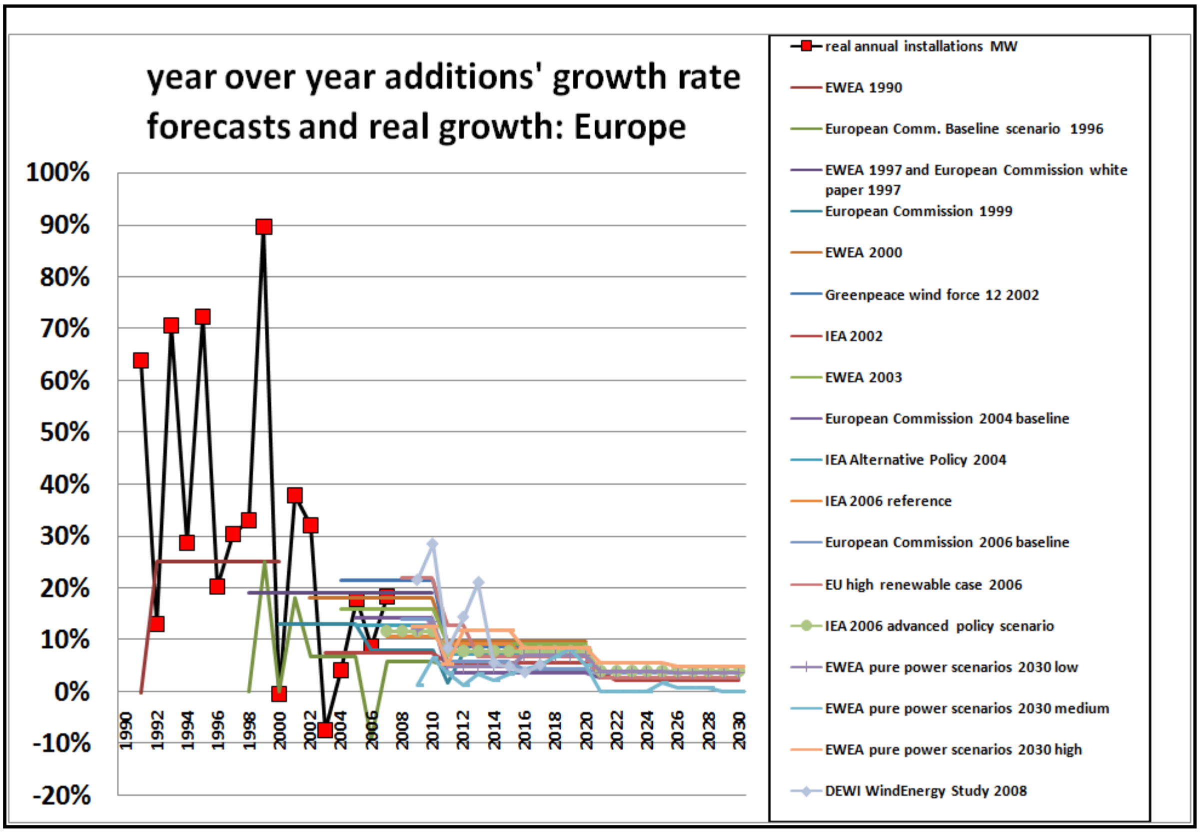

Figure 73 Growth rate forecasts of annual additions: Europe

Long-term growth rates of annual installations are a mirror of optimism or pessimism of forecasters. Some characteristics can be observed:

- All forecasts do expect a **steady decline of growth rates over time**. No one can imagine a “market conquest” as an impact of decline of fossil fuels, with fossil fuel price increases, or by a new Kyoto-style accord.
- We find that even the most optimistic forecasts do not exceed annual growth rates of more than 12 percent after 2013, and later they all tend to be lower than 10 percent when in the past the average growth rate exceeded 20 percent.
- No one of these forecasts is trying to reach an explicit goal - an idea of how much wind power should contribute to power production in the years coming. The highest market penetration is given by the EWEA-pure-power-scenario with a 20-29 percent market share in 2030, depending on consumption growth.[1]

No comment is given on the acceptability (positive or negative) of this value. Is there a fundamental fear to scare wind’s competitors such as gas, coal or nuclear? Is the understatement of wind power’s perspective a strategy to prevent unfriendly policy actions against the industry?

What do past forecasts for the world wind market tell us?

Forecasts by the International Energy Agency

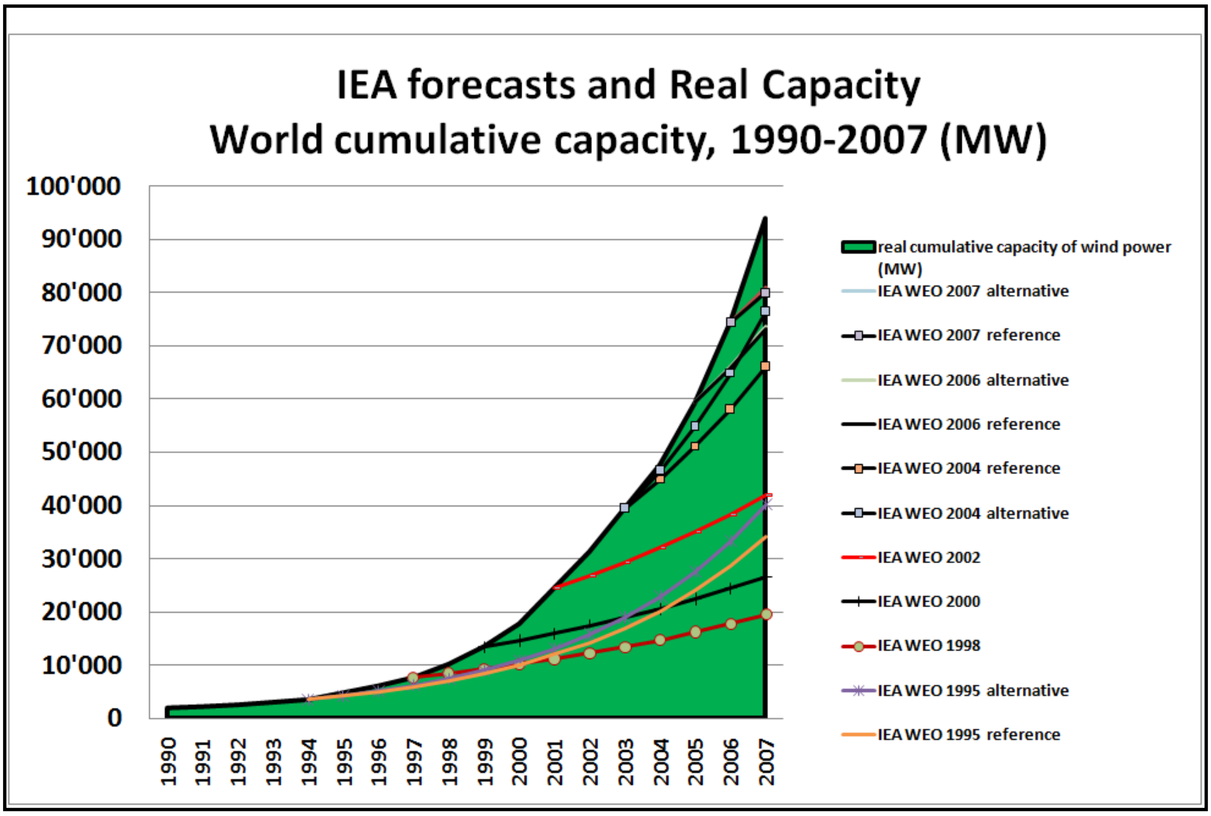

Figure 74 forecasts on world wind power capacities 1998-2006

On a world scale, all past IEA forecasts for cumulative wind power capacity have been exceeded by actually installed wind power capacity. To give an example: In 1998, the IEA World Energy Outlook predicted cumulative installations of 47.4 GW by 2020. The digit

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[1] EWEA: PURE POWER – WIND ENERGY SCENARIOS UP TO 2030, p.11

behind the point, expressed by the IEA, makes the forecast appear to be a result of complex or exact calculation. Not so! The IEA 2020-prediction of 47.4 given in 1998 was exceeded in real terms of world cumulative capacity by December 2004. And the IEA 2020-prediction given in 2002 of 104 GW was exceeded in real terms of world cumulative capacity by August 2008.

Date of forecast	Source	Year forecasted	forecast MW for that year	reality MW that year	Reality better/worse than forecast
1995	IEA WEO 1995 reference	2007	34211	93881	+174%
1995	IEA WEO 1995 alternative	2007	40077	93881	+134%
1998	IEA WEO 1998	2007	19449	93881	+383%
2000	IEA WEO 2000	2007	26614	93881	+253%
2002	IEA WEO 2002	2007	41952	93881	+124%
2004	IEA WEO 2004 reference	2007	66136	93881	+42%
2004	IEA WEO 2004 alternative	2007	76454	93881	+23%
2006	IEA WEO 2006 reference	2007	73031	93881	+29%
2006	IEA WEO 2006 alternative	2007	73559	93881	+28%

Figure 75 Reality check for IEA forecasts: cumulative world capacities 1990-2006

Later IEA forecasts could not completely ignore the industry's relentless growth. So they adopted higher start levels for wind power capacities, but beyond that indicated minimal growth again.

Every single IEA prediction failed even in the very short-term (such as the 2006/2007 preview). By 2007 the cumulative installed wind power capacity was 93.5 GW which was 383 percent more than the 17 GW predicted by IEA in 1998, or 124 percent more than the 2002 IEA reference case.

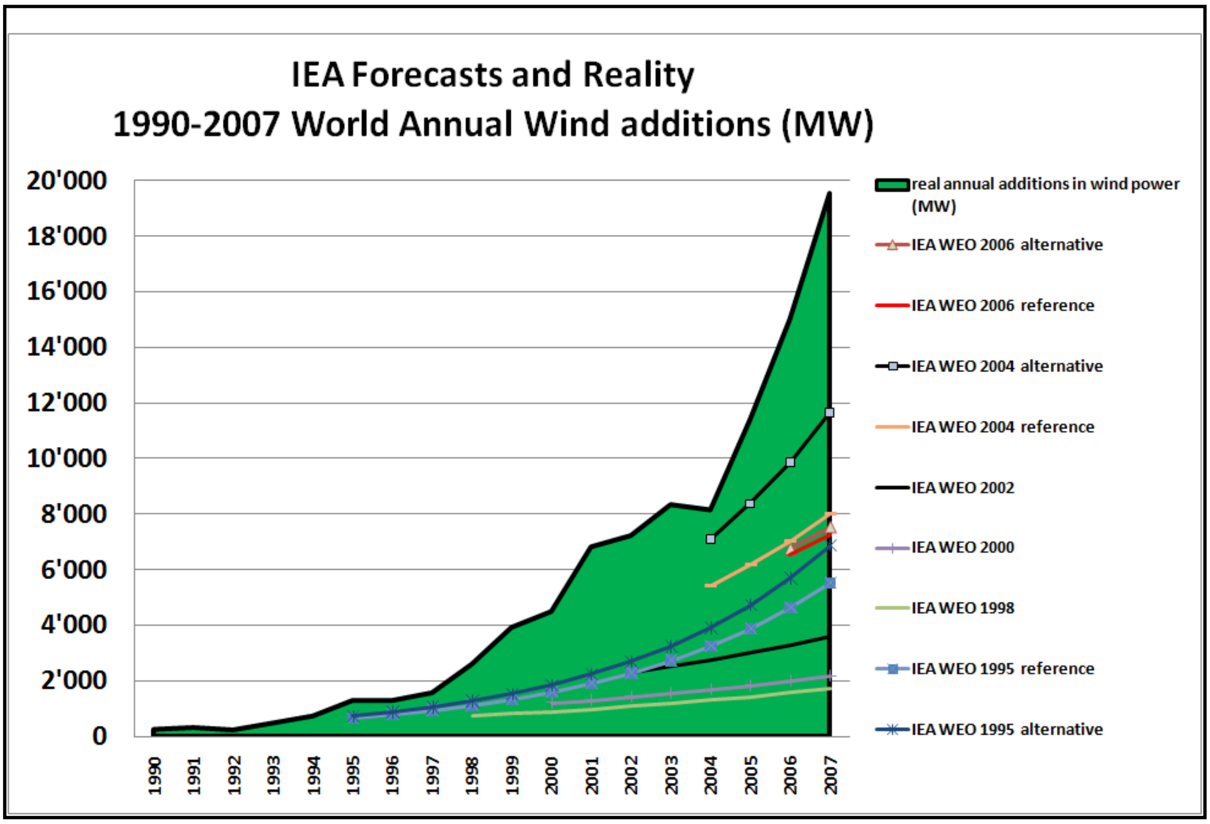


Figure 76 IEA: Predicting stagnation for annual additions despite relentless growth

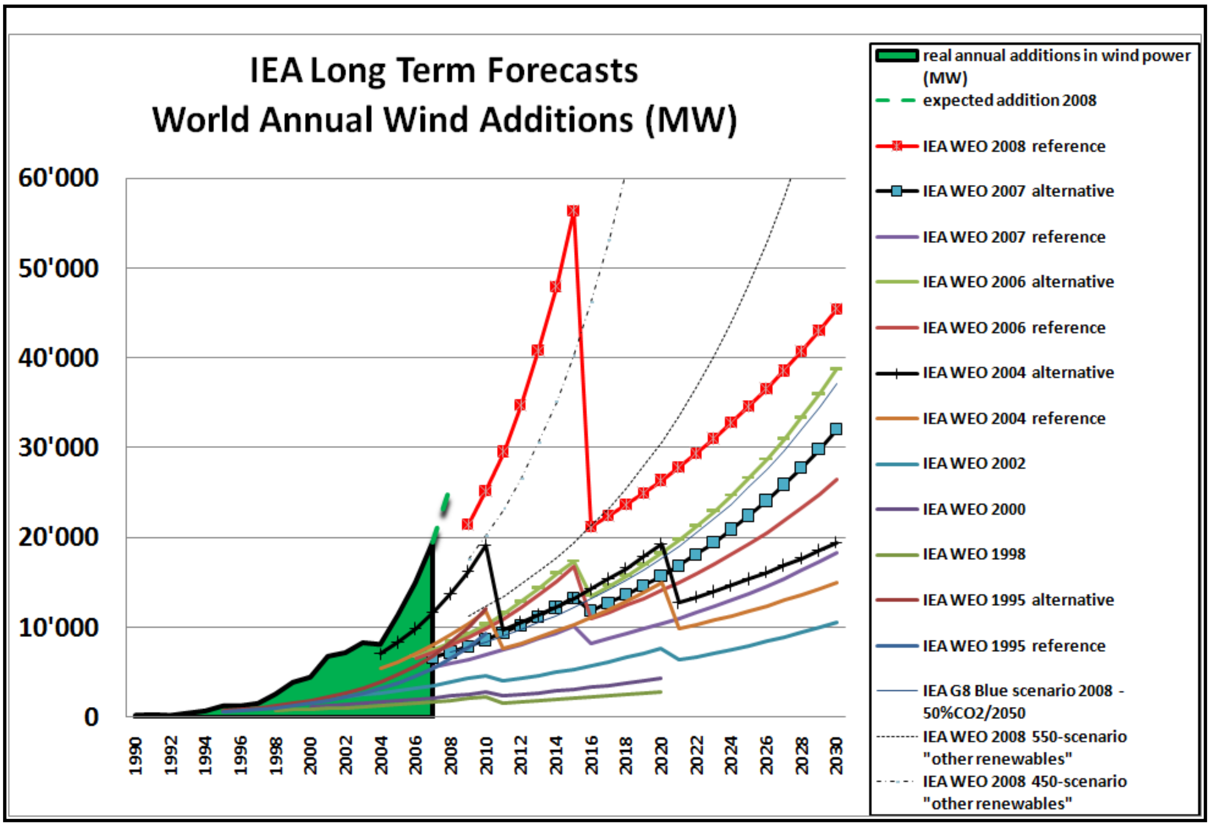
date of forecast	Source	forecast for 2007	reality in 2007	reality better than forecast by
1995	**IEA WEO 1995 reference**	**5511**	**19553**	**+255%**
1995	**IEA WEO 1995 alternative**	**6862**	**19553**	**+185%**
1998	**IEA WEO 1998**	**1736**	**19553**	**+1026%**
2000	**IEA WEO 2000**	**2175**	**19553**	**+799%**
2002	**IEA WEO 2002**	**3605**	**19553**	**+442%**
2004	**IEA WEO 2004 reference**	**8020**	**19553**	**+144%**
2004	**IEA WEO 2004 alternative**	**11662**	**19553**	**+68%**
2006	**IEA WEO 2006 reference**	**7237**	**19553**	**+170%**
2006	**IEA WEO 2006 alternative**	**7528**	**19553**	**+160%**
2007	**IEA WEO 2007 reference**	**5649**	**19553**	**+246%**
2007	**IEA WEO 2007 alternative**	**6690**	**19553**	**+192%**

Figure 77 reality check for IEA forecasts: world annual additions 1990-2007

Forecasts on annual installations were heavily exceeded by real annual additions. The worst forecast was the IEA 1998 World Energy Outlook. Reality was 1026 percent or some ten times better than the 1736 MW annual addition forecasted for 2007. The best forecast was the 2004 World Energy Outlook alternative energy approach which was surpassed three years later in real additions by an amount of “only” 68 percent.

The IEA persisted in its pessimistic attitude on wind power even after 2005, when oil prices moved strongly upwards. The 2007 World Energy Outlook included a lower estimate for annual additions than the 2004 reference and alternative cases – despite the heavy growth of the wind sector meanwhile. Any energy expert – and even non-experts – could observe high wind additions between 2005 and 2008. The highly illogical IEA numbers indicate that this institution does not analyze the wind power market in consistent terms.

No IEA-World Energy Outlook clarifies the IEA methods of analyzing wind power. Unlike the lengthy (and so far faulty too) IEA analyses on fossil fuels and prices, no profound wind resource analysis or generation cost reflection can be found in the IEA World Energy Outlook heavily publicized in the mass media.



<u>**Figure 78 IEA long-term forecasts annual additions: World**</u>

Regarding IEA scenarios beyond 2007 – neither ‘reference’ or ‘alternative’ – no continuous expansion of annual installations is expected over the long term. Despite wind industry indicators suggesting an expected level of at least 25 GW of annual additions in 2008, **IEA is predicting - beside a short flash in the pan in its WEO 2008 reference scenario – stagnation of wind power in virtually *all* its scenarios.**

After 2020, only the most optimistic IEA scenarios project growth rates creeping up to a 30,000-40,000 MW – a level that in reality is likely to be achieved by 2009/2010.

A doubling of world wind power additions from 10,000 to 20,000 MW was observed in a 2½-year period between end-2005 and start of 2008. So why should it take 22 years from now on for another doubling of wind additions when the prices of fossil and nuclear fuels are exploding? And what are the reasons for predicting a decline in annual installations such as in all 2000-2006 reference scenarios? Is there not enough wind resource? Are there doubts for the commercial viability of the technology? Is there a lack of grid technology or extensions? Is there a reduction of wind turbine manufacturing? And if so – then why would the IEA stay tacit on these issues instead of resolving these bottlenecks for an achievement of real energy security?

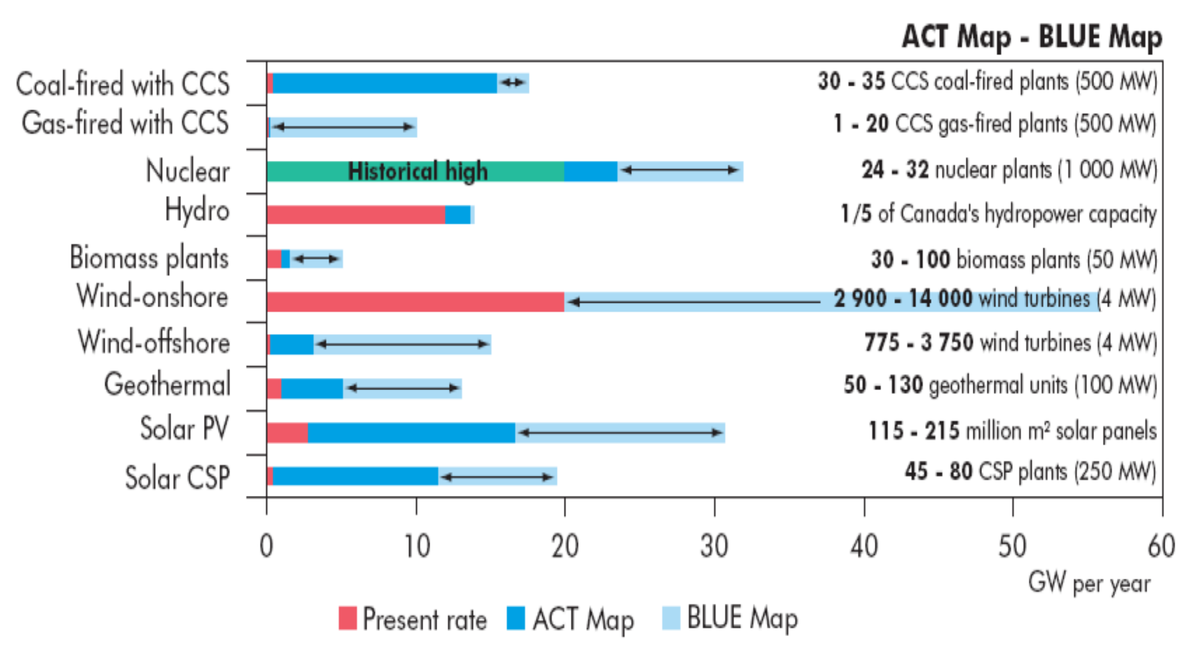
The 2008 IEA “blue scenario” for the G8

In its recently published study for the G8 members, the IEA concedes a bigger role for wind and solar contributing each some 5000 TWh in its greenhouse-gas-reduction scenario – called the "blue scenario".[1] However this positive role for wind and solar is only given as far as in 2050 (!).

The report was hailed by some experts saying that "*For the first time, the IEA has clearly acknowledged that wind power is now a mainstream energy technology, and the central role it must play in combating climate change,*" but they also criticized the fact "*that the IEA continues to underestimate wind power's mid-to long-term potential by about half*".[2]

In the same study for the G8, the IEA expects a tenfold increase of nuclear power and a virtual explosion of investments into carbon capture and storage technologies (CCS) when for wind power only a threefold increase of additions is predicted.

This is all the more illogical because CCS technology on an industrial scale is technically untested and – on a full cost scale including fuel costs – is more expensive than wind power, and so would be nuclear. The IEA 'alternatives' therefore are not convincing. With "clean coal" and "nuclear innovation" just a lot of lip service, scientific orthodoxy is fed – with doubious results.



<u>Figure 79 IEA forecast for the G8 a nuclear fudge</u> Source: IEA 2008[3]

In order to beef up nuclear, a manipulative act was started by orchestrating numbers of nuclear power additions: While for all other technologies the IEA used annual capacity additions, in 2010 to kick off its scenario, for nuclear it goes back in history to pick the best year the ill-fated technology ever achieved.

GWEC and WWEA repeatedly have been critical toward IEA and have seen this body rather as delaying the implementation of wind energy: "Unfortunately with the new report and

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[1] ENERGY TECHNOLOGY PERSPECTIVES 2008: FACT SHEET – THE BLUE SCENARIO; A sustainable energy future is possible – How can we achieve it? **http://www.iea.org/Textbase/techno/etp/ETP_2008.pdf** ; **http://www.iea.org/Textbase/techno/etp/ETP_2008.pdf**

[2] "While we believe that the IEA continues to underestimate wind power's mid-to long-term potential by about half, this scenario is much closer to what we believe is a sustainable energy future than anything we have seen from the IEA in the past," said GWEC Chairman Arthouros Zervos. "Wind power's technical maturity and speed of deployment is clearly acknowledged, along with the fact that there is no practical upper limit to the percentage of wind that can be integrated into the electricity system."

[3] ENERGY TECHNOLOGY PERSPECTIVES 2008: FACT SHEET – THE BLUE SCENARIO; A sustainable energy future is possible – How can we achieve it? P. 7

especially with the recommendations on renewable energy legislation, the IEA is in line with those who try to stop or delay the rapid growth of the wind industry. Germany still is a locomotive accelerating the wind energy utilization worldwide and a change of legislation as suggested by the IEA would retard developments, thus creating major problems for wind energy on the global scale."[1]

The IEA World Energy Outlook 2008

Revised oil supply and oil price projections

In the IEA's most recent World Energy Outlook (WEO), published in November 2008, the agency maintains that a "supply crunch" for oil could be avoided if the oil industry would invest enough. It insists that there is no geological shortage of oil in view ("peak oil").

But while in 2007, the agency was predicting that global oil production in 2030 would reach 116m barrels per day (mb/d), up from around 85mb/d, it has slashed that to 106mb/d in its 2008 WEO, which means that 10 mb/d of oil or some nine percent of world delivery disappeared within one year.

For oil, for the first time a sharply higher price level is assumed: The agency has doubled its oil price forecast. In 2007, it said the cost of crude would fall in the long term to less than $60 per barrel, but now it predicts an average of $100 per barrel until 2015, despite a deepening recession, and rising to $120 in real terms by 2030.[2] It concludes that the era of cheap oil is over and that the recent extreme price volatility will continue. And it acknowledges that the "*risk of a supply crunch*" for oil after 2010 could be "*driving up oil prices – possibly to new record highs*".[3]

World Energy Outlook 2008 and Wind power

For oil as well as for renewables there is something new in the 2008 Outlook that will appeal to everyone. The report correctly identifies renewable electricity and renewable heating (especially solar water heating) as areas poised for growth. It expects that renewable electricity generation will overtake natural gas to become the second-largest source of electricity by 2015, but will still lag far behind coal. Several next generation storage technologies, important for renewable electricity, are seen under development, including ultracapacitors, superconducting magnetic systems, and vanadium redox batteries.

However, the IEA also predicts that carbon dioxide emissions will continue to rise which seems questionable on the long run, regarding the higher prices predicted for oil and gas and the possibilities of the replacement of coal based electricity by affordable renewable based electricity. Again, the IEA reference scenario is not familiar with the idea that national or international regulations such as carbon taxes, emissions trading systems or feed-in tariffs could have an impact upon the future power mix.

In the 2008 IEA reference scenario, World demand for electricity is forecast to rise from 15,665 TWh in 2006 to 28,141 TWh in 2030. This amount is very close to the C and D scenarios of this study [with 1.8 percent annual consumption growth, see chapter 4].

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[1] Stefan Gsänger, Secretary General of WWEA, on the IEA critique of the German feed-in legislation in June 2007

[2] IEA: World Energy Outlook 2008, p.79

[3] IEA: World Energy Outlook 2008, p.92

Global output of wind power is forecast to grow from 130 TWh in 2006 to more than 660 TWh in 2015 [which is a bit higher than the B and D scenarios in this report, with 15.2 percent annual additions growth, but lower than the A, C trend scenarios with 30.4 historical mean growth rates). The IEA growth path for wind power in the "reference scenario" shows net additions growth rates of 18 percent per year over the 2009-2015 period. While historically, the annual growth rates were much higher in the past (30.4 percent 1998-2007), the new IEA growth path is not as far-off as former predictions published in the older World Energy Outlooks.

However, the IEA depicts a sharp trend reversal for wind power for the time after 2015: cumulative wind power capacity would grossly double to 1,490 TWh by 2030 only – an outcome which is far lower than historical trends. In our study, the moderate B and D-scenarios predict an output of 8283 TWh by 2030, based on a continuous 15.2 percent net installations growth, more than five times the IEA indication, and the A, C-scenarios with historical growth rates of 30.4 percent, extrapolated until 2030 would indicate 17,796 TWh from wind power or roughly ten times the IEA value.

The reasoning of such a 2016-2030 IEA trend reversal is not explained in the World Energy Outlook 2008. The twist in cumulative capacity growth translates into a sharp reduction of annual capacity additions after 2015 – from an expected 57 GW per year in 2015 down to an average of 32 GW for the 2016-2030 period only, a virtual stagnation of the wind industry, compared with the 25-26 GW addition expected already for 2008. No arguments are given by the IEA why the wind sector should suffer such a stagnation or even downturn of revenues after 2015.

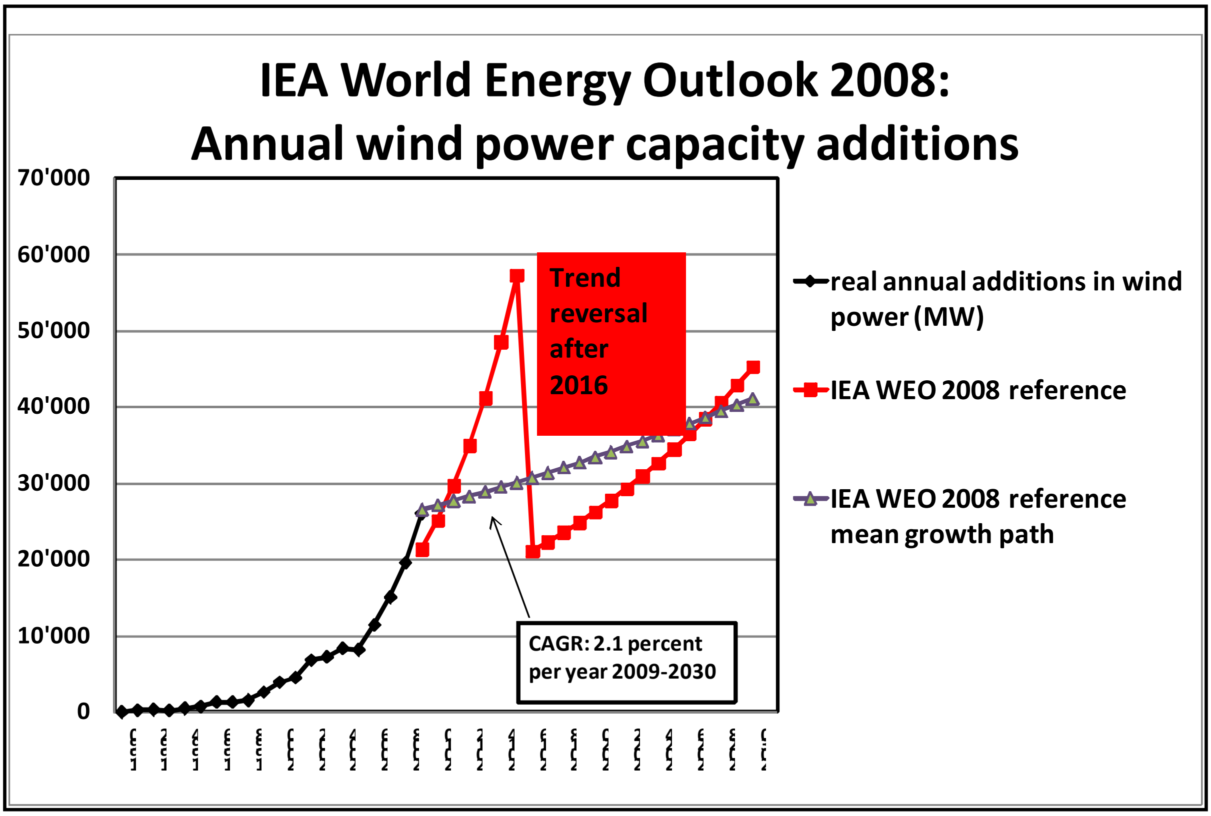

Figure 80 The IEA growth paths for wind power in the World Energy Outlook 2008

While for the 2009-2015 period the IEA acknowledges a compound annual growth rate (CAGR) of 17.5 percent for the wind sector, the percentage growth over the whole 2010-2030 period turns out to be 2.2 percent per year if we integrate the low growth over the second term

2016-2030, starting at an assumed 25.5 GW addition in 2008, ending at only 41 GW annual additions in 2030.

Again we ask: A doubling of wind power additions from 10,000 to 20,000 MW was observed in a 2½ year period between the end of 2005 and start of 2008 worldwide. So why should it take – again - 22 years going forward for another doubling of wind additions up to 2030, while the prices of fossil and nuclear fuels are insecure and – sometimes – exploding?

The Windpower Monthly Magazine spelled a comments of warnings toward the World Energy Outlook 2008 in its December-2008 edition:

"*Given the IEA's use of far lower growth rates for wind power than have actually been the case for the past three years; its ultra conservative view of wind power's potential until as recently as last year; its faith in nuclear, a technology in decline; and its great expectations of carbon capture and storage, a technology with a highly uncertain future beyond the certainty that it will be expensive, the thought of basing a global energy strategy on the strength of the agency's forecasts is nothing less than frightening. Yet this is what the IEA proposes its report be used for. Politicians would be better guided by the wind industry's own forecasts.*"

Indeed with 1410 TWh wind power in 2030, suggested by the IEA, cumulative capacity would stand at 854 GW (using the IEA relation of 1750 kWh/kW), the potential of wind power will barely be scratched. There must be other factors that could block the growth of the wind sector. Could it be that cost arguments would block the wind and solar sector? Two graphs from the IEA 2008 report might give some hints:

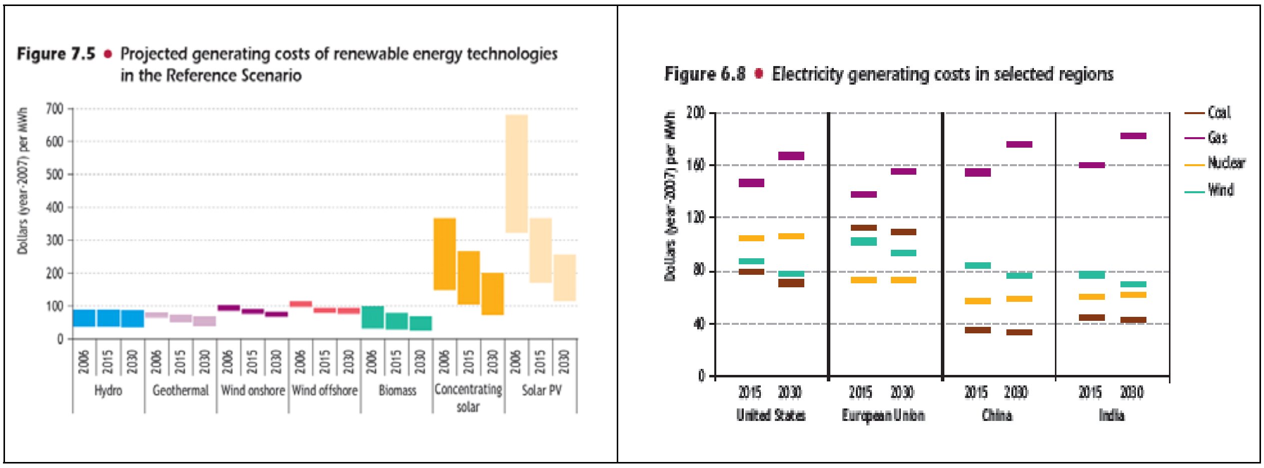

Figure 81 cost data of various power technologies, IEA World Energy Outlook 2008[1]

In the figure on the left the IEA gives indications on the cost of electricity from renewable energy up to 2030. In the figure on the right, wind power is shown to stay more expensive than coal or nuclear – or both – even by 2030. These numbers raise questions regarding the IEA data sources and cost estimate methodology:

- The IEA does not depict specific sources for these cost numbers. Therefore the data cannot be verified on a case by case ground.
- The IEA does not specify investment cost, interest rates, fuel costs or costs for waste disposal, emissions or decommissioning for these technologies.
- Learning curves within a variety of growth paths are not specified either. But growth rates and real experience with new technologies are a decisive factor for future cost levels in the case of relatively young technologies such as concentrated solar,

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[1] IEA World Energy Outlook2008 p. 164 and p. 154

photovoltaics or wind, in contrast to coal or nuclear. Instead, the IEA presents individual costs as intangible “black boxes” - not influenced by policy, but in reality the contrary is true.

- Then there is the life-cycle cost question: Capital intense power plants such as wind, photovoltaic’s, CSP or hydro tend to be more expensive in the first fifteen to twenty years than after. Once written off, the cost per kWh drops to the variable cost level, normally the cost of operation and maintenance. In the case of wind power a cost of less 1-3 Cents per kWh can be observed because no fuel costs play in. Depending on the life expectancy assumed for each power plant technology, huge cost reductions may result for wind and solar, not mentioned in the IEA 2008 Outlook.
- Finally, the IEA depicts coal and nuclear as ever cheaper than wind power. While this might well be true for older plants, questions arise if this stands true for new plants and for the future, considering recent price hikes and cost overruns for new nuclear power stations, for uranium and for coal, and an imminent shortage of coal projected by some experts when coal depending nations such as China are ever more relying on coal imports.

Even when we ignore these gnawing methodological questions, the IEA numbers are questionable even on pure data source grounds:

- Onshore Wind is rated by the IEA close to \$0.10/kWh, only slightly falling to some \$0.08/kWh until 2030. In the right figure wind power is seen as non-competitive with coal in the US or with nuclear in Europe and non-competitive with both (coal and nuclear) in China and India. In the US however, Wiser and Bolinger showed a wind power price as low as \$0.04/kWh in 2008 for a huge number of wind farms representing a combined 8303 MW. This is only half the cost indicated by the IEA and cheaper than coal, nuclear or natural gas.[1] If we include the Production Tax Credit paid by the government, a full cost of some \$0.055-0.063/kWh is more realistic for the first twenty years of operations, falling to \$0.01-0.02/kWh after, once the wind farm is written off.
- In China, the official minimum price is \$ 0.074-0.088/kWh, indicated by Windpower Monthly Magazine[2]. These feed-in tariffs are lower than the 9-10 Cents/kWh cost depicted by the IEA, and a dynamic expansion of Chinese wind power can be observed.
- If nuclear indeed would be as cheap as indicated by the IEA, why are investors expanding into wind power instead of nuclear or something else?
- And if a sudden drop in installations would overcome by 2016 – shouldn’t this lower installations prices because there would be a price war between wind turbine manufacturers who would need much less investments to finance sector growth, and therefore could live with lower revenues?

The IEA fails to revise its forecasts for renewable energies over the long run in recognition of rising fossil fuel and uranium prices and repeated cost overruns for new nuclear power plants. It clearly fails to strengthen its forecasts with transparent empirical data regarding actual prices of power plants, fuel and financing cost components. Instead, the IEA gives a contradicting and foggy picture of facts and the future that for many readers will seriously undermine the credibility of the report.

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[1] See chapter 7.

[2] Windpower Monthly Magazine special report: Opportunity and Risk in China, November 2008, p. 4

BTM Consult's world market forecasts

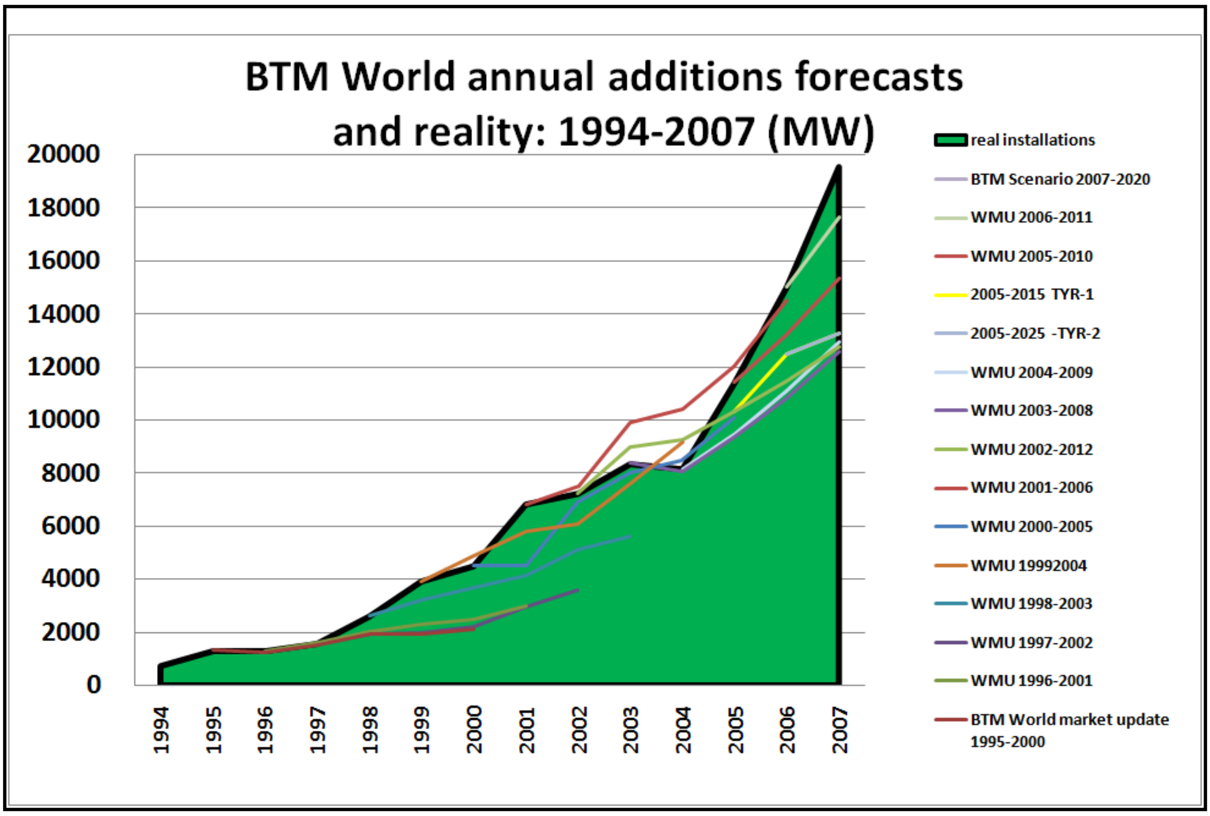

Figure 82 Annual installations and BTM 5-year-forecasts
Source: BTM Ten Year Review 2005/ Windpower Monthly Magazine

Date of forecast	Source	year forecasted	Forecast MW for that year	real installation in MW	reality better than forecast
1995	BTM World market update (WMU) 1995-2000	2000	2095	4495	115%
1996	WMU 1996-2001	2001	2990	6824	128%
1997	WMU 1997-2002	2002	3570	7227	102%
1998	WMU 1998-2003	2003	5590	8344	49%
1999	WMU 1999-2004	2004	9175	8154	-11%
2000	WMU 2000-2005	2005	10100	11407	13%
2001	WMU 2001-2006	2006	14500	15017	4%
2002	WMU 2002-2012	2007	12733	19553	54%

Forecasts ending after 2007					
Date of forecast	Source	Year forecasted	Forecast MW for that year	real installation in MW	reality better than forecast
2003	WMU 2003-2008	2007	12574	19553	+56%
2004	WMU 2004-2009	2007	12943	19553	+51%
2005	2005-2015 TYR-1	2007	13260	19553	+47%
2005	2005-2025 -TYR-2	2007	13260	19553	+47%
2005	WMU 2005-2010	2007	15349	19553	+27%
2006	WMU 2006-2011	2007	17630	19553	+11%
2007	BTM Scenario 07-2020	2007	17615	19553	+11%

Figure 83 reality check for BTM annual additions forecasts

Since 1995, BTM Consult, the renowned Danish market consulting company for wind power, every year carried out five-year-forecasts for the wind sector with some sporadic long-term scenarios. This forecasting was based – BTM declares – “on a retrospective approach using the lessons of experience” and it mostly followed a bottom-up nation-by-nation method.[1]

The five-year forecasts of BTM Consult were, despite their short-time horizon, mostly too low. **Real annual additions on average were 57 percent higher than BTM projections** in the World-Market-Updates (WMU) **ending in 2007 or before**.

The only exception exceeding slightly real installations was the 1999 WMU ending in the sluggish year of 2004. It gave an estimate of 9175 MW additions when real additions in that year came up 11 percent lower at 8154 MW. 2004 was the only year with declining additions compared to the year before.

BTM summarized its work that “the general experience both from BTM-C’s work on forecasting as well as others, is that the actual progress of wind power in the past ten years has exceeded everybody’s expectations.”[2] …“Neither BTM Consult nor other analysts in the industry could imagine in 1995 that the wind would progress as successfully as it has actually performed. The aggregate installed capacity has grown from 3531 MW to almost 48000 MW by the end of 2004.” [3]

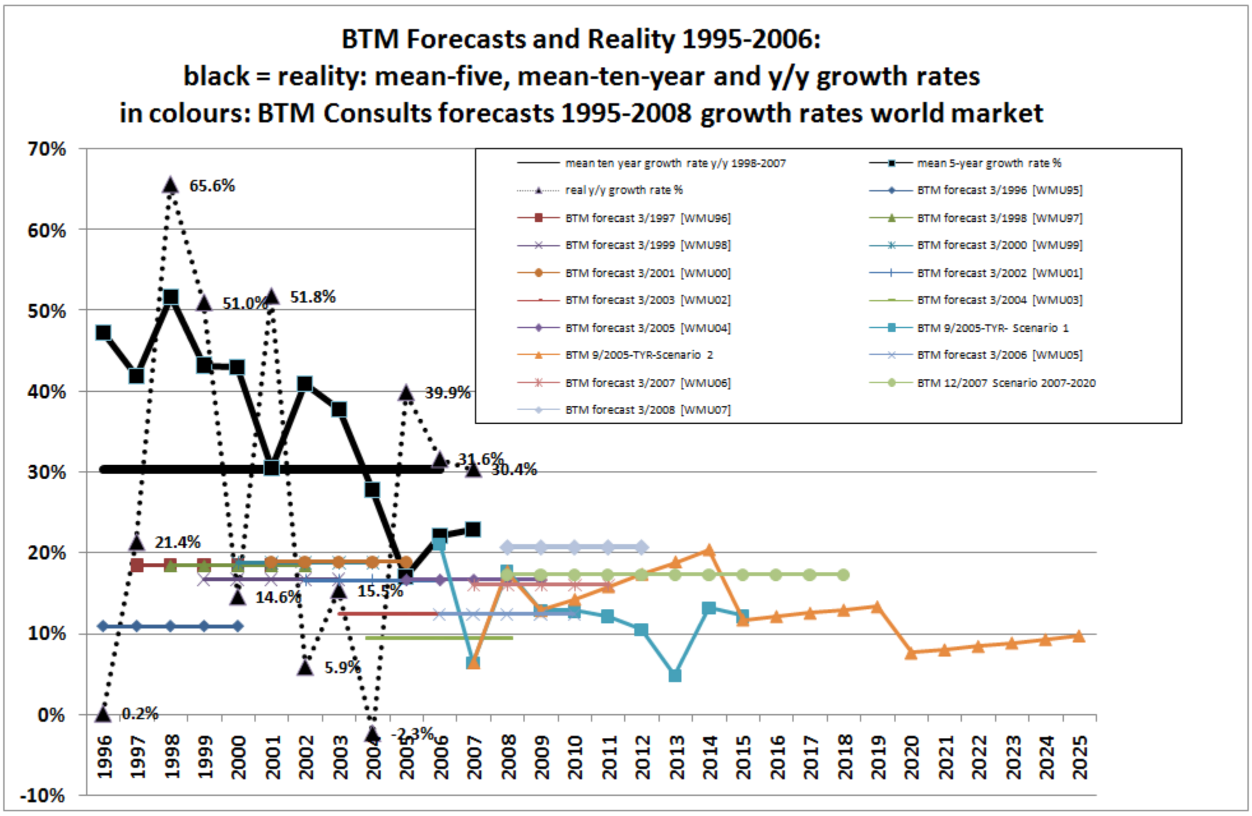

Figure 84 Growth rates of world annual additions: real growth (black) and BTM forecasts

BTM Consult’s record of being on the sure side of market forecasts might give a good feeling to investors – but for politicians and planners BTM’s advice is questionable. Planners in the power sector need a solid ground for security of supply. Planning of grid connections, storage facilities, exploration of new wind power sources and grid management therefore should be realistically conceived.

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[1] BTM: Ten Year Review 2005, 63

[2] BTM: Ten Year Review 2005, 63

[3] BTM: Ten Year Review 2005, 1

BTM Consult's method of communication with established suppliers of wind turbines might underestimate the emergence of newcomers – new wind markets and new suppliers of turbines and components. Year after year, BTM forecasts were exceeded by reality – but BTM still has not changed its method.

Wind industry's world forecasts

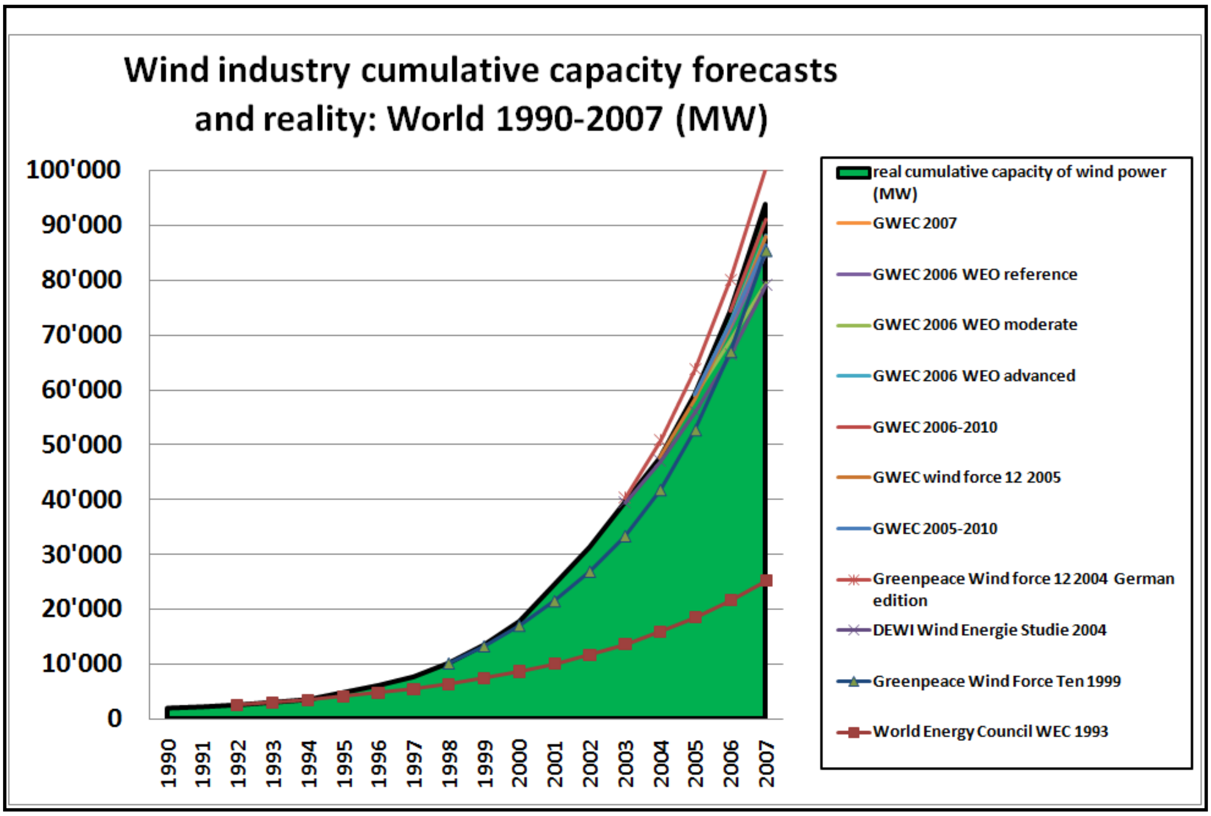

Figure 85 wind industry world cumulative capacity forecast and reality 1990-2007

date of forecast	Source	forecast 2007	reality 2007	reality better/worse than forecast
1993	World Energy Council WEC 1993	25128	93,881	+274%
1999	Greenpeace Wind Force Ten 1999	85407	93,881	+10%
2004	DEWI Wind Energie Studie 2004	79079	93,881	+19%
2004	Greenpeace Wind force 12 2004 German edition	100436	93,881	-7%
2005	GWEC wind force 12 2005	87883	93,881	+7%
2005	GWEC 2005-2010	86300	93,881	+9%
2006	GWEC 2006-2010	91000	93,881	+3%
2006	GWEC 2006 WEO reference	79510	93,881	+18%
2006	GWEC 2006 WEO moderate	84837	93,881	+11%
2006	GWEC 2006 WEO advanced	88080	93,881	+7%

Figure 86 Reality check for industry forecasts: world cumulative capacity

The wind power sector itself – and some NGOs accompanying the sector – was more successful in estimating the future than IEA and BTM Consult. Wind-force-10 and wind-force-12 reports edited by Greenpeace were quite precise in their outcome, predicting a **steady exponential growth of the global wind power capacities**.

On the other side, the World Energy Council (WEC) – a NGO with mainly coal, gas and nuclear interests – was not a good consultant in forecasting wind power. And Global Wind Energy Council (GWEC) in its recent studies shows high deviations from reality too, and always to the low side which – for a wind industry organization – is somehow surprising.

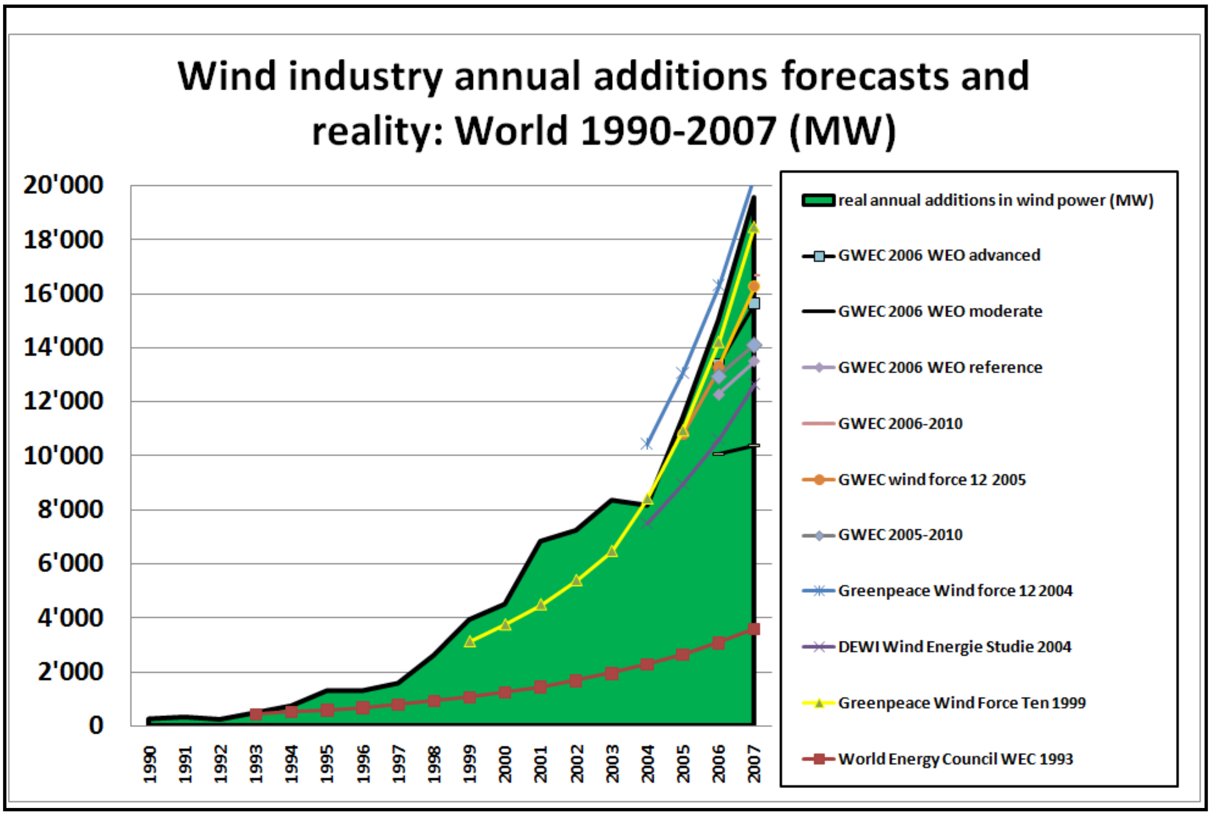

Figure 87 Annual installations and forecasts of the wind power sector 1990-2007

date of forecast	Source	forecast for 2007	reality in 2007	reality better/worse than forecast
1993	World Energy Council WEC 1993	3577	19553	+447%
1999	Greenpeace Wind Force Ten 1999	18478	19553	+6%
2004	DEWI Wind Energie Studie 2004	12626	19553	+55%
2004	Greenpeace Wind force 12 2004	20371	19553	-4%
2005	GWEC wind force 12 2005	16259	19553	+20%
2005	GWEC 2005-2010	14100	19553	+39%
2006	GWEC 2006-2010	16672	19553	+17%
2006	GWEC 2006 WEO moderate	10371	19553	+89%
2006	GWEC 2006 WEO reference	13493	19553	+45%
2006	GWEC 2006 WEO advanced	15631	19553	+25%

Figure 88 reality check for wind industry forecasts: world annual additions

The moderate approach of GWEC is illustrated in the annual additions expectations where most forecasts must be called pessimist. Reality even exceeded the very recent forecasts by 25 to 89 percent. It seems that GWEC did not have a much better methodology in predicting wind power’s success than others.

There is no surprise that reality was 447 percent better than the 1993 forecast by World Energy Council. The EWEA/Greenpeace 1999-Wind-force-Ten forecast was too moderate too, but has been exceeded by reality by 6 percent only, which seems a good result over a nine year forecast period. The only forecast of age that slightly exceeded wind market reality was the German Wind-Force-12-report by Greenpeace (2004). Its estimate for 2007 was 4 percent higher than reality, which as such seems to be a useful forecast too.

Outlook beyond 2007: World

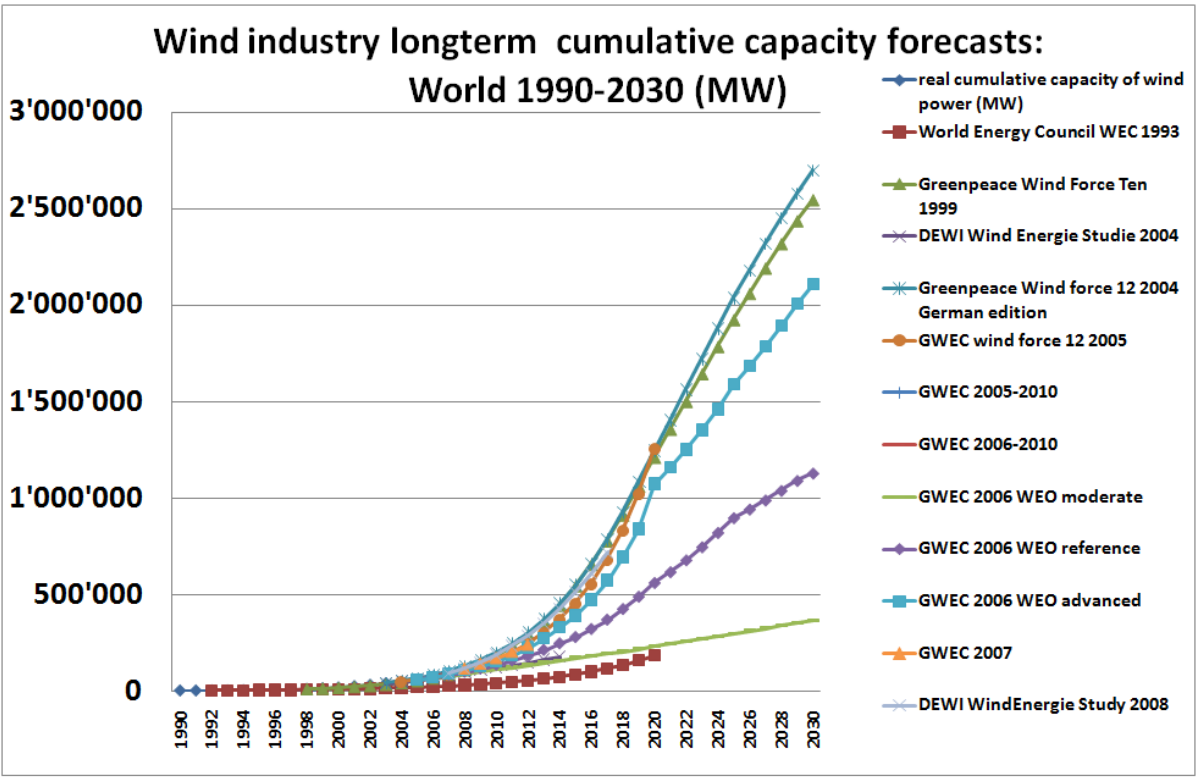

Figure 89 long-term wind industry forecasts cumulative capacity: World

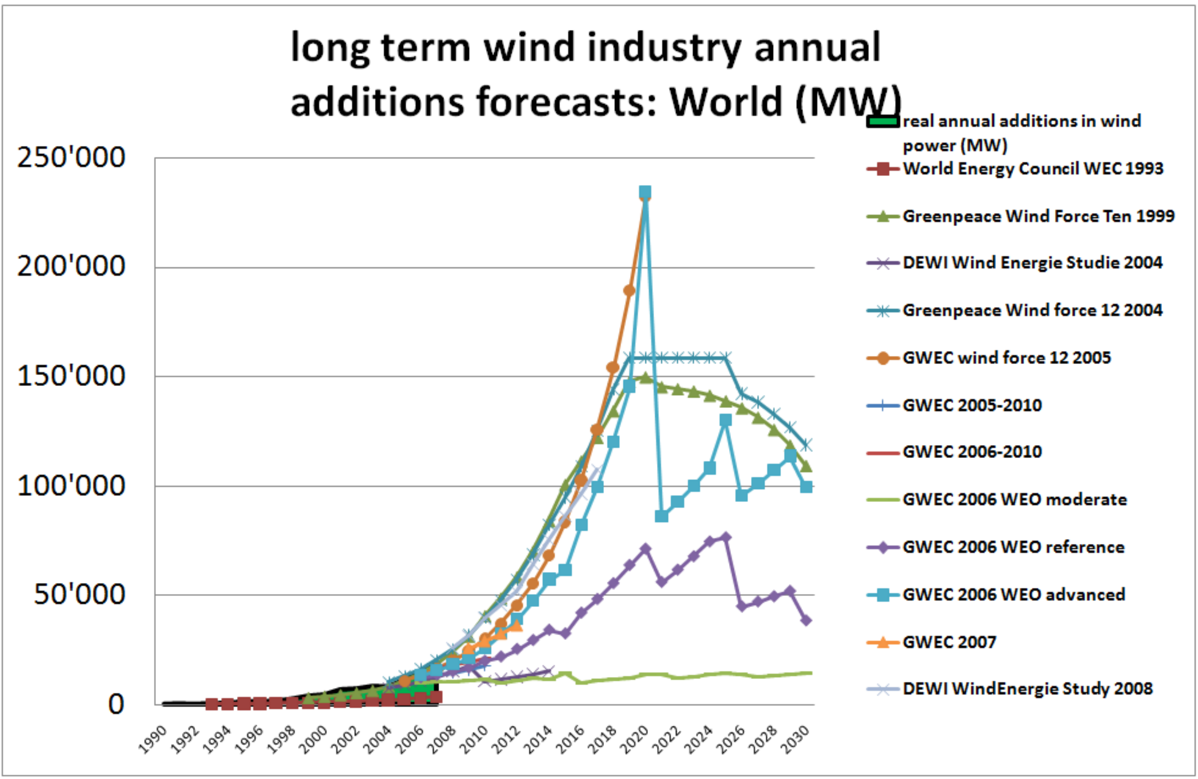

Figure 90 long-term wind industry annual additions forecasts: World

Concerning long-term forecasts of the wind industry, a variety of estimates can be found. They reveal that even some of the industry-near organizations repeatedly had to revise upward their original estimates. Some of these estimates meanwhile predict annual additions between 200 and 250 GW worldwide by 2020. But then, again, they reduce their annual additions after 2020.

The reasoning for such reductions, again, is not clear: Is it market saturation and if so – why should this be so? Are there technical constraints such as interconnection or grid management? Is there a resource problem with wind? Are cheaper technologies emerging, coal or solar?

Possible causes of stagnation

In any power system we expect that a any energy strategy can build up market shares depending on its price compared with other competitors. Wind power's price has steadily been falling over the past twenty years while cost of competing energy sources has gone up in absolute or relative terms. We therefore expect wind power to be able to satisfy a very large chunk of demand – together with other energy sources of similar low costs and low emissions, and some with the attribute to be of complementary character toward wind such as hydro, pumped hydro or stored concentrated solar. Demand for wind power will grow as long as a **number of conditions** are fulfilled:

- The presence of a viable wind resource (available sites > 4-5m/s wind speed)
- Sufficient social acceptance and public participation, minimizing NIMBY effects
- Manufacturers or importers offering turbines as requested
- No legal or technical hurdles for access to the grid
- A price covering the cost of power generation and a profit margin
- Capital available to buy wind turbines
- No unfair subsidies or market distortions in favor of competing power sources

So far, we cannot see any of these elements contributing to fundamental stagnation, despite interconnection bottlenecks over the short and mid-term. The relative cost of wind energy stays on the down slope compared to all other energies, and growth therefore is only limited by capacity constraints of the industry itself.

In 2007 and 2008, investments in new wind farms continued to boom and the main concern of the industry has been to resolve supply side bottlenecks. Heavy investments into the supply chain were observed though.[1] To ease these bottlenecks, huge facilities for manufacturing of turbines, nacelles, rotors, bearings, gearboxes and generators have been started, steadily coming online since. Capacity additions of 25-28 GW seem possible in 2008. For 2010, annual new installations of up to 32 GW were expected in early 2007[2], but an annual addition in the 45-50 GW-range is more probable in view of the recent US and Chinese gigawatt commitments to wind power.

Investments and installations of such a magnitude will influence the whole power sector, so a solid ground for planning of grid extension and extras should be communicated by institutions such as the IEA and GWEC and should be translated into grid additions by Transmission System Operators (TSOs).

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[1] Crispin Aubrey: Supply Chain: The race to meet demand, Wind Directions Jan/Feb 2007, 27-34

[2] Crispin Aubrey: Supply Chain: The race to meet demand, Wind Directions Jan/Feb 2007, 29

Meanwhile the “fact that there is no practical upper limit to the percentage of wind that can be integrated into the electricity system” is accepted at least by wind power experts. Therefore we should take another close look at past forecasts and comment on their outcome.

Comment on the German case of wind power forecast

Wind power developments are not a weather-related affair. Wind turbine outputs, unlike oil fields, do not grow and decline after time. Around each wind sector growth step, there is a constellation of resources, cost and price setting, and a market and interconnection environment.

The German forecasts of the 1990s clearly missed the wind reality in terms of forecasting accuracy. Reality in 2007 of cumulative wind capacity in Germany was an average 1575 percent better than the mean of six different forecasts published between 1990-2004, or 783 percent better regarding annual additions. The younger forecasts were somewhat better than the early ones, mainly due to the fact that there was a general slowdown of additions after the 2002 peak – with identified causes:

- Scarcity of wind site permits in the wake of wind-hostile policy action was one of the main reasons for the slow-down. Christian Democratic controlled State governments, such as in Baden-Württemberg, Bavaria and Hessen, for many years pushed a pro-nuclear agenda by systematically banning good wind sites from permissions to inherently create a ‘need’ for new nuclear plants.[1] This often happened against strong local majorities in communities where villagers asked for more wind installations and clean power. Many communities were banned by provincial governments from creating “Bürgerwindparks” (community wind farms),[2] a well organized top-down phenomenon, inspired by nuclear and (sometimes) coal addicted power monopolies.
- Growth of wind energy continued, however, in the northern and eastern parts of Germany, where ever bigger turbines were installed (2-5 MW size) and where nuclear power was less of a “religion”.
- A main cause for grid hurdles in Germany was the fact that grids have not been legally separated (unbundled) from power generating companies. Owners of coal and nuclear power plants were grid owners too and operators. They showed no interest in giving way for new independent power producers who, during times with high wind, were prone to force coal and nuclear plants to scale down their output.
- At times with strong winds therefore, wind power producers regularly had and have to scale down or stop their turbines for lack of grid capacity. This is a cause for repeated financial losses for the wind farmers. Additionally it banned the expansion of many new wind farms in Germany’s prolific northern regions.
- After 2005, the continuous reduction of feed-in tariffs by two percent a year, and additionally the lack of inflation-adjustment of these compensations began to bite. Copper, steel and turbine prices went way up on the world market and the market turned into a sellers’ market due to exploding demand. German wind turbine manufacturers shifted their supply to buyers from other nations who – backed by better feed-in tariffs or better wind sites – were able to pay more than German investors.

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[1] About the methods of the nuclear lobby against wind power see: Franz Alt, Jürgen Claus, Hermann Scheer: Windiger Protest. Konflikte um das Zukunftspotential der Windkraft

[2] For more details see Erneuerbare Energien: Baden-Württemberg kann mehr. Arbeitsgemeinschaft Erneuerbare Energien Baden-Württemberg, Stellungnahme vom 14.1.2008

Andalusia – similarities with Germany?

A temporary slow-down due to grid congestion and temporary political hostility was not unique for Germany. It happened in other places with early establishments and a later backlash. An example is Andalusia where after a first, powerful boom in the 1980s new capacity additions were blocked for years by persisting grid congestion.

After 2005, however the Andalusian government created special wind development zones (ZEDEs) and did extensive interconnection upgrading. A wave of new installation permits started in 2006, with a much higher penetration of homegrown wind power in sight. Local government officials now are prepared for 4800 MW of new wind installations by 2013, up from just some 600 MW in 2006.[1]

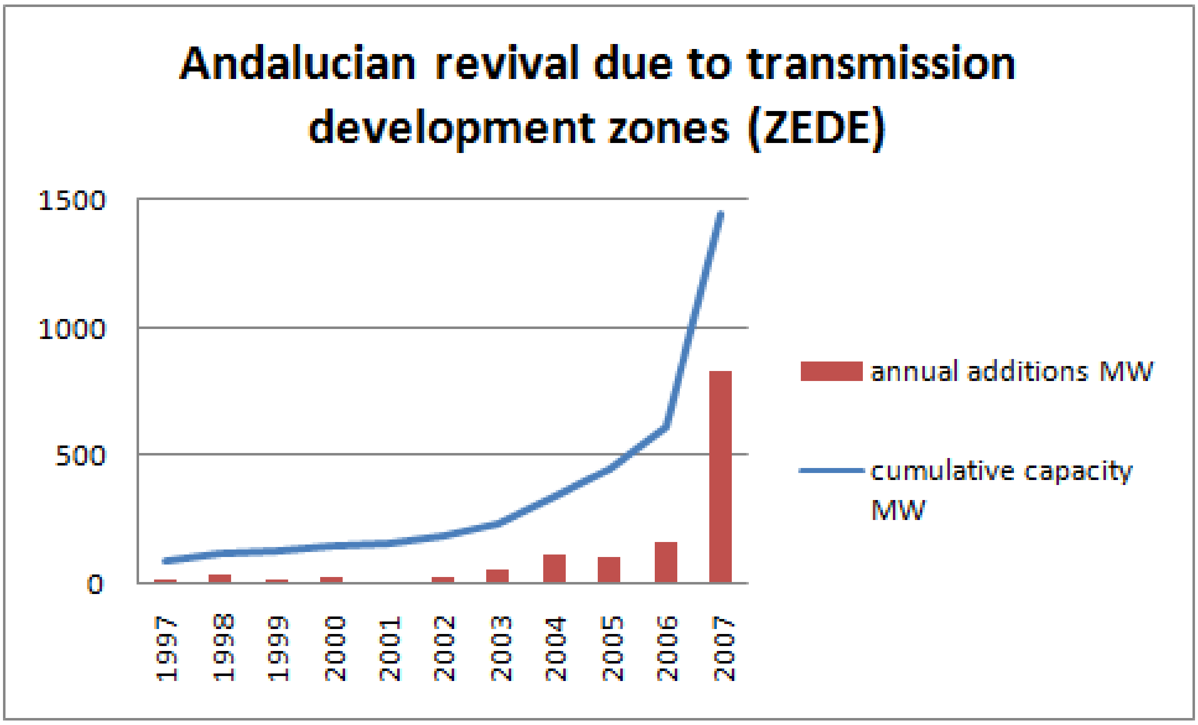

Figure 91 Grid bottlenecks caused ups and downs of the Andalusia wind market
source: Windpower Monthly 4/2008

In Germany, due to strong world demand for new wind capacities and high technical hurdles for offshore expansion, most wind companies decided to grow solidly onshore first.

But this could well change now. Big multi-megawatt machines (4-6 MW) are deployed at far-off sites offshore in 30-40 m depth and are in serial production since 2008. Better machines go along with better feed-in tariffs for offshore and a legal change in financing offshore grid connections, decided by German legislators in July 2008 will allow straight expansion.

There seems no fundamental obstacle for a new cycle of wind power growth in Germany:

- In the western and southern part of Germany (Schwarzwald and Bavaria), but also on the northern coast line and in the east, there are excellent onshore sites so far undeveloped. It is well possible that State governments revise their stand and find a more positive approach for tapping local resources, combined with better compensation for communities hosting wind turbines on their land.

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[1] Windpower Monthly Magazine4/2008 p.65

- Wind power today has a better financial performance compared to new gas, coal or nuclear plants, and a comeback of nuclear power in Germany looks ever more elusive.
- In the early 1990s, the very best places for wind energy were occupied by smaller, less efficient machines. So far – in 2008 – it was too early for most wind farms to replace older turbines with new ones, despite huge capacity additions possible. After 2010, a more intense repowering of existing sites is expected, and this could multiply wind production on older sites.
- In German coastal waters, there is a productive wind resource ranging from the shores of Eastern Netherlands to South Denmark in the North Sea and to Sweden and Poland in the Baltic Sea. Many companies are engaged in tapping this resource, with manufacturers opening shops for multi-megawatt machines on the German coast line.
- The fact that Germany by 2007 had no noteworthy offshore installations was on the one hand due to its specific geography and lacking grids. At the western coast most of the shallow area is within a sensitive natural protection area entirely banned for wind turbines (German Nationalpark Wattenmeer). The scarcity of shallow sites kept turbine manufacturers and investors away from offshore investment within German borders.[1] Instead, huge investments took place in British and Danish waters where easier places were available, financed in part by German utilities.

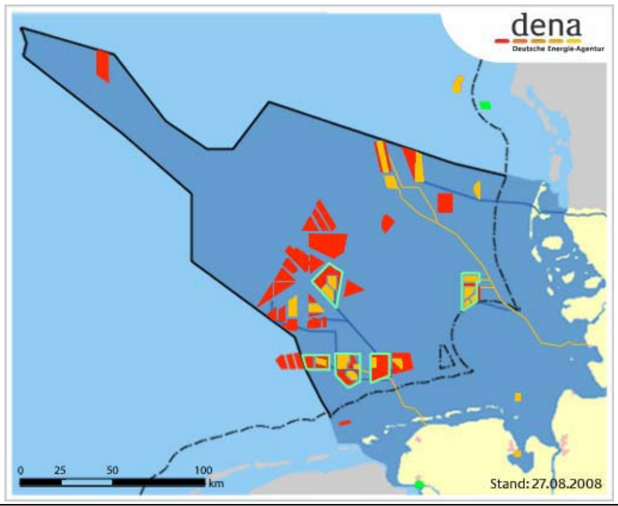	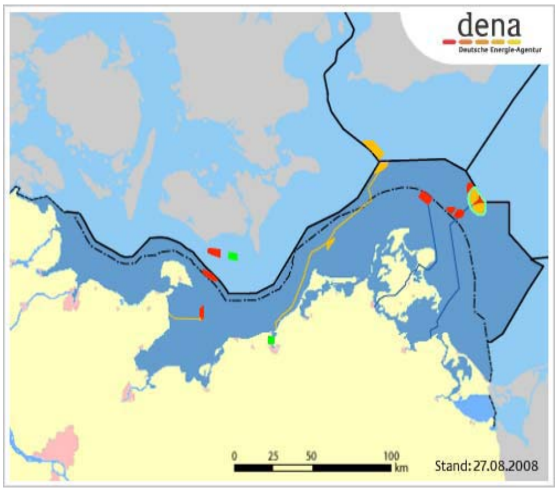
🟢 Wind farm Online 🟡 permitted 🔴 not yet permitted	🟩 Energy cabel online 🟨 Energy cabel permitted 🟦 Energy cabel not yet permitted 🟩 priority wind zones

Figure 92 German offshore wind sites as planned in 2008 source:dena[2]

Based on earlier experiences, one has to ask if the basically positive outlook of the German Bundesverband Windenergie (BWE) and DEWI could be as wrong as the forecasts of the early 1990s. An important question in Germany will be permission procedures for repowering projects and the speed of offshore development. If offshore emerges equally profitable as on

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[1] Obviously offshore projects required utility-size type of investors, and the German utilities did not invest for a long period. For most of the typical onshore investor funds offshore projects were too big to deal with. Butendiek, the only offshore Bürgerwindpark (community wind park) was sold to a big investor.

[2] Dena offshore wind site **http://www.offshore-wind.de/page/index.php?id=2620**

onshore, based on better wind speeds and better wind availabilities, offshore could be another very promising and affordable power source for Germany.

If successful, much more than 10 GW can be expected by 2020, and annual additions of 3 GW or more could be a reality soon – a number that onshore presented no problems in 2002. Such a boom could bring wind power's contribution to 50percent or more of German electricity consumption by 2020 or 2025. To compare this vision with actual forecasts, the 2008-DEWI forecast is reproduced here. In previous predictions, DEWI regularly was too pessimistic concerning onshore additions and too optimistic concerning offshore and repowering, but this could change over the next years.

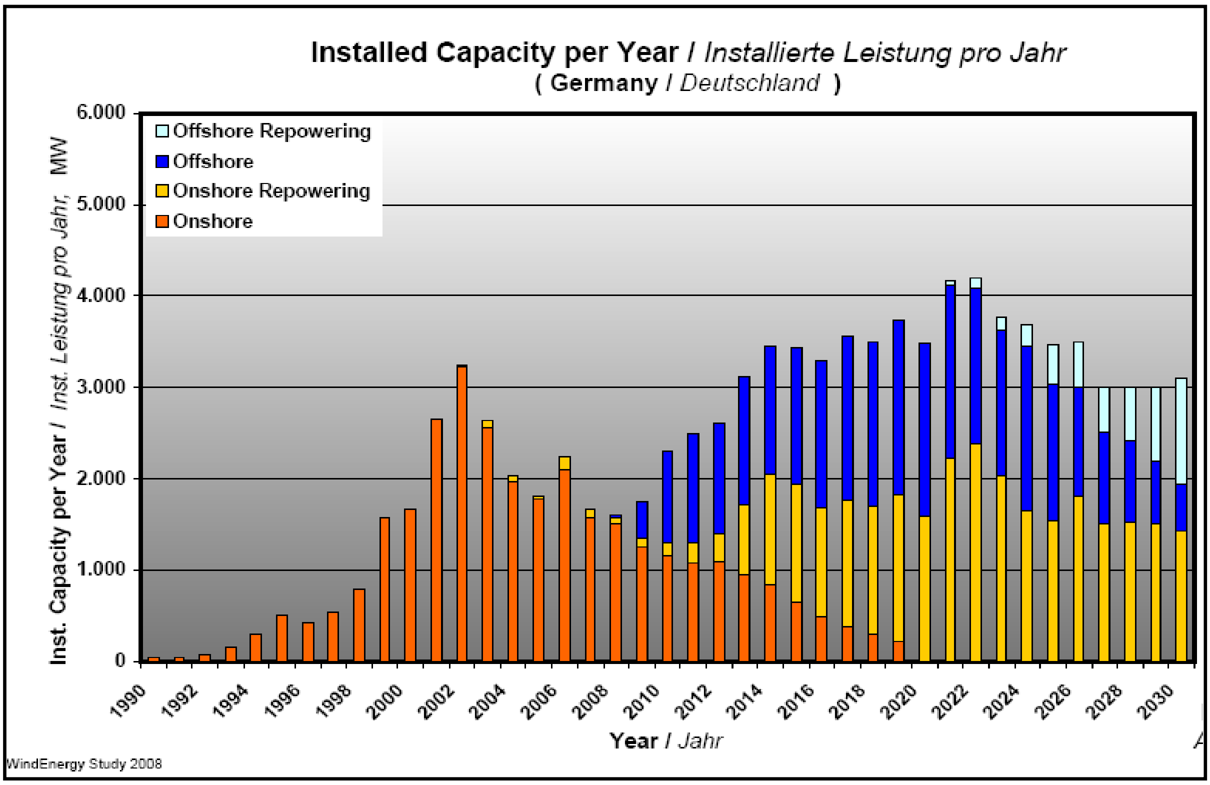

Figure 93 Market outlook for Germany by Husum WindEnergy Study 2008,written by German Wind Energy Institute (DEWI)[1]

The question on this chart from DEWI is: why should offshore wind additions – once routinely applied say, by 2012 – stagnate in the 1000-2000-MW range and drop off after 2022? On what terms could an addition of 3000-5000 MW per year be possible to create?

We finish the German analysis with the insight that even 20 years after the start of industrial German wind power, the sector still might bear surprises and open questions, which could reverse many business-as-usual forecasts.

Comment on European wind power forecasts

Most forecasts for wind power in Europe clearly missed the mark. Reality in 2007 of cumulative wind capacity in Europe was on average 153 percent better than the mean of ten different forecasts published between 1990-2004, or 376 percent better than forecasts based on annual additions.

Analyzing the European market we should keep in mind that we have a very unequal growth history due to "pioneer factors" that might disappear over time:

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[1] WindEnergy Study 2008 – Assessment of the wind energy market until 2017 **www.husumwindenergy.com**

- Before the 2005-2008 period, wind power was perceived as an expensive power generation. There was a lack of market structures in many countries that would have allowed investors to put their money into wind farms.
- Some core markets in Europe suffered from lengthy grid bottlenecks due to non-existent wind-integration policies or obstructive practices from grid owners/competitors.
- Wind power growth was concentrated in a small number of nations.

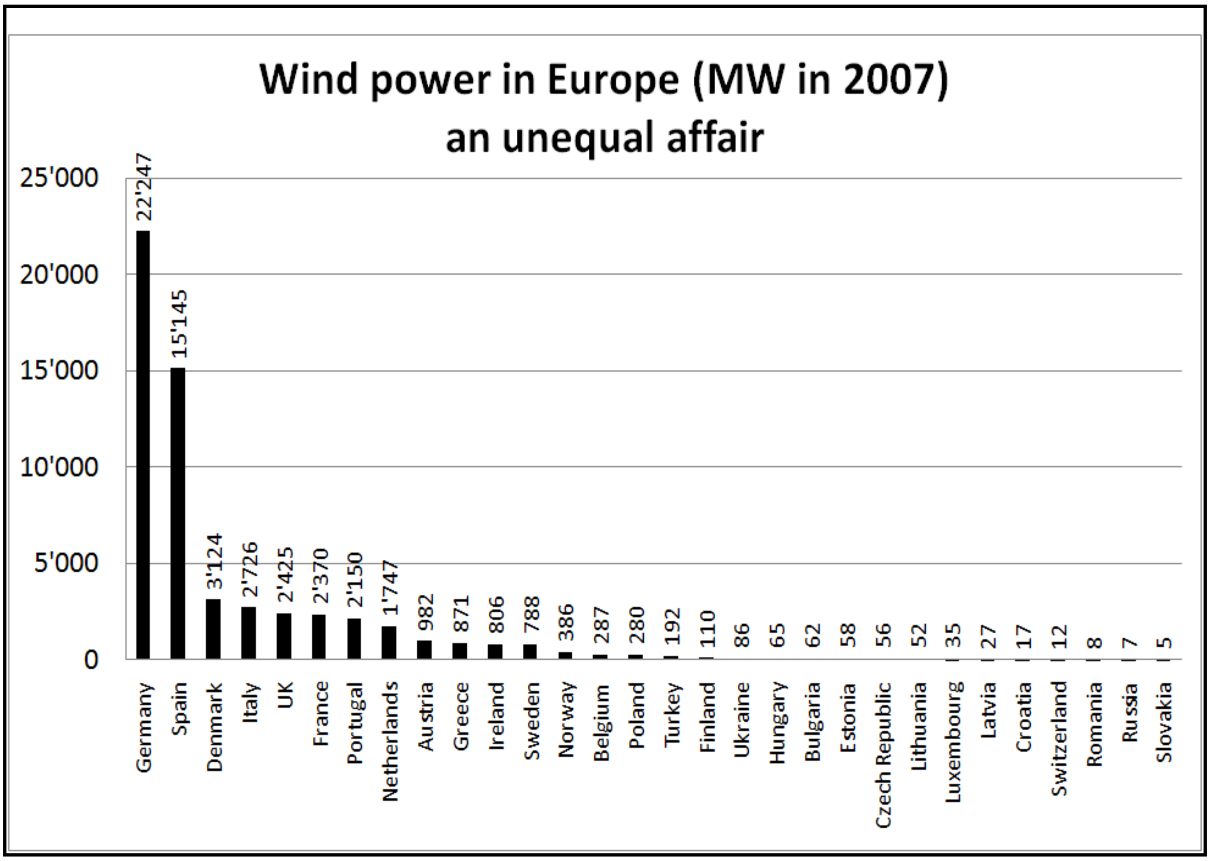

Figure 94 Wind power in Europe 2007: three nations covered 71 percent of all cumulative installations: Germany, Spain and Denmark[1]

- In the era before 2005, a general lack of serially produced offshore turbines was observed; there were many problems in the offshore sector including permission delays.
- The European grid is "balkanized". Wind-rich countries with less densely populated zones such as in Norway, Sweden, Portugal, or nations in Eastern Europe have not found sufficient market access so far to export wind power. The internal European market still suffers from gridlocks and bottlenecks in trans-national electricity trade. Power exchanges are growing, but they still make a rather small share of the overall market.
- From 2005 on, a high demand from abroad (US, China, Australia, Canada) – put a strain on the European supply chain. Demand for certain products such as gearboxes, bearings, rotor blades and else up to 2008 had to be satisfied mainly by European manufacturers. Overseas demand took crucial components from the European market

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[1] Data source Windpower Monthly 4/2008

and kept internal growth rates down. In the words of the BTM Consult Supply Chain Assessment from 2006:

> *"The assessment concludes that although wind turbine manufacturers are well prepared for high demand - demonstrated by the fact that the industry was able to cope with 40% growth in 2005 - the supply of vital key components is not able to keep up. These critical components, according to the assessment, are gearboxes, large bearings for gearboxes and the turbine drive train, and forged components for the main shaft, gears etc. This shortfall in supply is expected to last at least until the end of 2008. It is recognized in the assessment that huge efforts are being made to build up additional manufacturing capacity, particularly for large bearings and gearboxes. These efforts had already started in 2005-2006, but will take time to reach fruition. Those components creating bottlenecks for the wind power industry are mainly produced in Europe. An extension of manufacturing capacity is already under way in Asia, but turbine manufacturers located in the fast-growing markets of China and India will still have to depend for some time on European sources. By the end of 2008 the supply chain for wind turbine manufacture is expected to have reached a balance with anticipated demand. Future demand, however, is likely to be higher than previously expected by BTM Consult…"*[1]

So on the good side for the industry we might say that many of these negative factors mentioned – technical, financial support, grid and supply related barriers – have been eased or can be expected to ease until 2010.

- Wind is more and more perceived as a home grown, cheap and highly reliable, fluctuating resource. Creating one's own wind industry makes sense in terms of home markets and exports as well.
- With legal unbundling and independent system operators on the rise all over Europe, the speed of grid rearrangements and reinforcement is expected to grow.[2] Monopolistic abuse by competing power generation companies managing grids could decline.
- But supply constraints may persist due to the fact that wind power installations have a much higher value for investors in terms of more expensive fuel substituted than their actual cost of manufacturing.

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[1] BTM Press release International Wind Energy Development – Supply Chain Assessment 2006,December 2006, **http://www.btm.dk/Documents/SCA_press_CA.pdf**

[2] In its third liberalisation 'package' proposals unveiled on 19 September 2007, the Commission left member states with two options to complete the liberalisation of the EU gas and electricity sector:

- Forcing big energy firms to sell off their power transmission and gas storage assets in order to keep these activities fully separate from energy production ('Ownership unbundling'), or;
- allowing firms to maintain ownership of their transmission assets but leave their management to an Independent System Operator (ISO) responsible for taking investment and commercial decisions.

http://www.euractiv.com/en/energy/eu-states-oppose-unbundling-table-third-way/article-170048

Eight nations with mainly unbundled markets opposed the EU Commission: Austria, Bulgaria, France, Germany, Greece, Latvia, Luxembourg, Slovakia

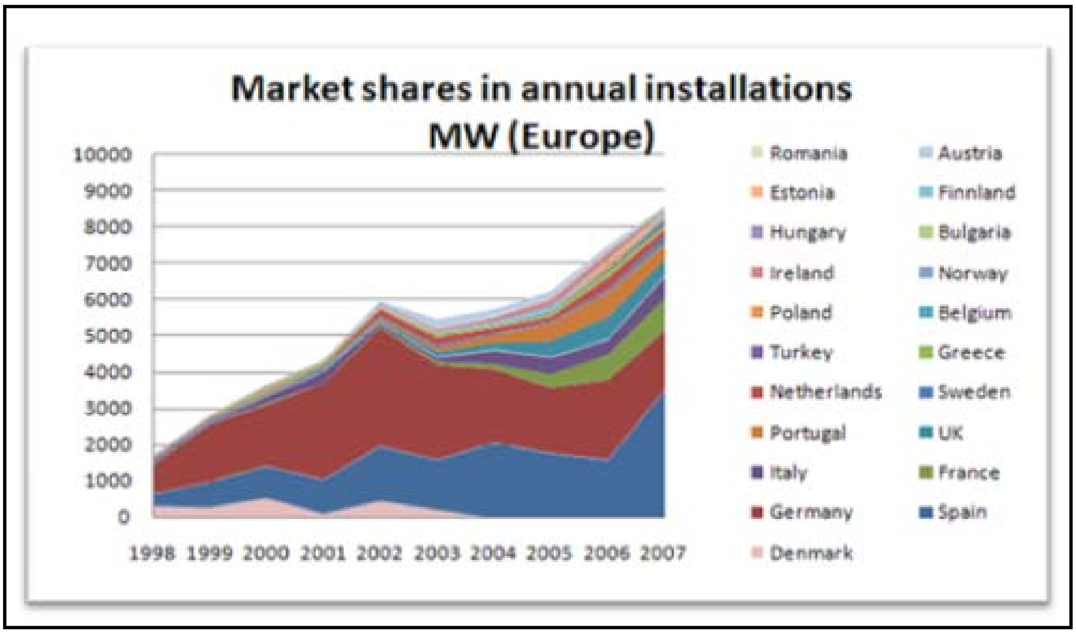

Figure 95: 20 largest markets in Europe 1998-2007, annual additions

After 2002, the number of wind additions outside of Germany, Spain and Denmark grew remarkably, and growth in more new territories is expected to come in much faster on the back of rising fuel prices for non-renewables.

A number of producers of wind power equipment for offshore installation, such as Vestas, Siemens, Gamesa, Repower, Areva/Multibrid and Bard, are ready for serial entry in the offshore market. Siemens has announced huge offshore expansion plans for Britain and elsewhere, and Vestas re-introduced its V90-3.0MW-offshore-machine in early 2008. A sharp rise of offshore installations can be expected in the 2009-2010 period and after. Europe is far ahead in offshore technologies, partially due to land constraints and lack of international interconnection. But the European Union now seems to have well understood the need for cross-border connections and coordinated action and has put wind farms and interconnection in the center of its most recent energy strategy.[1]

The wind industry itself, together with other renewable industries, has become a political factor in Brussels, and its contributions to exports and economic prosperity are perceived more positively than ever before. The European Union has released a number of obligations regarding renewable energies and carbon reductions.

Once the economic logic of high oil and gas prices matches the idea of wind power we can expect the European wind market to achieve much higher additions than in the 2005-2007 period, leading to double-digit levels of wind penetration never reached before.

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[1] http://ec.europa.eu/energy/strategies/2008/doc/2008_11_ser2/strategic_energy_review_memo.pdf

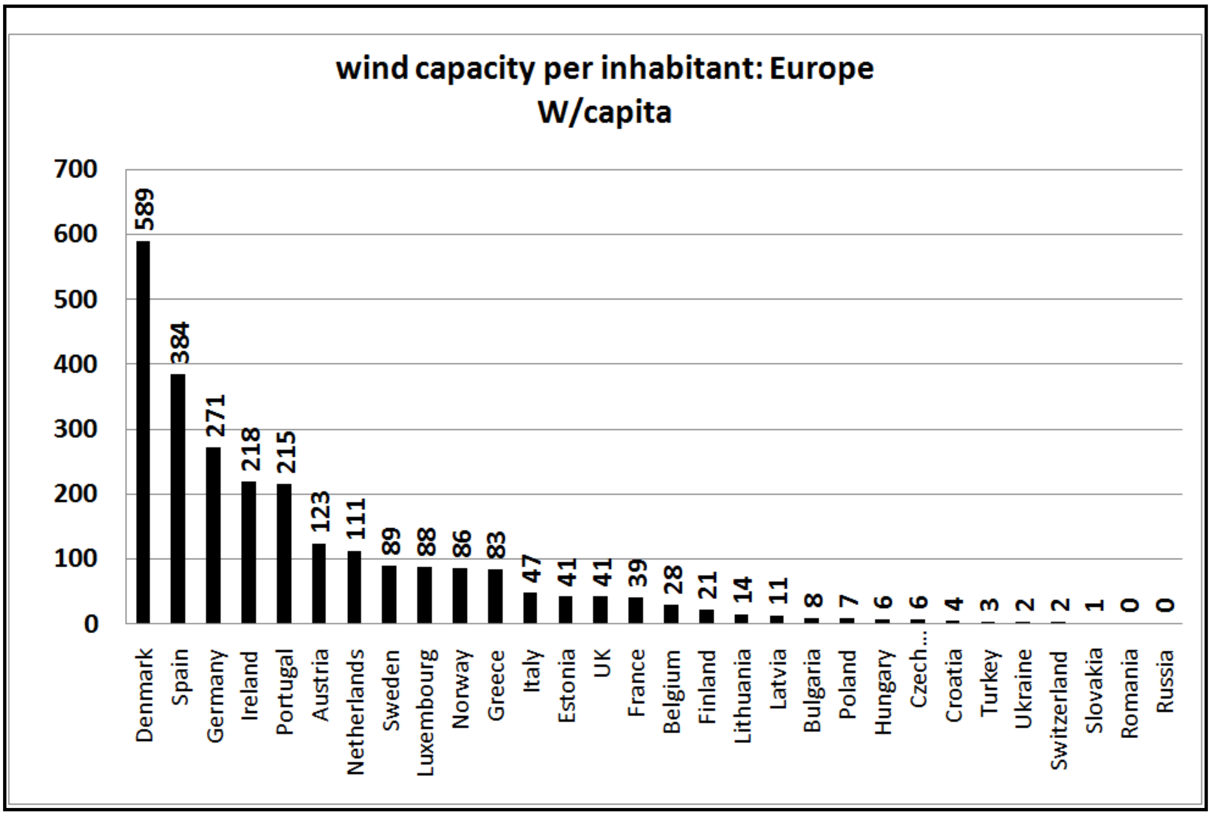

Figure 96 wind power capacity per inhabitant: Europe

With Germany, Spain and Denmark, some of the most densely populated areas have built highest wind penetration levels. There are many nations in Europe with vast areas and a low wind power penetration.

Once these less populated areas start to show the same penetration per person or per area (km^2), wind driven electricity will be a first class energy export commodity within Europe, and a boom for additional services such as interconnections, reserve capacities and pumped hydro peak power can be expected. In Switzerland, for example, huge investments have already started, with more than 6 GW additional hydro and pumped hydro capacities in planning or construction stage.[1] For Norway, similar developments are visible, including better connection to the European mainland.

Comment on the world market forecasts and IEA practices

The forecasts for wind power worldwide clearly missed the wind reality.

Source forecasts 1990-2004 on wind power	real capacity better than forecast (mean)	Number of publications
Forecasts by International Energy Agency (IEA)	162%	7
Five-year forecasts by BTM Consult	19%	9
Forecasts by power industry NGOs (Greenpeace, DEWI)	74%	3

Figure 97 forecast error on cumulative capacities, publications 1990-2004

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[1] In Switzerland an additional power capacity of 6 GW projected or in construction as an answer for higher wind penetration and 14 GW by hydro or pumped hydro is perceived to be viable. See: Rudolf Rechsteiner: Management of Renewable Energies and Storage Systems – The Swiss Case World Council for Renewable Energy and EUROSOLAR: First International Renewable Energy Storage Conference (IRES I), Towards energy autonomy with the storage of Renewable Energies, October 30 and 31, 2006 Science Park Gelsenkirchen/Germany http://www.rechsteiner-basel.ch/uploads/media/Renewable_energy_and_storage__The_Swiss_case.PDF

Source forecasts 1990-2004 on wind power	Real capacity additions better than forecast (mean)	Number of publications
Forecasts by International Energy Agency (IEA)	**417%**	**7**
Five-year forecasts by BTM Consult	**57%**	**9**
Forecasts by NGOs (Greenpeace, DEWI)	**162%**	**3**

Figure 98 forecast error on annual capacity additions, publications 1990-2004

As a branch of the Paris based Organization for Economic Co-operation and Development (OECD), it is financed by taxpayers working on "energy security" and should therefore be, one could believe, somewhat independent from energy lobbies. Not so. Among all publications. the International Energy Agency (IEA) by far is a leading issuer of faulty predictions.

The highest ever growth predicted by IEA was published in the 2007 World Energy Outlook Alternative Case. Following those numbers, a compound average growth rate (CAGR) of 7.05 percent can be assessed for new installations until 2030. Until 2006, the actual ten-year mean growth rate for annual installations stood at 29.5 percent.

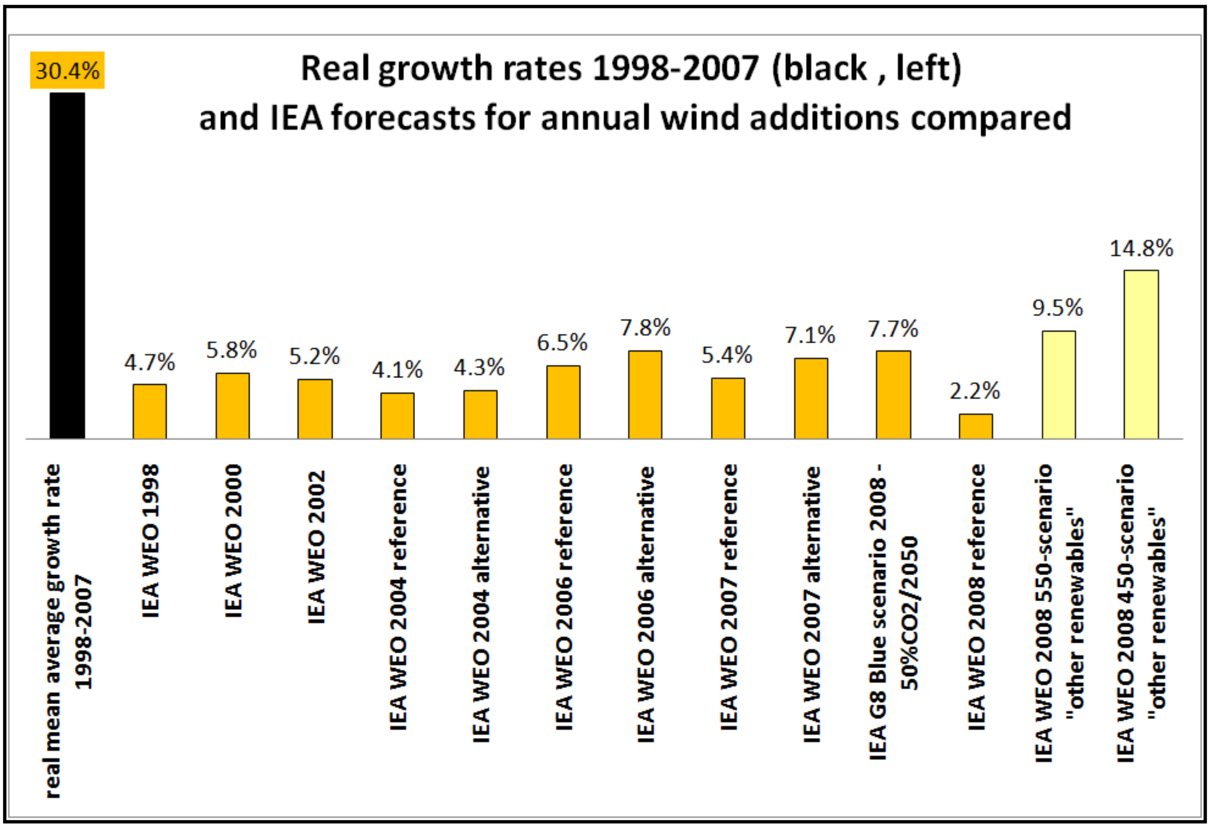

Figure 99 real wind power growth rates and growth rates expected in IEA forecasts

IEA experts seem reluctant to analyze properly the motivations for investments into wind power capacities. The Global Wind Energy Council (GWEC) complained in 2006 about this attitude because "*In Europe, wind energy has already developed into the second largest electricity generation technology, in terms of installed capacity, after gas [….]. In terms of new capacity, wind is already mainstream, which should be reflected in the WEO.*"[1]

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[1] GWEC Position Paper on the IEA World Energy Outlook 2006, p. 1

GWEC continued:

> *"For the USA, wind energy already now is competitive with gas, even without the Production Tax Credit (PTC), and will be competitive with coal in ten years' time (Platts). Thus, in the 2010-2030 timeframe, development similar to that which has occurred in Europe is expected in the USA and other regions. […] [GWEC-] scenarios show that wind energy is likely to make a much greater contribution towards satisfying the global need for clean, renewable electricity within the next 30 years than anticipated by the International Energy Agency. […]*
>
> *Under the WEO Reference Scenario, the share of wind energy in electricity production grows from around 0.5% in 2004 to 3.5% in 2030, and even under the Alternative Policy Scenario, this share would only rise to reach a share of 4.7%. […] GWEC projects that as much as 29.1% of the world's electricity needs could be met by wind energy by 2030…*
>
> *The development forecast by the WEO 2006 in sources of electricity generation capacity runs contrary to the markets' and politicians' responses to the climate change and security of supply concerns.."*

As part of the World Energy Outlook 2006, the IEA published another "alternative policy scenario" which focuses on nuclear and large hydro. "*There is no evidence of this path in energy markets around the globe*", commented GWEC. And in terms of technology choice the "IEA Alternative Scenario" is not an alternative one. A big part of communication by the IEA in these WEO Scenarios include policy measures for expansion of nuclear energy 'under discussion' in Russia, China and India. No one really knows if these plants ever will be started. On the other side, the IEA is tacit on discussions such as the Renewable Energy Portfolio Standard (RFP) in the United States or the European Parliament's adopted resolution to have renewables provide at least 20-30 percent of the EU energy mix by 2020 and 50percent by 2040 which means that in the electricity sector the renewable share would have to grow far beyond 30 percent.

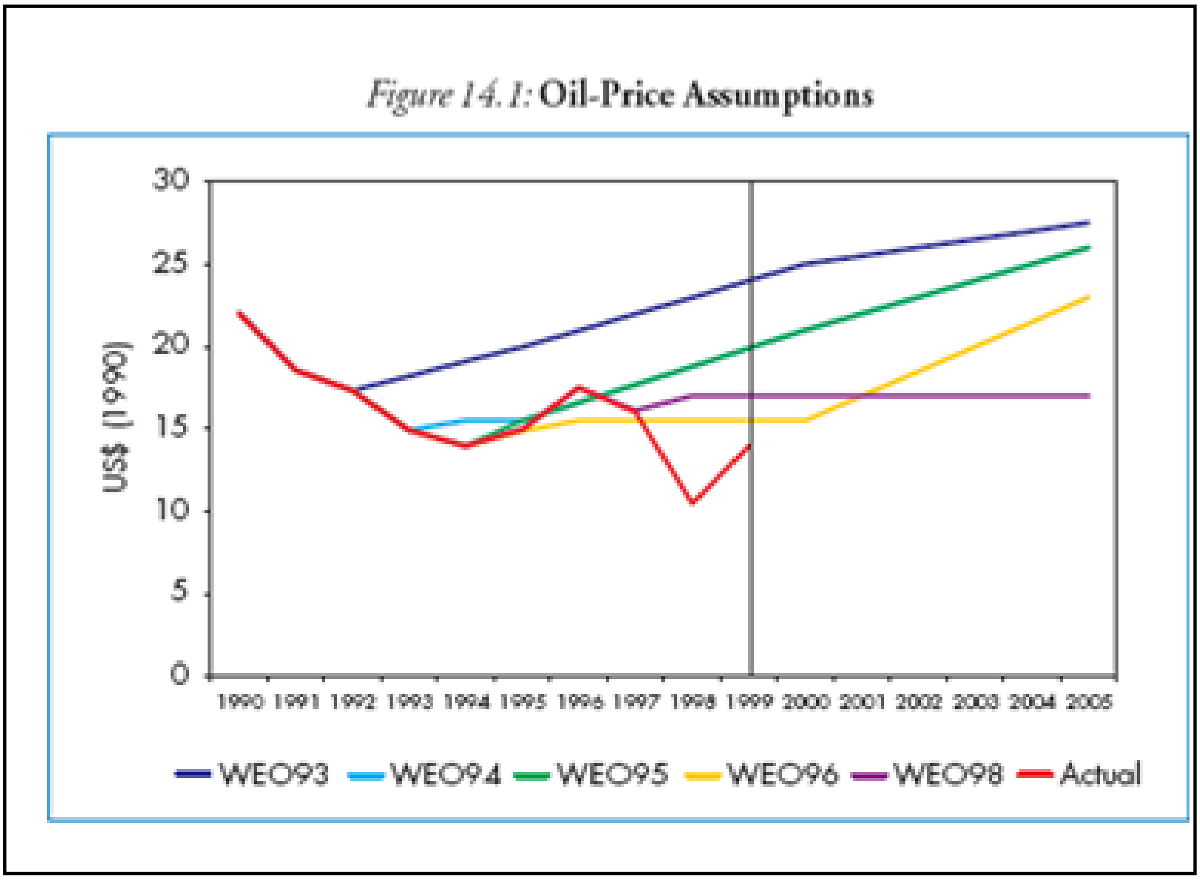

Figure 100 Oil price assumptions of International Energy Agency (IEA) 1993-1998 (price per barrel of oil) source: IEA World Energy Outlook 2000, p. 48

The selective information and misleading forecasts on wind energy do not stand alone. In its most prestigious and widely cited periodical, the World Energy Outlook (WEO), the IEA repeatedly forecasts a continued growth of oil, gas and coal supply at very low prices. These forecasts proved to be correct during the 1990s, but turned out to be completely wrong after 2000.

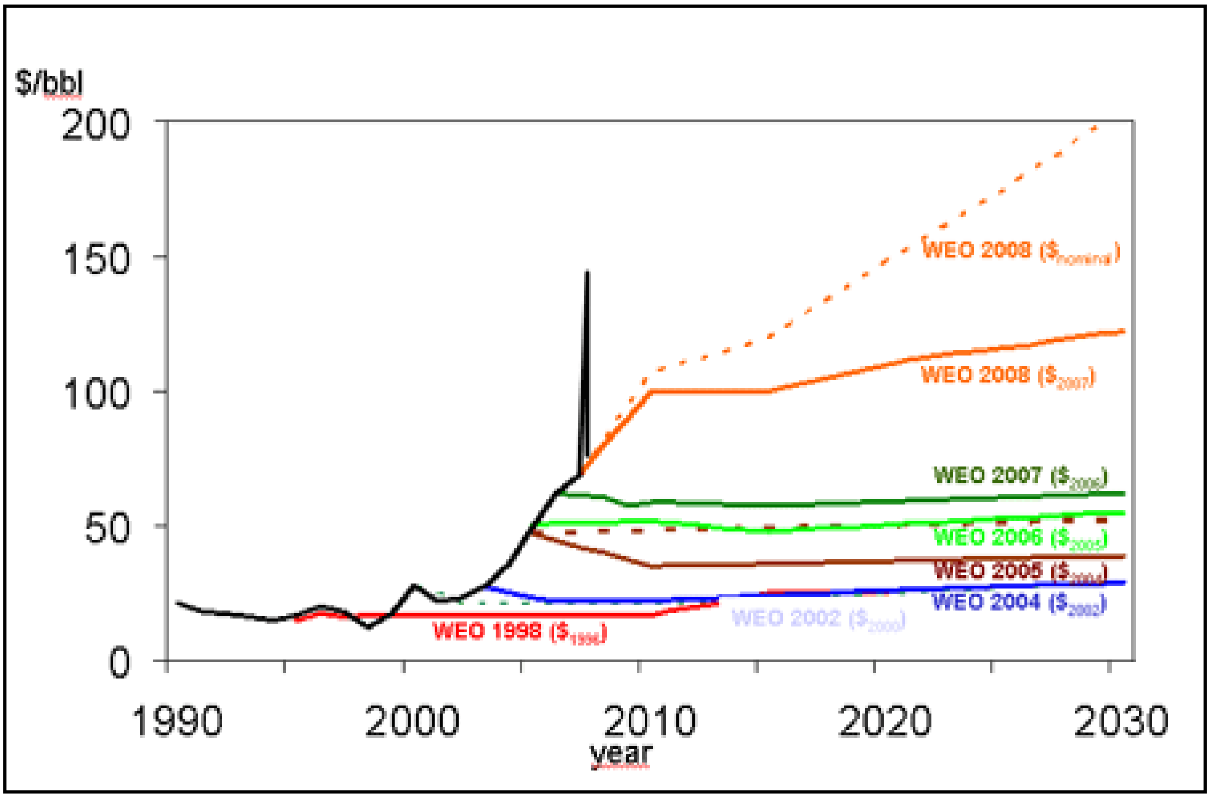

Figure 101 Oil price forecasts of International Energy Agency (IEA) 1998-2008 and oil price (black)
source: IEA World Energy Outlook editions 1998-2007[1]

In the 2002 World Energy Outlook, the IEA revealed: “The oil supply projections of this Outlook are derived from aggregated projections of oil demand…. Opec conventional oil production is assumed to fill the gap.“[2] The IEA methods of predicting are not based on facts such as resources and decline-analysis of existing fields but on wishful thinking and technology biases.

High IEA officials regularly demonstrate a behavior of neglect or ignorance toward renewable energy.

To give one clear example experienced by the author: On 8 September 2003, the deputy director or the International Energy Agency, Mr. William Ramsay, was a guest of the Swiss Parliament Energy Committee in Bern/Switzerland. His report denounced renewable energy as being too expensive. He criticized that “renewables still get 40 percent of the Swiss Energy Budget” and he counseled Switzerland to reduce these contributions.

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[1] Source: World Energy Outlook, various editions, compiled by Werner Zittel and Jörg Schindler, Ludwig Bölkow Stiftung LBST

[2] World Energy Outlook 2002 p. 95

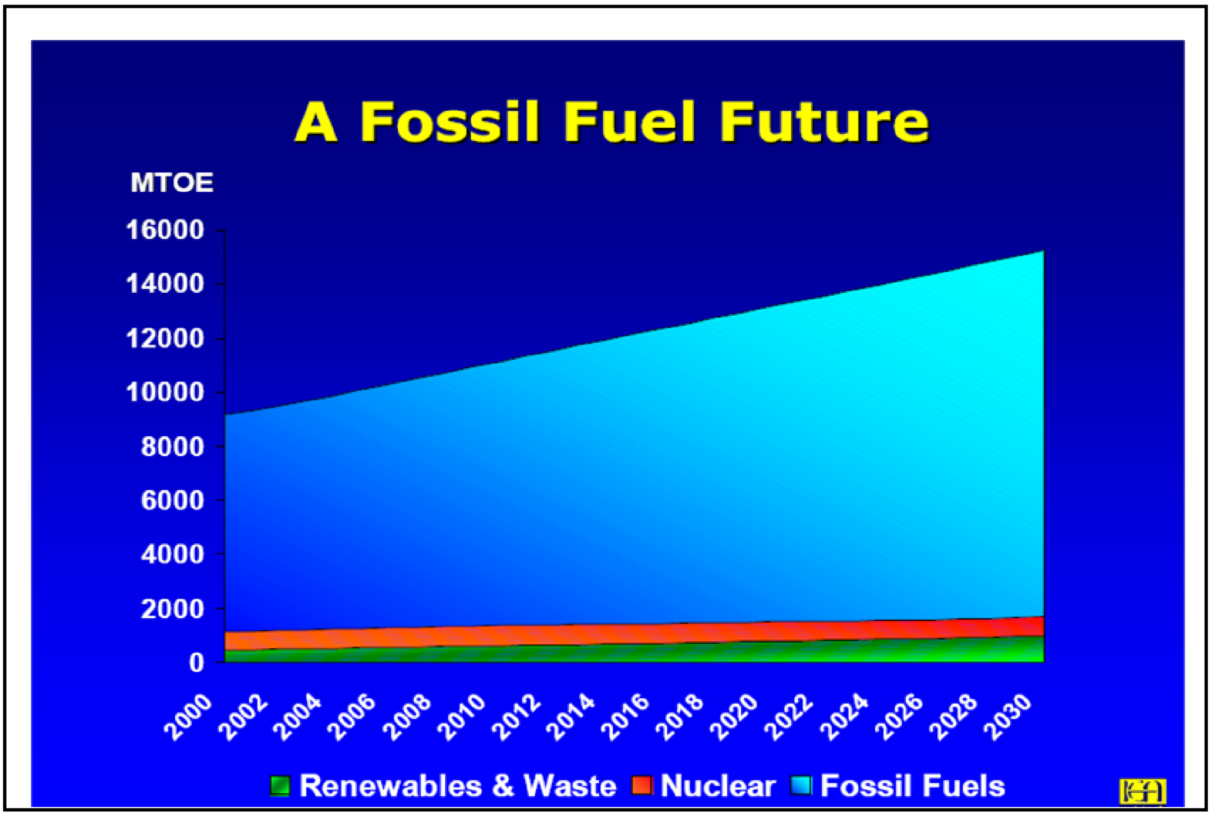

Figure 102 The long-term energy vision of IEA deputy chief William Ramsay (2003)[1]

In the world of the IEA, deputy director ever-cheap oil, gas and coal would dominate the market (see chart). Wind power was considered to be a marginal, non-profitable power source and this attitude has implicitly been expressed in all IEA Outlooks for many years.

Methodologically, the IEA is repeating every year the same mistakes: No proper resource analysis for wind power, oil and gas, no proper market analysis, ignoring long-term benefits such as absence of costs and fuel cost risks, over-optimist resource and price assessments of fossil and nuclear power sources.

It might be elusive to teach IEA anything on wind power. The best way to achieve better data and forecasts on renewables may be founding a better one such as IRENA, the International Agency on Renewable Energy, advocated by German member of Parliament Hermann Scheer and by the German coalition government.

Fundamentally positive world perspective

On a world basis, the perspectives for wind power are much better even than for Germany or for Europe due to the very rich resource found in many places such as the US, Russia or China. Advocating fossil and nuclear technologies based on faulty forecasts comes at a cost,

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[1] William Ramsay: Bern Parliament Presentation, 8 September 2003

including delays in interconnection, wrong incentives for oil, gas, coal and nuclear investments instead of renewables, and a lack of understanding of these benign technologies.

6. Key drivers of future growth

“When you look at renewables, there’s nothing better than wind today on a cost basis, and we believe that’s going to be the case for quite some time”, declared Victor Abate, Vice President of General Electric’s Renewables division at the European wind energy conference 2008 in Brussels.[1] There is a range of drivers who can explain the success of renewables in general and of wind specifically.

It is the simplicity of wind power and ongoing innovations in using the resource. There are many technical innovations going on that all in their specific way continue to push down the costs and tap into new potentials which before were not perceived viable:

- Innovations improving wind power generation technology
- Innovations improving the availability of wind resource
- Innovations improving system benefits
- Innovations from complementary power services such as smart grids, advanced reserve capacities and better weather forecasts

Innovations improving wind technology

Better blades

A consequence of the rapidly growing market is a virtuous cycle of technological improvement driving wind-generated electricity towards a cheaper-than-coal solution. The first turbines were cobbled together from components intended for ships and tractors. Now the engineers are borrowing from aircraft design, using sophisticated composite materials and variable-geometry blades to make those blades as long as possible (bigger is better with turbine technology) and as smart as possible. A blade that can flex when the wind blows too strongly, and thus “spill” part of that wind, is able to turn when other, less flexible turbines would have to be shut down for their own safety.

Some experts believe that nowhere near all the potential has been realized from improving the aerodynamic qualities of blades. The financial appeal is seducing: An improvement of just 3 percent in performance would basically finance the whole wind farm.

One way to a higher degree of efficiency is provided with bigger blade depths. Such new rotor blades are used by German wind manufacturer Enercon when they radically revised their blade design. Improvements include ‘winglets’ at the blade tips to inhibit turbulent flow, a more optimum profile between tip and root, slimmer outer blade sections and a major deepening of the blade root to improve energy capture near the turbine’s nacelle.

The measured aerodynamic efficiency of the resulting Enercon E33 blade, claimed by the company to be at 56 percent, is within striking distance of the 59.3 percent figure calculated by German physicist Albert Betz as being the maximum amount of the wind’s energy that a turbine could ever capture. Enercon questioned Betz’s calculations, dating from the mid-1920s, and used computational fluid dynamics to better model the conditions blades actually experience. “*As a result, it was able to improve the blade aerodynamics that turbine rotational speed could be reduced by five percent even while yield was improved (also by five percent). Reducing rotational speed cut the acoustic signature by 3dB – effectively halving the perceived noise. Reduced operating loads consequent on the improved dynamics enabled the diameter of Enercon’s 30m rotor to be increased to 33m for the same drive train and hub. The*

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[1] EWEA: Wind Directions, April/May 2008 p. 44

resulting greater area swept by the rotor is said to translate into a 25% improvement in yield." [1]

Another important change to the blade design by Enercon and some other turbine manufacturers will make transport easier. Some parts can involve the need for both police escorts and the temporary removal of "traffic furniture" – signs or bollards, for example. The Enercon E-126 blade is split into two parts, a shorter steel section connected to the rotor and a longer end section of glass fiber reinforced plastic. This means that the delivery process for the big E-126 turbine is similar to that for the much smaller E-82.

Turbine up-scaling

The up scaling of wind turbines has improved the cost-effectiveness of wind power. Bigger projects can be accomplished with fewer individual turbines. This also has an influence on landscape protection. For the human eye, it is not easy to distinguish a standard 1.5-MW-machine from a standard 2.5 MW or 3 MW machine, with rotor radius differences sometimes only at 6-12 meters. With fewer and slower rotating machines on the landscape, the number of installations can be reduced which in more densely populated areas can be helpful for consent.

Higher and cheaper towers

In many onshore locations a rise in turbine productivity is observed with higher towers. As a rule of thumb, a one meter additional elevation of the turbine's nacelle can bring an increase of 0.5-1 percent in output per year. A scaling-up of tower heights can be observed specifically in places with moderate wind speeds.

Experimental towers go beyond 110 meters. A prototype with a 90-meter rotor was erected during the middle of September 2006 on a 160-meter lattice-type tower near the village of Laasow, 150 km south east of Berlin. According to Fuhrländer, the machine during the first year of operation generated 30 percent more electricity compared with a similar installation on a 100 meter tower.

Additional innovations are observed with advanced concrete-steel hybrid towers that can mitigate higher steel prices.

New turbine designs

Most manufacturers offer variable speed turbines in the 2-3 MW size for bulk power. Behind the curtains a number of new turbine designs are under development.

Compared with figures from 1996, the costs of power electronics have fallen by a factor of 8-10, according to wind industry sources. The smaller frequency converter with the so-called "doubly fed induction generator" (DFIG) technology still is said to deliver an optimum system. DFIG has around 85 percent world market share, but a number of companies are developing new approaches. US-based wind company Clipper developed a gearbox with multiple generators, German Multibrid is pushing its slow-speed type drive solution with a single-stage gearbox, and German Enercon is selling direct drive technology with no gearbox.

A number of companies are introducing permanent-magnet type generators. With permanent field excitation, there is no need to generate the direct current normally required for field excitation, which results in a slightly higher partial load efficiency. Other advantages are better encapsulation for offshore and less maintenance costs due to elimination of gearboxes. Potential disadvantages are the loss of the field current strength control variable, a more

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[1] George Marsh: Patently innovative, Imagination in wind turbine technology continues to flourish, Renewable Energy Focus, 29.3.2007 p. 30-33

complex assembly and disassembly process, and the high cost of the neodymium (NdFeB) ferromagnetic material.[1]

More technical innovations can be expected with the introduction of superconductor technology – a field of intense research.

A large share of current design activity is dedicated for new wind turbine designs on behalf of Chinese manufacturers. Many companies are active in this field, including AMSC Windtec, REpower, Aerodyn, Vensys and Garrad Hassan.[2] The German Aerodyn company offers turbines specially adapted to specific local conditions. 'An example of design adaptations is dealing with large differences in operating temperature between summer and winter, or mechanically coping with sand storms in harsh desert conditions.' Other local industrial challenges Sönke Siegfriedsen mentions include the non-availability or limited availability of high-strength steel and/or high quality cast components in some regions of China. Such limitations require specific wind turbine design solutions and adaptations to meet local conditions and constraints.

Small wind systems

Small wind systems are enjoying a particular boom in China. A number of some 30 manufacturers are reported to be selling models with a capacity range from 100 W to 20 kW. By the end of 2006, the cumulated output of these turbines was estimated to have reached 51 MW in China. Turbines are used mainly in areas without road access and a low electricity demand, thus making grid extensions uneconomical. The output of these machines is reported to increase year by year, with the most common model to have passed from 100 W to 300 W, and with a growing share of 500-1000 W machines as a general trend. Collectively owned machines with hybrid systems wind/PV or wind/diesel are on the rise.[3]

Reduction of maintenance costs

According to Mr. Abate, CEO of General Electric's wind division, the average turbine was out of commission 15 percent of the time when GE entered the turbine business in 2002. Now the downtime is numbered less than 3 percent. As a result, the cost of the energy cranked out by these turbines has come down, in the words of Abate "to about 8 cents a kilowatt-hour (kWh) and is still falling".[4] 8 cents might seem to be high compared to some 5 cents for existing coal plants. But they are competitive when *new* coal plants are compared with these costs of *new* wind plants and when carbon emission fees play in.

Innovations regarding system benefits of wind power

Better weather forecasts

The power companies who buy the turbines are also getting smarter. They employ teams of meteorologists to scour the world for the best places to put turbines. It is not just a question of when the wind blows, but also of how powerfully. A difference of as little as one or two

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[1] Eize de Vries : Innovation: The ingenious is always simple, Renewable Energy World Nov 2007, **http://www.renewableenergyworld.com/rea/news/story?id=51445**

[2] Lou Schwartz and Ryan Hodum: China's Wind Power Industry: Localizing Equipment Manufacturing, **http://www.renewableenergyworld.com/rea/news/story?id=53076**

[3] Qi Hesheng, Zhuang Yuexing Shen Dechang: Current status of the small wind turbine generator systems development in China, Wind Energy international 2007/2008, p. 245

[4] The Economist 19 July 2008

kilometers an hour in average wind speed can have a significant effect on electrical output. And another contingent of meteorologists sit in the control centers, making detailed forecasts a day or two ahead to help a company manage its power load.

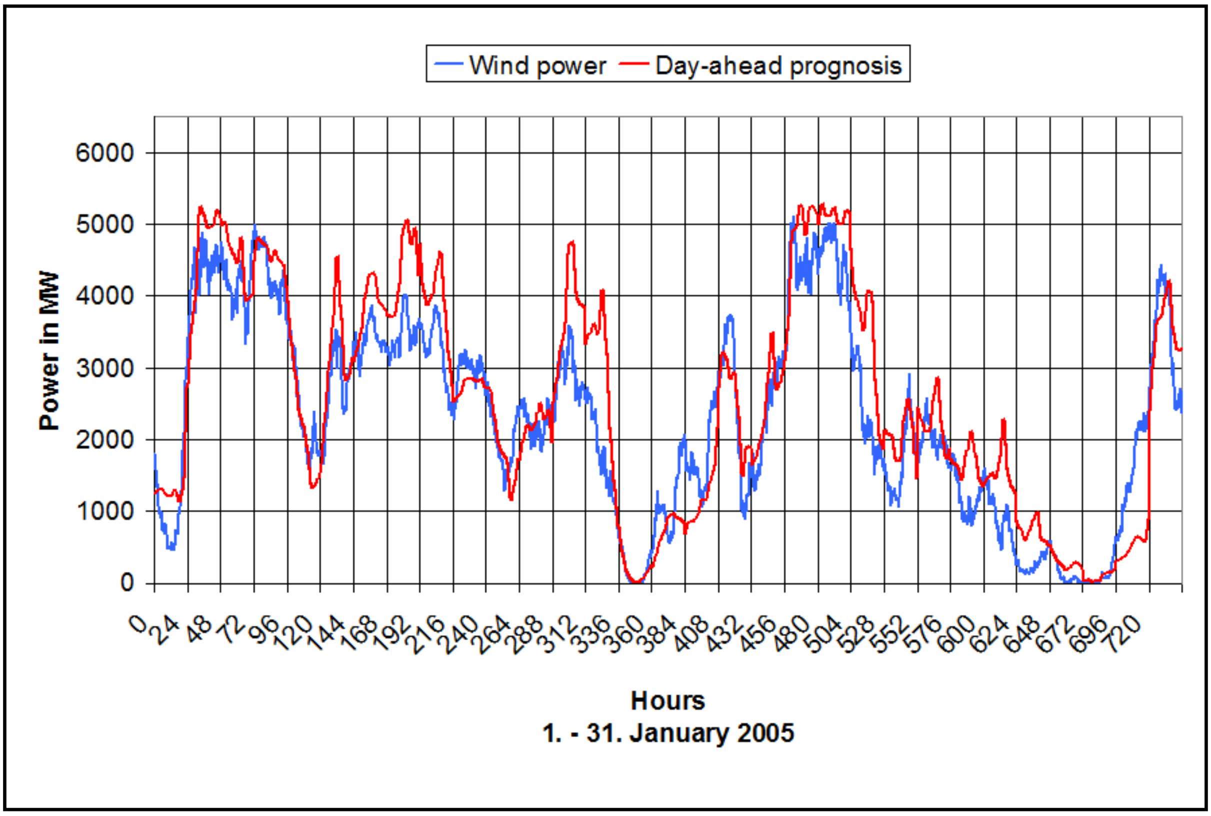

Figure 103 example of wind forecast and wind measurement (Germany)
source: EWEC 2008[1]

Over the past years, the art of weather prognosis has become much more reliable with a 90 percent probability of forecast accuracy within a 5-6 percent band.[2]

New grid rules and better “grid friendliness” of turbines

New grid rules for wind turbines came into effect in Germany in 2004 following a pioneering initiative of the German utility giant E.ON.

- As part of these compulsory new rules, wind turbines – in analogy to conventional power plants - have to remain grid-connected in the case of a major voltage dip. This grid rule model is being followed by other countries with major wind markets.
- A second common requirement of these tailored grid rule packages is that grid-connected wind turbines should have a built-in capacity to actively support the grid.

Both measures are designed to avoid a worst-case scenario, whereby instantly switching off a large chunk of wind generating capacity during an emergency could cause grid failure and a widespread blackout.

The widely used variable speed concept for wind turbines also offers possibilities of increased grid friendliness, with full-scale power converters giving reactive power compensation and a

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[1] Marian Klobasa: Analysis of demand response and wind integration in Germany's electricity market, Fraunhofer Institute for System und Innovation Research, European Wind Energy Conference 2008, original source: Vattenfall

[2] Sylvia Pilarsky-Grosch/Bundesverband Windenergie: Renewable Energy and grid structure, 19.November 2007 –INES II conference

smooth grid connection for the entire speed range. In the words of market expert BTM Consult[1]: “The status of wind power turbines is changing from being simple energy sources to power plant status with grid support characteristics…these include power/frequency control ability, voltage control ability and dynamic stability …with focus on the ability of wind farms to withstand some specific grid faults without being disconnected”.[2]

All these conditions are respected today by leading wind turbine producers; wind farms are able to become a dispatchable part of the entire power system carrying out duties that traditionally were done by conventional power plant such as gas, coal or hydro. So “the very fast development of power electronics offers both enlarged capabilities and a lower price per kW capacity”.[3]

Better interconnection

To ensure connection of remote wind farms, a number of old and new technology solutions are available, some of them basing on HVDC (high-voltage-direct-current) lines.

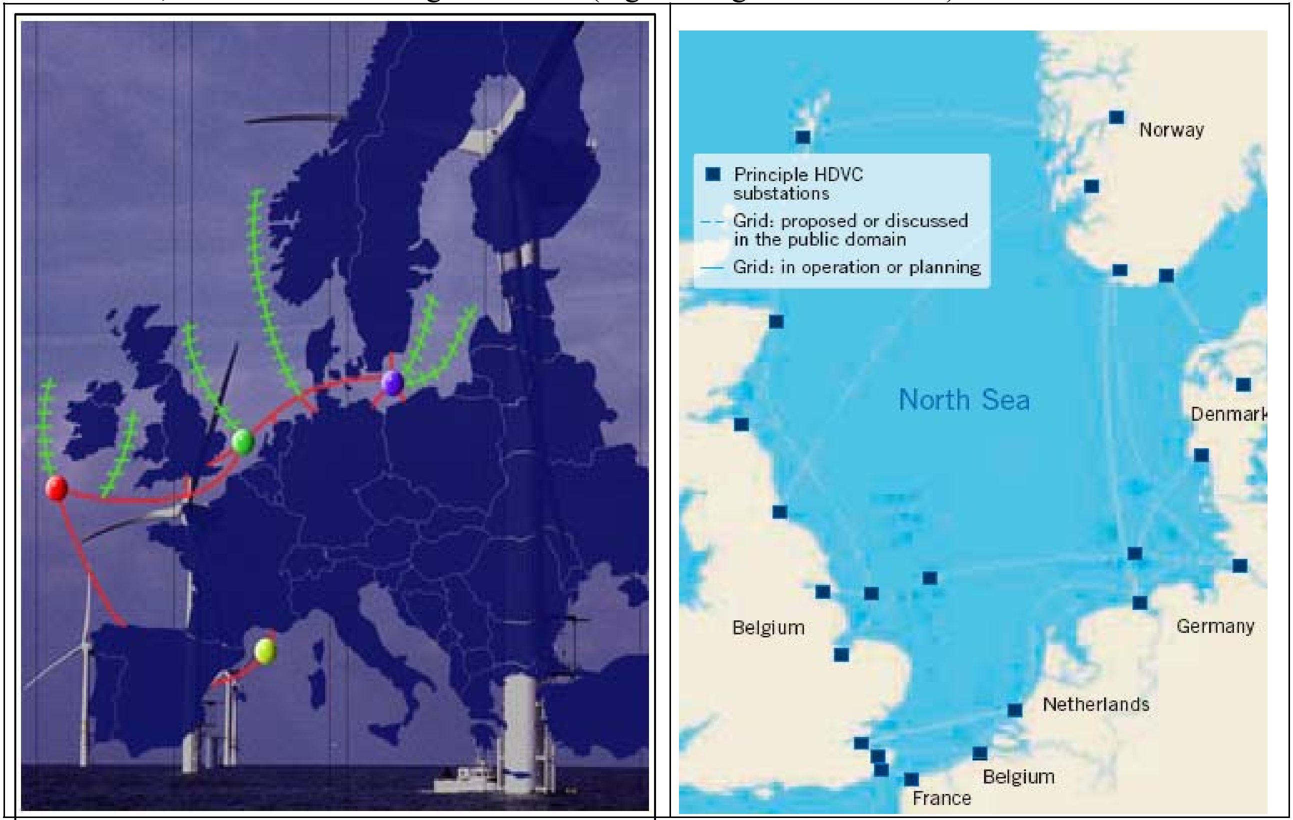

Figure 104 and 105 European “Super grid” proposals, developed by Airtricity’s Eddie O.Connor (left) and by Greenpeace (right) source: Airtricity[4], EWEA[5]

- Irish wind power developer Eddie O’Connor is one of the earliest advocates of a European “Supergrid”. The creation of a new master plan to deal with the layout of transmission is an urgent task. A super-grid could tie together all wind clusters from the Mediterranean to the North Sea and would minimize transmission costs and losses by using modern technology.

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[1] BTM: Ten Year Review 2005, 61

[2] BTM: Ten Year Review, 61

[3] BTM: Ten Year Review 2005, 54

[4] Eddie O.Connor, Airtricity: Presentation to the Eufores Conference October 6 2007

[5] EWEA: Wind Directions: September/October 2008, p. 36

- The Greenpeace analysis, "A North Sea Electricity Grid Revolution", shows how a total of 6,200 kilometres of new undersea cables would connect up the UK, France, Belgium, the Netherlands, Germany, Denmark and Norway (see map). Linked to them by 2020-30 would be 68.4 GW of offshore wind farms generating an annual output of 247 TWh. The study assumes that, if all the transmission lines have a capacity of 1 GW, the proposed offshore grid would cost € 15-20 billion. By comparison, Greenpeace says, the cost of building an HVDC cable connecting Norway and the Netherlands with a capacity of 700 MW was € 600 m. During its first two months of operation this interconnector has generated revenues of € 50 m – more than € 800,000 per day. The advantages of building an offshore grid in the North Sea, Greenpeace emphasizes, are that it facilitates trade between countries, increases security of supply and allows offshore wind farms to dispatch their output to different countries depending on the highest demand. By enabling the offshore wind bank to be aggregated, it would also contribute to reducing variability. An additional benefit is that it allows the import of electricity from Norway's massive hydro power resource into the British and UCTE (central European) systems.[1]
- German utility E.ON Netz recently announced a €300 million investment in a high-voltage DC (HVDC) cable that will connect multiple future offshore wind farms in the German Cluster Borkum 2 region to the national electricity network. As part of the unique development each of the wind farms will be connected to E.ON's offshore high voltage station by means of multi-socket connection and an individual sea cable. From there, a single export cable transports the power to shore, a much more cost-effective solution compared to the alternative whereby each wind farm is connected by its own export cable.[2]
- ABB has been contracted to build cable connection over 100 km to the German north coast. The first phase involves a 400 MW line that is due to be operational in 2009. For the cable connection ABB uses its HVDC Light technology that it says enables efficient energy transport over long distances and a stable connection to the network onshore.

Interconnection in this way can bring new qualities of multi-functional behavior into the power sector: It will (1) bring power from new, prolific wind resources to consumers, (2) smooth fluctuations in the energy profile over various sites geographically well dispersed and (3) will give way to new, existing reserve capacities such as stored hydro which before have been out of reach and (4) accelerate competition between the best and cheapest clean power resources and therefore lower prices for consumers.

Better regulations for interconnection

In November 2006, there was an important breakthrough for the offshore market, when the German federal Council of Ministers passed a law, which aims to speed up the planning procedure for infrastructural projects. Central to this new legislation was that the grid connection of offshore wind farms has to be provided and financed by the national grid operators.

Grid connection costs for offshore turbines can add up to 30 percent of total investment costs. Thanks to the new rules the costs will be distributed over the total grid – as is the case with all other type power plants. Suddenly, investments in German offshore wind energy projects were becoming much more lucrative.[3]

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[1] Wind Directions: September/October 2008, p. 36

[2] Eize de Vries : Husum 2007 Wind technology overview, Renewable Energy World
http://www.renewableenergyworld.com/rea/news/story?id=51444

[3] Eize de Vries: A solid foundation: Technological developments from the DEWEK conference
http://www.renewableenergyworld.com/rea/news/story?id=51565

Creation of renewable energy zones (CREZ)

In 2005, the Texas Public Utility Commission created eight so-called Competitive Renewable Energy Zones (CREZ). These encourage the creation of wind farms by marking future sites of major transmission construction. Companies in the wind business get the acknowledgment that if they build within a CREZ, transmission lines will be promptly available.

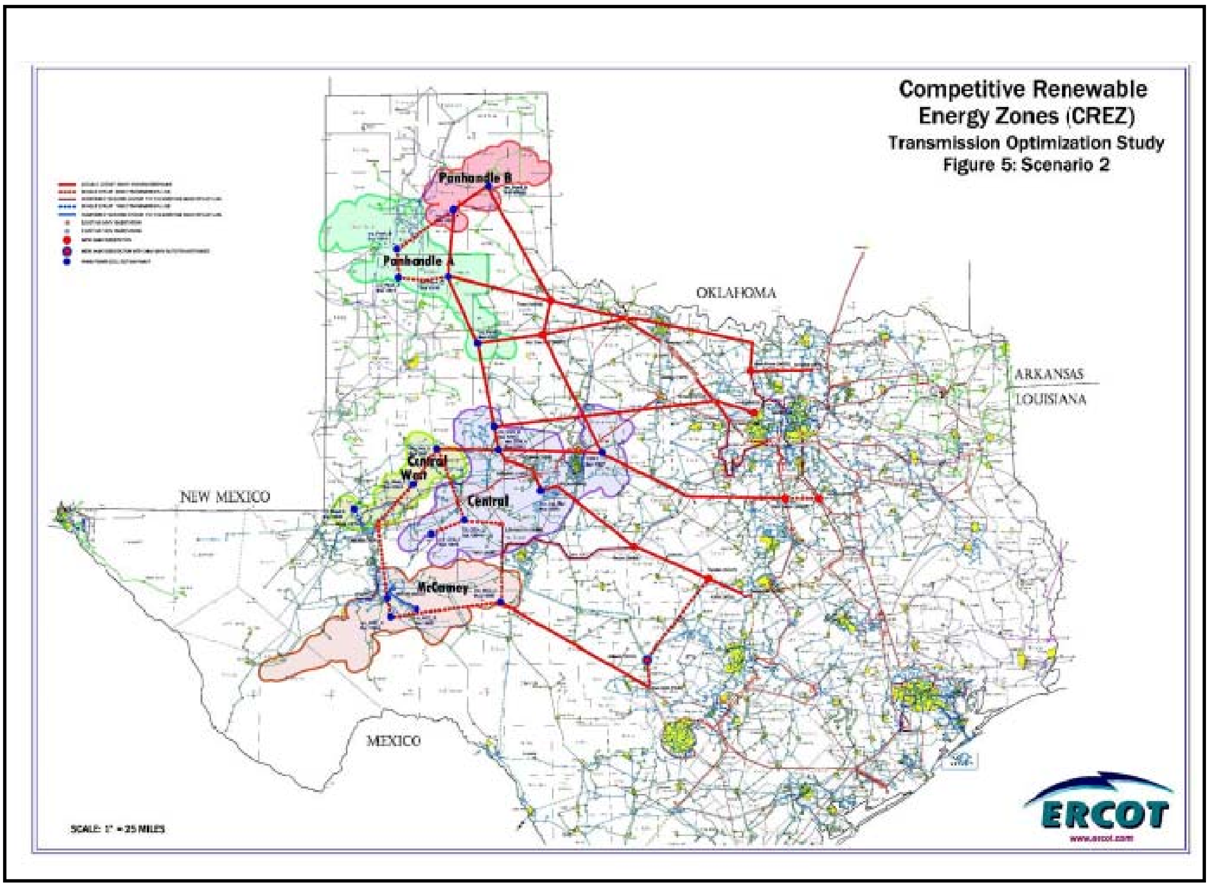

Figure 106 the Texas wind integration plan adopted by the Texas PUC
source: ERCOT[1]

By the creation of CREZ, the best sites within a region can be designated for wind power in a competitive way. This can bring substantial cost reductions. It is a more comprehensive approach compared with the step-by-step developments within existing grid zones that do not always offer the best wind conditions.

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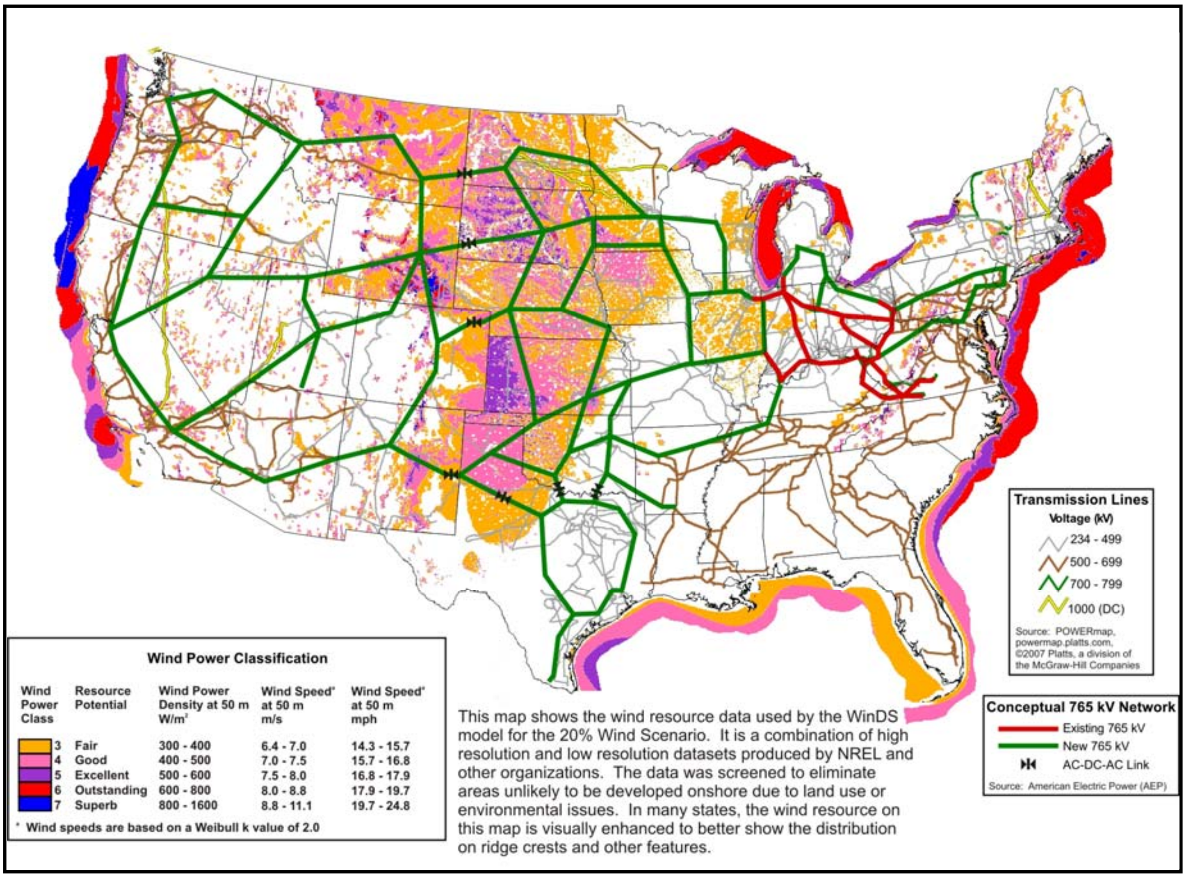
[1] ERCOT: Competitive Renewable Energy Zones (CREZ) Transmission Optimization Study April 2008 p. 25



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed* at 50 m m/s	Wind Speed* at 50 m mph
🟧 3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
🟪 4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
🟪 5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
🟥 6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
🟦 7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

* Wind speeds are based on a Weibull k value of 2.0

This map shows the wind resource data used by the WinDS model for the 20% Wind Scenario. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.

Figure 107 A highway for wind power – the AES plan for a US “super grid”

American Electric Power (AEP), a huge investor-owned utility serving customers in eleven US states has created a vision of what a nationwide transmission superhighway would look like. A transmission build-out to obtain 20 percent of US electricity from wind would include 19,000 miles of new 765-kilovolt (kV) transmission lines, for an estimated price tag of US $60 billion. Given that electricity transmission infrastructure typically remains in service for 50 years or more, the cost of this investment for the average household was estimated at only about US $0.35 per month thereby reducing the electricity sector natural gas bill by 50 percent.

Meanwhile Germany, the UK, France, Spain and other nations approach a more comprehensive planning renewable energy zones with interconnection cleared too.

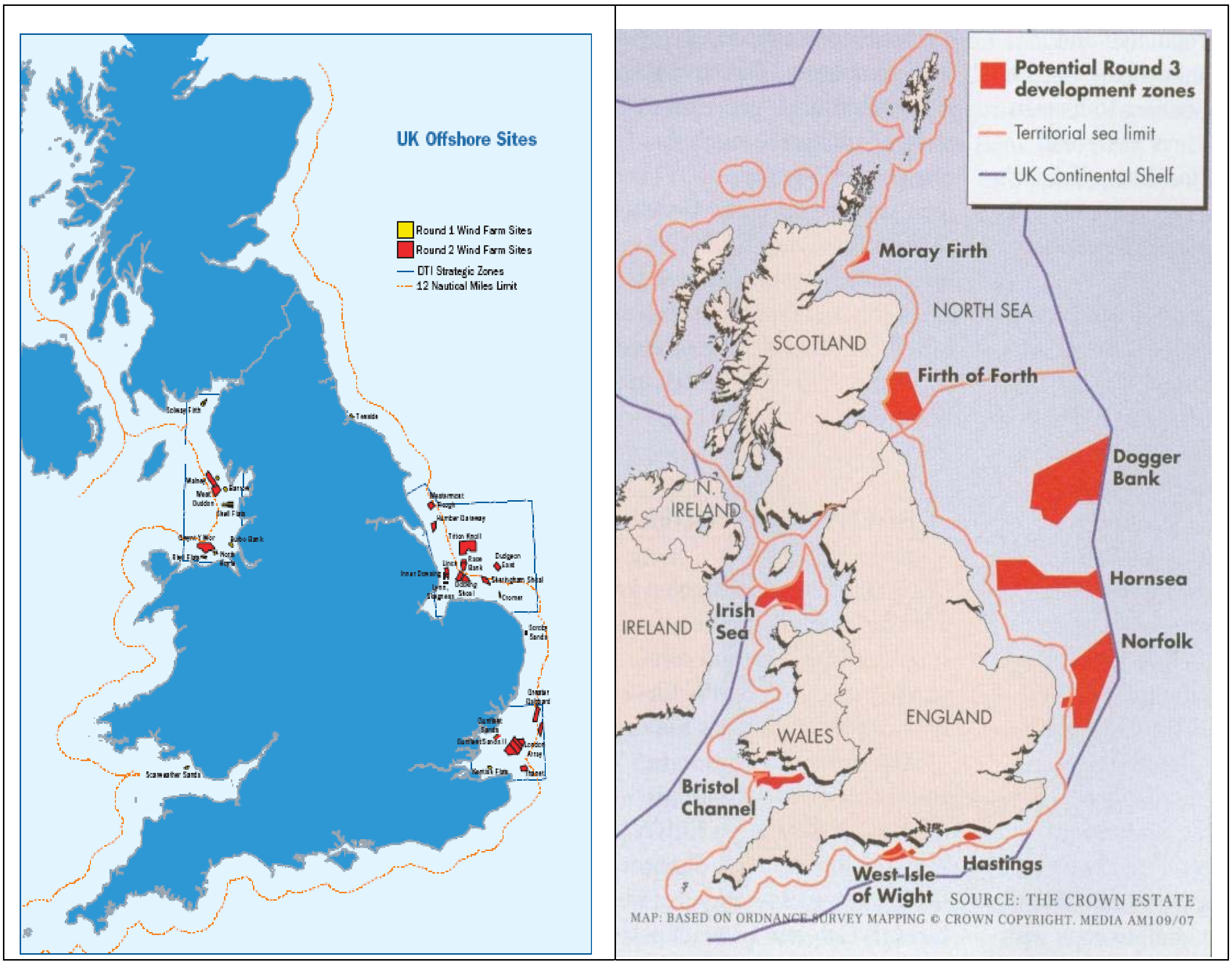


Figure 108 and 109: British offshore wind areas Round 1, 2 (left) and Round 3 (right) source: renewable energy focus[1]

Similar to the Texas CREZ concept, the British Crown Estate has opened vast areas for wind development. When in 2004 the round 2 projects for 8 GW were mostly small areas within the territorial sea limit, in 2008 the round 3 development zones were placed mostly outside, barely visible from land and with much larger areas, giving way for at least 25 GW of additional wind capacities by 2020. The Crown Estate in its 3rd round chose a new approach playing an active role in developing the sites. It is planning to co-fund up to 50 percent of the development costs to speed up the consenting process, but wants to back out of projects once consent has been secured, leaving the partners to construct and operate the wind farms. [2]

Round three projects enjoy a much more strategic approach from government's institutions that before were rather known for their obstructing role than for advancing wind power. The approach is similar now to the development of oil and gas in the North Sea. "But the truth is… that the oil and gas sector had massive subsidies in those early years that represented many, many times what the renewables obligation system means to us," as cited by captain Peter Hodgetts af SeaRoc, a firm of marine engineering consultants in Britain.[3]

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[1] Wind Directions Nov. 2004, p.29, Windpower Monthly Magazine October 2008

[2] Windpower Monthly Magazine July 2008 p. 29

[3] Windpower Monthly Magazine July 2008 p. 30

In the South of Europe a concentrated use of wind resource with high productivity may be developed too: Moncada, an Italian company operating wind farms in Sicily is erecting a 400 kV merchant lines from Albania and from Tunisia to Italy to import wind and other renewable energies. It has plans to erect 500 MW of wind power in each of these countries. Italy has bilateral agreements with Albania and Tunisia by which renewable energy imported will be paid for under Italy's lucrative incentive system.[1]

Enlarging the wind resource

Wind as a growing resource

The estimates for world wind power potentials override those of hydro power by a factor of several hundred.[2] And with every increase of turbine efficiency, more areas become accessible who before were conceived not to be viable.

- In 2002, Christina L. Archer & Marc Z. Jacobson concluded that "the winds over possibly one quarter of the U.S. are strong enough to provide electric power at a direct cost equal to that of a new natural gas or coal power plant"[3].
- The authors had chosen a conservative method: they only took into account wind on land from stations which belong to class 3 or higher (i.e., annual mean wind speed ≥ 6.9 m/s at 80 m) which in that period were judged suitable for wind power generation. Meanwhile some new turbine types show reasonable productivity with lower wind speeds in the 4-5 m/s range. And natural gas, coal and uranium prices have gone up since 2002. Therefore more than one quarter of the US land area should by now be able to produce wind power with a profit.
- In another study on worldwide wind potentials, Archer and Jacobson concluded that "global wind power generated at locations with mean annual wind speeds ≥ 6.9 m/s at 80 m is found to be ~72 TW (~54,000 Mtoe) for the year 2000. Even if only ~20 percent of this power could be captured, it could satisfy 100 percent of the world's energy demand for all purposes (6995-10177 Mtoe) and over seven times the world's electricity needs (1.6-1.8 TW)."[4]
- These estimates were derived from land stations, excluding offshore. The average calculated wind speed on 80 m over ground was 4.59 m/s (class 1), derived from 8199 measuring stations worldwide. This means that with high enough towers and advanced turbine technology wind power will be available in most regions of the world.

Nations like Germany or Austria have proved that even in places with lower wind speeds (4.5-6.8 m/s at 80 m) a production of wind power is viable at a cost below power from natural gas. A study by Hantsch&Moidl points out that most estimates of the wind potentials are too conservative due to wrong perceptions of technical progress:

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[1] Windpower Monthly Magazine July 2008 p.62

[2] Eurec.Agency/Eurosolar estimates wind power potential to be 3084 x 10^{13}kWh and hydro 4,3 x 10^{13}kWh, wind power potential is estimated 750 times more prolific than hydro power potentials, cf. "Eurec.Agency/Eurosolar WIP: Power for the World – A Common Concept"

[3] Cristina L. Archer and Mark Z. Jacobson: The Spatial and Temporal Distributions of U.S. Winds and Windpower at 80 m Derived from Measurements, Submitted to Journal of Geophysical Research, Atmospheres, January 9, 2002, Revised December 14, 2002.

[4] Cristina L. Archer and Mark Z. Jacobson: Evaluation of Global Wind Power, Department of Civil and Environmental Engineering, Stanford University, Stanford, CA, 2004, published in Journal of Geophysical Research - Atmospheres in 2005, http://www.stanford.edu/group/efmh/winds/global_winds.html

- “*A number of estimations of possible wind power resources in Austria range from 3000 GWh up to close of 20,000 GWh. Most estimates relied on present stage of technology. Technical advancements which can be observed with wind power at an extreme extent have practically never been anticipated.*”[1]

Many wind turbines meanwhile have been deployed over areas which until recently were perceived as ”no-wind-areas“ in land-locked Austria. They reach an annual production comparable to turbines formerly erected at the coastline of the North Sea.

- “Strikingly there are excellent yields in the States of Burgenland and Niederösterreich. In Burgenland more than 50% of wind energy has been delivered by turbines reaching between 2200 and 2400 full-load-hours… The main cause for these good results is the ever higher efficiency of wind turbines…”[2]

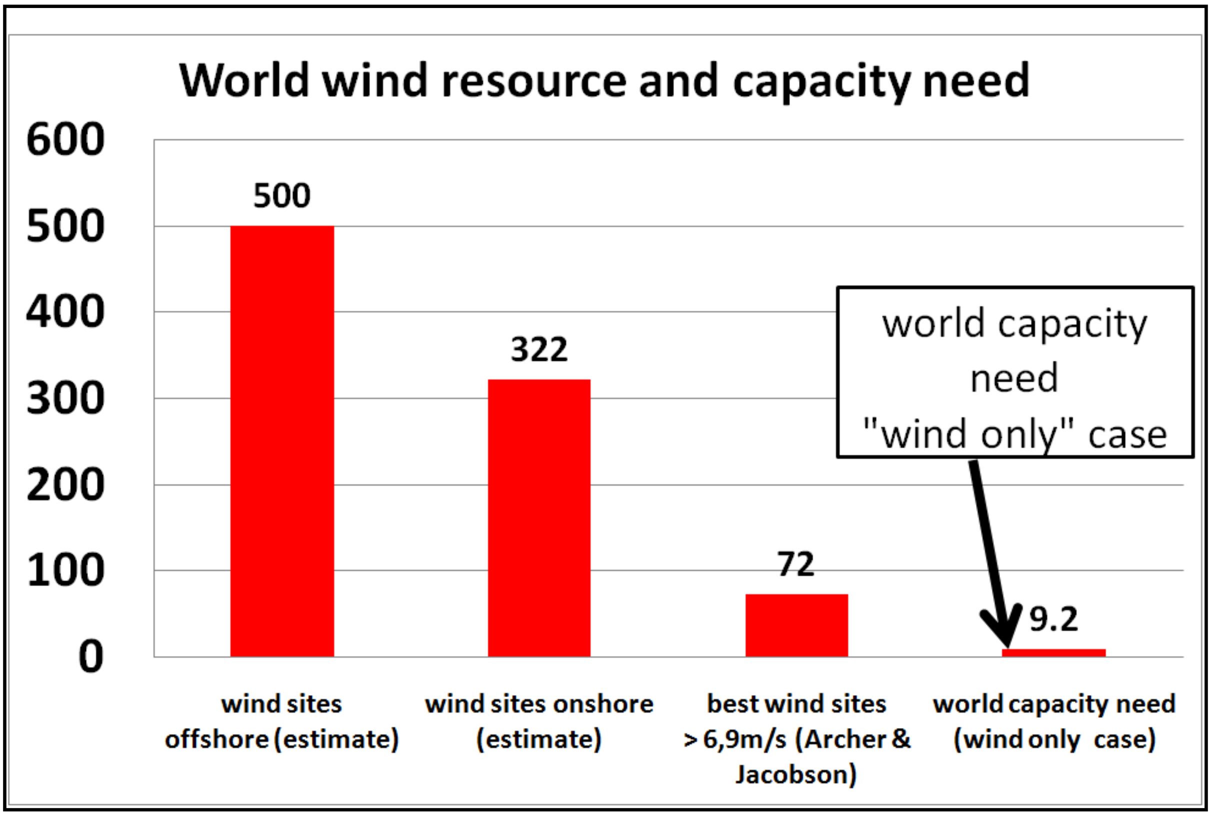

Figure 110 an estimate on available wind power potentials world wide source: estimate by the author including less than best wind sites, based on works of Archer & Jacobson

Development of peripheral locations

In earlier periods, wind farms had to be located geographically within areas connected to the high-voltage grid. Not so any more. Some off-grid-locations are so attractive in terms of wind speed that wind farmers themselves start to build high-voltage-connections to load centers, provided bureaucratic hurdles for merchant lines are removed.

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[1] Stefan Hantsch, Stefan Moidl: Das realisierbare Windkraftpotenzial in Österreich bis 2020 St.Pölten, Juli 2007 (Translation RR)

[2] Stefan Hantsch, Stefan Moidl: Das realisierbare Windkraftpotenzial in Österreich bis 2020 St.Pölten, Juli 2007 (Translation RR)

A strong demand for big turbines is expected from wind farms placed in areas with a low population density, not too far from load centers. And political pressures of these rural regions – who vote mainly conservative – for better grid connections might change overall political majorities and attitudes toward wind power.

Financial benefits for landowners are substantial: between $2000 and $20,000 per turbine or MW are cited as a "normal benefit for the land owners" in the US. Corn or wheat farmers who have a wind contract get more income from wind turbines than from agriculture, without being forced abandoning the latter.

There are many regions where wind plants will deliver giant amounts of power to more distant city populations including the US Midwest and Southern Canada, Mexico, Brazil's North-East, Patagonia, Morocco, Egypt and the Red Sea region, Norway, North Sea and Atlantic Ocean coasts, North-West Russia and the Baltic States, Southern Russia, Turkey, Iran and India, Inner Mongolia, South China, Central Vietnam, South Australia, New Zealand and South Africa. They all have excellent wind conditions and potentially large customers within a 1000-mile range, easily accessible to AC connections or proved HVDC grid technology. Many proposals for projects are moving forward in those regions:

- At the end of 2007, there were 225 GW of wind power capacity registered in the interconnection queues of the United States - more than 13 times the installed wind capacity at the end of that year,[1] much of it in the less populated Midwest.
- New power deliveries do not necessarily have their origin within the US. In 2007, a number of cross-border sales into the United States have been initiated, despite the fact that those facilities are not eligible for U.S. tax incentives:
  - A portion of the West Cape wind project, located in Prince Edward Island (New Brunswick), began exporting power and renewable energy certificates (RECs) to New England in mid-2007.
  - Hydro-Quebec received permission to sell into New England from two of its wind facilities.
  - San Diego Gas & Electric announced a 20-year contract with the proposed 250-MW La Rumorosa wind project in Baja California, Mexico.[2]

  These free-market deals give profound testimony of the competitiveness of wind power.
- For Northern Africa and the Middle East, the DESERTEC Concept proposes large wind and solar installations developed mainly in deserts. Harnessing the winds in Morocco and on land around the Red Sea would generate huge supplies of electricity, exceeding internal demand of these regions.[3] With solar thermal as a storage option, combinations for dispatchable deliveries are possible in regions where pumped hydro will not be easy to achieve.
- In China, the Gansu province has plans for 20 GW in the Jiuquan corridor until 2020 and 40 GW later. Inner Mongolia is expected to have 5 GW online by 2010 and for Shangdong Province, a coastal province bordering the East China Sea, provincial officials estimated a more than 67 GW wind power resource, to cite just some examples; the 67 GW potential could deliver the equivalent to three Three Gorges Projects. The Daan city region in Jilin Province with an area of some 1200 square

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[1] Wiser & Bolinger 2008 p. 9

[2] Wiser & Bolinger 2008 p. 16

[3] For details see http://www.desertec.org./concept.html

kilometers has the potential to develop as much as 6 GW of wind power and there are plans to do so quickly.[1]

Offshore power generation

In Europe, two offshore wind projects, totaling 200 MW, were installed in 2007, bringing total worldwide offshore wind capacity to 1077 MW by the end of that year, which equals around 1 percent of the global wind capacity. (In a similar range is today's global capacity of small-scale wind turbines, of which hundreds of thousands have been installed, especially in China).[2]

The availability of ever-bigger turbines will help for a smooth transition to offshore installations in regions where onshore sites have come in short supply.

A wide variety of dedicated product developments show the new dynamics of the offshore sector. While the 2-3 MW turbines still dominated in 2007, larger machines are entering the market, with four companies so far offering turbines bigger than 3 MW for offshore use: Siemens (3.6 MW model), Repower (5 MW), Multibrid/Areva (5 MW) and Bard (5 MW). Bard is a completely new company owned by a Russian investor who set up production from scratch in Northern Germany.

- Wind technology expert Eize de Vries commented that "the fast and unexpected development of the 5 MW BARD VM turbine shows the trust which new investors place in the potential of offshore wind power as a contribution to solving the world's continuous and growing hunger for clean energy."[3]

The higher cost of offshore wind technology over time will be offset by higher productivity at these sites. REpower of Germany erected a 5 MW wind turbine off the Scottish coast under very demanding conditions. The average wind speed at the site was measured at 10.5 m/s. Among many marine modifications carried out is the installation of dehumidifiers in the tower and nacelle, which keep air humidity constant. This prevents condensation of water on cold surfaces and thus reduces corrosion risk.

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[1] Lou Schwartz & Ryan Hodum, China Strategies, LLC: China's Wind Power Industry: Blowing Past Expectations, RenewableEnergyWorld.com, **http://www.renewableenergyworld.com/rea/news/story?id=53076**

[2] An overview of offshore projects and small scale turbines can be found in WWEA: Wind Energy International 2007/2008

[3] Eize de Vries: The challenge of growth: Supply chain and wind turbine upscaling challenges **www.renewableenergyworld.com/rea/news/story?id=51446**

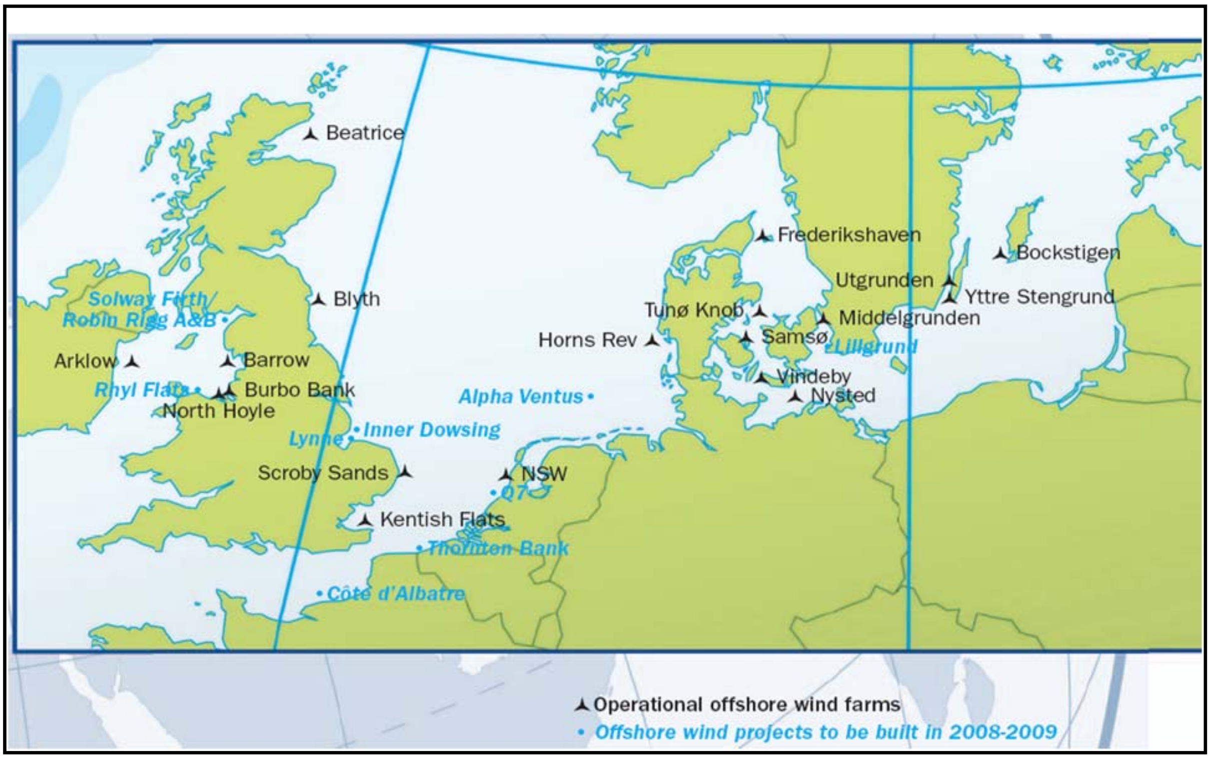

Figure 111 offshore wind farms in Europe and projects to be built in 2009/2010 source: EWEC 2008[1]

New offshore foundations

Various new foundation technologies for offshore turbines are moving to the market:

- New offshore installations such as the Thornton Bank development at 30 km distance to the Belgian coast have gravity-based concrete foundations. These require sophisticated formwork systems and new transport logistics methods to deal with component masses between 3000 and 7000 metric tons for each 5-MW-turbine. Concrete foundations are designed for a 30-50 year operational life span.[2]
- One significant concept is suction buckets or suction anchors, which firmly fix free standing foundations of offshore turbines. The advantage claimed is that seabed preparation is not necessary, as the structure can be put exactly in a level position by adjusting the vacuum in each individual leg.

Floating turbines

A number of companies are developing concepts and pilot installations for floating offshore turbines. Companies such as Siemens, Norsk Hydro, Sea of Solutions BV from Netherlands and others are involved. Floating turbines can generally be installed at sites with much greater water depths when compared to installations on fixed foundation structures. Obvious advantages are the reduced visibility, reduced interference with bird migration and increased power production due to strong and stable wind conditions.

- Norsk Hydro expects to apply this technology in the future on sites located 90 km–180 km offshore and in water depths up to 700 meters. The design by Hydro comprises a

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[1] BWEA graph, EWEC 2008

[2] C-Power:Thorntonbank farshore windturbinepark, presentation EWEC 2008

three-leg able tethered system similar to the concept used in oilrigs and a long submerged floating concrete cylinder that is ballasted.

- Norwegian engineering company Force Technology has developed a new patent-pending offshore wind technology, known as WindSea. An unmanned floating structure is self-orientating towards the wind. The company claims over three decades experience in the design, maintenance of offshore structures and marine corrosion protection. The initial structure is calculated to accommodate three wind turbines of 3.2 MW each.
- Netherlands-based industry newcomer Blue H Technology has developed another floating turbine system and has installed the first deep-water floating prototype wind turbine of 80 kW at 19.6 km off the southern Italian coast near Puglia, at water depth of 108 meters. The system is named the Submerged Deepwater Platform (SDP). Among Blue H's medium to long-term development plans are proposals to scale up the turbines to about 3.5 MW.

Positive implications

Advancing peripheral wind resources such as far-off land, deserts and the sea have a number of positive implications:

- Since many large load centers are located near coasts, turbines can be installed closer to load, decreasing transmission losses and reducing congestion. The same is true for use of deserts. Some deserts such as the Mojave (California/Nevada) the Gobi (China) or the Thar desert (India/Pakistan) are located relatively close to population centers.
- The placement of turbines over-the-horizon and undersea transmission lines eliminate some of the aesthetic concerns that are sometimes raised in conjunction with onshore turbines (the US offshore projects are actually facing major opposition from local communities). There is less interference with landscape protection or neighbors because there are none.
- Bird issues can be avoided, especially with use of offshore zones some 20-40 kilometers off the coast.
- Because people mostly do not live in places where the wind blows hardest, peripheral locations have excellent capacity factors. In west Texas, for example, capacity factors are in the range of 37.1-43.3 percent[1]. In the Denmark offshore zone of Horns Rev, a capacity factor of 45 percent has been measured.
- Cost saving is claimed to be achieved when foundations can be floated to the construction site. Re-floating and towing the machine inshore for maintenance, repairs and major overhauls, or for final disposal at the end of the operational lifetime, is relatively easily achieved by reversing the installation process.

There are many areas anticipated for development where wind developments so far are barely existent, despite huge neighboring populations waiting for clean energy.

In the next decade – with adequate technologies established – many far-off sites will more than pay for the additional costs in transmission, construction and maintenance. Therefore, it is more and more accepted that grid costs are an issue of all consumers and not of a specific wind farmer who would have to pay for it solely.

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[1] ERCOT: Analysis of Transmission Alternatives for Competitive Renewable Energy Zones in Texas, ERCOT System Planning, December, 2006, p. 46 **http://www.windcoalition.org/PDFs/crez_analysis.pdf**

New investors

In an environment of improved economics for wind power, utilities and oil companies are entering the wind sector with huge plans. “Wind with its economic attractiveness, will be the first choice of utilities, driven by regulations which make a shift to renewable energy sources compulsory.”[1] Oil and gas companies also have shown up for wind power now that it is cheaper than oil and gas, and the offshore know-how of oil companies is urgently needed in the wind industry. Some examples:

- British Petroleum is partnering with Clipper Windpower for a giant 5000 MW wind farm in South Dakota.[2] Many other companies from the oil sector, such as British Shell, Danish Oil and Gas Company (DONG) or China National Offshore Oil Corporation (CNOOC), are active in wind power now.[3]
- In Texas, oil tycoon T. Boone Pickens is willing to invest up to 10 billion US-Dollars in new wind capacities of 2000-4000 MW; he also is spending some 50 million Dollars on a public campaign emphasizing the benefits of wind power. This is quite remarkable regarding the fact that Pickens was one of the main sponsors of the US Republican Party and of President George W. Bush – who both rather opposed renewables in favor of coal and nuclear. Pickens offered Texas landowners $4,500 per turbine upfront and payments for the electricity produced, starting at 4 percent and rising to 5 percent after eight years.[4] In Texas, there are no State permissions needed for wind turbines provided the landowners consent.[5] “Pickens said he's prepared to pay for transmission lines, if necessary, to get the electricity from his Pampa Wind Project to metro areas where it's needed.”[6]

Utilities started investing in wind energy too, many of them not in their own supply area but in foreign territory.

- NRG Energy, for example, Texas' No. 2 power generation company, operates largely in South Texas. They therefore wanted a “modest transmission scenario that takes wind power to North and Central Texas, not to their home region,” wrote The Dallas Morning Star.[7]
- French utility EDF invested in more than 1000 MW new wind power in the US and Italy but erected many hurdles for new wind power in its home country France before admitting that it could be a valuable option for France. By the end of 2007, it denied the need for another new nuclear reactor beyond the European Pressurized Reactor EPR erected in Flammanville/Normandy.[8]

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[1] BTM: Ten Year Review 2005, 20

[2] CLIPPER WINDPOWER AND BP ALTERNATIVE ENERGY FORM JOINT VENTURE TO DEVELOP UP TO 5,050 MW, Wind Energy Project To Be The World’s Largest (July 30, 2008) http://www.clipperwind.com/pr_073008.html

[3] CNOOC announced installation of its first offshore wind turbine in 2007; Wan Zhihong (China Daily): Nation eyes offshore wind power, 2007-12-10

[4] Texas oilman wants to build world's biggest wind farm, Jim Fuquay MCT News Service, Texas Morning Call, 19.6.2007

[5] Windpower Monthly Magazine July 2008

[6] Vicki Vaughan: Going big with wind, Express-News staff writer 05/24/2008

[7] Elizabeth Souder Debate flares over wind power in Texas, July 6, 2008, The Dallas Morning News

[8] EDF, Suez disagree on new French EPR reactor / PARIS, Nov 30 2007 (Reuters) - French power group EDF <EDF.PA>and utility Suez <LYOE.PA> do not agree on the need to build asecond European pressurised nuclear reactor (EPR) in France, French daily Les Echos reported on Friday. EDF estimates that the future Flamanville reactor, which is under construction, will meet power needs until 2020, the

Many of these big players are not looking to simply develop wind projects or buy their power but to own and operate them. Their participation will have a lot of implications:

- Utilities have deep pockets and are recognized to be creditworthy by secondary lenders such as banks and investment funds.
- Utilities are often in public hands and have a more easy access to credits. They also pay lower interest rates compared to wind investment funds or small private owners. In a business where more than 70 percent of cost is financing, a reduction of interest rate by 1 percent can bring an overall cost reduction of some 10 percent. Projects that before were recognized as not financially viable gain ground and are realized by these new actors.
- With this new demand, the size of wind orders changes into a new class: multi-year agreements of hundreds or thousands of turbines are registered and allow a more steady flow of investments implying a much more stable demand for manufacturers than before, giving more security for the supply chain too. With the early boom and bust cycles gone, risk premiums shrink, production can be optimized and overall costs can be reduced for all partners involved.
- With wind power growing into double digit market shares in many countries all over the world, more and better research funding by governments will be available.

With overall revenues growing, the risk factor for new technology such as offshore or floating turbines is reduced for every individual wind company. A breakdown of a single pilot offshore test wind farm will not put in danger these companies any more as happened in 2002 when Vestas had to replace all its 90 2-MW machines at Horns Rev/Denmark.

Utilities in general execute heavy influence on energy policy and lawmakers. Once the idea of wind power is established in these circles, the former hostile attitude toward grid enforcements and reserve capacities will change and give access to necessary regulations.

But there can also be risks: involvement of big investors can lead to problems, delays and public opposition. A balance between small and large-scale developments will be needed to create acceptance.

Investments by emerging economies

Newly industrialized countries, such as India, China, Vietnam or others, are facing new energy realities. Wherever these countries try to step into energy contracts, they are in stiff competition with the rest of the world, all trying to cope a shortening of supply – a situation not common until recently. In this new environment, the use of home-grown renewable resources is appealing to preempt dependence on volatile world market prices for energy.

There are indicators that these newly industrialized countries could leapfrog some of the mistakes of the older industrialized nations. The manufacturing of wind turbines and advanced solar technologies is moving to Asia very fast. This trend will have significant implications. Manufacturing in Asia is coupled with cost reductions compared to countries with high wages such as Denmark, Germany or he US.[1] Poor countries in this way will develop their own energy industry. The next stage will be exports.

A growing awareness can be observed especially by fossil fuels producer countries, such as countries in the Middle East or Latin America, becoming alert to the opportunities that renewable energy options provide. Facing declining oil and gas production and rising

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paper said. But Suez believes that there is room for a least one aditional plant, it said. Suez and EDF could not be immediately reached for comment. (Reporting by Dominique Vidalon)

[1] BTM Ten Years Review 2005, 39

opportunity costs for burning oil or gas for their own power generation, rather than exporting it at soaring world market prices, the attractiveness of wind (or solar) options are compelling and the funding needed to buy renewable installations is available as long as there is a profit margin between wind power investments and fossil fuels.

New manufacturers

By 2008, the industry is characterized by the fact that almost all leading suppliers are owned by big multinational companies with a 50 years or more track record in the power generation business. Despite these actors with deep pockets, a worldwide “shortage of wind turbines” is deplored. Therefore manufacturers from Europe are expanding fast into new markets.

- Manufacturers from continental Europe are investing in nations such as China, India, the US, Canada, Turkey, Portugal, Brazil and UK, among others, following the exploding local demand.
- New sub-suppliers such as manufacturers for gearboxes are entering the market, some of them diversifying away from the struggling transport sector.

But then there is a second trend: Emerging industrialized countries themselves are getting active and starting technology transfer of wind technology from Europe:

- India’s Suzlon did this by buying a majority stake of German REpower company which also had a cooperation agreement with Chinese Dongfang.[1]
- Chinese manufacturer Goldwind has a license agreement with German REpower too. It recently bought a majority stake of German Vensys Energiesysteme with which it had a cooperation agreement too. Jointly, the two companies have developed a very promising new, gearless wind turbine which may play a very important role in future Chinese exports to the world markets.
- A third German producer with Chinese ties is Fuhrländer which has license agreements with Chinese Sinovel (a spin-off from Dalian Heavy Industries) and a number of Chinese producers of wind turbines. Sinovel bought Fuhrländer licenses and design concepts for 3-MW and 5-MW wind turbines. Sinovel’s world market share exploded from close to 0 percent in 2005 to 3.1 percent in 2007!
- German Aerodyn Energiesysteme GmbH is said to have sold the firm’s design for converters with capacities from 1.5 to 2.5 MW to half a dozen Chinese manufacturers alone.[2]
- Japanese Mitsubishi is working with Chinese Wuzhong Instrument Company.

Besides market leaders Goldwind and Sinovel, several Chinese firms are said to have 1.5 MW machines ready for market, including Dalian Heavy Industry, Shanghai Electric, Dongfang, Shenyang Huachuang and Xiangdian Wind Power. The trend is that Europe still has a lead in wind power development, but with Asia and the US showing the highest annual growth rates since 2003, things are changing fast.

All these investments will facilitate the deployment of wind power in many ways:

- Cost reductions will be achieved due to reduced transportation distances.

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[1] Hanne May: Wind over the Wall, report on the World Wind Energy Conference 2004 in Beijing, **www.newenergy.info/index.php?id=854**

[2] New energy 5/07 page 26 **http://www.newenergy.info/index.php?id=1542**

- More local value added in local markets will make wind power "our own business", strengthening political support for grid access and for fair competition in many power markets.
- Chinese exports will put pressure on prices in Europe and the US. The first deals for Chinese wind turbines sold in the US have been rumored already.[1]

Drivers from the non-renewable power sector

Competing with new power plants instead of old

In the 1990s, wind power often had to compete with fully amortized fossil fuel plants. This changed after 2003. The liberalization of electricity markets spelled the end of many old coal plants that could no longer be maintained in a competitive environment. Rising oil and gas prices and rising consumption triggered the construction of new power plants with higher efficiency (NGCC) or of plants not relying on volatile fuel prices at all such as wind power.

In emerging economies, the choice today mostly is between new fossil or new wind plants. In some of these nations, the infrastructure to operate large central power stations is missing or inadequate. And even if technology and financing can be secured, it often takes years to build large-scale facilities, with huge delays for industrial and social development.

Wind energy does not require central grids and a long lead-time. It can be established where and when it is needed and capacity build-up can be implemented stepwise.[2] Typically, in India, it was the textile sector which invested first into wind farms to satisfy its own demands. We can expect such a self-reliant development for many industries operating in nations with weak grids.

Problems of the non-renewable sector

One of the main reasons for wind and solar power's success is the fact that non-renewable power technologies have their own problems to fight.

- Coal and natural gas are in decline. Resource quality and resource availability is steadily shrinking over the next decades; this translates into higher costs and a lower energy-return-on-energy-investment (EROEI) for every new coal or natural gas power source;
- Natural gas can be used for transports; with rising demand and shortages for gasoline, compressed natural gas (CNG) for the transport sector could drive natural gas prices upwards toward gasoline price levels; this of course would accelerate the growth of wind and solar power generation.
- With rising costs of global warming due to storm damages, reduced agricultural crops and other threads as rising sea levels, the fight against climate change might accelerate.
- Nuclear power has its own bottlenecks and risks. In the short run – before 2020 – big capacity additions will not be available due to lengthy planning procedures, eroded knowledge and a shortage of components. There is actually a scarcity of deliveries of specialized vessels; and a scarcity in uranium is looming, reflected in the price surge and a higher volatility.

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[1] Guangdong Mingyang Wind Power Technology Company Limited signed a contract with GreenHunter Energy Incorporated in late November for 72 sets of 1.5-megawatt (MW) cold-weather wind turbines to New York, the Mingyang Electric Group announced in December 2007.

[2] BTM Ten Yerar review 1995-2004, p.9

- With a better availability of renewable energy, “no-coal-no-nuclear” political positions will win political majorities. Why should anybody take security and pollution risks when a cleaner and cheaper source of energy is available in abundant amounts?

If you divide the world’s nations into fossil energy-buyers and fossil energy-sellers, the problems of fossil energy importing nations are growing:

- They have to import an ever-growing share of energy at unpredictable (but most likely higher) prices in competition with the rest of the world and at a growing environmental cost.[1]
- Regardless of whether they are successful in energy diplomacy or not, they have no security about future costs of energy they will be paying to maintain current supply.

New demand from new rich or isolated economies

With oil prices beyond $100/barrel, there is a wide range of applications where wind power immediately reduces the cost of power generation.

- Still, today, on many islands or in remote regions such as in the far North and South, expensive diesel fuel oil or natural gas is used for power generation.
- The same applies for a range of oil exporting nations such as Saudi Arabia, Venezuela, Mexico or Russia. There a substitution of internal use of oil and natural gas for electricity can improve export levels for oil and gas. Oil exporters can well afford to buy wind power systems in significant amounts within a short time and are expected to do so once more turbines are available.[2] With Russia, however, it might take longer due to the dominance of the coal and nuclear sector and due to the very early stage of the Russian wind industry.

Environmental pressures

Danish BTM Consult in 2005 warned for the first time that concern about environmental pressures and about dependence on fossil fuel and security of supply could build a context where “wind power will be much in demand, and the limitations will become more to do with firstly, whether manufacturing capacity can expand in time to meet demand, and secondly, how much wind power is manageable in our electricity system.”

Exactly this situation can be observed now. Fossil and nuclear lobbies drove consumers into dependence on economically and ecologically frustrating technologies, with scarce supply, rising costs and environmental risks and damages.

New publications such as the Stern and IPCC Reports make it clear that mitigation of climate change is cheaper than accelerating damages. The pressure from the environmental side will persist and accelerate with every new flood or nuclear accident.

Learning from each other – Political uncertainties reduced

Recent developments (2005-2008) in the wind business must be reflected as part of a general turmoil in the conventional power market. In its beginnings, the actors favoring wind power were rich countries, eager for environmental progress, carried by Social Democratic and Green Parties. Public spending and feed-in tariffs were introduced to stimulate the market,

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[1] EWEA; RESPONSE TO THE EUROPEAN COMMISSION’S GREEN PAPER: A EUROPEAN STRATEGY FOR SUSTAINABLE, COMPETITIVE AND SECURE ENERGY
http://www.ewea.org/fileadmin/ewea_documents/documents/publications/position_papers/0906_pp_greenpaper.pdf

[2] The so called „Masdar“-project launched in the Arab Emirates is an example for such moves.

with developments overshadowed by political uncertainty and, sometimes, hostility, implying boom and bust periods making orderly planning difficult.

- At the beginning, only few idealists were investing in a rather altruistic way in wind energy; there was no insurance for stable returns, not even when the technology and site developments worked well. Therefore wind power was not really perceived as a serious investment. Due to high risk most profit-oriented investors stayed cautious with engagements.
- Then with feed-in tariffs adopted by many nations, small investors and small companies were able to find credits at moderate costs without excessive risk premiums.[1] Step by step, every major project generated new scale efficiencies and increased the trust into wind power as a predictable source of power.

Today it is a general experience that if a particular institutional framework for renewable energy is successful in one country, it will be replicated in new markets, with some modifications depending on local conditions.[2] The increase of oil and gas prices and the fierce competition for wind turbines today is a key driver for governments to have revised their incentive structure. Due to higher steel and copper prices Germany raised its feed-in tariffs for wind power in July 2008, mainly to keep the home market going and to expand offshore capacities faster.

Since wind power shows clear cost advantages, even in the short period everything goes faster than ever before. In the words of Wouter van Kempen, president of Duke Energy Generation Services, after investing into 500 MW of new wind power:

“This is just the beginning. All of us are very committed to making renewable energy in the years to come. I think we're looking broadly at a lot of different technologies, and the advantage that wind has is that it is cheaper than a lot of the technologies; so you can build large scale, you can build them very fast and you can build them much cheaper.”[3]

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[1] For a worldwide survey see: Paul Gipe: Tables of Specific Renewable Energy Tariffs **http://www.wind-works.org/FeedLaws/TableofRenewableTariffsorFeed-InTariffsWorldwide.html**

[2] BTM: Ten Year Review, 63

[3] Lauren Berry: Wind appears on the verge of becoming a power player - Duke acquires a stake in a Texas wind farm said to be one of the world's largest The Charlotte Observer 26.6.2008

7. The cost of wind power - empirical trends

There are several items that influence the cost of electricity:

- the initial investment amount, and the discount rate used to amortize it;
- the fuel costs (for those power plants that need a fuel, like coal, natural gas or uranium);
- the operation and maintenance (O&M) costs;
- the internalized emission costs such as the amount of CO_2-certificates to be acquired over time, the cost of nuclear waste disposal for the plant owner etc.
- the externalities, i.e. the cost imposed on society by the power plant, if not internalized by regulation.
- side benefits such as income and investment perspectives for rural areas, job creation, improved infrastructure, local taxes.

Any comparison between various power sources that does not explicitly state which assumptions are made with regards to fuel costs and discount rate should be considered as dubious.

Eroding costs over time - the golden end of renewable power systems

Wind power comes at an average cost of some 5.5 US-Cent/kWh in the US and at some 5-8 Euro-Cents/kWh in less windy Europe. But this is only the beginning of the story. Wind power and other renewables have a golden end and therefore are cheaper than they look at the start.

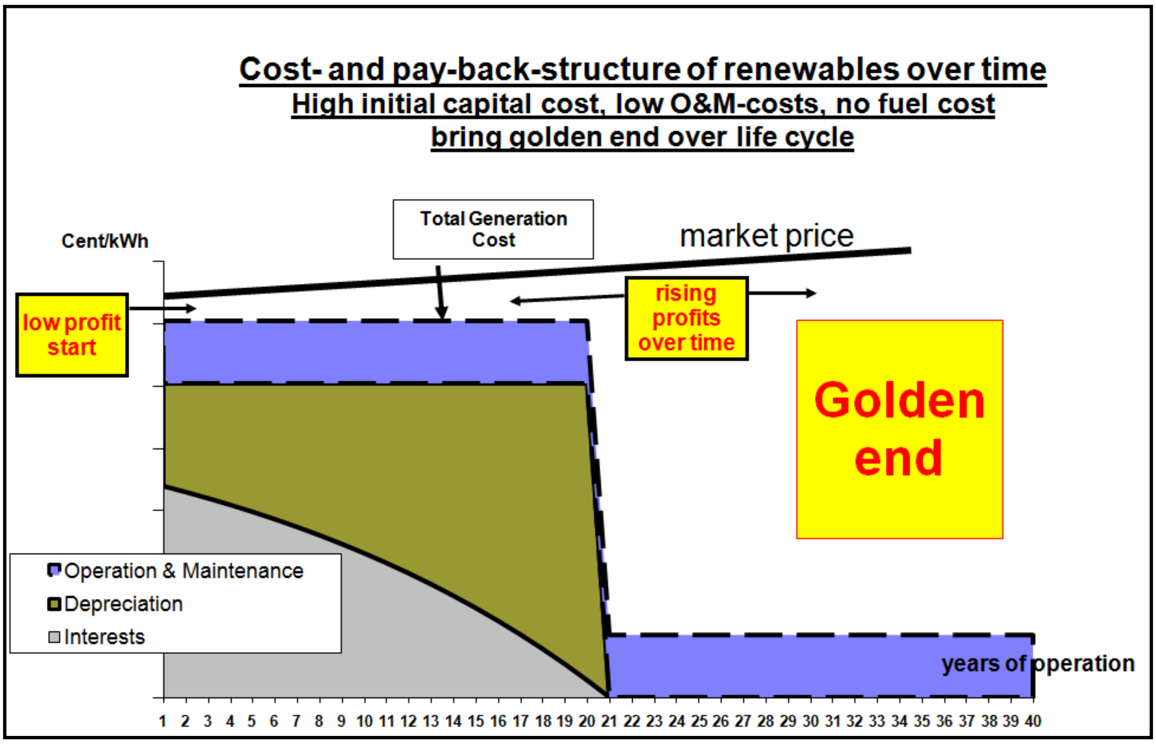


Figure 112 Cost, profits and pay-back-profile of renewable energy over time

Wind turbines show high initial upfront cost due to heavy reliance on capital investments. Once the initial capital is paid back over a usual commercial period of, say, 12-20 years, the turbines regularly work beyond at no capital and fuel costs. Profit margins from that moment grow massively. This period, therefore, is called the Golden End of renewable power plant.

These mechanisms are well established with hydro plants, that after decades of operation and with initial capital paid back, yield generation costs of less than 1-2 Euro-Cents/kWh. The profit margin then can grow to a level of more than 100 percent, with wholesale prices for electricity at 7 Euro-Cent/kWh or more (2008).

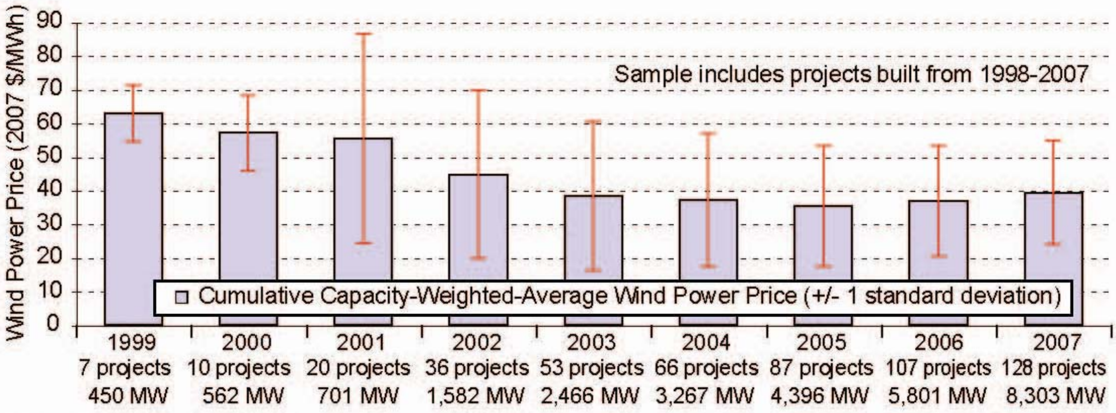
Investments in wind power therefore are an attractive option for investors with a long-term vision, such as utilities or pension funds.

Due to these mechanisms, life-cycle costs of wind power are only some two thirds or less the amount which feed-in tariffs initially suggest. To cope with initial high capital costs, all support schemes put a higher benefit at the beginning of the turbine's life and reduce the amount of guarantees later.

Despite the initial predominantly public support for wind power, consumers nevertheless can participate in these profits when wind production is ousting the more expensive technologies from the market, such as natural gas or new nuclear. At the moment of original investment, though, these benefits are not reflected in the current payback-schemes. For new investments, an insecurity persists regarding future market prices of electricity, future maintenance costs and life expectancy of new wind installation, especially with new technologies put in place.

Cost data of wind power in the USA 1999-2007

In the US, the costs of a big number of wind farms have been evaluated by Wiser & Bolinger working for the US Department of Energy's Lawrence Berkeley Laboratory (LBL). Their study gives an excellent survey of a number of cost and productivity indicators that deserve to be replicated here.



Source: Berkeley Lab database.

Figure 13. Cumulative Capacity-Weighted-Average Wind Power Prices Over Time

Figure 113 Cumulative Capacity-Weighted-Average Wind Power Prices Over Time source: Wiser & Bolinger 2008 [1]

The weighted-average price of wind power in 1999 was nearly 6.3 US-Cents/kWh (expressed in 2007 dollars). By 2007, in contrast, the cumulative sample of projects built from 1998 through 2007 totaling 8,303 MW showed an average price of just under $4 US-Cents/kWh (with a range extending from 2.4 to 5.5 US-Cents/kWh).[2]

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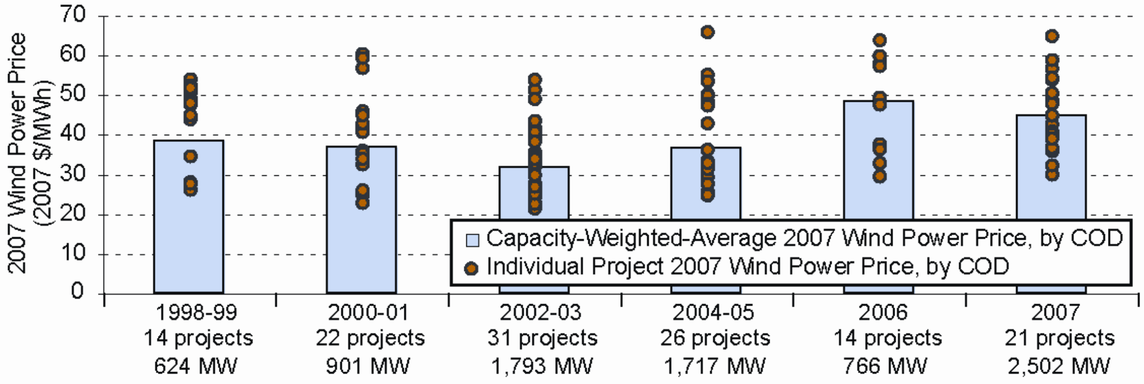
[1] Ryan Wiser, Mark Bolinger: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, May 2008 ed. US Department of Energy

[2] The prices depicted in this US database reflect the price of electricity as sold by the project owner. The figure shows the cumulative capacity weighted average wind power price in each calendar year from 1999 through 2007.



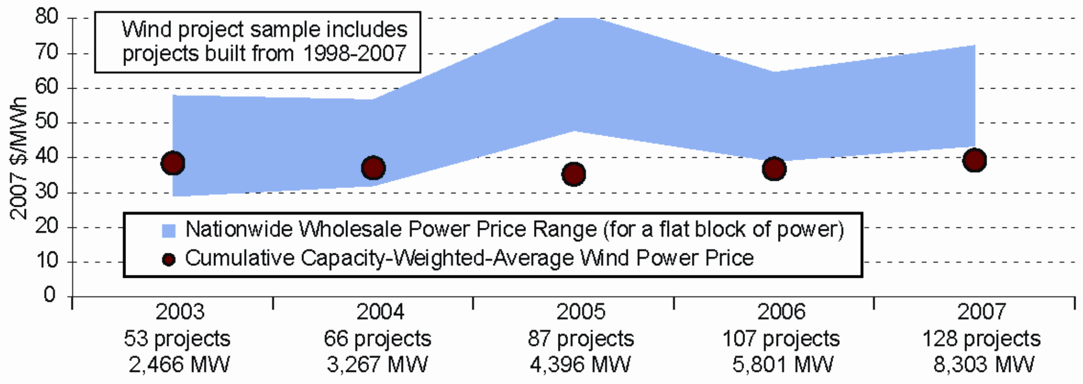
Source: Berkeley Lab database.

Figure 14. 2007 Wind Power Prices by Commercial Operation Date (COD)

Figure 114 Cumulative Capacity-Weighted-Average Wind Power Prices Over Time source: Wiser & Bolinger 2008

In 2007, the weakness of the dollar, rising materials costs, a concerted movement towards increased manufacturer profitability, and a shortage of components and turbines put an upward pressure on wind turbine costs. Although the figure does show a modest increase in the weighted average wind power price in 2006 and 2007, reflecting rising prices from new projects, the cumulative nature of the graphic mutes the degree of increase.

The capacity-weighted average 2007 sales price for projects built in 2007 was roughly 4.5 US-Cents/kWh (with a range of 3 to 6.5 US-Cents/kWh). This price is slightly less than the average of $4.8 US-Cents/kWh for projects built in 2006. It is still higher than the average price of 3.7 US-Cents/kWh for the sample of projects built in 2004 and 2005, as well as the 3.2 US-Cents/kWh for the sample of projects built in 2002 and 2003.



Source: FERC 2006 and 2004 "State of the Market" reports, Berkeley Lab database, Ventyx.

Figure 17. Average Cumulative Wind and Wholesale Power Prices Over Time

Figure 115 Cumulative Capacity-Weighted-Average Wind Power Prices Over Time source: US-DOE 2008[1]

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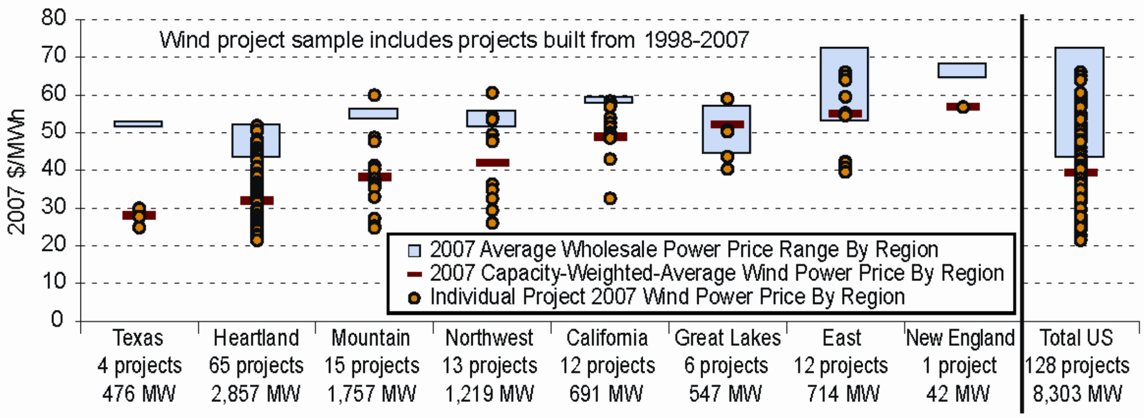
[1] Ryan Wiser, Mark Bolinger: Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, May 2008 ed. US Department of Energy, p. 17

A comparison of the wind prices with wholesale power prices throughout the United States demonstrates that wind power has been competitive over the past years. The figure shows the range (minimum and maximum) of average annual wholesale power prices for a flat block of power going back to 2003 at twenty-three different US pricing nodes located throughout the country.

The red dots show the cumulative capacity-weighted-average price received by wind projects in each year with commercial operation dates of 1998 through 2007. At least on a cumulative basis within the sample of projects reported, average wind power prices have consistently been at or below the low end of the wholesale power price range.

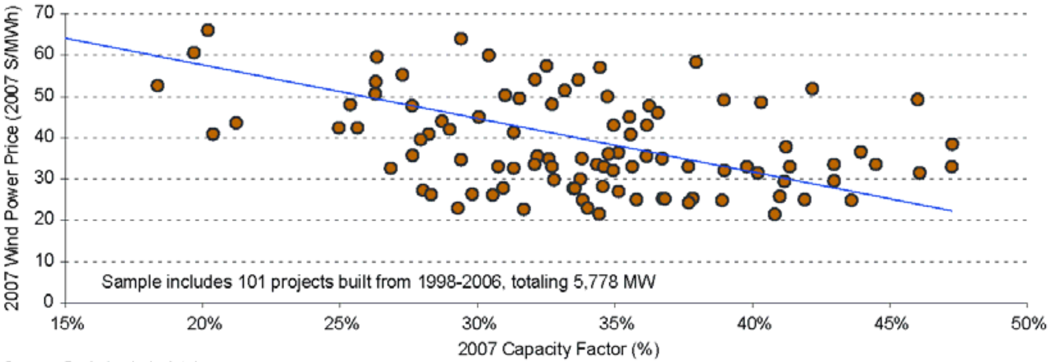


Source: Berkeley Lab database, Ventyx.

Figure 18. Wind and Wholesale Power Prices by Region: 1998-2007 Projects

Figure 116 Wind and Wholesale Power Prices by Region: 1998-2007 Projects

There are regional differences in wholesale power prices and in the average price of wind power. Although there is quite a bit of variability, in most regions the average wind power price was below wholesale prices in 2007. This in parts was so because "rising wholesale power prices since earlier in the decade have, to a degree, mitigated the impact of rising wind power prices on wind's competitive position."[1]



Source: Berkeley Lab database.

Figure 21. 2007 Wind Power Price as a Function of 2007 Capacity Factor

Figure 117 2007 Wind Power Price as a Function of 2007 Capacity Factor

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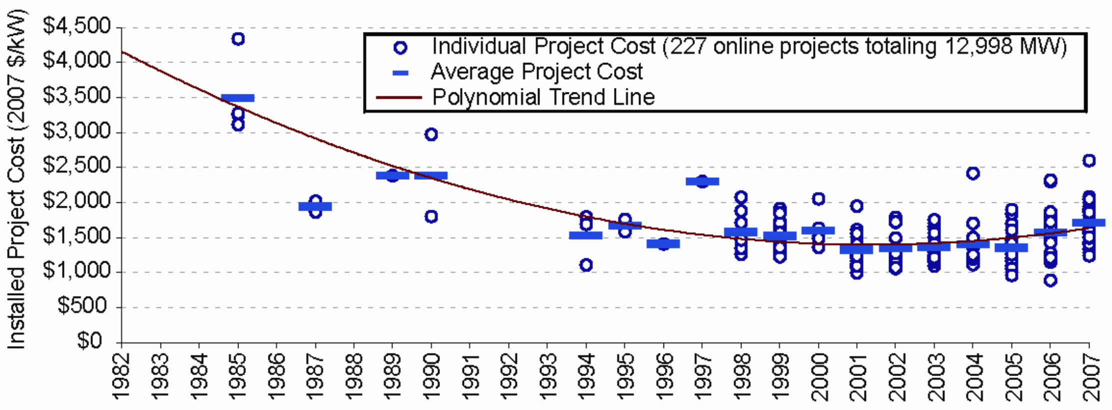
[1] Wiser & Bolinger 2008, p.19

The relationship between project-level capacity factors and power sales prices for a sample of more than 5,700 MW of wind projects is shown in this figure. Not surprisingly, projects with higher capacity factors generally have lower wind power prices.



Source: Berkeley Lab database (some data points suppressed to protect confidentiality).

Figure 22. Installed Wind Project Costs Over Time

Figure 118 Installed Wind Project Costs Over Time

Wind power sales prices are affected by a number of factors, the most important of which are installed project costs, project performance and operation and management (O&M) costs. In the US, installed project costs continued to rise in 2007, after a long period of decline. In general, reported project costs reflect turbine purchase and installation, balance of plant, and any substation and/or interconnection expenses.

“Wind project installed costs declined dramatically from the beginnings of the industry in California in the 1980s to the early 2000s, falling by roughly $2,700/kW over this period. More recently, however, costs have increased. Among the sample of projects built in 2007, reported installed costs ranged from $1,240/kW to $2,600/kW, with an average cost of $1,710/kW. This average is up $140/kW (9%) from the average cost of installed projects in 2006 ($1,570/kW), and up roughly $370/kW (27%) from the average cost of projects installed from 2001 through 2003.”[1]

Though recent turbine and installed project cost increases have driven wind power prices higher, productivity improvements in wind project performance have mitigated these impacts to a large degree. In particular, higher capacity factors and technological advancements, including reductions in operation & maintenance (O&M) costs show a positive trend.

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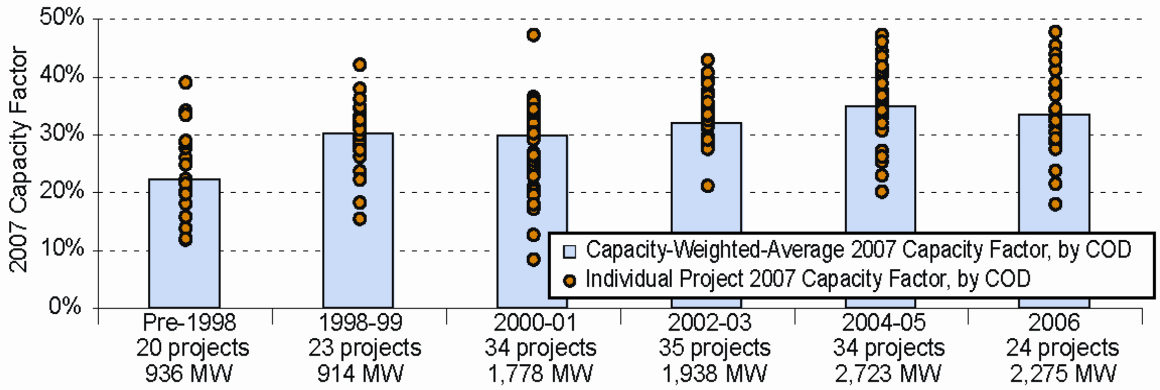
[1] Wiser & Bolinger 2008 p. 21



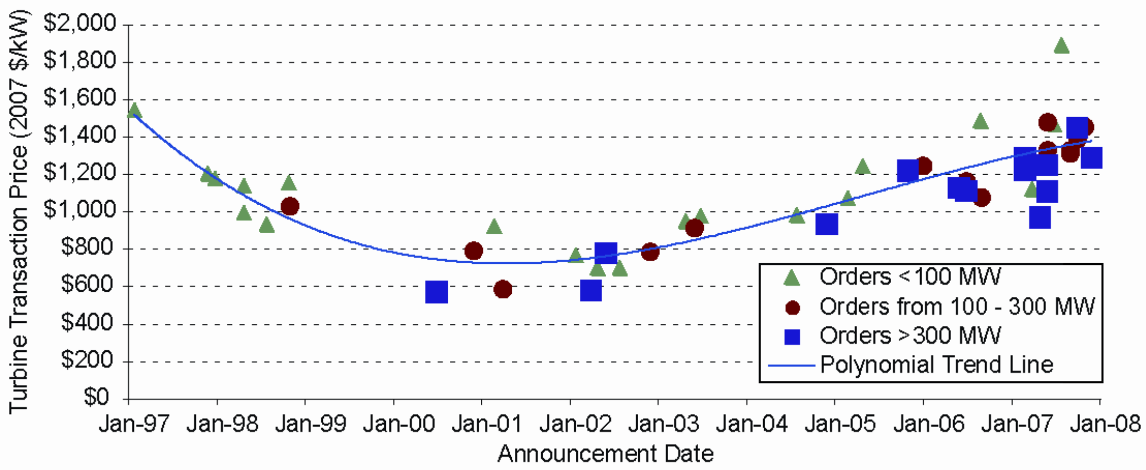
Source: Berkeley Lab database.

Figure 26. 2007 Project Capacity Factors by Commercial Operation Date

Figure 119 2007 Project Capacity Factors by Commercial Operation Date

For the US, the capacity-weighted-average 2007 capacity factors in the US-DOE-sample increased from 22% for wind projects installed before 1998 to roughly 30%-32% for projects installed from 1998-2003, and to roughly 33%-35% for projects installed in 2004-2006. This means that over a decade the average capacity factor improved by around 50%!

"In the best wind resource areas, capacity factors in excess of 40% are increasingly common. These increases in capacity factors over time suggest that improved turbine designs, higher hub heights, and/or improved siting are outweighing the otherwise-presumed trend towards lower-value wind resource sites as the best locations are developed." [1]



Source: Berkeley Lab database.

Figure 25. Reported U.S. Wind Turbine Transaction Prices Over Time

Figure 120 reported US Wind turbine prices 1997-2008

Turbine prices did not rise the same way for everybody. Larger turbine orders (> 300 MW) have generally lower prices than smaller orders (< 100 MW).

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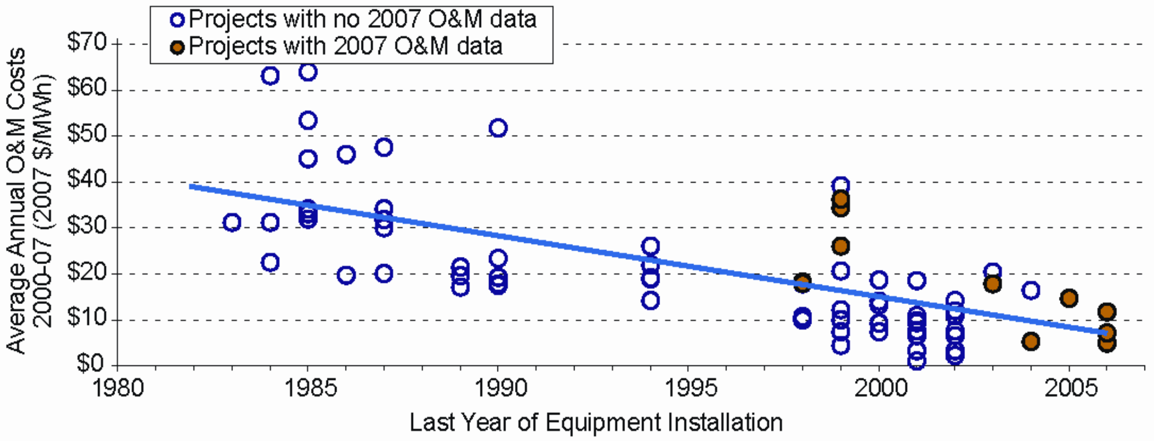
[1] Wiser & Bolinger 2008 p. 23-24



Source: Berkeley Lab database; five data points suppressed to protect confidentiality.

Figure 28. Average O&M Costs for Available Data Years from 2000-2007, by Last Year of Equipment Installation

Figure 121 Average O&M Costs for Available Data Years from 2000-2007, by Last Year of equipment Installation

Operations and maintenance (O&M) costs are a significant component of the overall cost of wind projects, but can vary widely among projects. The US-DOE has compiled O&M cost data for 95 installed wind plants in the United States, totaling 4,319 MW of capacity, with commercial operation dates of 1982 through 2006. Reported values include the costs of wages and materials as well as rent (land lease payments). Other ongoing expenses, including taxes, property insurance, and workers' compensation insurance, are generally not included. The above figure shows project-level O&M costs by year of project installation.[1]

The US-DOE data suggests "that projects installed more recently have, on average, incurred much lower O&M costs. Specifically, capacity-weighted- average 2000-2007 O&M costs for projects in the sample constructed in the 1980s equal 3 US-Cents/kWh, dropping to 2 US-Cents/kWh for projects installed in the 1990s, and to 0.9 US-Cents/kWh for projects installed in the 2000s."

This drop in O&M costs may be due to a combination of at least two factors:

- O&M costs generally increase as turbines age, component failures become more common, and as manufacturer warranties expire; and
- Projects installed more recently, with larger turbines and more sophisticated designs, may experience lower overall O&M costs on a per-kWh basis.

Wind integration costs

Wind integration costs are costs that arise due to the fluctuating character of the wind resource. Power storages or energy from other sources has to held on stand-by for periods where wind does not cover the needs it is supposed to. The US-DOE study gives an insight into wind integration costs:

"Key conclusions from the growing body of integration literature include: (1) wind integration costs are well below $10/MWh [=1 US-Cent/kWh] — and typically below

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[1] i.e., the last year that original equipment was installed, or the last year of project repowering

$5/MWh [= 0.5 US-Cents/kWh] — for wind capacity penetrations of as much as 30 percent of the peak load of the system in which the wind power is delivered; (2) regulation impacts are often found to be relatively small, whereas the impacts of wind on load-following and unit commitment are typically found to be more significant; (3) larger balancing areas, such as those found in RTOs and ISOs, make it possible to integrate wind more easily and at lower cost than is the case in small balancing areas; and (4) the use of wind power forecasts can significantly reduce integration challenges and costs."[1]

Wind power full costs in the US

The numbers dispersed by Wiser & Bolinger from LBL about wind's "price" contain subsidies to a certain degree – namely the US Production Tax Credit of some 1.8-2.1 US-Cents/kWh, paid for the first ten years. Additionally, they do not fully reflect recent turbine price rises and therefore give a picture that could be a bit too optimistic reflecting the real full costs of wind power.

If we account for these factors, the full cost of wind power in the US may amount to 6-8 US-Cent/kWh rather than the 5.5 cents deployed by Wiser & Bolinger.

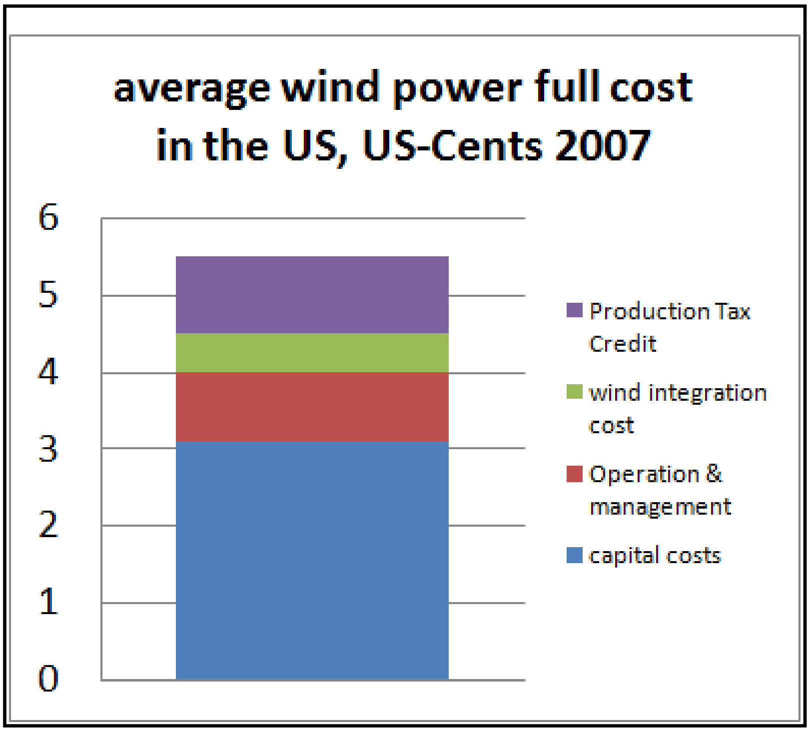

Figure 122 wind power full costs in US-Cent/kWh in 2007, estimation compiled from US-DOE data including wind integration costs

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[1] Wiser & Bolinger 2008 p.21

The cost situation in Europe

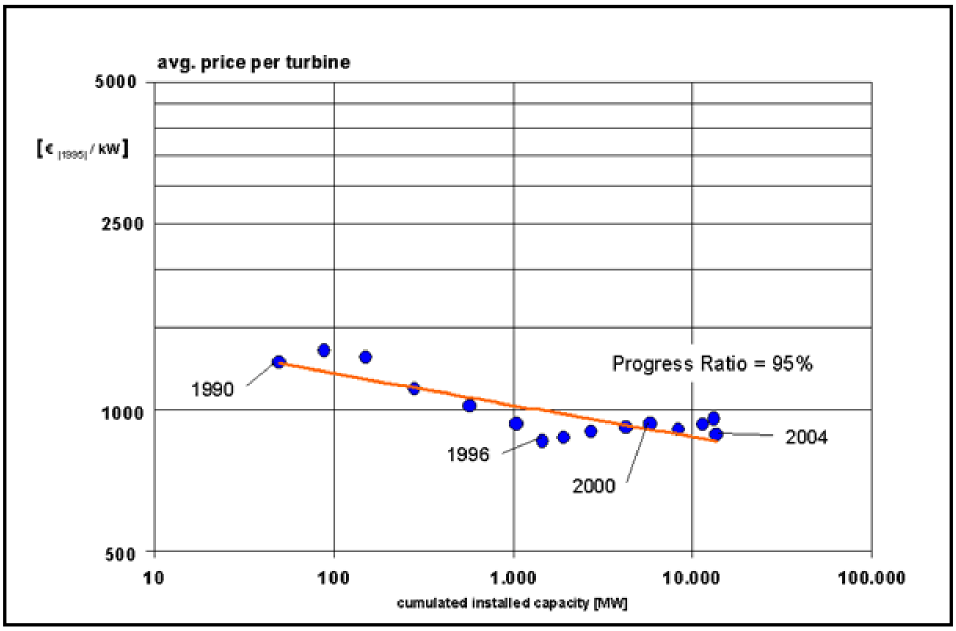

Figure 123 development of German turbine prices 1990-2004 source: ISET

The trend to generally lower wind power costs, however, is confirmed for Germany over the long term (last twenty years). Positive frame conditions, such as state research, development and funding measures, favorable financing possibilities and minimum price system regulations have contributed to this success by systematically reducing risk factors. The development of specific costs with a steady increase of production numbers of wind turbines is depicted as a learning curve for the period from 1990 to 2004. From about 1,260 € / kW with 60 MW cumulative installed capacity in 1990, the specific plant costs have fallen to around 890 € / kW with 14,000 MW capacity in 2004. The "progress ratio" for this learning curve lies at 95 percent. This means that over this period the price reduction of plants was approx. 5 percent, with every doubling of cumulative installed capacity.[1]

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[1] ISET: REISI These evaluations relate to prices for individual turbines, according to the results included in the market overview of the German wind association BWE and generally include delivery and installation. The included prices are inflation adjusted and standardized to the prices from 1995.

http://reisi.iset.uni-kassel.de/pls/w3reisiwebdad/www_reisi_page_new.show_page?page_nr=239&lang=en

Operation & management (O&M) costs

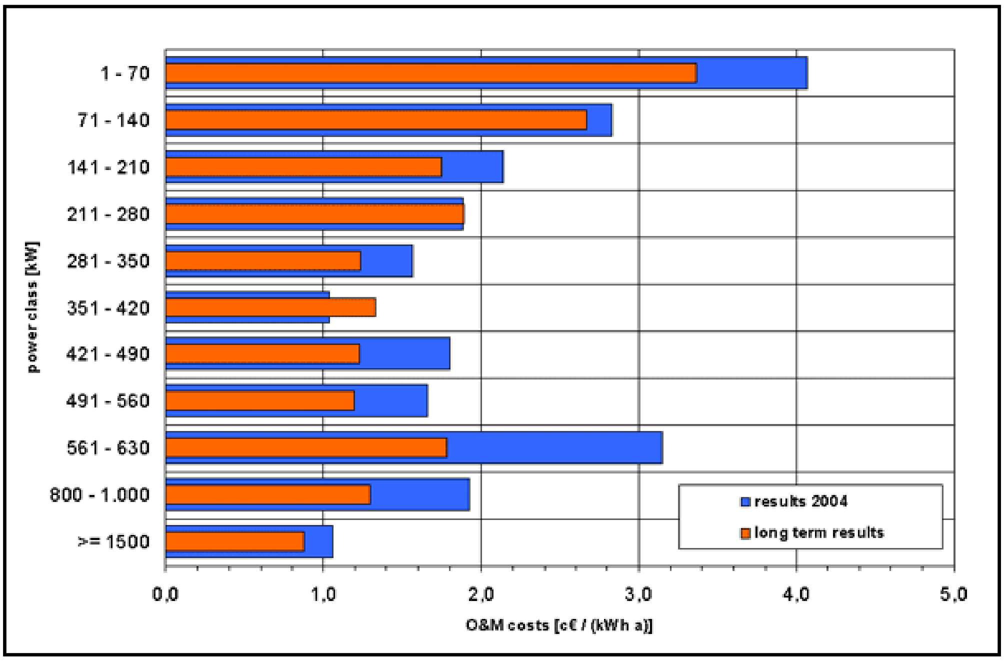

Figure 124 O&M Costs in Germany according to turbine size
source: ISET,IWET[1]

Lower O&M costs have been confirmed by German data sets where for turbines of more than 1.5 MW size, an annual cost of less than 1.0 Euro-Cent/kWh has been recorded. The evaluation depicts the costs for repair, spare parts, operating supply, wages, travelling expenses, service and maintenance contracts etc., according to information provided by operators. This data is reduced by the corresponding amount in the case of possible reimbursement from insurers. Insurance costs for these larger turbines are depicted at some 0.2 Euro-Cent/kWh for turbine sizes of 1.5 MW or more.[2]

There is some uncertainty about these numbers because we do not know exactly yet what the real O&M costs will be once these turbines reach an age of more than 10-15 years.

Many manufacturers offer their customers complete contracts including all services such as insurance, maintenance, spare parts and repairs, but in many markets competition from independent service companies is emerging.

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[1] Institut für solare Energietechniken (ISET): Scientific Measurement and Evaluation Programme (WMEP) 2006

http://reisi.iset.uni-kassel.de/pls/w3reisiwebdad/www_reisi_page_new.show_page?page_nr=237&lang=en

[2] ISET 2006 http://reisi.iset.uni-kassel.de/pls/w3reisiwebdad/www_reisi_page_new.show_page?page_nr=236&lang=de

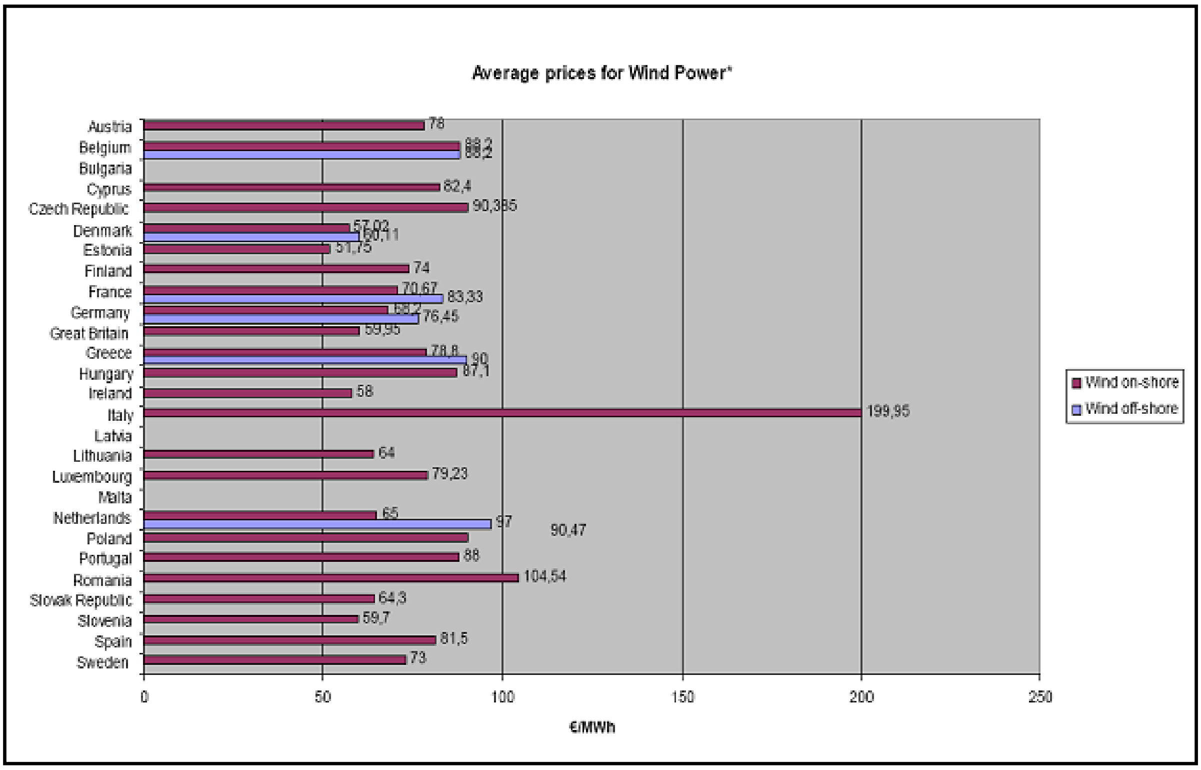

Figure 125 feed-in tariffs for wind power in Europe 2006 source: EREF[1]

A survey on European feed-in tariffs by EREF shows that the main range of prices paid for wind energy in 2006 was between 5.8 and 9.7 Euro-Cents/kWh. This compensation was paid for new turbines in a booming market, while older turbines in many feed-in schemes get lower compensations. Based on a life-cycle analysis, wind power in Europe may come in more expensive than in the US by some 1 or 2 Euro-Cents/kWh, due to less favorable wind conditions. The exceptionally high tariffs paid in Italy are due to a spurious certificate systems and high wholesale prices on the Italian market combined.

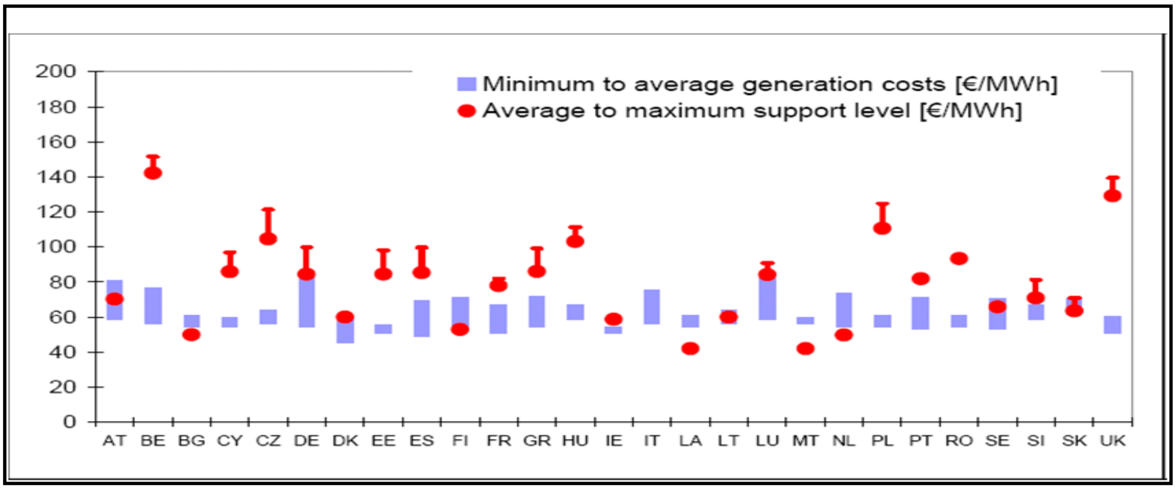

Figure 126 generation costs and maximum support levels in the EU source: OPTRES[2]

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[1] EREF: European Renewable Energies Federation (EREF): Prices for Renewable Energies in Europe:Feed-in-tariffs versus Quota Systems – a comparison Report 2006/2007 EREF

[2] OPTRES, 2007 European Commission (COM(2008)19 final), cited in Gemma Reece, Ecofys UK: Renewable Energy policy developments in the EU-27, Results of the OPTRES, PROGRESS and Futures-e projects, EWEC 2008 presentation

In the most recent survey of the European Commission, generation costs of wind power are described in a range of 4.5-8.5 Euro-Cent/kWh. In most European countries, there exists a wind resource which makes wind electricity no more expensive than some 6 Euro-Cents/kWh. However, costs can vary along different wind endowments. In some countries, support levels are fairly high or have been raised recently to bolster wind power growth rates. Exceptionally high payments in nations such as Britain, Belgium, Poland and Italy are mainly due to ineffective certificate systems; because the certificate price is not guaranteed over a wind turbine's life time investors ask for higher risk premiums. Market structuring with certificates is more expensive than with feed-in tariffs.

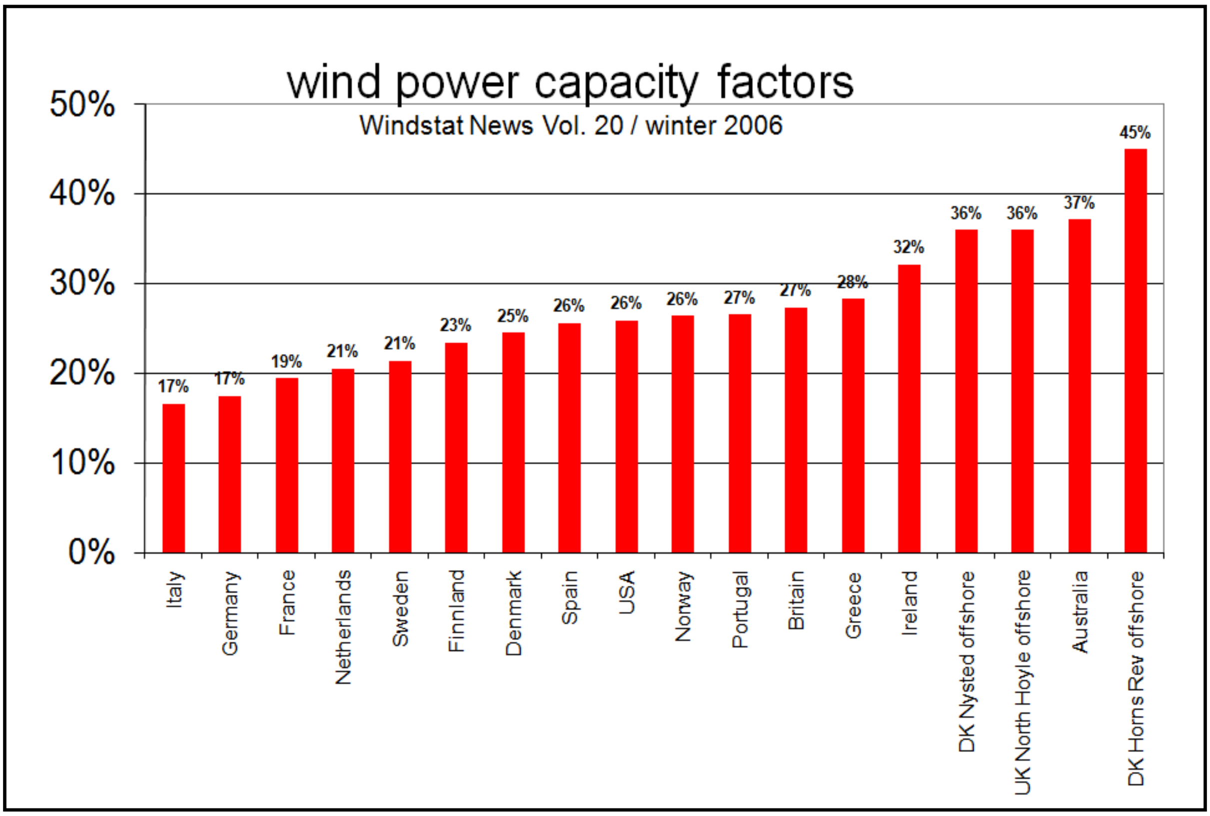

Figure 127 wind capacity factors (2005) source: Windstat Newsletter[1]

The higher cost in Europe is due to lower capacity factors compared to the US. But a trend for better capacity factors could emerge with developments at more peripheral sites with higher capacity factors such as in Sweden, Norway, France, Portugal and Turkey, and with more offshore developments. Conversely, the higher capacity factors in the US can go down as high wind sites are exhausted and developers have to move toward lower speed wind regimes.

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[1] Windstat News Vol. 20/ winter 2006

8. The economics of wind power over the next decade

The key drivers

The four key drivers for renewable energy investments are:

- environmental policy – an ever-tightening ratchet of legislation,
- market liberalization,
- the velocity and falling costs of new technologies, and
- the wish of independence and decentralization of energy supply, going hand in hand with local participation in the benefits of wind power generation.

In the end, it is the economics that will be a deciding factor. The key issue is balancing risk versus return, and a regulated risk in a developed country is one of the best risks there is. With feed-in tariffs, investors have a known price to work with; if utilities must buy all renewable power generated, then there is no demand risk; and, if there is a standardized development process, that results in minimized development risk.

Facing an ever more risky supply of fossil fuels, many governments adopted energy policies over the last couple of years that reduced the risks of renewable investments considerably. The most important issues for wind power identified by BTM in their latest world market update are:

- *national energy plans and government support for renewable energy,*
- *growth in the market, and the present dynamics of the industry,*
- *assessment of wind resources and how they can be used,*
- *technological development,*
- *assessment of previous patterns of market development in similar markets,*
- *information about specific large projects, and*
- *increased engagement of utilities and large energy companies.*

Most of these factors appear favorable for the industry at the moment. There is strong political support for wind energy, both as a carbon reduction measure, and for energy security. More factors expected to influence a continuing growth are:

- *continuing competitiveness of wind with fossil fuels,*
- *deregulated markets removing excess conventional power capacity,*
- *new conventional capacity likely to be more expensive than wind,*
- *social acceptance of wind and renewable energy projects,*
- *many countries may find that they are well off their international CO2 reduction commitments, and need to install some new renewable capacity very quickly,*
- *security of supply questions will continue to support wind power, and*

oil prices will continue to remain high, as will demand for fossil fuels. [1]

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[1] Edward Milford: Record Growth for Wind: What Comes Next? Renewable Energy World July/August 2008

Feed-in tariffs rehabilitated?

Most recently, the IEA concluded in a rather unusual report that feed-in tariffs are both more effective at developing renewable energy as well as less costly to consumers than quota systems:[1]

"*The group of countries with the highest effectiveness (Germany, Spain, Denmark and, more recently, Portugal) used feed-in tariffs (FITs) to encourage wind power deployment. Their success in deploying onshore wind stems from high investment stability guaranteed by the long term FITs, an appropriate framework with low administrative and regulatory barriers, and relatively favorable grid access conditions. In 2005, the average remuneration levels in these countries (USD 0.09-0.11/kWh) were lower than those in countries applying quota obligation systems with tradable green certificates (TGCs) (USD 0.13-0.17/kWh). Beyond some minimum threshold level, higher remuneration levels do not necessarily lead to greater levels of policy effectiveness. The highest levels of remuneration on a per-unit generated basis for wind among the countries studied are seen in Italy, Belgium, and the United Kingdom, which have all implemented quota obligation systems with TGCs. Yet none of these countries scored high levels of deployment effectiveness. This is likely related to the existence of high non-economic barriers as well as to intrinsic problems with the design of tradable green certificate systems in these countries, which cause higher investor risk premiums."* [2]

The international accounting firm, Ernst & Young too, has concluded that Germany's system of feed-in tariffs delivers more renewable energy at lower cost to consumers than Britain's Renewable Obligation and its certificate trading system. The conclusion turns on its head the common misperception that feed-in tariffs cost consumers more than so-called "market-friendly" polices, such as tendering and certificate trading systems:

"feed-in tariffs have the benefit of curbing the cost to the energy consumer of renewables in the context of rising oil prices. The challenge for those countries which prefer more market based mechanisms is to provide the levels of support renewables technologies need, whilst avoiding excessive cost should wholesale electricity prices continue to rise." And it concludes that in Germany an average of 2.6 p./kWh is paid per unit renewable power while in Britain it is 3.2 p./kWh. They concluded that Germany – with 72 TWh renewable electricity in 2006 – generated much more renewable energy at lower costs than Britain (18 TWh, 2006). [3]

Wind farms with a higher value than their costs

The key driver in the market has been and will be strong demand. Rapidly increasing oil prices, closely followed by natural gas, are boosting demand in a unprecedented way. Prices for turbines have edged up, too. But the real value of wind turbines for investors might be even better than their price. This conclusion may be derived from the price of second-hand deals of wind farms:

In September 2008, Windpower Monthly reported that a price of 1.963 million Euros per MW has been paid for an installed capacities of 420 MW, sold by Babcock & Brown in Spain.[4] This price for running machines was some 50 percent higher than the average price paid for

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[1] Many thanks go to long-time wind professional Paul Gipe for these references.

[2] IEA Summary: Deploying Renewables, Paris 2008, p. 17 and p. 19
http://www.iea.org/Textbase/npsum/DeployRenew2008SUM.pdf

[3] Ernest & Young: Renewable energy attractiveness indices, Quarter 1-2 2008, p.13

[4] Windpower Monthly Magazine September 2008 p. 35

new installations in 2007, which for onshore stood at 1300 €/kW, as reported by the same wind magazine in January 2007:

“*Taking a representative sample of the reported costs of over 40 wind farms in 2007 with a cumulative capacity of 3000 MW, the average installed cost of wind plant comes in at just under EUR 1300/kW.*”[1]

Market prices for finished wind farms today are definitely higher than their initial costs – therefore the run for new wind turbines, all because of strong demand and higher fuel costs of conventional plants.

The major cost of an installed wind plant lies in the wind turbines. From prices reported during 2007 for a sample of 3700 MW of wind plant across the world, the average price of a wind turbine was EUR 972/kW, some 17 percent higher than last year, reported Windpower Monthly. The rest of costs up to the mentioned 1300 EUR/kW installed project costs are civil works and interconnection costs.

price data for	**Euros/kW**	**$/kW**	**Source**
average wind projects installed costs 2007 US	**1179**	**1710**	**Wiser & Bolinger 2008 p. 21**
average wind projects installed costs 2007 onshore, global	**1300**	**1885**	**Windpower Monthly 1/2008**[2]
wind projects onshore sold on the second hand market (Spain)	**1963**	**2847**	**Windpower Monthly 9/2008**
expected turnkey price 2008/9 onshore	**1461**	**2119**	**BTM consult WMU 2008**

Figure 128 price of new wind capacities in 2007/2008 and expectations for 2008/2009

If wind power installations have a higher value than actual turbine costs, it is highly rational for manufacturers to further lift their profit margins and to accelerate investments for expansion of their manufacturing capacities.

In fact, this is precisely what many are predicting: “*The market has seen very high levels of growth in the past three years and that is likely to continue. Furthermore, the increased engagement of larger companies brings with it more expertise to deal with the financial, engineering and supply chain problems that have been associated with rapid growth in the past….The hedge of electricity supply without a fuel cost is likely to become increasingly attractive to many companies and utilities. At some stage, rising fuel costs could lead to demand for wind energy becoming almost infinite.*”[3]

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[1] Windpower Monthly Magazine January 2008 p. 51f.

[2] WPM = Windpower Monthly Magazine

[3] Edward Milford: Record Growth for Wind: What Comes Next? Renewable Energy World July/August 2008

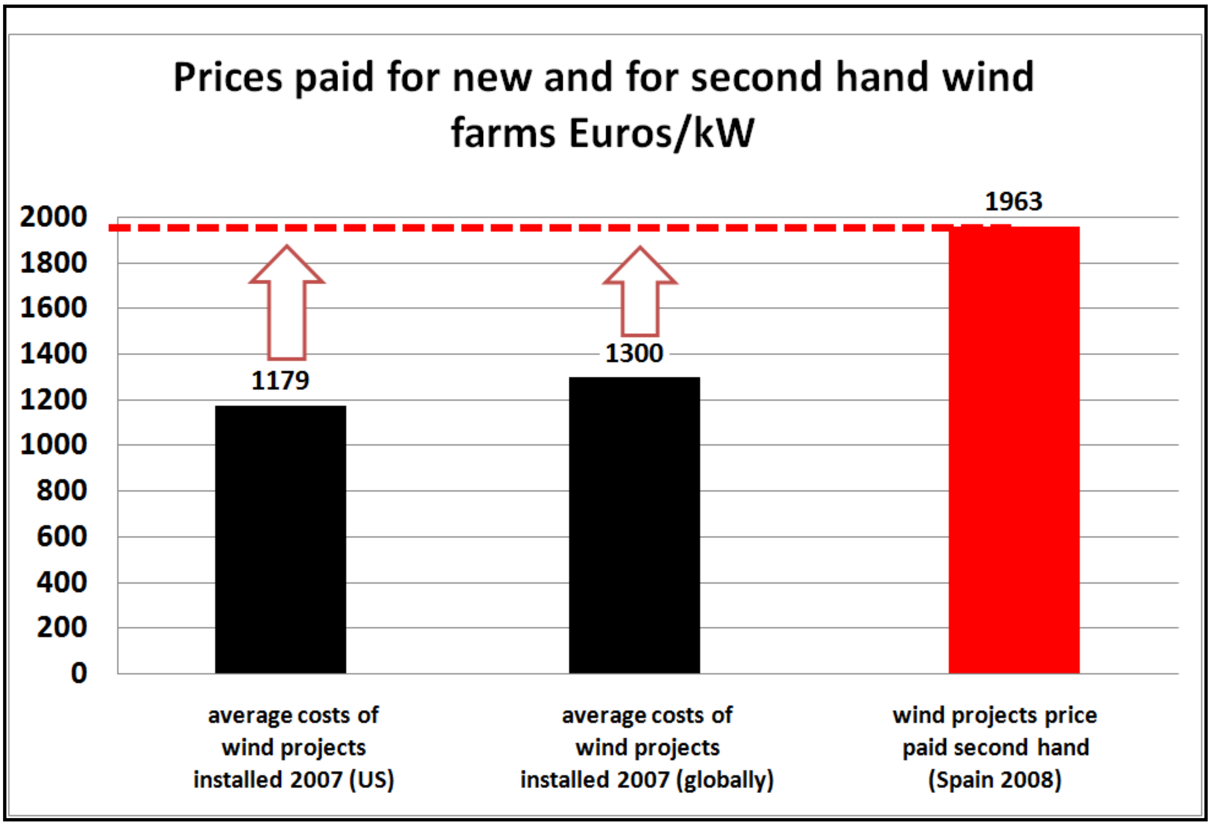

Figure 129 the price paid for wind installations and its recent costs

Higher margins for turbines allow manufacturers also to pay their costs, which are also on the rise due to higher prices for materials and wages. The increase of prices is a necessary condition to stay competitive with other power industries for factor input.

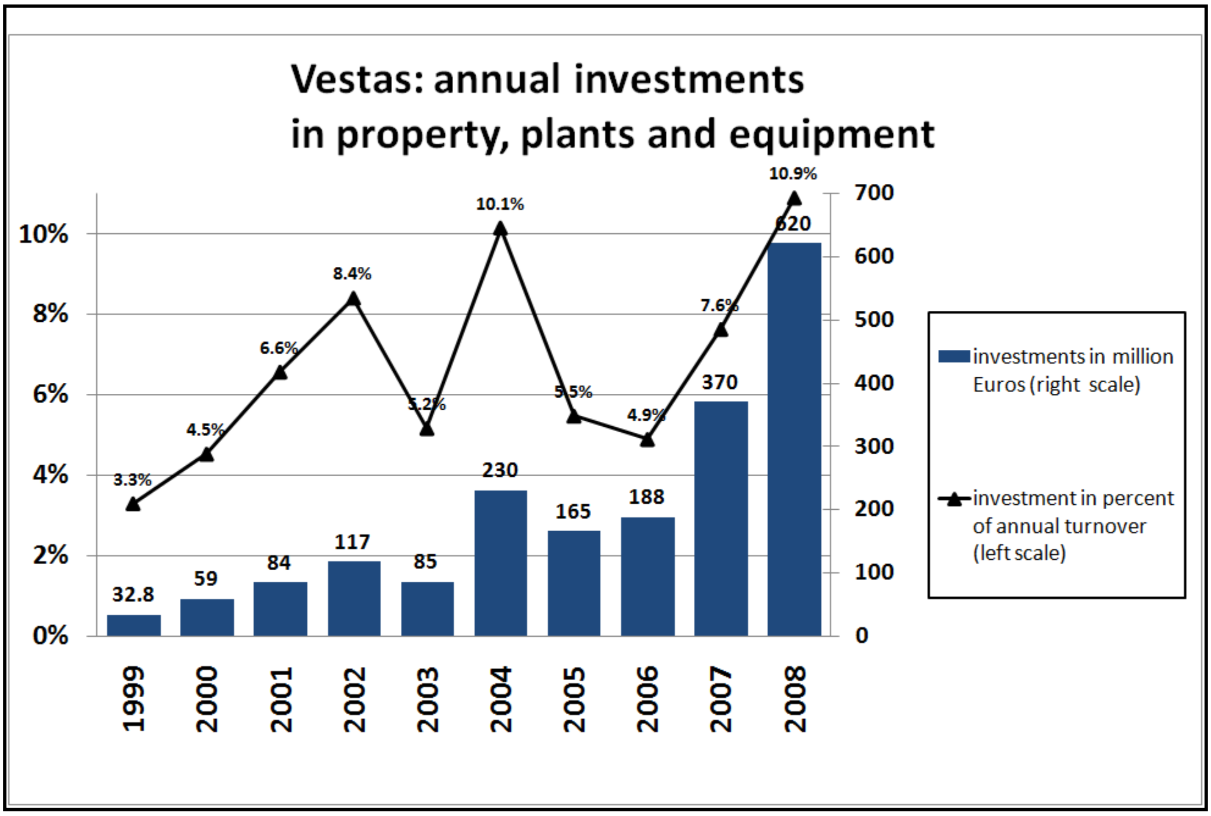

Figure 130 investments market leader Vestas

Higher profit margins allow manufacturers to steeply accelerate their investments in expanding turbine production. Feed-in tariffs allow high profit margins. This then allows for expansion. Low prices, and low margins means the companies can't expand.

An example is market leader Vestas which took steps for in-house vertical expansion while not abandoning external sourcing. Vestas' investments in new property, plants and equipment rose to a record level of 620 million Euros, corresponding to a record of 11 percent of overall revenues in 2008 – and this high quota is expected to persist due to announcements of rapid expansion in the US and elsewhere.

Turbine manufacturers are also shifting costs toward customers by shortening guarantee periods, which normally were at around five years before 2007/2008, and amount to only one to two years for new contracts.

To some degree, supply bottlenecks are a normal side effect of a boom, as demand expands more quickly than the capacities of suppliers. Under market conditions, this is a self-regulating mechanism, as prices for scarce resources go up, dampening demand. In the case of renewable energy, the price increases are significant, and have partly reversed the effect that economies of scale are expected to have on generation cost. Price reductions associated with economies of scale have not been observed for the 2005-2008 period. Higher prices are likely to persist as long as the 'sellers' market' stays in place, with rapidly growing demand chasing a not quite so rapidly growing number of turbines as manufacturing capacity lags.

Turbine manufacturers have been able to keep prices firm to ensure that they get healthy margins from their businesses. In addition, as with other manufacturing industries, the wind industry was also facing rising costs of raw materials, transport fuels and energy. As a result, BTM in its 2008 report anticipated that the turnkey price for onshore wind would likely raise to the order of US$2119 (~ 1461EUR) per kW, and offshore at $3654 (2520 EUR) per kW.

In case of a slow-down of the wind industry – which is not in sight yet however – a price reduction can be expected because a much lower level of new investments would be needed to be financed by the wind sector's clients. Wind power in that moment will be available at a significantly lower price and all the hidden productivity gains will finally come to the consumer's advantage. Competition would squeeze profit margins at the same time, while today, net profit margins of 10 percent or more can be achieved by some successful manufacturers.

The price of power compared over the next 10 years

Three main items influence the cost of a power plant owner:

- capital costs,
- fuel costs, and
- operation and maintenance (O&M) costs including waste and emissions costs.

Generation costs in 2008

Capital costs of wind are higher than those of coal or natural gas projects. But for the latter, fuel costs are on the rise. Once a wind or solar project is up and running, amortizing capital investments and ongoing maintenance are the only expenditures.

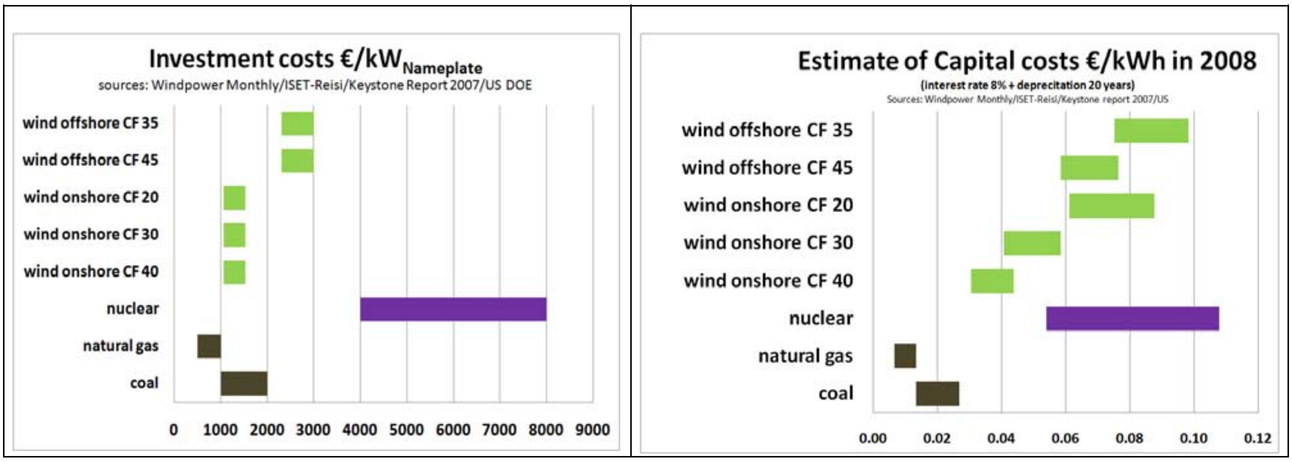

Figure 131 investment costs of different generation technologies compared – 2008

Investment costs for wind power stood at an average 1300 Euros per kW at the end of 2007.[1] This is – as a nameplate capacity investment – as cheap as coal or natural gas, and much cheaper than nuclear.

A fair comparison however has to compare the cost per power delivered and there the number of full load hours, the costs of fuels and O&M play a big role. In our calculation the different capacity factors are included as follows:

	capacity factor (CF)	investment Euros/kW lower band	investment Euros/kW upper band
coal	85%	1000	2000
natural gas	85%	500	1000
nuclear	85%	4000	8000
wind onshore CF 40	40%	1066	1532
wind onshore CF 30	30%	1066	1532
wind onshore CF 20	20%	1066	1532
wind offshore CF 45	45%	2300	3000
wind offshore CF 35	35%	2300	3000

Figure 132 capacity factors and capital costs used for cost comparisons

Concerning capital costs, coal and gas are cheaper than wind power while nuclear is on a par with low-wind onshore and offshore installations.

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[1] "Taking a representative sample of the reported costs of over 40 wind farms in 2007 with a cumulative capacity of 3000 MW, the average installed cost of wind plant comes in at just under EUR 1300/kW. This is only 11% higher than for 2006. As always, the spread of prices in the sample is wide, but two-thirds lie between EUR 1066/kW and EUR 1532/kW." Windpower Monthly Magazine January 2007 p. 51f.

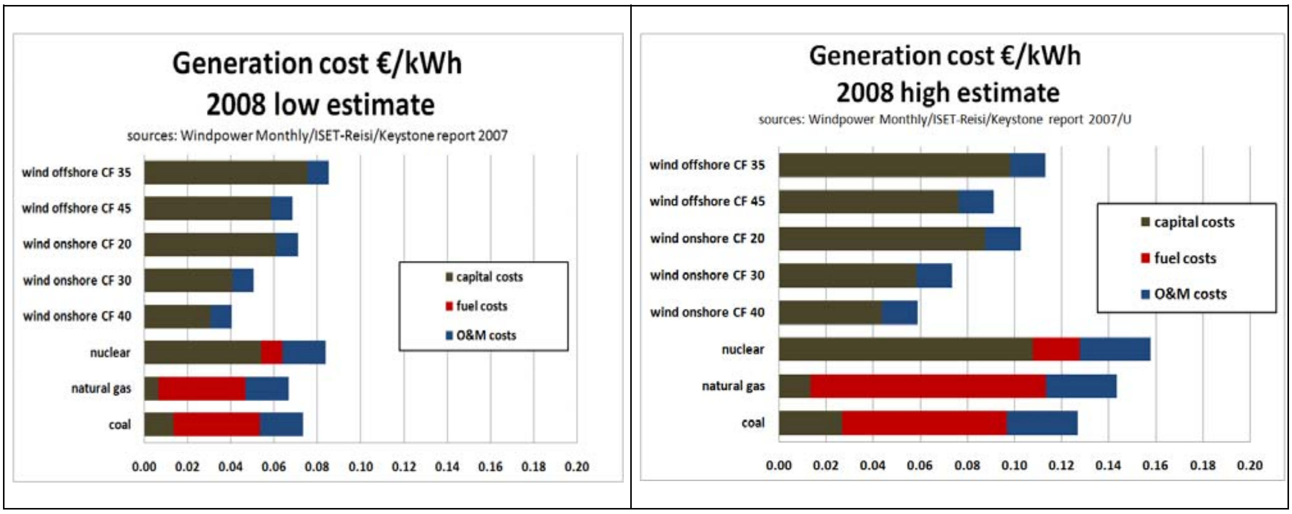

Figure 133 full costs compared – 2008 estimate

Looking at full generation costs, we find that onshore wind today is cheaper than conventional energy. Offshore wind power comes at a par with gas, coal and nuclear and in some places is more expensive than coal and gas.

Furthermore, high raw material prices and technology supply bottlenecks are also having an impact on conventional power generation technologies; hence the relative competitive position of renewable energy is unlikely to be fundamentally affected.

The cost situation in 2020

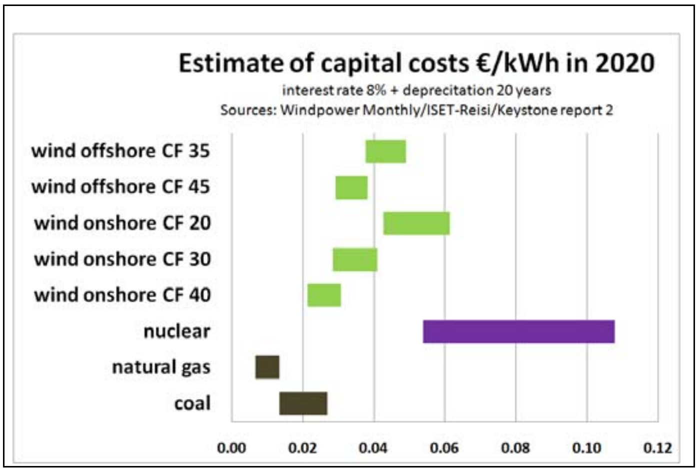

Figure 134 Estimated capital costs per kWh in 2020

If we suppose that offshore wind will have the same success as did offshore oil, a reduction by 50 percent can be expected for offshore investment costs while onshore a reduction of 30 percent is thought to be possible. Because nuclear, gas and coal are fairly major technologies, no comparable cost reductions are expected in their field – quite the contrary might be the case when carbon pricing and additional nuclear safety measures are requested by governments.

As a result, the competitive position of wind power investments is expected to improve compared to conventional technologies. Capital costs are expected to be only 3-6 Euro-Cents per kWh while nuclear will stay at 5-11 Euro-Cent per kWh.

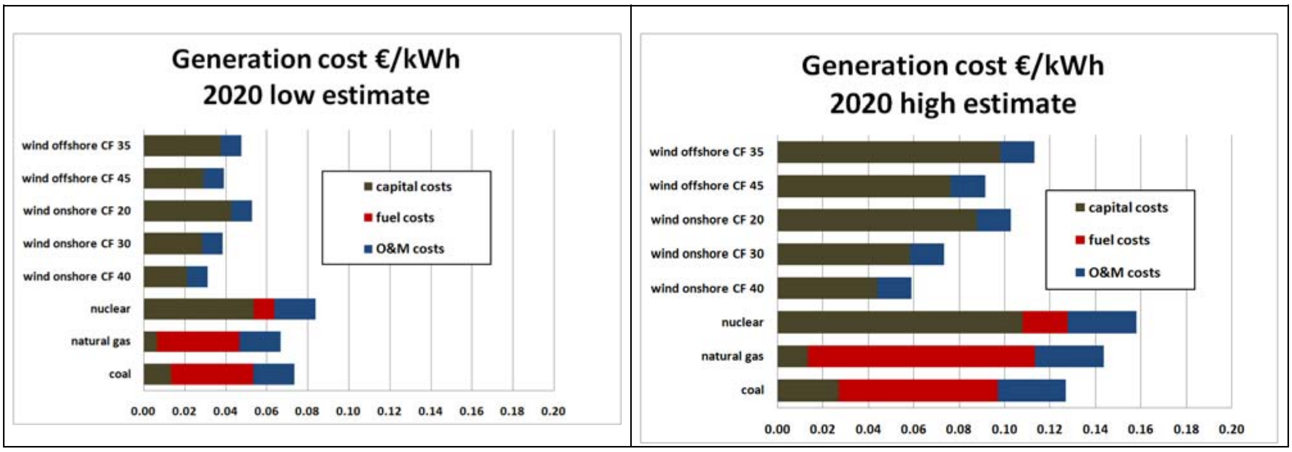

Figure 135 prospective estimate for wind power costs in 2020, compared with fossil and nuclear at 2008 fuel costs

By 2020, economies of scale and technical improvements will further strengthen the competitiveness of wind power compared to all other conventional technologies. Even if rising raw material prices and supply bottlenecks raise the cost of renewable power generation, the position relative to conventional fuels is likely to improve. This is based on our assessment that the high level of oil, gas and coal spot prices is based on structural factors that are likely to last over the longer-term – despite temporary price drops in situations of recession or financial crisis – while bottlenecks in renewable energy technology supply chains will eventually be overcome.

Renewable energy – boom or hype?

Experts clearly speak of a “renewable energy boom”. This boom differs in several ways from the dotcom-hype and other stock market exuberances:

- Comparing the P/E ratios (market capitalization divided by net annual profit) of wind energy companies in the past two years with those of telecommunications and Internet players shows wind power companies mostly within a healthy range. While major telecommunications and Internet companies had either negative (due to losses rather than profits) or extremely high P/E ratios, “the market capitalizations of renewable energy corporations generally appear to be much more reasonable”.[1]
- Factors stabilizing the development include the diverse national systems and technology portfolios of utilities, which mitigate risk of policy changes in all markets.
- Also, the fact that demand for electricity is well established and growing is a key difference from the Internet and telecommunications booms, which were built in part on anticipated rather than existing demand.

Due to its least or low cost character, wind power is not so exposed to policy changes as is solar. Therefore, we believe that wind power is much less vulnerable to a sudden bust than any other renewable or non-renewable power source.

Obviously, many other technology options are competing for market shares. These technologies are energy efficiency, nuclear, and carbon capture and storage (CCS).

However, CCS will certainly not be available on a large scale by 2020, thus giving renewables time to penetrate the market and further optimize costs. And the lengthy planning and construction terms for nuclear power can easily be outdone by wind power, which in

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[1] Orlando Wagner and Jochen Hauff: Renewables Are Booming: Is a Bust Inevitable? Renewable Energy World July/August 2008

terms of new installations has surpassed nuclear today, and will do so in multiple dimensions over the next 5-10 years.

As would be expected in a maturing market, there are considerable changes in the wind energy industry, particularly when viewed over a period of several years.

We will see a diversification in wind technology: On the one hand, the size of wind farms continues to grow, as does the size of the wind turbines, which populate them. And, while offshore installations are only a small fraction of the current total wind market – with a roughly a 1 percent market share – this sector is likely to grow in a big way in the years to come. On the other side, the demand for medium and small-scale wind turbines could well explode too, mainly from developing countries and for rural electrification, be it of villages or individual households.

The manufacturing of turbines is an increasingly globalized business. A convergence of costs can be expected due to growing international competition and decentralization of component manufacturing. Decentralized manufacturing may also lower transport costs of the more bulky components such as rotors, nacelles and large bearings.

At some places, the emergence of "Gigawatt giants" – large wind farms with several GW capacity – will ease the situation of manufacturers and may reduce specific costs per MW for planning, civil works, marketing and monitoring too. Many of these gigawatt complexes are eager to grow as fast as possible – and they are ready to absorb a high number of turbines in case of permission delays for other projects. At other places, small and medium sized wind turbines, in combination with other renewable energy technologies, will replace nonrenewable power generation.

Some remarks on coal-fired power, compared with wind

Coal-fired plants are one of the oldest ways to generate electrical power, and they still represent most of the generation capacity in a number of countries, including the USA (more than 50%) and China (more than 80%).

- Initial investments were modest, typically $1000-1200/kW, but recently a rise of prices for new coal plants toward $2000/kW has been experienced,[1] In some regions, such as China, rumors of coal shortages emerged.
- Fuel costs have historically been low, but recently a fourfold surge of coal prices has been registered.
- Externalities are the outstanding issue for coal, as it is the worst producer of greenhouse gases and other hazardous emissions.

Carbon emissions, air pollution and mining spillovers are the weakness of coal. In general, coal power costs are rated at about 5 US cents a kWh. New coal power plants might have risen to 7-9 US-Cents/kWh or 5-7 Euro-Cents/kWh in Europe. The imminent costs of dealing with CO2 release, by either sequestration or by buying an allowance in a cap-and-trade market, is now higher than the cost of coal itself. These costs will be even greater if CO2 capture and storage (CCS) becomes compulsory.

"*We think that you will be able to do CO2 capture and storage (CCS) for coal-fired power plants at a cost of 50 dollars per ton of CO2 abated, which is not cheap,*" says Dolf Gielen from the International Energy Agency (IEA). "*The real challenge for CCS is that you will need 20 to 30 demonstration plants in the very near future. And each of these plants cost one to two billion dollars apiece. Investors are shying away from that amount.…. But so far,*

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[1] Handelsblatt, cited in: Stellungnahme des Bundesverband WindEnergie (BWE) zum EEG-Referentenentwurf Berlin 14.11.2007

demonstration for coal-fired power plants are lacking, and that is what the key option would be. It is still stuck somewhere between good will and reality."[1]

If we compare this cost with the expected cost of some 5 Euro-Cent/kWh for new wind power, the whole CCS strategy looks rather weak on economical grounds. Even if technical obstacles can be removed, wind power by 2020 is expected to be cheaper on a full-cost basis than cost of CCS alone – and far cheaper than overall costs of coal technology including fuel, O&M and capital costs.

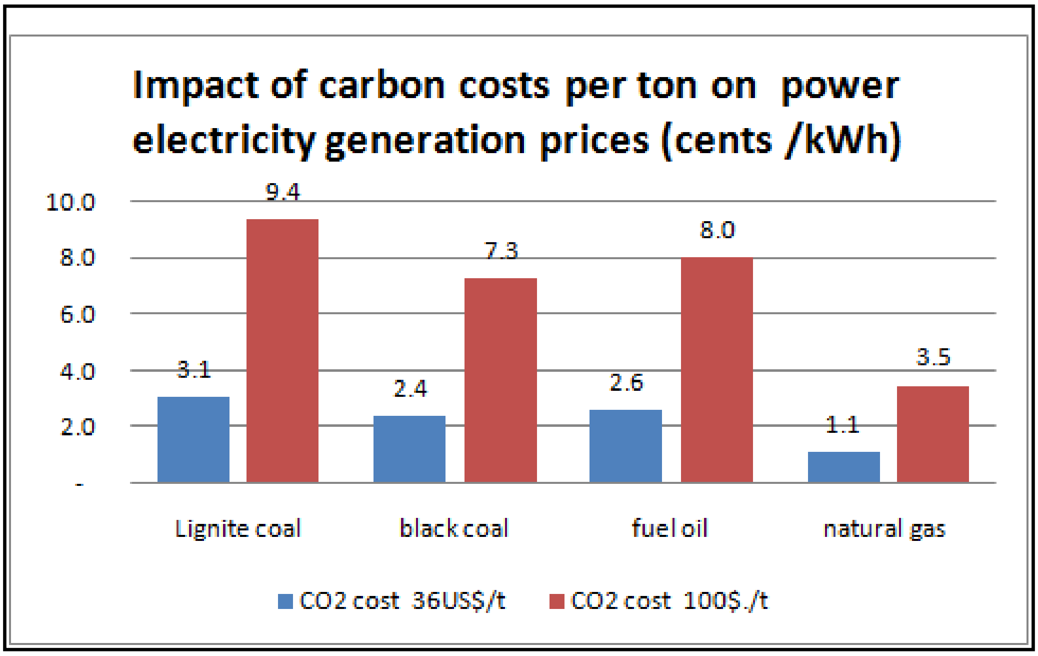

Figure 136 impact of CO_2-costs on the cost of electricity source: ISI and Fritsche[2]

CO_2-costs of between \$35 and \$100 per ton would add an extra cost of 2.5-9.4 Cents per kWh on electricity costs from new coal plants. Even if such rules are not introduced immediately, their imminent character can have an influence on investment decisions.

Any internalization of carbon costs will have a positive impact on the competitiveness of wind power. The same is true for the European carbon trade system, which is due for a start by 2013 – with carbon certificates auctioned and no more given for free.

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[1] Dolf Gielen, International Energy Agency, Co-author of IEA Energy Technology Perspectives, cited in: IEA Energy Scenarios: Change We Have to Believe In (2008) http://knowledge.allianz.com/en/globalissues/climate_change/climate_solutions/iea_gielen_climate_energy_technology_perspectives.html

[2] Excel-Tool for CO_2-emissions of stationary combustion www.isi.fraunhofer.de/n/tools/excel-tool-vollversion.xls The calculations are based on following coefficients for CO2 and power plant effecencies:

	(Tons CO2 per TJ input)	Best efficiency[2]
Lignite	30.6	40%
Black coal	25.4	40%
Fuel oil	21.3	35%
Natural gas	15.0	59%

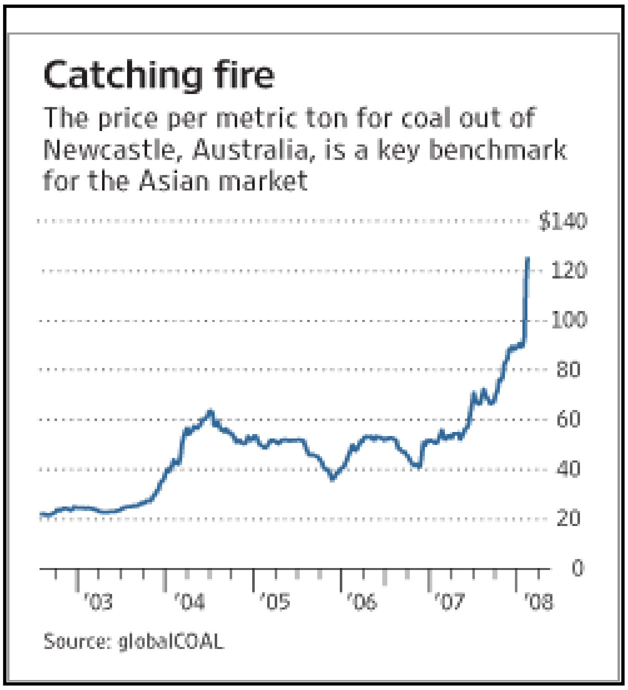

Figure 137 volatility of Australian coal price

As can be seen, the costs of coal have moved upward recently. It remains to be seen if this level will persist in the long-term.

Conclusions

For new coal plants, cost advantages against wind power are declining. With more turbines on the market, the choice of many coal power companies might turn toward wind power. Any carbon cost for new coal plants makes coal less attractive while in the absence of a climate policy -- and possibly even with coal prices receding somewhat – new coal plants might at best come on a par with the costs of wind power.

With wind, there is no carbon or air pollution and no fuel cost risk. The conclusion therefore is that investors who are able to change from coal to wind power will exactly do that to protect themselves from carbon cost risks and effluent taxes.

Some remarks on the costs of gas-fired electricity

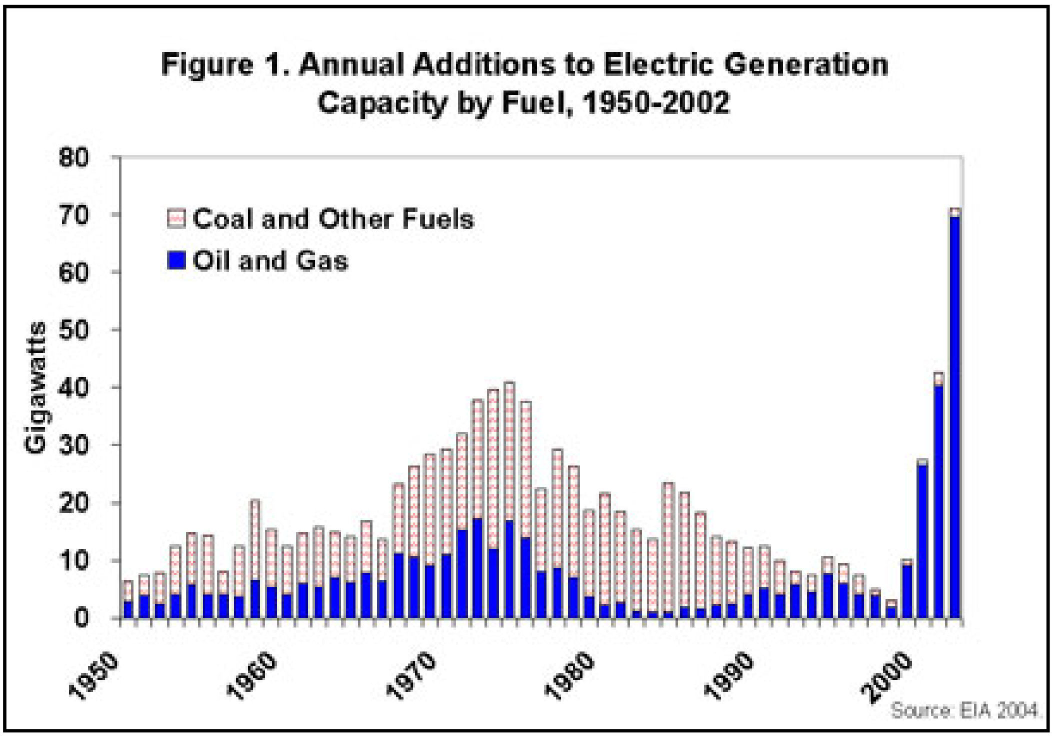

Figure 138 The rush for natural gas powered plants in the US
Source: EIA[1]

Gas-fired plants have been the big story of the last decade, with massive investment in a number of countries, especially the US and the UK, and it has reached a significant share of generation (20 percent in the US). Natural gas often acts as the price setter for wholesale electricity as it usually is the marginal cost producer – that with the highest short-term cost – and thus the one setting the price to provide a given number of kWh at any given moment.

- Initial investments are low, typically $500/kW, and the size of plants is quite flexible, which makes it possible to amortize that investment fairly easily, making the technology a favorite of the financial markets and thus of private power producers;
- Fuel costs are linked to the price of oil, which, until 2005, was quite low. Then that price has suddenly shot up enormously, making the sector much less competitive;
- Pollution is less than with coal as natural gas is mostly methane and burns cleanly, but carbon dioxide contributes to carbon emissions.
- The issue of security of supply has come to the forefront, with fears of shortages in both the US and the UK, due to faster than expected field depletion and a growing dependence of Russian and Middle East gas imports in Europe.

In the US, natural gas was priced for years on a par with crude oil. At a price of $120 per barrel, this would translate into 75 US-Cents/liter or 7.5 US-Cents/kWh if the long-term thermal equivalent of oil and gas is considered. With the most modern combined gas plants at a very best efficiency of 59 percent[2], fuel costs alone would amount to some 13 US-Cent/kWh.

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[1] Cited by Jerome Guillet: The real cost of electricity - some numbers, Eurotrib 2006, http://www.eurotrib.com/story/2006/3/5/19821/21750

[2] Tony Kaiser (Alstom): Das Potential und die Nutzung von Gas-Kombi-Kraftwerken aus der Sicht der Nachhaltigkeit, 13.9.2007 http://www.forumvera.ch/praesentationen/2007/Gas-Kombi-Kraftwerk_Toni%20Kaiser.pdf

Power producers with natural gas will be happy to turn to wind power therefore – and then sell their gas contracts at the spot market with a profit.

Natural gas will play a role in the power sector for peak power and as a reserve fuel as long as hydro storages are not available for the same purposes, but for base load it will be substituted, mostly by wind.

The costs of nuclear power

Nuclear power plants were massively developed in the 1970s following the first oil crisis, and by 2007 they provided about 13.8 percent of world electricity. There has been little investment in the sector in the past 20 years as fears of accidents like in Chernobyl or Three Mile Island and concern about radioactive waste storage prevailed. Most investments took place in Asia (India, China, South Korea and Japan) where monopolistic electricity companies could proceed without manifest competition or democratic control.

- Initial investment is typically rated by the industry at a low of $2000-$3000/kW but a more realistic price tag is at 4000-8000 €/kW or more.
- Plant size is necessarily big (1000 MW or more), thus making the absolute investments high;
- Fuel costs accelerated and will so in the future. They still are at some 1 €Cent/kWh while O&M costs, including waste treatment, show a cost of some 2-3 Euro-Cents/kWh;
- Externalities are difficult to calculate. Nuclear is not carbon-free, due to carbon emissions for uranium mining, construction and disposal of power plants and radioactive waste treatment. The risks of accidents, terrorism, or misuse of fissile materials (low probability, but potentially high impact) are hard to assess. De-commissioning and waste storage put a cost on future generations.

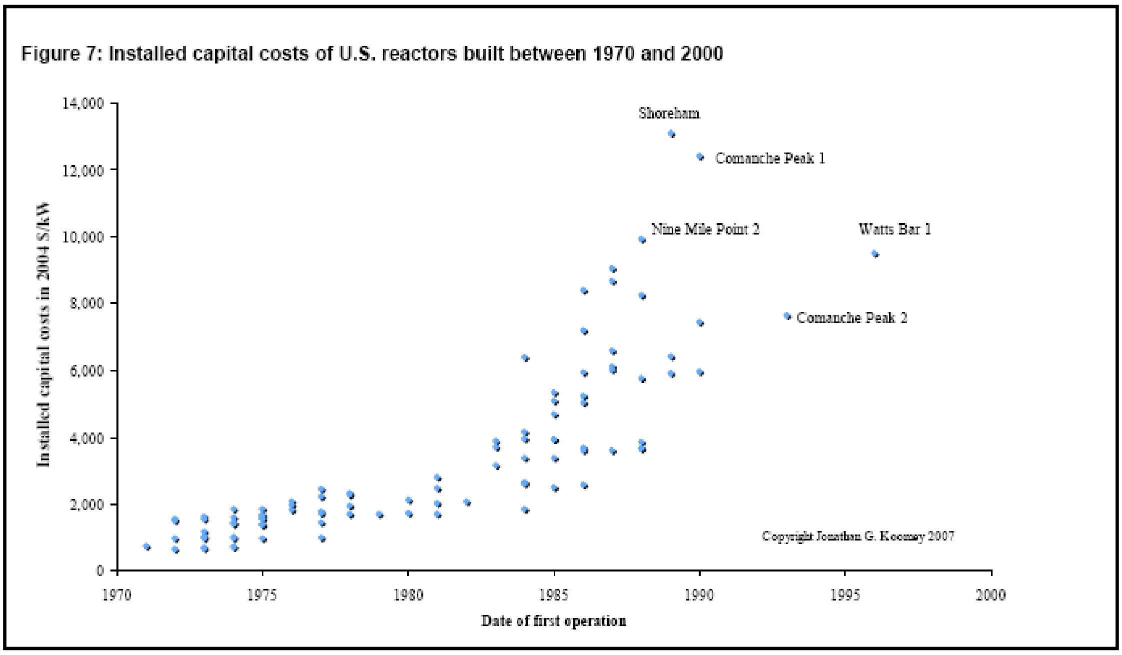
Figure 7: Installed capital costs of U.S. reactors built between 1970 and 2000

Figure 139 Cost overruns of nuclear power plants in the US
source: Keystone report[1]

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[1] The Keystone Center: NUCLEAR POWER JOINT FACT-FINDING, June 2007, Washington DC, S.31 http://www.keystone.org/spp/documents/FinalReport_NJFF6_12_2007(1).pdf

Many nuclear projects budgets have been exceeded by real costs. This can be seen for the US where in the 1990s the final investment costs of nuclear plants ranged from $8000-$13000 per kW or more. A similar cost explosion – though less transparent – happens with the prestigious Euro-reactors in construction in Olkiluoto (Finland) and Flammanville that both experienced delays and were put on hold by nuclear control authorities.

In September 2007, the Olkiluoto operator, TVO, announced that the project was at least two years behind schedule:

"*Flawed welds for the reactor's steel liner, unusable water- coolant pipes and suspect concrete in the foundation already have pushed back the delivery date of the Olkiluoto-3 unit by at least two years…. Olkiluoto-3, the first nuclear plant ordered in Western Europe since the 1986 Chernobyl disaster, is also more than 25 percent over its 3 billion-euro ($4 billion) budget. If Finland's experience is any guide, the ``nuclear renaissance'' touted by the global atomic power industry as an economically viable alternative to coal and natural gas may not offer much progress from a generation ago, when schedule and budgetary overruns for new reactors cost investors billions of dollars.*"[1]

In October 2008, another announcement means a delay of another half year. According to TVO, the reactor is now scheduled to start electricity generation only in the year 2012, meaning a delay of three years. In 2007, TVO announced that the reactor would not be in operation before 2011 and that the total project costs have gone up from 3 billion to 4.5 billion €, meaning that Areva will loose at least 1.5 billion € (some $2.2 billion).[2]

In Finland, it is the French tax payer who will pay for cost overruns for the Finish buyers bought at a fixed price of some 3.2 billion Euro.[3] The real costs of this reactor delivered by the French nationalized Areva Group will never be made transparent, and even less so in the case of the French EPR in Flammanville. For Finland, a price tag of at least 4.5 billion € has been communicated by "les Echos". More aid for the reactor came from EU member states who gave low interest export credits and other low interest procurements.[4]

Construction at Flammanville has been hit by problems with concrete and steel reinforcements. In May 2008, the French nuclear safety agency, ASN, ordered a suspension of work until these issues were resolved.

Liability exemption and more

In Europe and in the US, nuclear power plants are shielded by law from full liability that exempts them from paying adequate compensation in case of an accident.

The Price-Anderson Act in the US, a law dating from the 1950s, caps the industry's liability at about $10 billion in the event of an accident, even though studies show that a major nuclear meltdown could easily run 50 times that.[5]

The Energy Policy Act of 2005 contains more than $13 billion in tax breaks and subsidies for companies willing to invest in new nuclear plants. It provides for loan guarantees of up to 80 percent of a new nuclear project's cost, while it also gives a tax credit of 1.8-2.1 US Cents per

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[1] Alan Katz: Nuclear Bid to Rival Coal Chilled by Flaws, Delay in Finland, Bloomberg 5.September 2007; regarding Olkiluoto see: Areva: First Half 2006 Financial Results, Press Release on Sept. 27, 2006 and Nucleonics Week: "Host of Problems Caused Delays at Olkiluoto-3, Regulators Say," Sept. 13, 2006, pp 3-8. "The original contract cost was $2,350/kW, and current overrun estimates yield a final cost as high as $3,750/kW." **http://www.bloomberg.com/apps/news?pid=20601087&sid=aFh1ySJ.lYQc&refer=home**

[2] TVO press release of October 17, 2008: Start-up of Olkiluoto 3 may be postponed until 2012, **http://www.tvo.fi/www/page/2960/**

[3] EREF European Renewable Energy Federation: EU investigation requested into illegal aid to Finnish nuclear plant, 13.12.2004

[4] For further details see: Amory Lovins and Imran Sheikh: The Nuclear Illusion, Ambio Nov 08

[5] Mark Clayton: Nuclear power surge coming – In the next 15 months, US regulators expect applications for up to 28 new plants, The Christian Science Monitor, September 28, 2007

kilowatt-hour for 6,000 megawatts of capacity for the first eight years of operation. An amount of up to $5.7 billion in production tax credits is ready for any reactors under construction by 2014 and in operation by 2021.[1] Furthermore, among the law's incentives are $2 billion to help cover the cost resulting from any delays in licensing for the first six new reactors, including setbacks caused by federal regulators or lawsuits.

So far no new nuclear plant has started construction or has got permission in the US. But there is a waiting list for federal subsidies where a number of potential investors have lined up.

Over the last five years, cost estimates for new nuclear power plants have been continually revised upward. The infamous nuclear "renaissance" therefore might end before it started. Energy publisher Ken Silverstein noted: "*Nuclear Energy Slows Down: – While nuclear developers are doing the necessary groundwork to build, they still have not committed themselves. Most immediately, the credit markets are weak and the cost of raw materials such as cement, copper and steel is expensive. Those dynamics have caused Berkshire Hathaway's MidAmerican Energy to put off developing a nuclear plant in Idaho as well as South Carolina Electric & Gas to postpone submitting a combined license application to federal regulators…*"

When the first applications were submitted in 2007, the developers had estimated the cost to construct to be in the $4 billion to $6 billion range. Now, though, the price is in the $7 billion to $8 billion range -- the single greatest factor causing MidAmerican to get cold feet.[2]

In Europe some prestigious leaders of the pro-nuclear camp such as Eon's boss Wulf Bernotat put the price tag for a nuclear of some 1600 MW plant at 6 billion Euro[3] while the Wall Street Journal put the price sticker at "$5 billion to $12 billion a plant, double to quadruple earlier rough estimates".[4]

The price for most wind turbines in 2007 was around 1300 Euros per kW (nameplate). So at a 30 percent capacity factor, wind power's capital costs come in at 4300 € per kW for a 8760 hours full-load supply. New nuclear at 4000 € per kW (nameplate) and an 85 percent capacity factor comes in at 4700 € per kW for a 8760 hours full-load supply – with no waste treatment costs included!

Wind, therefore, is no more expensive than nuclear in terms of investments[5], and wind power is much cheaper in variable costs than nuclear and has a more benign risk structure. With nuclear, the long construction terms have to be considered too; they often spiral up additional costs. And for private investors there are more risks: in case of a big accident such as in Chernobyl a shutdown of many or all nuclear plants is imminent provided the accident is happening within a Western industrialized nation.

Then there is the difficult question of nuclear waste treatment costs. In Britain, estimates for cleaning up the dead power stations over the coming decades has risen to 73 billion Pounds.[6] If we translate this into a cost per kWh over the 2493 TWh nuclear energy produced[7], it is an

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[1] "Bids for nuclear power soar", McClatchy-Tribune Regional News - Greg Edwards Richmond Times-Dispatch, Va., Dec 10 2007

[2] Ken Silverstein, EnergyBiz Insider: Nuclear Energy Slows Down, March 14, 2008, http://www.energycentral.com/centers/energybiz/ebi_detail.cfm?id=477

[3] The Times, May 5, 2008

[4] Rebecca Smith: New Wave of Nuclear Plants Faces High Costs, The Wall Street Journal May 12, 2008

[5] nuclear has at best an average capacity factor of 90%

[6] Cost of nuclear clean-up rises to £73bn, The Guardian, Thursday October 11 2007

[7] BP Statistical Review on World Energy 2008; the nuclear production of the 1955-1964 period (some 100 TWh) – some 3% of overall production is missing in this calculation.

amount of 2.9 pence or some 3.6 Euro-Cents per kWh. There are no statistics which consider these costs as long as taxpayers are paying for them, in Britain as well as in France or the US.

All this said, and with regard to O&M costs of less than 1 Euro-Cent/kWh for wind power as well as no fuel and no waste costs, it becomes quite clear that nuclear is not the cheap, low carbon alternative that believers in nuclear are fighting for.

It is the combination of negative aspects that make nuclear unattractive and unacceptable: long lead times, higher-than-wind construction costs, higher-than-wind operation costs, higher fuel costs and the risk of fuel and radioactive waste cost increases. On an open market, all of this causes capitalists to turn away from the pursuit of nuclear dreams.

Conclusion regarding cost comparisons

We finish this chapter by stating that today overall costs of new wind power is below that of coal, natural gas and nuclear power, even without taking into account externalities. The overall cost is a combination of a number of variables that can change over time, such as interest rates, fuel costs and emission taxes. All these elements have to be considered.

Technology	Investment cost	Fuel	O&M	Carbon cost	Social cost (waste, pollution, risks)
Wind	Medium to high[1]	none	Low	none	Very low
Coal	Low	medium	Low	High	High
Nuclear	High	medium	Medium[2]	Low	High
Natural gas	low	high	Medium	medium	Medium

Figure 140 survey on costs

Wind power is better than coal in terms of fuel and carbon costs and resulting damages from pollution. In the overall costs per kWh, **new coal plants might at best come at a par with wind power** but face future cost risks from carbon taxes and fuel price hikes.

Wind power is **definitely cheaper than nuclear** because it has about the same or less capital expenses per kWh but is better in all other aspects (fuel, O&M, waste treatment and risks). The only aspect touted by the defenders of nuclear energy is the non-intermittent nature of nuclear power. In reality, any nuclear accident can turn nuclear plants into a nuclear disaster. And the inflexibility of centrally-produced base-load power turns into a disadvantage, compared with the more flexible, decentralized wind power among other renewables, accompanied by flexible storage systems, reserves and market-driven power management.

Wind power is **definitely cheaper than natural gas** based on actual fuel cost; while natural gas is better in terms of capital expenses; the cost of gas and the demand from the traffic sector put a risk on any new gas plant investments.

Why more wind power comes at a profit

Emerging evidence from Germany, Denmark, Ireland and Spain shows that increased use of wind actually reduces prices paid by consumers, despite some additional costs for feed-in tariffs.

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[1] Depending on capacity factors and onshore/offshore siting

[2] Radioactive waste costs included

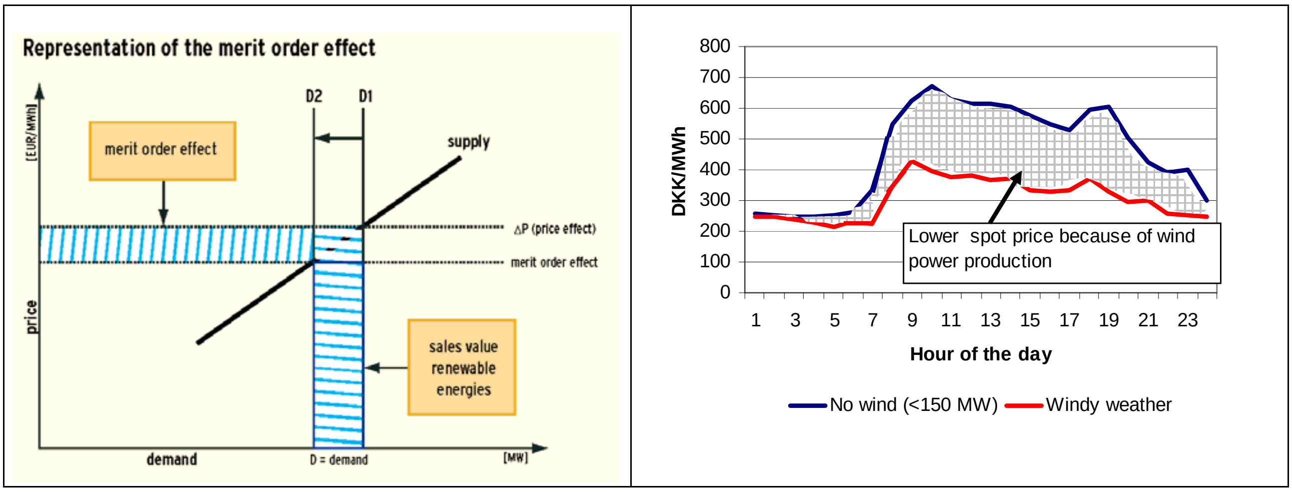

Figure 141 merit order effect: wind drives off the most expensive plants – followed by a reduction of the spot market price for electricity[1] (left)

Once capital construction costs are paid, wind is virtually free to use – marginal costs of wind power are zero. Therefore, the electricity network uses wind energy whenever it is available as the lowest cost supply. Wind power drives off other power plants: in a well regulated electricity system the most expensive plants are taken from the grid.[2]

The market price of electricity is determined just by the most expensive power station still needed to satisfy the demand for electricity (merit order). When demand for conventional electricity is reduced by wind power, the most expensive power plants are no longer needed to meet demand, and the market price falls accordingly. This effect is known as the merit order effect.

For Germany, the merit order effect was numbered by the Federal ministry of environment (BMU). BMU numbered the merit order effect as a 4.98 billion € savings for consumers while the specific costs of all feed-in tariffs (photovoltaics included) was numbered at 3.3 billion €. Therefore, in Germany, the additional costs of feed-in tariffs have been compensated by more than 100 percent by the price reductions due to the merit order effect. On average, renewable energy financed by the German feed-in-law had a cost reduction impact of .783 €-Cents/kWh sold in Germany. [3]

For Denmark, wind energy specialist Poul Eric Morthorst found an overall reduction of spot market prices by 12-14 percent, corresponding to a medium reduction of spot market prices of 0.25-0.45 Euro-Cents per kWh.[4] For Denmark, the additional cost of feed in tariffs in 2007

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[1] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): Renewable energy sources in Germany, Status June 2008, Berlin 2008

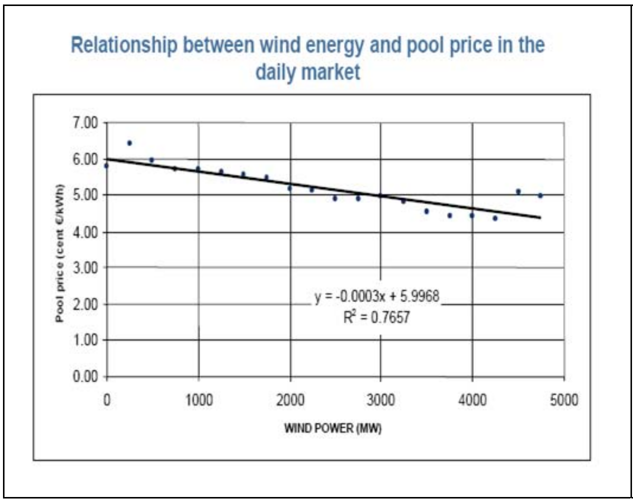
[2] Sven Bode: On the impact of renewable energy support schemes on power prices, HWWI Research Paper 4-7, Hamburg 2006 **http://www.hwwi.de/Publikationen_Einzel.5118.0.html?&tx_wilpubdb_pi1[publication_id]=290&tx_wilpubdb_pi1[back]=50&cHash=e38b4c498f**

[3] „Für das Jahr 2006 ist Summe aus Marktwert und Merit-Order-Effekt sogar höher als die gesamte EEG-Vergütungssumme.“ In Frank Sensfuß, Mario Ragwitz: Analyse des Preiseffektes der Stromerzeugung aus erneuerbaren Energien auf die Börsenpreise im deutschen Stromhandel -Analyse für das Jahr 2006- Gutachten im Rahmen von Beratungsleistungen für das Bundesministerium für Umwelt,Naturschutz und Reaktorsicherheit (BMU), p. 14

[4] Poul Eric Morthorst: market impacts of wind integration, EWEC conference paper Milan 2007 and Rune Moesgaard and Poul Erik Morthorst: The effect of wind power on spot market prices, Danish Wind Industry Association – Risoe/DTU EWEC 2007

was offset in large parts by the reduction of electricity prices.[1] The same effect was described for Spain where a similar dimension of wind related cost reductions were observed (see figure below by Alberto Ceña/AEE).

It is notable that overall market prices and futures prices for electricity rose sharply over the 2005-2008 period. Thereby, the net costs of feed-in tariffs were additionally reduced. Therefore, the cost share of feed-in tariffs cost is expected to “only increase at a below-average rate over the next few years” or could even turn out as an additional net profit (beside the merit order effect) when feed-in tariffs stay below the market price for during ever more hours per year.



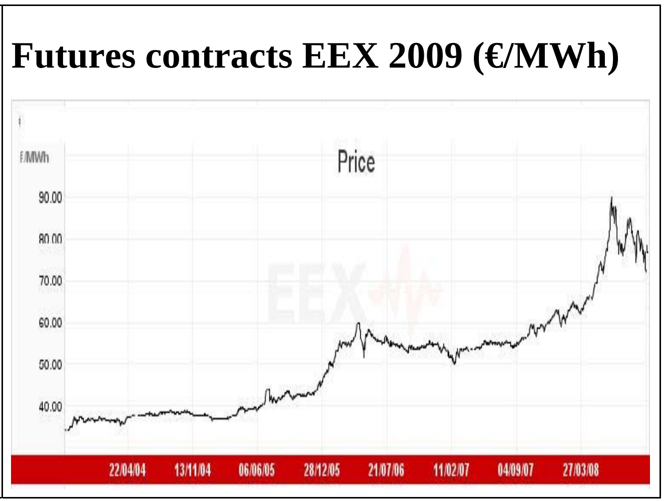


Figure 142 reduction of Spanish electricity pool prices at times of high wind penetration
source: Alberto Ceña, AEE[2]

Figure 143 Rising price for futures contracts on the European power market, Phelix Baseload Year Futures (Cal-09)
source EEX [3]

More recently, another fact has been observed in power markets: the net cost of feed-in tariffs has been offset by the rise of electricity prices. The final feed-in tariff for wind power at 5.02 €-Cents/kWh is lower meanwhile than the market price, while the initial feed-in tariff, lifted at 9.2 €-Cents/kWh by Parliament decision in July 2008, is still somewhat higher than the European EEX futures price. [4]

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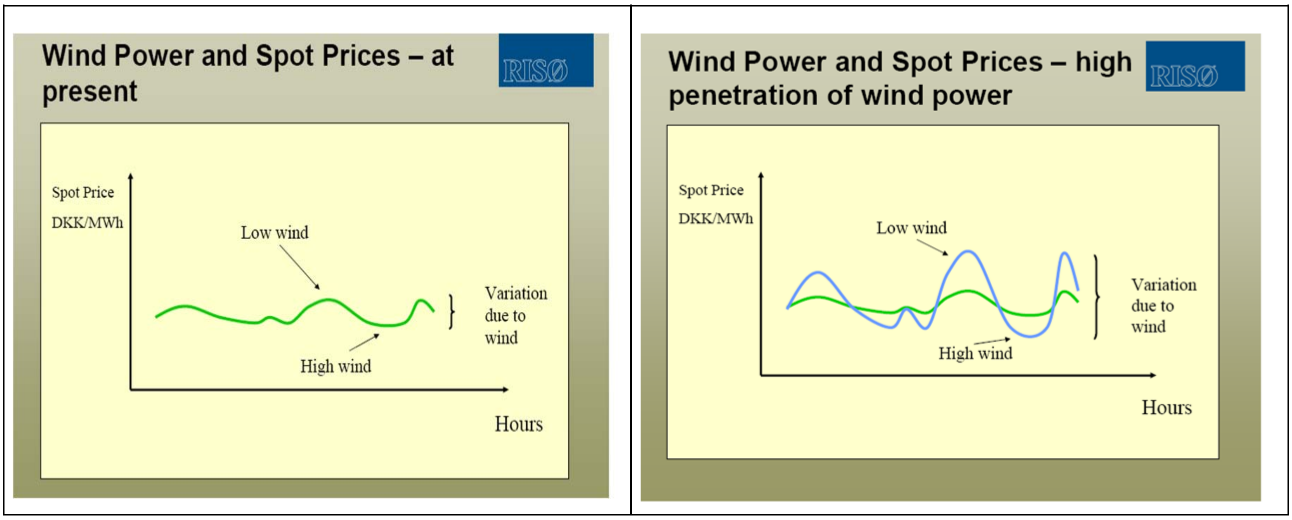
[1] Rune Moesgaard and Poul Erik Morthorst: The effect of wind power on spot market prices, Danish Wind Industry Association – Risoe/DTU EWEC 2007

[2] Alberto Ceña, Asociación Empresarial Eólica: Large scale integration of wind Energy, EWEC 2006 **http://www.ewea.org/fileadmin/ewea_documents/documents/events/2006_grid/alberto_cena.pdf**

[3] **http://www.eex.com/en/Market%20Data/Trading%20Data/Power/Phelix%20Futures%20Chart%20%7C%20Derivatives/futures-chart/F1BY/2009.01/2008-10-23**

[4] Erneuerbare Energien-Gesetz EEG, see: **http://www.erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/eeg_verguetungsregelungen_en.pdf**



Wind Power and Spot Prices – at present

Wind Power and Spot Prices – high penetration of wind power

<u>Figure 144 and 145 higher price volatility due to additional wind power (blue) compared to today's level (green)</u> source: P.E. Morthorst, EWEC 2007[1]

With penetration of wind on the rise, a higher volatility of market prices is to be expected. Wind power tends to reduce market prices when more expensive generators are put to rest.

But with more wind power in the system, the risk is that it will always deliver at times when prices are low. Therefore the idea of a "floor price," such as defined in Turkey, could be helpful. Cheap wind power should not be punished for its contribution to lower overall prices.

Additional steps might be needed to reduce price spikes:

- Grid extensions are in the best interest of the wind industry because they give access to new markets in cases of excess supply and by integrating larger areas help to smooth the price for power.
- Storage facilities may be constructed and managed based on cheap excess power. They can take power away from the market in times of excess supply, lifting prices for wind producers, and they bring additional supply in periods of peak demand and/or low wind, lowering the price for consumers.[2]

Some regions (e.g. West Denmark, North of Germany and Galicia in Spain) have practical experience with integration of high wind power penetrations, at certain day times exceeding 50 or 100 percent of hourly consumption.

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[1] source: P.E. Morthorst: Market Impacts of Wind Power Integration, proceedings EWEC 2007

[2] Klaus Skytte: Implication of Large-Scale Wind Power in Northern Europe, EWEC 2008 ; he clearly speaks of "reduced profitability with increased wind capacity (in € per MWh)" …" when wind generation is high, prices drop….[this] reduces income on wind generation compared to average prices…The more wind is in the system, the less profitable it becomes. [The] Relationship between wind and hourly price disappears in hydro systems [because] Hydro power perfectly balances wind (to some extend), But wind affects Water Values and decreases prices levels" **http://www.ewec2008proceedings.info/statscounter.php?id=2&IDABSTRACT=524**

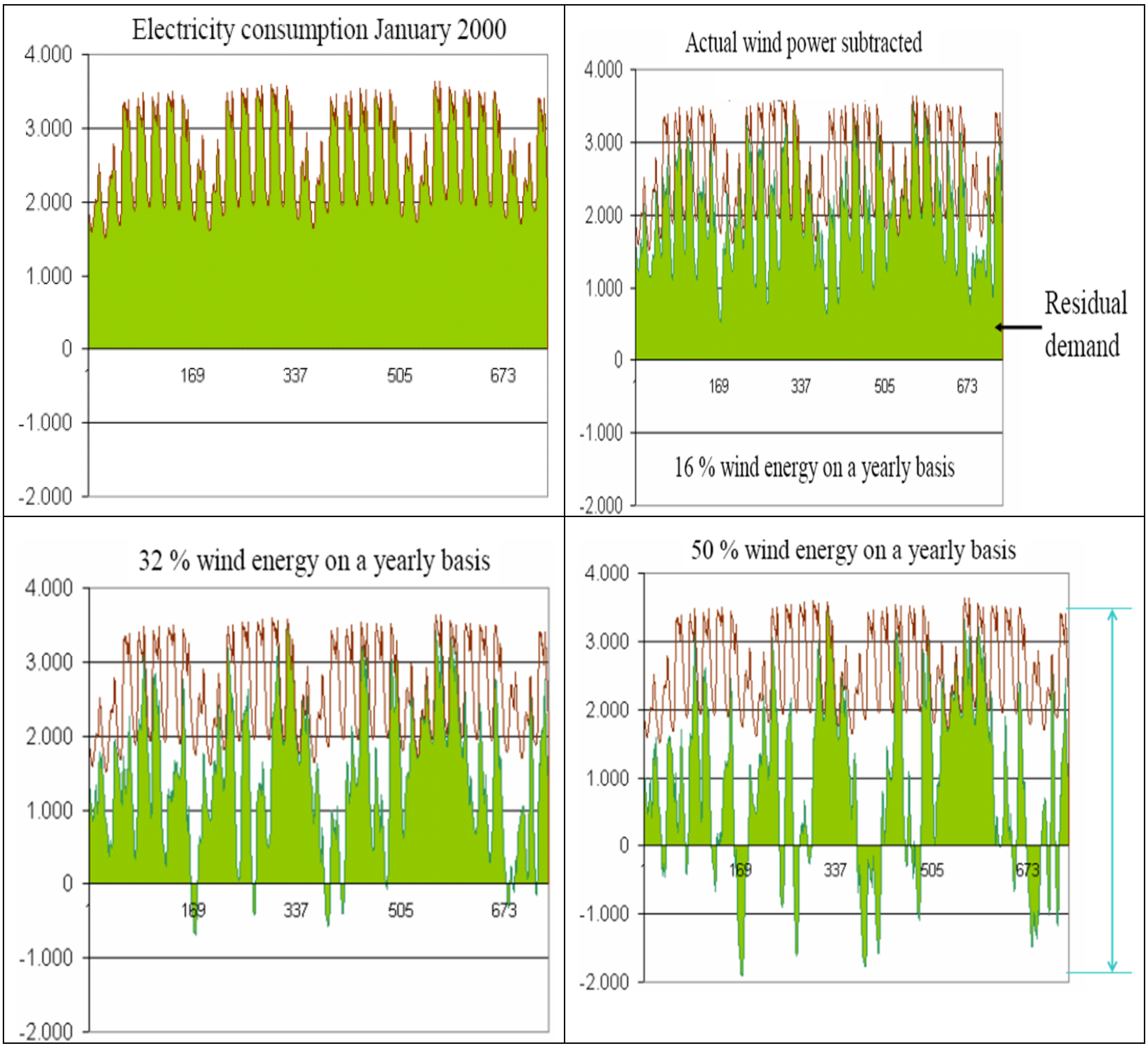

Figure 146 power consumption and wind penetration in Western Denmark for 16% (existing), 32% and 50% wind power penetration source: BWE[1]

These regions show very steep variations in supply. With wind capacities growing toward one third or half of overall power consumption, these regions turn out to be net exporters or importers during some periods as determined by wind conditions.

It makes perfect sense for such regions to be integrated in a pan-European power pool and selling the excess electricity. And importing wind power at times when wind is abundant and cheap makes perfect sense for customers in other regions.

In Europe, an embryo DC “supergrid” today links Scandinavia, northern Germany and the Netherlands, and it is being extended. New lines across the North Sea to the British Isles are in construction or in planning:

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[1] Ralf Bischof: Integration of large scale renewable energy into the grid, 7th Inter-Parliamentary Meeting on Renewables Berlin, October 5th + 6th 2007

Existent Interconnection	
West-Denmark – Norway (Skagerrak DC line, 1972-75,1992)	1.040 MW
West-Denmark– Sweden (Konti-Skan DC line, 1965 and 1969):	740 MW
Germany–West-Denmark	1350 MW
East-Denmark–Sweden	1900 MW
East Denmark–Germany (DC line Kontek)	600 MW
Germany– Sweden (Baltic)[1]	450 MW
Poland-Sweden (SwePol)	450 MW
Interconnection in planning or construction (2007/8)	
2008: Netherlands– Norway (NorNed) DC line (580 km, 550 m€)	700 MW
2008+: West-Denmark –East-Denmark:	600 MW
2011: Germany– Norway: (NorGer - EWE/EGL/Agder/Lyse):	700 MW
2012+: West-Denmark– Norway (Skagerrak 4),	600 MW
201x: Germany – Sweden (Vattenfall)	not specified

Figure 147 Scandinavian interconnection: a new hydro-wind cluster

By connecting distant points, the grids not only deliver power to market, they also allow the system some slack. The grid offers more access to Norwegian hydroelectric plants and pumped storage facilities, ready for use when demand spikes, and the interconnection lines can be seen as “open source” too, offering new occasions for wind power feed-in and more security and diversification of supply.

Figure 148 offshore storage islands for excess wind energy; source: KEMA

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[1] Ralf Bischof, Managing Director German Wind Energy Association: Integration of large scale renewable energy into the grid, 7th Inter-Parliamentary Meeting on Renewables Berlin, October 5th + 6th 2007

By creating their own storage facilities, prolific wind regions might curtail their supply and sell excess power during peak periods, when the price is high. For the Netherlands, the idea of offshore storage islands were presented at EWEC 2008.[1]

But new storage facilities do not necessarily have to be placed in the same regions where wind turbines are placed. Switzerland, Norway and other world regions, such as Quebec and Nevada with their huge hydro storages, may choose the role as a hub on their own.

Reduction of volatility by integration over vast areas

With enlarged interconnected areas, combining hundreds of wind farms and thousands of wind turbines, the volatility of the wind power delivery is heavily reduced. (The numbers on the horizontal axis are number of hours (continuous enumeration), the percentage on the vertical axis shows the power delivery in percent of totally installed wind power capacity).

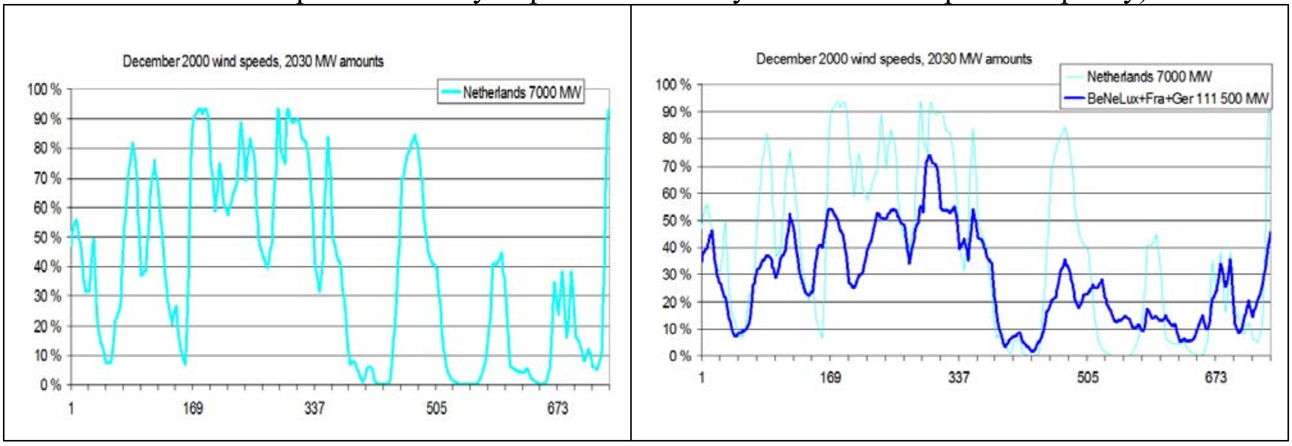

Figure 149 and 150 December 2000, power delivery profile of wind power in the Netherlands at a simulated 7000 MW wind capacity (left) and power profile for Benelux, France and Germany combined at 111,500 MW wind power (right) source Lemström/Tradewind 2008[2]

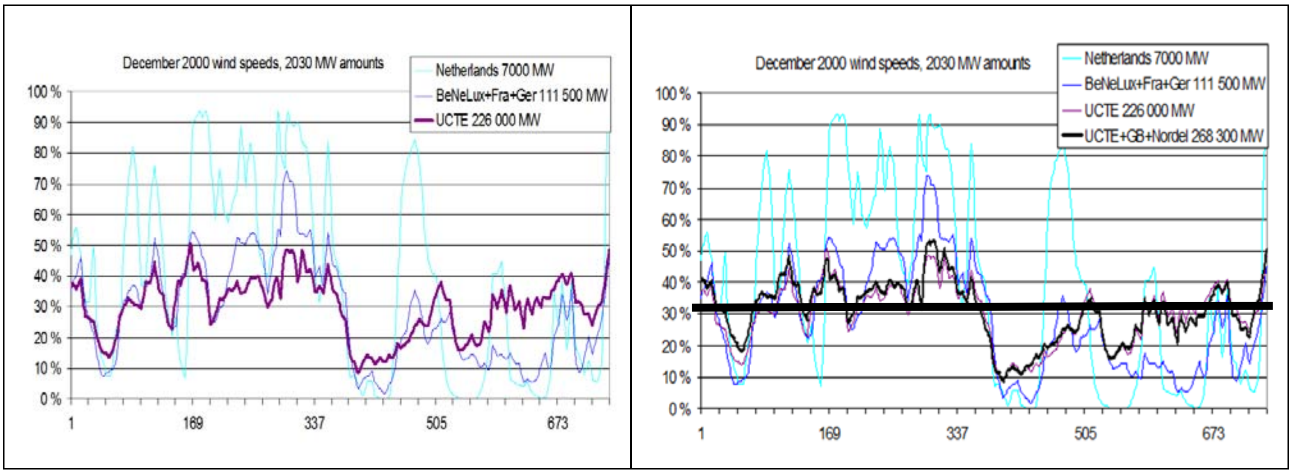

Figure 151 and 152 December 2000, power profile of UCTE at 226,0000 MW and power profile of UCTE+Nordel+UK with 268 GW capacity; source: Lemström/TradeWind 2008

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[1] Natalia Moldovan, KEMA Consulting: Methodology to value wind energy in a liberalised electricity market, EWEC 2008 proceedings

[2] Bettina Lemström: Wind power integration and transmission in Europe, EWEC 2008 presentation; the data were simulated based on 300 data points measuring wind speeds all over Europe and with 2000-2006 data, measured over seven years

The above simulation for an integrated European power market depicts the reduction of volatility when geographically large areas are interconnected and working together. Ups and downs shrink by some 50 percent in the very large area compared to an isolated market such as the Netherlands.

Capacity MW	Area	Volatility of capacity factor
7000	Netherlands	0-95%
111,500	Benelux+France+Germany	3-75%
226,000	UCTE	9-49%
268,300	UVTE+GB+NORDEL	9-52%

With low winds, additional peak power capacities will be needed from storages such as pumped hydro, fly wheels, batteries or natural gas.

Wind energy as a base load source

There is a growing consensus that wind can provide a portion of base load energy, and that peaking energy would be provided by other sources. Archer and Jacobson state that "ccontrary to common knowledge, an average of 33% and a maximum of 47% of yearly-averaged wind power from interconnected farms can be used as reliable, base load electric power."[1]

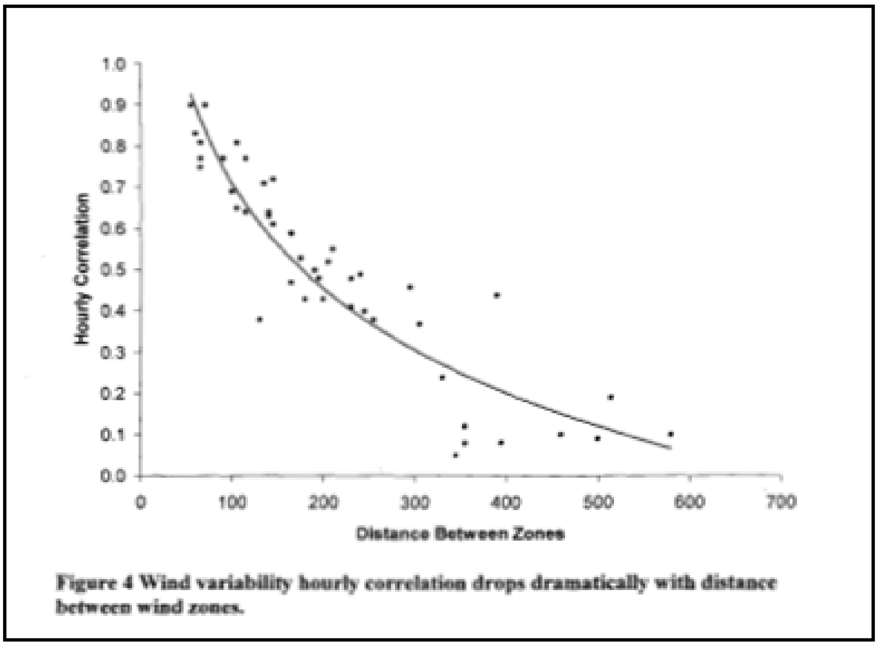

Figure 4 Wind variability hourly correlation drops dramatically with distance between wind zones.

Figure 153 geographical diversity of wind zones in Texas reduces wind variability source: Texas Public Utility Commission (PUC)[2]

The benefits of interconnected wind power are growing with the size of catchment areas. Statistical correlation among stations is the key factor in understanding why.

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[1] CRISTINA L. ARCHER AND MARK Z. JACOBSON: Supplying Baseload Power and Reducing Transmission Requirements by Interconnecting Wind Farms, JOURNAL OF APPLIED METEOROLOGY AND CLIMATOLOGY NOVEMBER 2007, http://www.stanford.edu/group/efmh/winds/aj07_jamc.pdf

[2] Brendan Kirby: Evaluating Transmission Costs and Wind Benefits in Texas: Examining the ERCOT CREZ Transmission Study, (PUC DOCKET NO. 33672, PUBLIC UTILITY COMMISSION OF TEXAS), April 2007, p.14

In fact, weather conditions may not vary over small areas as reflected in a high correlation among nearby wind farms. However, as distance between farms or terrain variability increases, the correlation among farms becomes smaller. Marginal benefits decrease.

For example, by doubling the number of sites connected together, the availability at low wind speeds improved by only ~14 percent. Whether or not a zero-correlation can eventually be reached is still an open question. This effect is referred to as the saturation of benefits, to indicate that, at some point, no incremental benefits are found in increasing the array size.

General conclusions on increase in balancing requirement will depend on the region's size relevant for balancing, initial load variations and how concentrated/distributed wind power is sited.

Variability of wind power impacts also on how the conventional capacity is run. Wind power matches well in combination with stored hydro or solar[1] power, with photovoltaic power[2] or natural gas. Conflicts arise with technologies that deliver flat power such as nuclear plants or coal base load plants.

Case studies for wind integration: Texas and else

As many studies show the costs of wind energy integration are modest compared to the savings of switching from gas, oil or even coal to wind power. One of the best and most updated in-deep-study has been accomplished for Texas: "*The simple and clear results of the ERCOT study are that 1) significant wind generation can be developed throughout Texas, 2) transmission enhancements are required to reliably deliver the wind generated electricity to loads, and 3) the benefits exceed the costs.*" [3]

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[1] Such can be found with the emerging concentrated solar thermal power plants

[2] Due to the fact that when it is hottest wind availability might be rather low.

[3] Brendan Kirby: Evaluating Transmission Costs and Wind Benefits in Texas: Examining the ERCOT CREZ Transmission Study, (PUC DOCKET NO. 33672, PUBLIC UTILITY COMMISSION OF TEXAS), April 2007, p.11

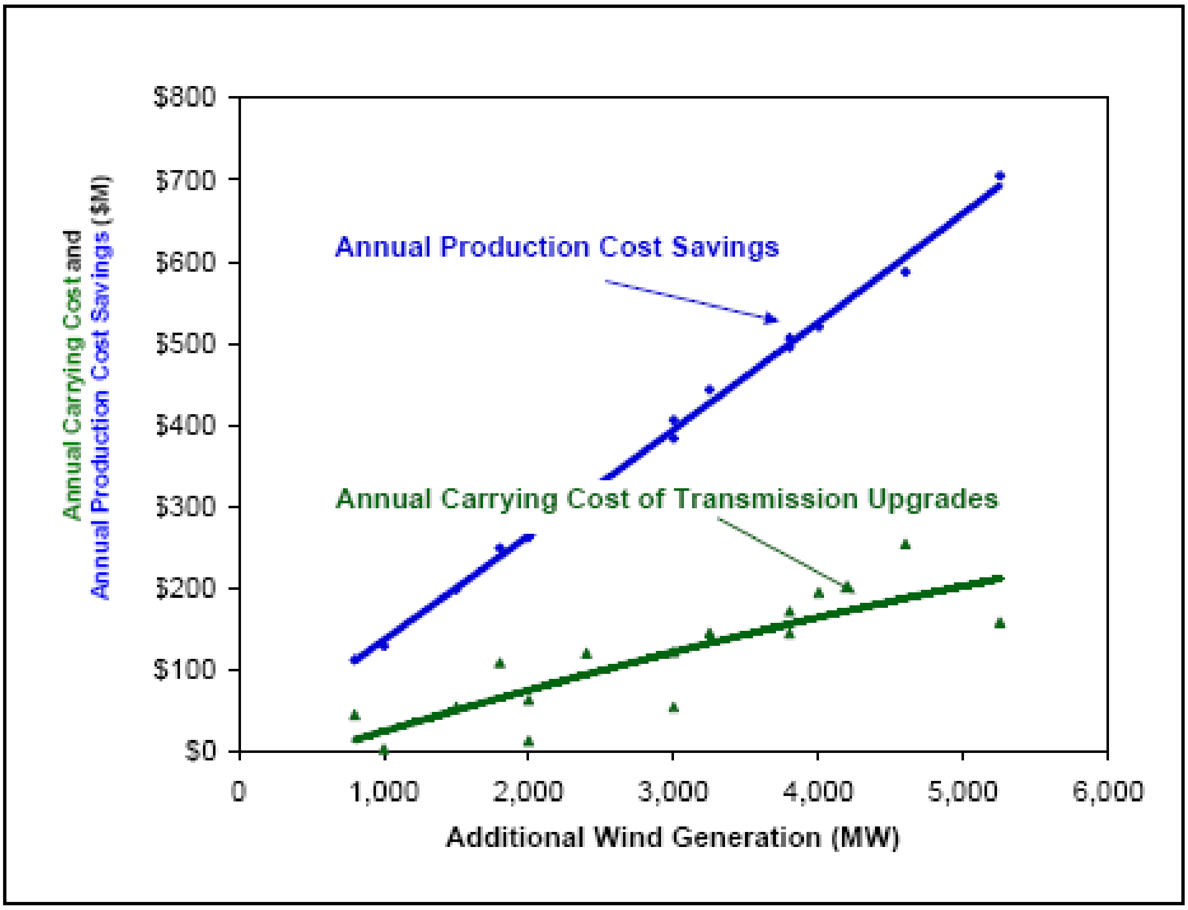

Figure 154 cost reduction in Texas by additional wind energy.

“Adding wind generation increases transmission capital costs but reduces generation production costs. It also reduces generator revenues and the market clearing prices wind and other generators receive.” [1] These savings should be considered conservative in regard of the future because “Delivered price of natural gas to generating units was set to $7/MMBTU”[2] when in reality the price in the second half 2007 and first half 2008 regularly exceeded $7/ MMBTU, with a price peak at more than $13/MMBTU in July 2008.

In July 2008, the Public Utility Commission (PUC) of Texas selected a transmission scenario that will give access to a total of 18,456 MW of wind power from West Texas and the Texas Panhandle to metropolitan areas of the state. The selected Scenario is estimated to cost US$4.93 billion, or around US$4/month per residential customer once construction is complete and costs are reflected in rates.

The benefits, however, are much higher than the 4.93 billion invested in transmission: The new wind brought online will save $1.7 billion *per year* in fuel costs, repaying the $4.9 billion cost of the investment in 2.9 years because the “*average system fuel-cost savings for each megawatt-hour of wind in this scenario was $38/MWh* [3.8 US-Cents/kWh].”[3]

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[1] Brendan Kirby: Evaluating Transmission Costs and Wind Benefits in Texas: Examining the ERCOT CREZ Transmission Study, (PUC DOCKET NO. 33672, PUBLIC UTILITY COMMISSION OF TEXAS), April 2007, p.12

[2] Brendan Kirby: Evaluating Transmission Costs and Wind Benefits in Texas: Examining the ERCOT CREZ Transmission Study, (PUC DOCKET NO. 33672, PUBLIC UTILITY COMMISSION OF TEXAS), April 2007 p. 12

[3] ERCOT: Competitive Renewable Energy Zones (CREZ) Transmission Optimization Study 2008 p. 24

Texas currently depends on natural gas to generate 49 percent of its electricity, and natural gas plants make up 71 percent of the state's generating capacity. From 1998 to 2006, natural gas prices in the state tripled, which caused the price of electricity for the average residential consumer to increase from US 7.6 cents per kWh to US 12.9 cents per kWh – an increase of US $64 monthly, or over US $750 per year, for the average household.

In contrast, the transmission investments identified in ERCOT's report would cost the average Texas household around US 30-40 cents per month.

Based on production-cost modeling, an expected average annual wind curtailment would be 2.31 percent,[1] with a total wind generation of 64,031 GWh. The plan contains 2334 miles of new 345-kV right-of-way, and 42 miles of new 138-kV right-of-way. The estimated collection costs for this plan range from $580 million to $820 million.

HVDC solutions were not integrated in the 2008 Texas decisions. They were not seen as cost effective at this level of wind generation capacity because transport of wind generation over very long distances was not required, Texas officials declared. (But there was a scenario with an 2000-MW-HVDC line to be added from Scurry in Central Texas to Houston).[2]

The chicken and egg problem

Transmission system planners are faced with a difficult design problem when expanding the transmission system. Both transmission costs and land required (per MW transmitted) drop as voltage is increased (per MW transmitted). Unfortunately, the minimum conductor line size increases. This creates two related problems for transmission planners. The simpler problem is that higher voltage lines have higher minimum sizes. A 765 kV line costs only about one-third as much as a 345 kV line per MW of capacity but the minimum size is about six times larger. As incremental transmission capacity is required (either due to load growth or due to generation additions – this is not a wind-specific problem) the full capacity of a 765 kV line may not be required for many years.

A shortcoming of incremental analysis is that it can be difficult to justify building the 765 kV line now even if it will be the better solution later. It might well be that the Texas interconnection will be short of capacity before being finished, and additional solutions such as HVDC-lines will be added after, servicing more distant areas.

More case studies

Most of the following examples are derived from IEA studies[3] accomplished in the period before 2006/2007 when oil, gas, uranium and coal prices were much lower than today. Therefore, they emphasize the cost of wind integration rather than explaining the savings that can be achieved in terms of fuel costs and additional security of supply.

- The **German** Energy Agency’s (dena) study “Planning of the integration of wind energy into the German grids ashore and offshore regarding the economy of energy supply” ascertained that the integration of a total of 36 GW of wind power capacity

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[1] Wind curtailment means that at certain times with high winds, wind power generation is restricted to optimize transmission costs.

[2] See: ERCOT, Competitive Reneweable Energy Zones (CREZ) Transmisson Optimization Study Figure 6, Szenario 3, 2008 April 2, Attachement A

[3] State of the art of Design and Operation of Power Systems with Large Amounts of Wind Power, Summary of IEA Wind collaboration by Hannele Holttinen, Peter Meibom, Cornel Ensslin, Lutz Hofmann, Aidan Tuohy, John Olav Tande, Ana Estanqueiro, Emilio Gomez, Lennar Söder, Anser Shakoor, J. Charles Smith, Brian Parsons,Frans van Hulle, EWEC 2007 presentation by H.Holtinnen

into the German transmission system in 2015 will be possible with approximately 850 km of 380kV transmission routes as well as reinforcement of 390 km of existing power lines.

- The Ireland SEI study from 2004 findings were that fuel cost and CO2 savings up to a 1500MW wind power penetration in the Republic of Ireland (ROI) system went proportional with wind energy penetration. It found that wind did reduce overall system operation costs while leading to a small increase in operating reserve costs: 0.2 €/MWh [0.02 €-Cents/kWh] for 1300 MW wind and 0.5 €/MWh [0.05 €-Cents/kWh] for 1950 MW of wind.
- Three case studies from the **UK** (2002, 2003 and 2007) claim extra reserve costs amount to £2.38 per MWh [0.238 pence/kWh] of wind produced for 10% wind penetration, rising to £2.85/MWh [0.285 pence/kWh] at 20% penetration. If onshore wind generation were developed across Great Britain including England and Wales, then transmission reinforcement costs could be significantly smaller. The transmission reinforcement cost was found to be between £1.7b and £3.3b for 26 GW wind (£65/kW to £125/kW of wind capacity). For a small level of wind penetration, the capacity value of wind was roughly equal to its load factor, approximately 35%. But as the capacity of wind generation increases, marginal contributions decline. For the level of wind penetration of 26 GW, about 5GW of conventional capacity could be displaced, giving a capacity credit of about 20%. (Capacity credit (sometimes called capacity value) is the contribution that a given generator makes to overall system adequacy. Even the availability of conventional generation is not assured at all times because there is always a non-zero risk of mechanical or electrical failure.)
- For the **Netherlands,** consequences of 6000 MW offshore wind power showed that additional investment costs to the grid were estimated at 344-660 million Euros or about 4% of the estimated total investment for 6 GW wind.
- For **Portugal**, in the period 2005–2010, the investment directly attributable to renewables, mostly for wind parks, will total 200 Million €.
- Different studies were carried out by **Spanish and Portuguese** TSOs to determine the maximum wind power capacity that the Iberian grid could handle. Two scenarios were studied with 17500 MW of installed wind power. Its major conclusions were that with 75% of wind power technically adapted, transient stability was supported for 14,000 MW wind power production in a peak demand scenario and 10,000 MW in a valley one. The importance of a future 400 KV D/C interconnection line with France was highlighted.
- The impact of wind power for one region in **Norway** was assessed using data from a real life regional hydro-based power system with a predicted need for new generation and/or reinforcement of interconnections to meet future demand. Wind power was found to have a positive effect on system adequacy, reducing the LOLP (loss of load probability) and improving the energy balance. Adding 3 TWh of wind or 3 TWh of gas generation are found to contribute equally to the energy balance, both on a weekly and annual basis. The smoothing effect due to geographical distribution of wind power had a significant impact on the wind capacity value at high penetration.
- A **Minnesota** Dept. of Commerce Study (2004) estimated the cost of wind integration in a 2010 scenario of 1500 MW of wind in a 10 GW peak load system at $4.60/MWh [0.46 US-Cents/kWh]. The second Minnesota study (2006) consolidated four main balancing areas into a single area. The 2020 system peak load was estimated at 20,000 MW, and the installed wind capacity at 5700 MW for the 25% wind energy case.

Three years of high resolution wind and load data were used and the cost of wind integration ranged from a low of \$2.11/MWh [0.211 US-Cents/kWh] of wind generation for 15% wind penetration to a high of \$4.41/MWh [0.441 US-Cents/kWh]for 25% wind penetration, compared to the same energy delivered in firm, flat blocks on a daily basis. These total costs included both the cost of additional reserves, and cost of variability and day-ahead forecast error associated with the wind generation.

- The NYSERDA/GE Energy Study for the **New York** ISO completed in 2005 estimated the impact of wind in a 2008 scenario of 3300 MW of wind in a 33GW peak load system. Incremental regulation due to wind was found to be 36 MW. No additional spinning reserve was needed. Incremental intra-hour load following burden increased 12 MW/5 min. Hourly ramp increased from 858 MW to 910 MW. All increased needs can be met by existing NY resources and market processes. Capacity credit was at 10% average onshore and 36% offshore. Significant system cost savings of \$335-\$455 million for assumed 2008 natural gas prices of 6.50-6.80\$/MMBTU were found (In reality in the January-July 2008-period natural gas prices ranged between 9-12\$/MMBTU).
- The Xcel **Colorado**/Enernex Study (2006) with 10% and 15% penetration cases (wind nameplate to peak load) for a ~7 GW peak load system gave a wind integration cost range of \$2.20-\$3.30/MWh [0.22-0.33 US-Cents/kWh]. The impact of variability and uncertainty on the dispatch of the gas system which supplies fuel to more than 50% of the system capacity was estimated at additional costs of \$1.25\$-1.45/MWh [0.125-0.145 US-Cents/kWh] bringing the total integration costs to the \$3.70- \$5.00/MWh [0.37-0.5 US-Cents/kWh] range, with fuel economies at actual natural gas prices not lined out.
- The **California** RPS Integration Cost Project examined impacts of existing installed renewables (wind 4% on a capacity basis). Regulation cost for wind was \$0.46/MWh [0.046 US-Cents/kWh]. Load following had minimal impact. A wind capacity credit of 23%-25% of a benchmark gas unit was found.
- A US Midwest Independent System Operator (MISO) study found annual net savings of US \$600 million by developing 16,000 megawatts (MW) of wind within its system along with 5,000 miles of new 765-kV transmission lines to deliver the power from the Dakotas to the New York City area. These savings arise in the form of lower wholesale power costs and prices in the eastern U.S. resulting from greater access to lower cost generation in the western states such as Iowa and the Dakotas.
- An Idaho National Laboratory recently released a study concluding that five proposed transmission lines in the western U.S. would provide US \$55-85 billion in annual benefits.
- In Britain, a government study concluded: “The generation costs of onshore wind power are around 3.2p/kWh (+/-0.3p/kWh), with offshore at around 5.5p/kWh…The additional system cost is estimated to be around 0.17p/kWh, when there is 20% wind power on the system. Generation costs are likely to decrease over time as the technology improves, but this will be balanced against increased costs for integrating higher levels of wind generation into the system”.[1]

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[1] Cited in: Sustainable Development Commission: Wind Power in the UK **www.sd-commission.org.uk/pages/media/list/wind.html**

Conclusion: wind integration is doable – interconnection a cost saver!

These many examples demonstrate that more wind power necessitates new connection and operation rules, an updating in connecting requirements, new protection equipment, remote metering and control, and resolution of constraints of wind plant clustering. Transmission networks must be updated too.

The additional costs are more than balanced out by the economies of fuel for non-renewable energies. In many cases, it is difficult to obtain cost figures, since grid reinforcements and new lines are needed anyway whenever electrical demand grows.

- Many measures to cope with wind power fluctuations have side benefits for all consumers. Interconnection brings more competition in a formerly closed market and can bring lower prices.
- Any investment into grids will reduce congestions and power losses during operation.
- Many grids are old and were designed for a different era. Over the next years many networks need to be upgraded or replaced irrespective of the need for renewables. This provides a once in a lifetime opportunity to meet the 21st century economic and environmental needs.

9. Obstacles and how to resolve them

Wind's only obstacle today is the still widespread perception that it is not a "serious" energy source, that it's only a small part of the solution, and that it's not reliable anyway. But as power generation manufacturers like GE, Siemens and others get an increasingly large share of their turnover from selling wind turbines, as foundries, steel makers, gearbox manufacturers, shipping companies and others see massively increasing orders coming from the wind industry, and as local farmers and public officials realize that they can get extra income and extra local jobs, maybe the tide of "seriousness" will turn.

The usual more technical arguments against wind power are:

- It kills birds;
- It is ugly;
- It is unreliable.

Birds

The bird issue is addressed in each project but is usually a minor topic. The main reason this topic is raised is because of the California Altamont Pass wind farm, which was built in the early 80s on a bird migration path. Though nobody is saying that wildlife issues will curtail wind development, some environmentalists say that much more care should go into picking locations for wind farms.

The wind industry in many places is partnering with NGOs such as the Audubon Society and Bat Conservation International to make sure that all wind sites are selected to minimize their impacts on birds and bats.

A number of studies have been done on this issue. A Danish study about offshore wind farms says:

Migrating birds seldom dice with death among the spinning blades of wind turbines. Instead, they give them a wide berth, according to a study of a Danish offshore wind farm. To see whether the 13,000 offshore turbines planned for European waters would be a hazard to migrating birds, Mark Desholm and Johnny Kahlert of the National Environmental Research Institute in Rønde, Denmark, used radar to track flocks of geese and eider ducks around the Nysted wind farm in the Baltic Sea. The farm's 72 turbines are laid out in rows with their blades 480 meters apart. They found that the birds flew almost exclusively down the corridors between the turbines, with less than 1 per cent getting close enough to risk collision. The birds gave the turbines an even wider berth at night, sticking more closely to the middle of the corridors. Many also avoided the wind farm altogether. The researchers found that while 40 per cent of flocks in the survey area crossed the wind farm site before construction started, only 9 per cent ventured among the turbines once they were operating.[1]

The (British) Royal Society for the Protection of Birds views climate change "*as the most serious long-term threat to wildlife in the UK and globally and, therefore, we support the Government's target to source 15% of electricity from renewables by 2015. The available evidence suggests that appropriately positioned wind farms do not pose a significant hazard for birds. However, evidence from the US and Spain confirms that poorly sited wind farms can cause severe problems for birds, through disturbance, habitat loss/damage or collision with turbines. The RSPB insists that wind farm proposals that may affect sensitive bird*

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[1] Wind turbines a breeze for migrating birds, New Scientist, 18 June 2005 / **http://environment.newscientist.com/article/mg18625045.500.html** , Biology Letters, DOI: 10.1098/rsbl.2005.0336

populations or their habitats are subject to rigorous environmental assessment… We will, and do, object to specific wind farm proposals where there is an inadequate environmental assessment, where the assessment reveals potential environmental problems that cannot be mitigated, or where there is insufficient knowledge about the threat to sensitive bird populations or their habitats to conclude that there will not be a problem.”[1]

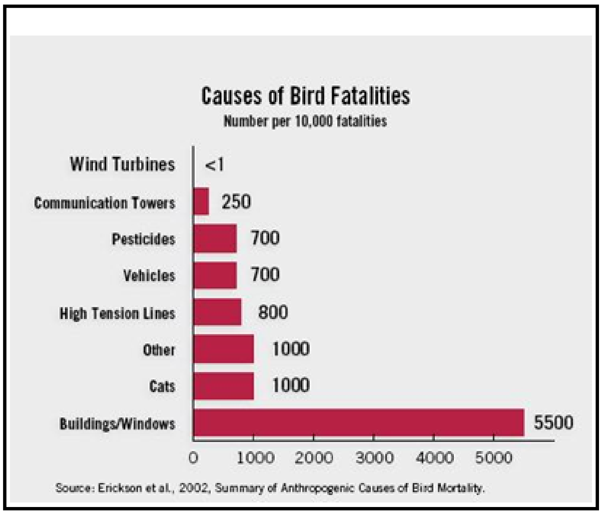

Figure 155 Bird fatalities compared
source: AWEA[2]

The leading killers of birds and bats are cats, windows, tall buildings, cars, airplanes, and communications towers. Wind turbines are still ways down on the list, but with one million turbines deployed, the issue might step up on the agenda. The wind power industry should try to compensate for bird kills:

- Research should be financed by wind energy associations, on cooperation with bird and bat protection
- A small part of wind power’s revenue should finance protection of birds, protection of selected areas and breeding programs for endangered species.

In Switzerland a so-called landscape-Cent – a small tax on hydro power revenues – is intended to protect landscapes and to compensate communities who do without hydro power plants in favor of nature. Wind lobbyists should be wise enough to deliver such services because it could decisively strengthen their case.

Ugly wind farms?

In February 2003, the Scottish Executive ordered to conduct a survey research among people living close to Scotland's operational wind farms. A total of 1810 adults were interviewed. All respondents lived within a 20 km zone of wind farms. The survey obtained results that are representative of people living within three zones (up to 5 km of a wind farm, 5-10 km and 10-20 km), and are representative of people living within 20 km of each of the ten wind farms. The results:

Just five people (0.3%) spontaneously mention wind farms as a negative aspect of their area.

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[1] RSPB: Wind farms and birds http://www.rspb.org.uk/ourwork/policy/windfarms/index.asp

[2] Erickson, W.P., G.D. Johnson, and D.P. Young. 2004. Summary of anthropogenic causes of bird mortality. Proceedings of the 2002 International Partner's in Flight Conference, Monterrey, California

Three times the number of residents say that their local wind farm has had a broadly positive impact on the area (20%) as say that it has had a negative impact (7%). Most people feel that it has had neither a positive nor a negative impact.

People who lived in their homes before the wind farm was developed say that, in advance of the wind farm development, they thought that problems might be caused by its impact on the landscape (27%), traffic during construction (19%) and noise during construction (15%). By comparison, since the wind farm development, only 12% are concerned about the impact on the landscape, 6% say that during construction there were problems with additional traffic, and 4% say there was noise or disturbance during construction.

There is substantial support for the idea of enlarging existing wind farm sites among those who live close to them, particularly if the increase in the number of turbines involves the addition of no more than 50% of the existing number. A majority (54%) would support an expansion of their local wind farm by half the number of turbines again, while one in eleven is opposed (9%). Support drops somewhat if the proposal is to double the number of turbines. In this case, four in ten would be in favor (42%) and one in five (21%) would be opposed.

People living closest to the wind farms tend to be **most positive about them** (44% of those living within 5km say the wind farm has had a positive impact, compared with 16% of those living 10-20km away). They are **also most supportive of expansion** of the sites (65% of those in the 5km zone support 50% expansion, compared with 53% of those in the 10-20km zone).

Similarly, **those who most frequently see the wind farms** in their day-to-day lives tend to be **most favorable towards them** (33% of those who see the turbines all the time or frequently say the wind farms have had a positive impact on the area, while 18% of those who only see them occasionally say the same).

While many say that they feel that nuclear, coal and oil generation should be reduced, clear majorities favor increasing the proportion of electricity through wind energy (82%). [1]

Another 190 page investigation into the potential impact of wind farms on tourism in Scotland which found both positives and negatives provides paths for controlling negative impacts of wind turbines: "*In summary, most respondents were of the view that as long as wind farms were 'sensitively sited' i.e. out with designated areas such as National Parks and National Nature Reserves as well as those areas which are regarded as key tourist 'honey pot' locations then wind farms should have few negative impacts on tourists and tourism businesses*."[2]

The conclusion is: Involve people, best with community power approaches, as investors, real stakeholders.

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[1] MORI Scotland: Public Attitudes to Windfarms, Energy Policy Unit General Research, Research Findings No.12/2003 **http://www.scotland.gov.uk/Publications/2003/08/18050/25620**

[2] NFO System: POTENTIAL IMPACT OF WIND FARMS ON TOURISM IN SCOTLAND, FINAL REPORT Prepared for: VisitScotland

Polls show strong support for wind power

Public opinion, despite persistent anti-wind lobbying by the coal or nuke industries and a few well-funded NIMBY associations, is massively behind wind power, as was revealed in the “Harris poll” 2008:[1]

"How much do you favor or oppose building new nuclear power plants in [the UK, France, Germany, Italy, Spain, the U.S.]?" (Base: All EU adults in five countries and US adults)

	Great Britain	France	Italy	Spain	Germany	United States
	%	%	%	%	%	%
Unweighted base	1087	1076	1045	1109	1111	1020
FAVOR (NET)	**45**	**49**	**58**	**32**	**36**	**52**
Strongly favor	13	15	29	12	12	20
Favor more than oppose	32	34	30	20	25	32
OPPOSE (NET)	**55**	**51**	**42**	**68**	**64**	**48**
Oppose more than favor	35	31	21	28	29	31
Strongly oppose	20	20	21	40	35	17

Figure 156 attitudes toward BUILDING NEW NUCLEAR POWER PLANTS, source: Harris poll 2008

"How much do you favor or oppose a large increase in the number of wind farms in [the UK, France, Germany, Italy, Spain, the U.S.]?" (Base: All EU adults in five countries and US adults)

	Great Britain	France	Italy	Spain	Germany	United States
	%	%	%	%	%	%
Unweighted base	1087	1076	1045	1109	1111	1020
FAVOR (NET)	**87**	**89**	**91**	**90**	**79**	**92**
Strongly favor	48	49	64	55	34	61
Favor more than oppose	39	40	27	35	45	31
OPPOSE (NET)	**13**	**11**	**9**	**10**	**21**	**8**
Oppose more than favor	9	8	8	7	14	7
Strongly oppose	4	3	2	3	7	1

Figure 157 attitudes toward increasing the number of wind farms, source: Harris poll 2008

Wind enjoys overwhelming support by public opinion; this support might grow as soon as more offshore wind farms come online, with practically no visual impacts for consumers.

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[1] The Harris Poll® #21, February 26, 2008: Adults in Five Largest European Countries and the U.S. Supportive of Renewable Energy, But Unwilling to Pay Much More for Itu http://www.harrisinteractive.com/harris_poll/index.asp?PID=875

10. Transmission – chief roadblock or key to save money?

In its recently released report "20 Percent Wind Energy by 2030," the U.S. Department of Energy (DOE) identified transmission limitations as a chief roadblock to realizing the economic, environmental and energy security benefits of obtaining 20 percent of electricity from wind.[1] The lack of electricity transmission infrastructure is particularly burdensome for wind because the best resources tend to be located at a significant distance from population centers. "*The Nation possesses affordable wind energy resources far in excess of those needed to enable a 20% scenario*", is declared by US officials.

Due to rising fuel costs for non-renewables, we expect that interconnection, balancing and storage issues can and will be resolved within a reasonable time. The main driver of this movement is market economics. Incentives for wind integration are inherent in fuel cost savings and the availability of excess wind power at very cheap prices in times of low demand. Wherever wind power is used, consumers will save money and pollution will be reduced. This combination of arguments has a high appeal for lawmakers of all political orientations.

Wind fears

In many places though, the idea of high penetration of wind power is somewhat foreign and deep-rooted misconceptions prevail in conventional wisdom of public, media and elected officials.

"Grid bottlenecks", "additional costs" and the "danger of blackouts" during low-wind/peak-load-periods are excessively highlighted. Grid balance and grid extension costs are routinely raised as issues by nuclear and coal lobbies who, with a growing wind power penetration, are losing market shares.

In December 2006, *New York Times* writer Matthew L. Wald questioned wind power in a fundamental way:

"*Wind, almost everybody's best hope for big supplies of clean, affordable electricity, is turning out to have complications…. Wind…generates a big problem: because it is unpredictable and often fails to blow when electricity is most needed, wind is not reliable enough to assure supplies for an electric grid that must be prepared to deliver power to everybody who wants it -- even when it is in greatest demand…. In Texas, as in many other parts of the country, power companies are scrambling to build generating stations to meet growing peak demands, generally driven by air-conditioning for new homes and businesses. But power plants that run on coal or gas must "be built along with every megawatt of wind capacity," said William Bojorquez, director of system planning at the Electric Reliability Council of Texas.,, A wind machine is a bit like a bicycle that a commuter keeps in the garage for sunny days. It saves gasoline, but the commuter has to own a car anyway….*

Frank P. Prager, managing director of environmental policy at the company, said that the higher the reliance on wind, the more an electricity transmission grid would need to keep conventional generators on standby -- generally low-efficiency plants that run on natural gas and can be started and stopped quickly.

He said that in one of the states the company serves, Colorado, planners calculate that if wind machines reach 20 percent of total generating capacity, the cost of standby generators will reach $8 a megawatt-hour of wind. That is on top of a generating cost of $50 or $60 a megawatt-hour, after including a federal tax credit of $18 a megawatt-hour…. Without major advances in ways to store

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[1] 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply, prepared by the U.S. Department of Energy with contributions from the National Renewable Energy Laboratory, the American Wind Energy Association, Black & Veatch and others from the energy sector.

large quantities of electricity or big changes in the way regional power grids are organized, wind may run up against its practical limits sooner than expected."[1]

In July 2008, the *Dallas Morning News* complained:

"*The wind blows hardest before the sun comes up, when people aren't using much power. It tends to die down during the afternoon – especially in the summer – just when people demand more juice. Solving each issue will cost money….even with enough transmission lines, the on-again, off-again nature of wind can leave coal and natural gas-fired power plants scrambling to fill in the gaps.*"[2]

And the Fort Worth *Star Telegram* feared

"*Nobody -- including regulators and the operators of the Texas power grid -- knows now how much the transmission lines will cost, yet plans are moving forward aggressively. Everyone agrees that the price will be in the billions…*"[3].

In Britain attacks against wind installations are notoriously hateful, raising mistrust and ignorance. Based on an article in *Energy Policy* by Jim Oswald and co-authors, titled *Will British weather provide reliable electricity?,* Lewis Page wrote:

"*Not only does the large continental wind base exhibit nasty rollercoaster surges in aggregate output, these surges tend to match those to be expected in the UK…*"

And therefore

"*when the wind isn't blowing across most of the UK, it isn't blowing in Germany, Denmark etc."…"this happens in the dead of winter when electricity demand is highest". Oswald says that "most people, in allowing for gas backup to wind farms, assume that the current situation of gas-turbine usage applies. Not so. Gas turbines used to compensate for wind will need to be cheap (as they won't be on and earning money as often as today's) and resilient (to cope with being throttled up and down so much). Even though the hardware will be cheap and tough, it will break often under such treatment; meaning increased maintenance costs and a need for even more backup plants to cover busted backup plants. Thus, the scheme overall will be more expensive than the current gas sector …-emitting more carbon than people now assume,..high-efficiency base load plant is not designed or developed for load cycling ... Load cycling CCGT plant will induce thermal stress cracking in hot components ... The other impact on the individual plant is a reduction in the plant's utilization.*"[4]

However, the fluctuation argument has been advanced and knocked down many times in the last two decades. Every single official study has shown that intermittency can be accommodated without excessive cost.

For Quebec for example, grid reinforcements accounted for 1.3 and grid management costs for 0.5 Canadian Cents/kWh, as part of a 2000 MW tender.[5]

For the US *"[t]he consensus view is that wind power impacts can be managed with proper design and operation of the system"* was concluded by the Utility Wind Integration Group of the U.S.[6]

Similar conclusions were published by the official British System Operator after studying the issue. He wrote in 2006: *Based on recent analyses of the incidence and variation of wind speed, the expected intermittency of the national wind portfolio would not appear to pose a*

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[1] MATTHEW L. WALD; It's Free, Plentiful and Fickle, NYT December 28, 2006

[2] Elizabeth Souder: Debate flares over wind power in Texas / The Dallas Morning News, July 6, 2008

[3] Texas R.A. DYER: Cost of wind power generating controversy, Star-Telegram September 17, 2007

[4] Lewis Page: Research: Wind power pricier, emits more CO_2 than thought, The Register, Thursday 3rd July 2008 **http://www.theregister.co.uk/2008/07/03/wind_power_needs_dirty_pricey_gas_backup_report/**

[5] Enercon Windblatt 03/2008

[6] **http://www.uwig.org/UWIGWindIntegration052006.pdf**

technical ceiling on the amount of wind generation that may be accommodated and adequately managed.[1]

A comprehensive study by IEA experts concluded that "at wind penetrations of up to 30% of system peak demand, system operating cost increases arising from wind variability and uncertainty amounted to about 1-4 €/MWh or 0.1-0.4 Euro-Cent/kWh.. This is 10% or less of the wholesale value of the wind energy."[2]

The frequently stated claim of wind power requiring an equal amount of reserve power for back up is not correct. A substantial adjustment tolerance is already built in to our power networks, and the impacts of wind power fluctuations can be further balanced through a variety of measures.

Conventional plant – coal, gas, nuclear – cannot be completely relied upon at times of peak demand either. There is, very approximately, a one-in-ten chance that unexpected failures (or "forced outages") in power plant or electricity transmission networks will cause any individual conventional generating unit to be unavailable. Even within purely conventional power systems, there is no absolute guarantee that any electricity system can meet all demands at all times.[3]

The tasks

Excess power and reserves

Wind power production introduces more uncertainty in operating a power system: it is continuously variable and more difficult to predict than the use of conventional power in the short run. But there is a huge advantage compared to other energy sources: with wind power there is no decline of resource such as for oil, gas or coal.[4] Wind is predictable. Unlike other sources of generation that can go offline in 1/60th of a second, wind's declining output tends to be gradual over a matter of hours, giving system operators more time to respond to changes. And wind is free and inexhaustible, a highly reliable player within a well established mix of a flexible power system, provided investments in interconnection, grid and storage facilities are sufficient and achieved in time.

With higher wind penetrations there are times where wind power will be available in excess. This excess energy is virtually cost-free and will feed storage facilities at a very low cost. Therefore in any region with excess wind power, we can expect storage facilities to be built – principally hydro storages with a system of two artificial lakes on different altitudes.

- In Spain, new pumped storage systems are in construction. One project by Spanish utility Iberdrola is sited on the Jucar River. The facility is expected to start operation in 2012, expanding the capacity of the existing La Muela pumped storage station by some 850 MW, the facility being expected to deliver reliable and uninterruptable power to the grid, integrating a huge chunk of the Spanish wind capacities.
- The cheaper way to generate new storage capacities is by connecting wind farms with existing hydro storages which generate power from a natural inflow. These facilities create peak power at a very low cost because there are no pump losses and,

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[1] National Grid, Great Britain System Operator (GBSO): GB Seven year statement 2006, Fluctuating Unpredictable Output and Standby Capacity http://www.nationalgrid.com/uk/sys_06/print.asp?chap=all See also the paper "A shift to wind is not unfeasible", by Dale, Milborrow, Slark & Strbac, Power UK Issue 109, March 2003

[2] Holtinnen et al. 2007 p. 6

[3] Robert Gross et al: The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network, UK Energy Research Centre, March 2006

[4] See Energy Watch Group: Coal: Resources and Future Production, 2007

additionally, they easily can be converted easily to work as pumped hydro systems. Such facilities sometimes can help water management, preventing inundations after excessive rainfalls, or they may serve as an additional drinking water reservoir.

How much back-up energy and back-up capacity is needed?

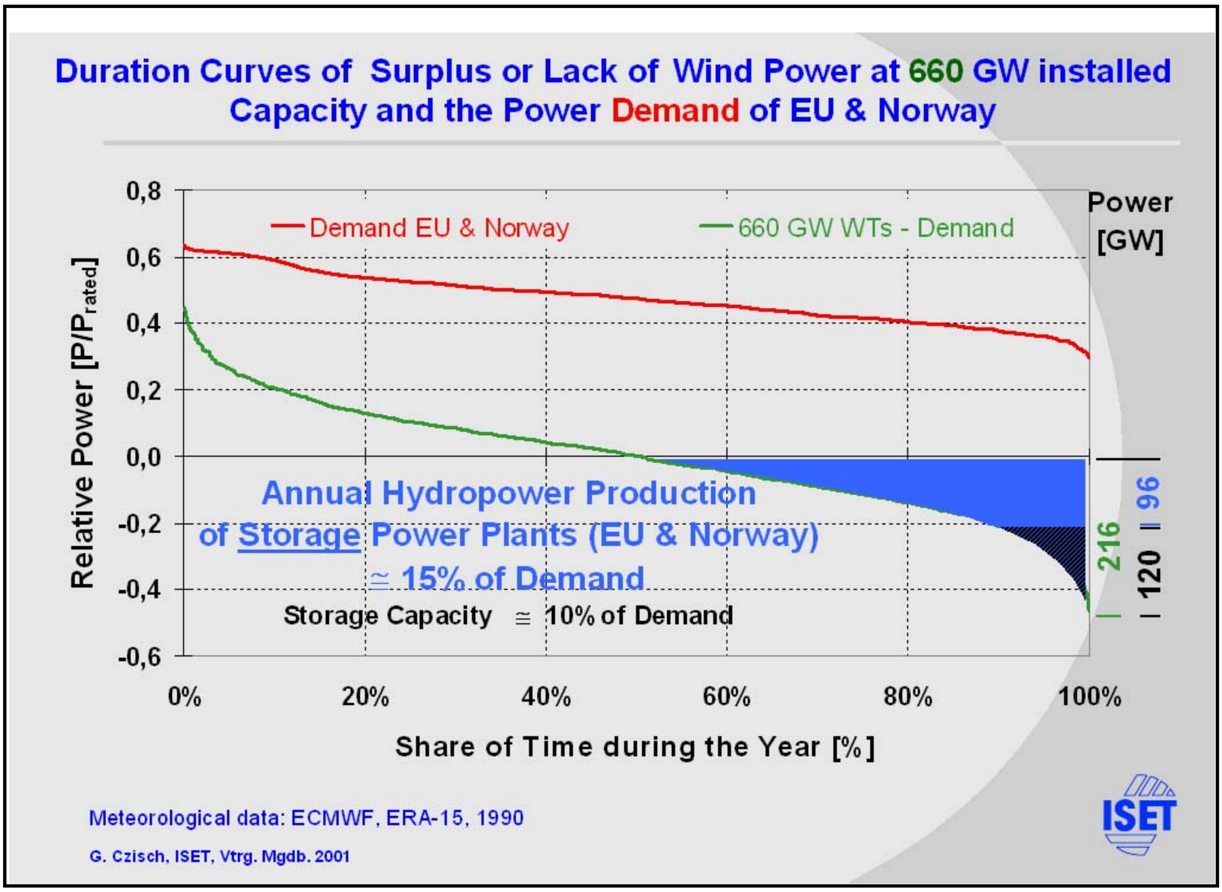

Figure 158 excess power and storage needs for Europe calculated by Gregor Czisch
source: Czisch / ISET

For a full renewable demand-supply equilibrium of the EU and Norway, German physicist Gregor Czisch in 2001 calculated a necessary installation of 660 GW of wind power located over all European regions (and some neighboring parts). This combined expanded trans-European network would need some 9 percent back-up *energy* and 26 percent back-up *capacity* as a percentage of wind turbine capacity to deliver full security of supply, thereby integrating existing hydro and some natural storages as well.

	Wind power capacity GW	capacity factor	yearly hours 1000	expected power generation from wind	Back-up percentage necessary	necessary back-up
Generation	**660**	**0.3**	**8.64**	**1710.72**	**9%**	**153 TWh**
Capacity	**660**				**26%**	**172 GW**

Figure 159 Wind power generation and back-up necessities
source: Gregor Czisch[1]

These numbers could turn out even lower when wind power would be combined with other renewable sources of a different delivery profile such as solar, biomass and geothermal energy.

We may conclude that even with a very high wind penetration most electric power consumed will be produced just-in-time, and that for Europe only a share of less than 10 percent of power consumption would come in from storages at a somewhat higher cost.

Unlike the US, Europe has a widespread hydro storage reserve comprising 49 GW of hydro capacity with an energy reserve capacity of 57 TWh in the UCTE-countries and an additional power capacity of 46 GW with 123 TWh in the Nordel area of Sweden, Norway and Finland. When these power sources are connected and made available for wind management, some 20 percent of power capacity and some ten percent of energy consumption may be covered by existing capacities alone.

How much flexibility is needed in a supply region depends on the level of wind penetration and on the flexibility of the complementing power system. Variability of wind power also impacts on how the conventional capacity is run.[2] As wind generation is added to the power system, other generation must back down. Which generation backs down determines what fuel, emissions, and economic savings will result. With an efficient market, as with a centrally optimized economic dispatch, it is the most expensive marginal unit that is reduced each hour; at actual prices, it is primarily natural gas.

Balancing, peak reserves, grid issues

Balancing

Balancing costs are what producers must pay in some power regions if they produce less, or more, power than they informed the network operator (usually the day before). Wind producers are naturally penalized by such system. This has not prevented projects from being built and from power being sold on terms that make it profitable.

At low penetration levels, wind farmers usually sold their power to big utilities which manage the fluctuations within their larger portfolio, and charge the wind power producers for the service.

At higher wind penetration levels, increasing balancing is needed in allocation and use of short-term reserves (timescale minute to half an hour). Wind power then has an impact on efficiency and unit commitment of existing power capacities depending on wind availability and prediction errors.

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[1] Dipl.-Phys. Gregor Czisch (ISET) Global Renewable Energy Potential - Approaches to its Use – speech held in Magdeburg

Germany, September 2001 http://www.iset.uni-kassel.de/abt/w3-w/folien/magdeb030901/overview.html

[2] State of the art of Design and Operation of Power Systems with Large Amounts of Wind Power, Summary of IEA Wind collaboration by Hannele Holttinen, Peter Meibom, Cornel Ensslin, Lutz Hofmann, Aidan Tuohy, John Olav Tande, Ana Estanqueiro, Emilio Gomez, Lennar Söder, Anser Shakoor, J. Charles Smith, Brian Parsons ,Frans van Hulle, EWEC 2007 conference, 7-10May 2007, Milan, Italy

To save costs, unpredicted parts of variations of wind within a large area should be combined with any other unpredicted variations the power system sees, such as unpredicted variations in load.

Smart grids and demand side management

Smarter grids will help to smooth fluctuating demand elements with power supply. A smart grid will constantly monitor its load and (this is the impressive part) take particular consumers offline, with their prior agreement and in exchange for a lower price, if that load surges beyond a preset level.

For this purpose, a consumer may not necessarily be the same as a customer. The grid’s software would be able to identify particular circuits, or even particular appliances, in a home, office or factory. Their owners would decide in what circumstances they should shut down or boost up, and the smart grid’s software would then do the job. Water heaters and air-conditioners might stock up on heat or cold in anticipation of such shutdowns. Refrigerators would know how long they could manage without power before they had to switch on again.

With improvements in battery technology and a shift of the transport system to electric drive, vehicle-to-grid applications might deliver more energy storages for fluctuating power sources.

Adequacy of power: wind’s capacity credit

Sufficient supply has to be available during peak load situations. The estimation of the required generation capacity includes the system load demand and the maintenance needs of production units.

An issue is the proper assessment of wind power’s aggregate capacity credit in the relevant peak load situations – taking into account the effect of geographical dispersion and interconnection. The French System Operator commented on wind's contribution to peak demand in his 2007 report: “*despite wind's intermittency, wind farms reduce the need in thermal power plants to ensure the requisite level of supply security. One can speak of substituted capacity. The capacity substitution rate (ratio of thermal capacity replaced to installed wind capacity) is close to the average capacity factor of wind farms in winter (around 30%) for a small proportion of wind in the system (a few GW). It goes down as that proportion increases, but remains above 20% with around 15GW of wind power.*”[1]

Adequacy of power: Grids

The creation of energy reserves, peak capacity reserves and advanced interconnection might go hand in hand. The requests for additional transmission depends on the location of wind power plants relative to the load, and the correlation between wind power production and load consumption.

Wind power affects the power flow in the network. It may change the power flow direction, reduce or increase power losses and bottleneck situations. There is a variety of means to maximize the use of existing transmission lines like use of online information (temperature, loads) and wind power plant output control. Fortunately the amount of visual impact, land used or electromagnetic pollution by new interconnection lines and storages does not grow proportionally with additional wind capacities:

- The amount of power a transmission line can carry increases with the square of the voltage, which is why a 765-kV line can carry as much power as six 345-kV lines, using one-fourth as much land and with one-tenth of the electricity losses.

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[1] Gestionnaire du Réseau de transport de l’électricité, Bilan prévisionel de l’équilibre offre-demande d’électricité en France 2007 p. 105, **http://www.rte-france.com/htm/fr/mediatheque/telecharge/bilan_complet_2007.pdf**

- A stronger grid will be more reliable and more resilient in the face of potential disruptions caused by accidents or supply problems of non-renewable energies too. At a certain point "saturation" will be achieved in terms of reserves too.
- HVDC carry much more power than conventional AC-power systems. Up to 6 GW might be transported in one single connection as in construction in China by ABB over a distance of more than 2000 kilometers. DC systems have even more advantages: they reduce power losses over large distances and generate no electromagnetic pollution.

Although the multiple benefits of investing in new transmission outweigh the costs, thus far policymakers have been slow to take action.

Across the world, hundreds of wind projects comprising tens of thousands of wind turbines are on hold because no one wants to step forward and pay for upgrades that will primarily benefit others. Reforming the patchwork of policies that currently govern the allocation of transmission costs and the siting of new transmission lines will require cooperation among local, state, regional, national and transnational entities. A large-scale investment in a transmission superhighway plan is a critical first step and on each continent attempts in this direction are proceeding.

Since almost all new generation technologies are dependent on developing new transmission infrastructure, significant investments are essential for the transition to a lower carbon future. The benefits of new transmission will outweigh their costs. Grid and reserve extensions should be perceived as a common good to be financed by consumers over regular grid rates, and they should not be a burden paid by a specific renewable resource.

Stage	time frame	technology achievement	Siting	system integration stage
Preindustrial	Up to 1980	Turbines producing electricity for local use	Local: farms, off-grid, pre-industrial	Compatibility with owner's electricity demand
Pioneer period	1980-1995	Turbines producing electricity for local grids	Embedded production in areas where grids were available with few extensions	grid compatibility of new turbines
Take-off period	1996-2004	Bigger and cheaper turbines with higher efficiency, onshore	Advanced integration	Turbines optimized for grid stability; fossil fuels as back-up
Globalization	Since 2005	Worldwide deployment of most efficient technology, diversification of technology, offshore, small scale wind and new storage solutions ready to go	Siting starting in peripheral regions with strong winds, new grids erected specifically for wind; renewed off-grid applications for remote areas and rural electrification	Continental interconnection for wind integration; better wind forecasts; backup capacities by renewable systems (pumped hydro, biomass, geothermal air storage, plug-in hybrids).

Figure 160 Stages of wind energy technology and integration

The idea is that we are on the way to an overall renewable future where a balanced system of generation, interconnection and reserves will satisfy all power needs. The first preindustrial era of wind power asked for compatibility of turbines for isolated systems. The next stage was grid compatibility, followed by turbines optimized for grid stability, with fossil fuels still as a backup. The last step toward a globalized renewable provision is the full integration of wind power in continental systems with back-up power also based on renewables.

The ISO's job!

Ensuring power reserves, grids and peak power capacities is a main task for the Independent System Operators (ISOs). In open electricity markets, a working market for reserve capacities can emerge on its own. After the initial opening of European power markets, a generally higher volatility of power prices and of trade was observed. With responsible system operators allowing high prices at times of short delivery, an autonomous market for reserve and peak power will emerge, and not only new but mainly *existing storage facilities* will be dedicated as an add-on to the entire system, when before they were part of the daily supply curve of a non-trading vertically organized power supplier.

In that way for instance, Swiss and Norwegian power suppliers will stop delivering on schedule at noon but they will deliver at times when the wind is not blowing. And they will spare and fill up hydro capacities in times of high winds at low price. There will be various regulative and technical tools which all can contribute to a better matching of supply and demand, including

- Advanced interconnection, allowing to trade scarce/excessive power,
- Geographic diversification of renewable sources,
- Diversification of supply into different renewable technologies: running hydro, wind and solar strategically accompanied by stored hydro, pumped hydro, concentrated solar power heat storage, geothermal and biomass-CHP,
- Interconnection by HVDC super grids which extend over several weather zones to reap energy where and when ever it appears naturally,
- Introduction of real time tariffs, smart meters and ripple control to curtail or expand consumption along supply profiles,
- New storage options including batteries, compressed air, hybrid cars, fly wheels, thermal storages, and
- Managed storage of fossil fuels (natural gas, coal or fuel oil), with mothballed old plants for emergency backup (extremely dry seasons for example).

Reserve and peak capacity needs will find their specific solutions for every single supply area. Spain is a showcase in this transformation. Just five years ago, the Spanish Transmissions System Operator REE (*Red Electrica de España*) viewed the former national wind target of 9.5 GW for 2010 as a “system security suicide” – and, in 2008, Spain has more than 15 GW. REE argued that wind could not produce more than 12 percent of Spain’s electricity without risking security of supply.

Meanwhile, better interconnection, better grid management, and the extension of weather forecast models for wind power all have contributed to the integration of bigger shares of wind power. More reserve capacities, such as pumped hydro extensions of existing hydro facilities, are in construction. In the words of Luis Atienza, the president of REE since 2004, “Spain has become an international reference for integrating wind.” Wind power spot penetration levels are often 20-30 percent, recently touching 40 percent of overall supply, and “flexible dispatch and scheduling is the key” with all of the mentioned recipes playing in.

Creating a low cost back-up hierarchy

Matching wind power generation with demand is not such a new task as some would make believe. Bulk power from coal or nuclear plants do not match daily load variations. They need complementary services delivered by hydro power, biomass, natural gas or coal.

“Integrating wind energy into Europe’s electricity supply mix […] should not be regarded as more problematic than getting any other power source to the market. What it requires is the appropriate approach. ‘Look at the 1600 MW nuclear plant with a single generator being built in Finland. For this we had to increase generating reserves, reinforce the grid, build a connector from Finland to Sweden and reinforce the grid in Sweden. But with all these costs, we don't talk about integration costs – all this is done because we want to get nuclear power to the market," says Hannele Holtinnen, from VTT technical research centre in Finland. [1]

Integration costs depend on the "generation environment" as has been documented:

- Wind power integration costs are lower in hydro dominated countries (especially Norway) compared to thermal production dominated countries (Germany, Denmark). Hydro power has very low costs at part load operation and startup. Hydro dominated systems are generally not constrained in regulating capacity.[2]
- Integration costs are on the rise when wind power is unevenly distributed such as in Germany with Northern Germany having a high share of wind power relatively to the electricity demand and the export possibilities out of the region.
- A study of 4000 MW wind power in Sweden has concluded that in power systems with large consumption variations, like the Swedish, lower additional reserves are required compared with power systems with lower consumption variations. In many cases these extra requirements come at no extra investments.[3]
- With natural gas prices on the rise, a rather large number of natural gas power plants – among them the older and lesser efficient ones – are taken out of service in favor of wind or more efficient natural gas plants, with reasonable savings for consumers. In practice these conventional plants could well be kept mothballed (but will hardly be ever used) for emergencies. Capacity costs of such reserve units will be very modest. Vast underground natural gas storages exist and are ready to stabilize the system in case hydro storages are not sufficient.
- As a "lender of the last resort," a number of older coal power plants with longer ramp up periods might be kept on stock for security of supply reasons too, just for "once in a decade" cases. In terms of cost and pollution, this would be negligible.

In this way a back-up hierarchy can be built, with a cascade of flexibilities:

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[1] Windpower Monthly, December 2006, p. 59

[2] Holtinnen et al 2007

[3] Holtinnen et al 2007

Tool	Goal	Frequency of use	Additional Cost
National interconnection and exchange	matching demand, smoothing of national renewables supply	Daily	Very low
International interconnection and exchange	Exporting renewable power exceeding internal demand	Daily	Low
Natural hydro storage management	storage of natural hydro inflows used for peak demand	Daily	None to low
Other renewable power generation such as solar, CHP from sewage gas, geothermal, biomass	Smoothing of homemade renewables, matching demand	Daily	Low
Pumped hydro storage	Matching peak demand, active shaving of supply peaks, storage	Daily	Loss of some 20-30% of power input
Natural gas plants	Matching demand peaks and/or base load demand	daily/weekly/yearly Depending on renewables' penetration	Higher cost than wind power and hydro
Coal plants / mothballed coal plants	"lender of the last resort" in case all other reserve capacities are exhausted	Once in ten years (?) depending on renewables' penetration	Low reserve costs, high variable costs (emission restrictions)

Figure 161 Back-stop-hierarchy at a high renewables penetration

The availability of energy storages and reserve capacities will strengthen the overall system and provide security of supply. Increasing the proportion of wind power in the electricity system in this way does not increase "back up" capacity, as is often believed, but it does slightly increase the capacity costs due to coal and gas plants standing idle (and saving fuels).

The higher the proportion of wind on the grid, the lower its "capacity value," and the lower are the quantities of conventional technology it firmly displaces. Nevertheless, wind continues to reduce carbon emissions.

Conclusion

Due to rising fuel costs for non-renewables we expect that interconnection, balancing and storage issues can and will be resolved within reasonable terms and at reasonable costs. The main driver of this movement is market economics. Incentives for wind integration are given by cost savings. Incentives for storage facilities are given by excess wind power which is and will be available in huge and cheap volumes at times of low demand. These additional supplies will drive the construction of new, affordable back-up storages.

Globalization of wind turbine manufacturing, liberalization of power generation and the unbundling of production and transmission in the electricity sector has transformed the wind power industry from a local into an internationally connected business. This relates to the use of wind resources, too: with an expected acceleration of transmission, a diversification of geographic origins of energy is in sight, improving capacity factors and competitiveness even more.

Wind power and wind power components therefore will be one of the most traded international commodities, conquering a high market share in the energy sector within a very short period. It will emerge as a backbone of the power business. And it will expand into new sectors such as traffic, heating and industry demand for energy – markets which for decades were dominated by fossil fuels.

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