ENERGYWATCHGROUP

Supported by Ludwig Bölkow Stiftung

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

Executive summary


December 2008

Author/Responsibility for this report:
Dr. Rudolf Rechsteiner
Murbacherstrasse 34, 4056 Basel/ Switzerland, rechsteiner@rechsteiner-basel.ch
Member of the Swiss Parliament and its Energy Committee
www.rechsteiner-basel.ch

Full report see at **www.energywatchgroup.org**

© Energy Watch Group / Ludwig-Boelkow-Foundation

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.

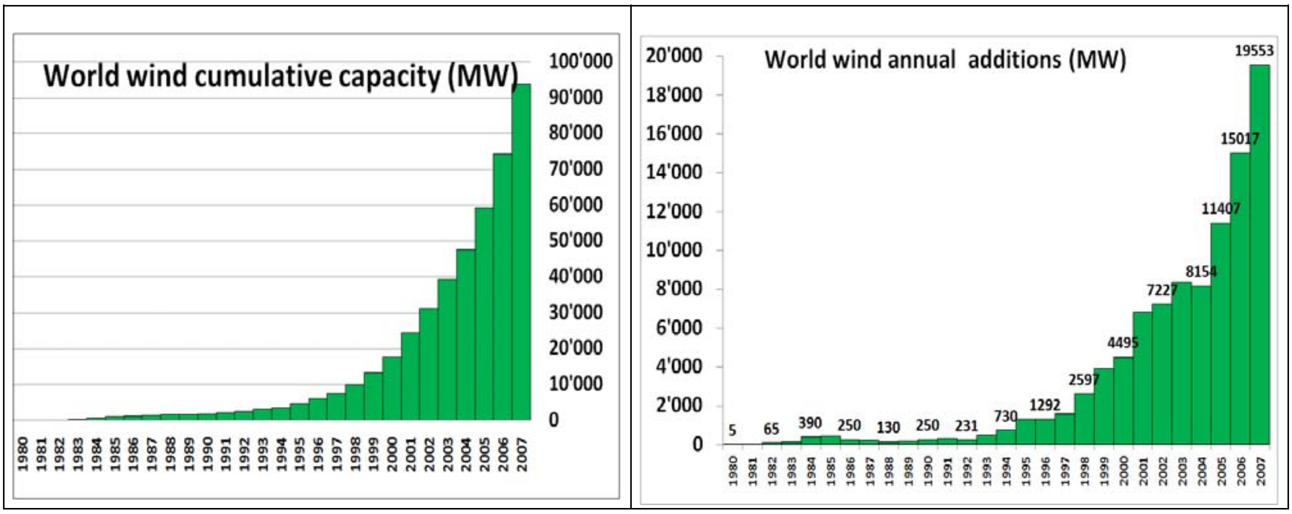


Figure 1 world wind power capacity and annual additions

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.

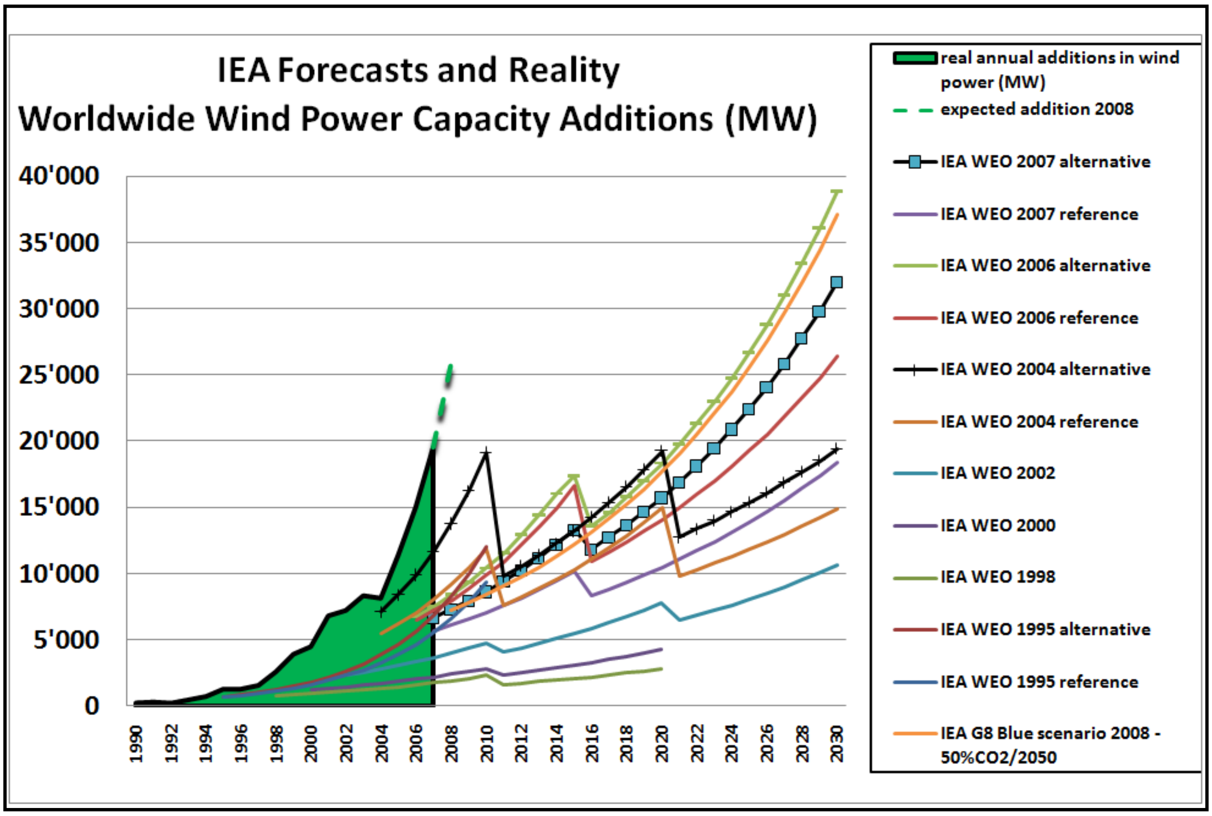


Figure 3 IEA long-term forecasts of annual additions: World

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.

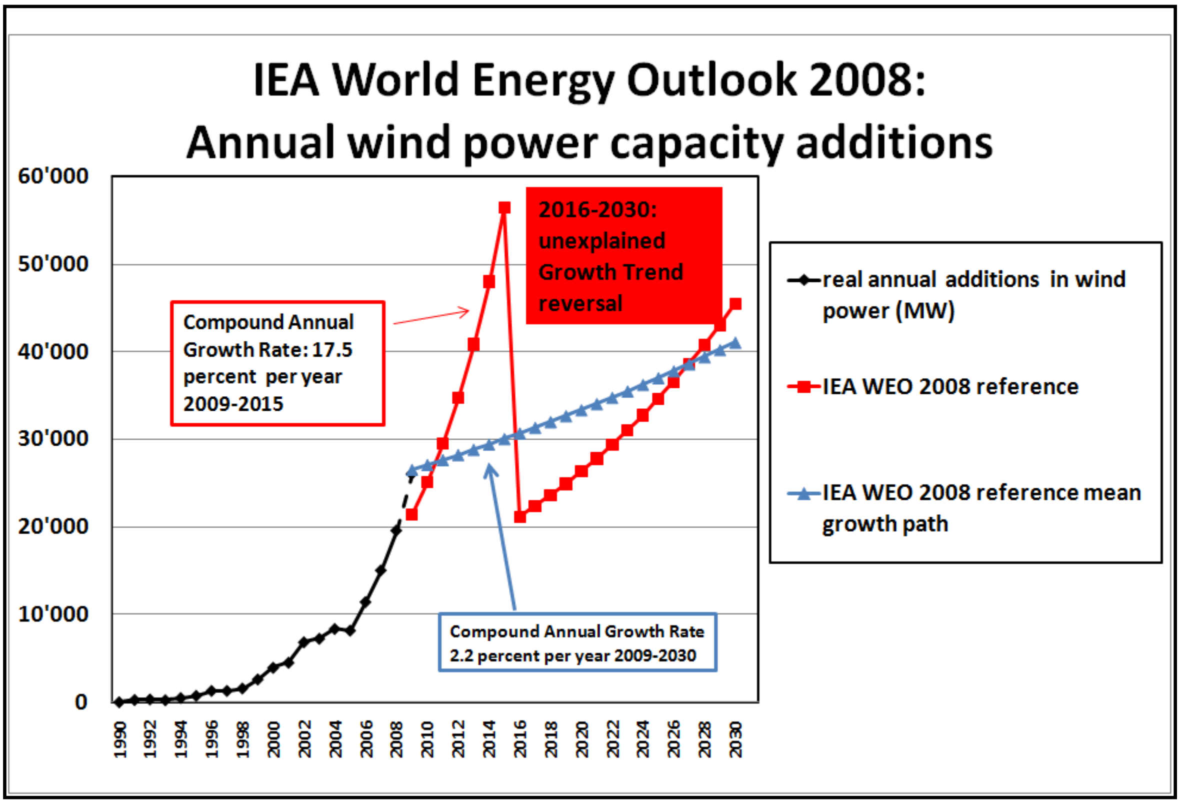


Figure 4 IEA projection of annual wind capacity additions 2010-2030, from World Energy Outlook 2008

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.

---

[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.

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

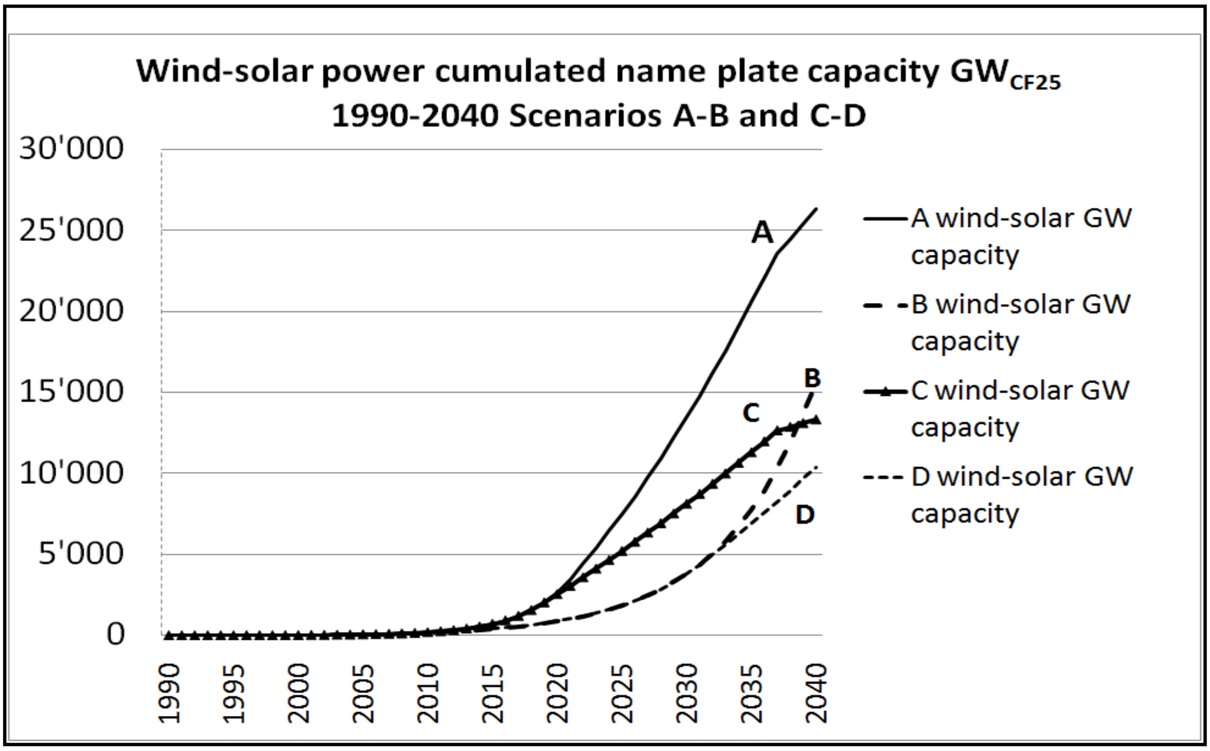


Figure 6 cumulative wind power capacity (accompanied by solar)

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.

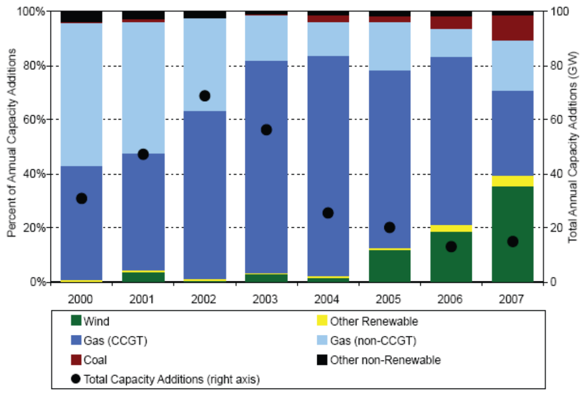
2025	Wind (incl. solar)	other renew-ables	Conventional (fossil/ nuclear)
scenario A	44%	12.2%	44%
scenario B	11%	12.2%	77%
scenario C	42%	16.8%	42%
scenario D	15%	16.8%	69%

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

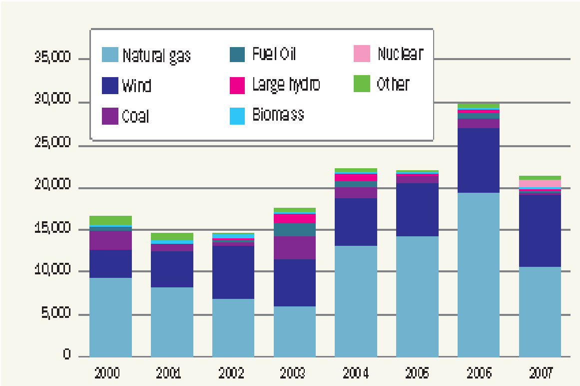


Figure 8 Power Mix of Capacity Additions in the US and in Europe 2000-2007[1]

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.

[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.

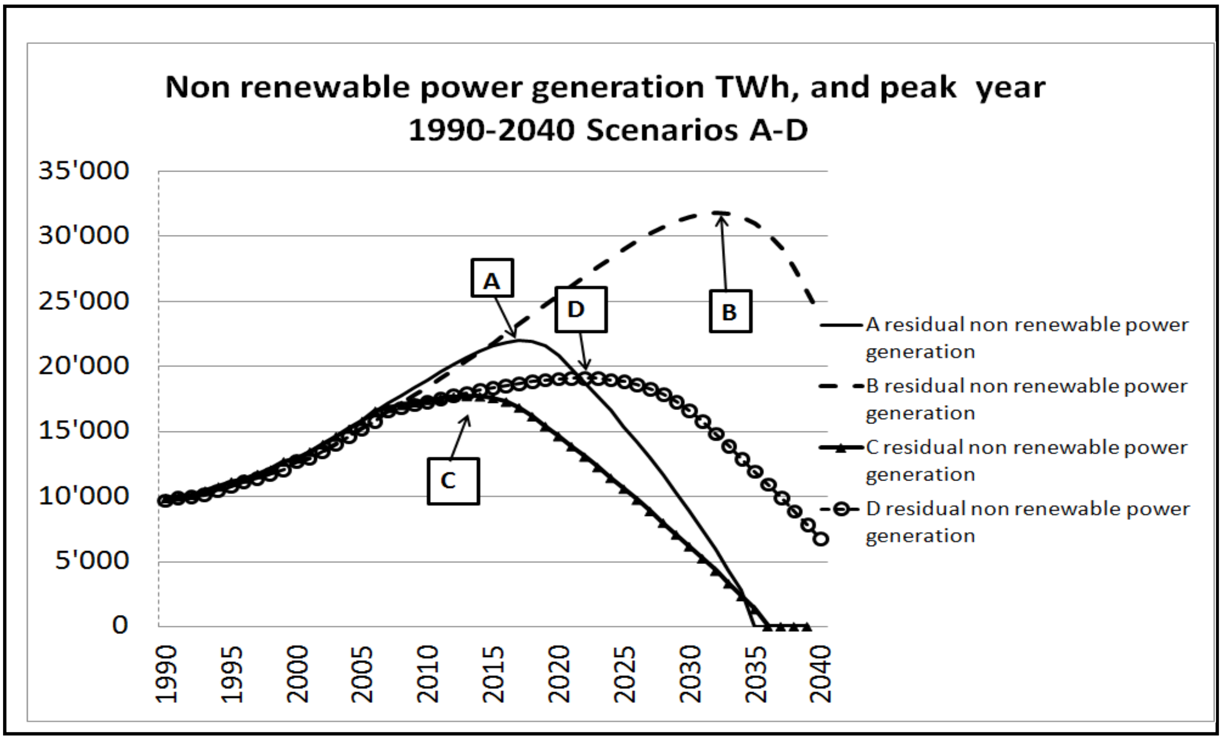


Figure 10 non-renewable power generation 1990-2040

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.

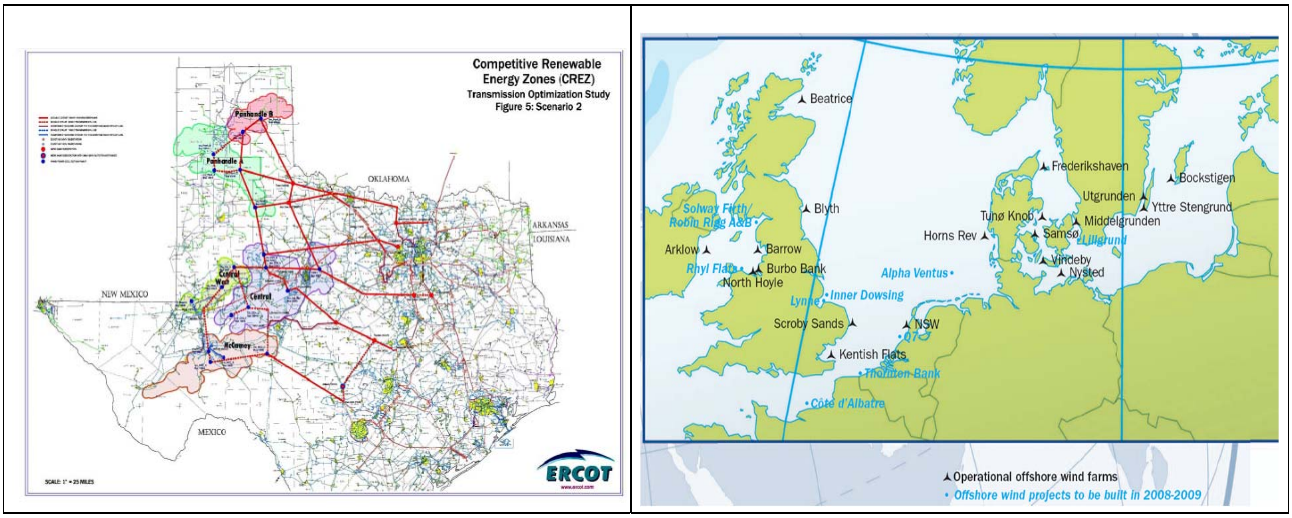


Figure 12 Texas wind integration plan adopted by the Texas PUC (left) and offshore developments 2009/2010 in European waters (right)

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]."

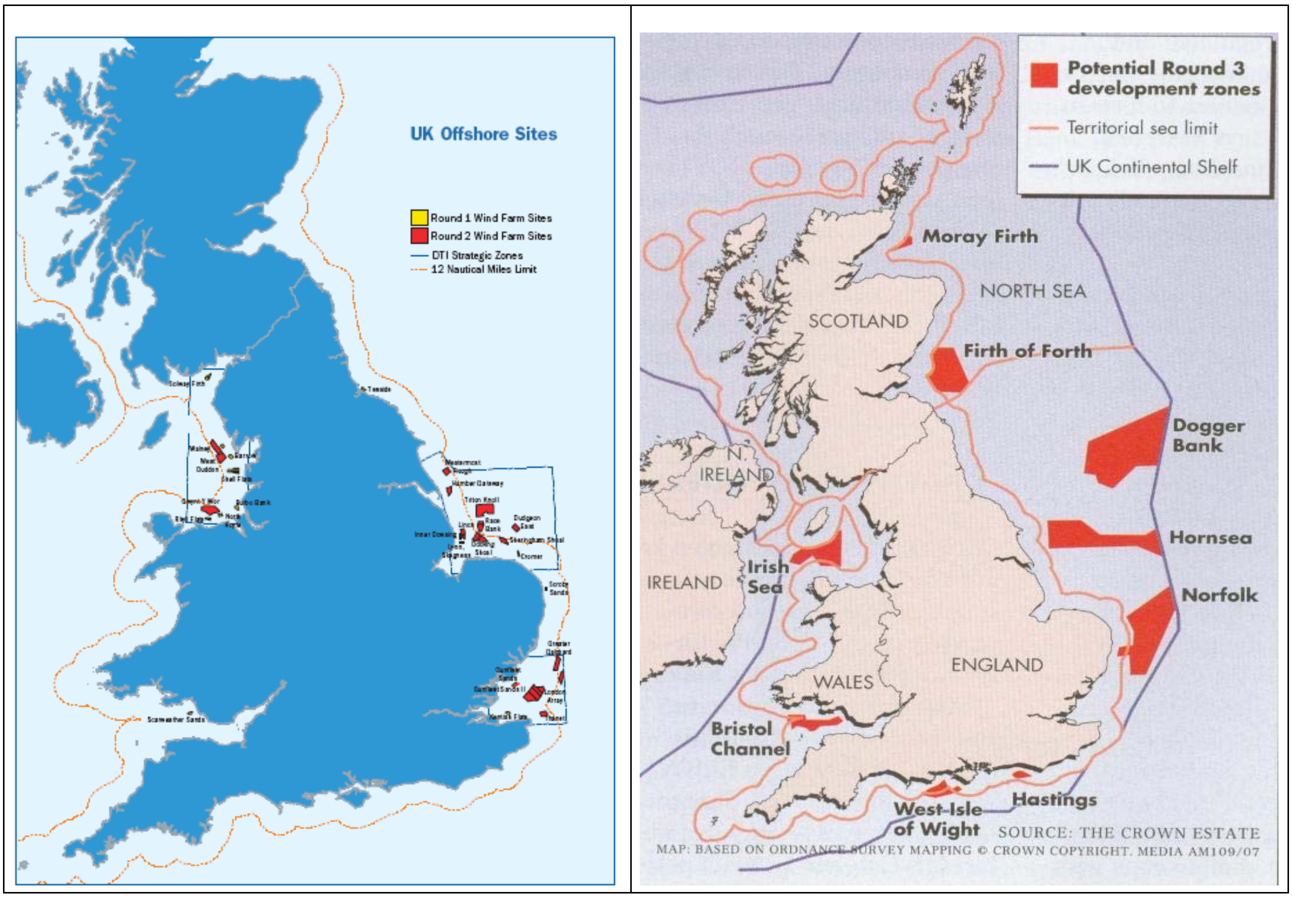


Figure 13 British offshore wind areas Round 1, 2 (left) and Round 3 (right)

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.