EWEA THE EUROPEAN WIND ENERGY ASSOCIATION | German Wind Energy Association (BWE) | VDMA

Power Systems

BRIEFING May 10 2005

German Energy Agency Dena study demonstrates that large scale integration of wind energy in the electricity system is technically and economically feasible.

The topline results:

- ***Wind energy installations in Germany can expand from almost 17 GW today to 36 GW in 2015, and 48 GW in 2020***
- ***Wind energy annual production can triple from 23.5 TWh in 2003 to 77.2 TWh in 2015, providing 14% of the German net electricity consumption in 2015***
- ***Wind energy requires only minor expansion of the grid***
- ***Wind energy does not require construction of additional 'balancing' power stations***
- ***Wind energy increases only marginally the cost of electricity for the consumers***
- ***Wind energy can help to maintain the system security of supply even with a very significant percentage of the power supply***

The dena grid study is presented in detail at the international "*Conference on the integration of wind energy into the German Electricity Supply"*, May 10 2005 in Berlin. This briefing explains the background of the report and gives an overview of the main results.

Background of the dena study "*Planning of the grid integration of wind energy in Germany onshore and offshore up to the year 2020*":

The grid study was initiated and moderated by dena. It was financed and controlled by the steering group formed by the German Ministry of Economy, the wind energy branch, manufacturers and suppliers of wind turbines, producers of power plants, major utilities and their associations. The dena grid study has been elaborated and accomplished by the consortium of the German Wind Energy Institute DEWI, the Institute for Energy Industry at the University of Cologne EWI and the major German grid operators E.ON Netz, RWE Netz und Vattenfall Transmission.

The dena grid study consists of three parts. The first shows a scenario of the development of wind energy, the second analyses grid upgrades and extensions and the third the effects on conventional power stations. The study compares different scenarios with and without an extension of wind energy and analyses the cost development.

Purpose of the report (quotes from the summary of the DENA study)

Long term planning
"In industrialised countries like Germany medium to long-term energy-economy and energy policy decisions require long term preparation and planning procedures. Thus a favourable climate for investments for a sustainable economic development can be promoted."

Increasing renewables' share
"One important way to accomplish these CO_2 reductions is an increased use of renewable energy sources. In Germany the share in electric power generation from renewable energy sources reached 10% in 2004. Till 2010 this shall rise to at least 12.5% and by 2020, to at least 20%. Wind power will contribute substantially to these goals."

Changing energy supply mix
"The renewal and restructuring of German energy economy due to plant age and phasing out of nuclear power stations give wider scope for more integration of wind power. Of the 121,000 MW of gross power generation capacity presently installed in Germany, the plants to be shut down in this process by 2020 account for about 40,000MW."

Large scale wind integration
"For the further development of renewable energy, an efficient integration of onshore and offshore wind energy into the power system is very important. In the medium term, wind power has the greatest potential for increasing the share of renewable energy in electricity generation."

The dena study investigates the long-term consequences of an increased share of renewable energy in Germany, for the electrical system, with a time horizon of up to 2020. The extension of wind power will lead to strong geographic concentration in Northern Germany, a region with relatively low electricity demand. The integration of large amounts of wind energy into the grid creates challenges for the entire power system. The dena grid study shows that these challenges can be managed technically in a cost effective way.

The German and the European wind energy sector welcome the main results of the dena grid study. Further investigations need to address a number of questions not fully addressed in the study. Instruments like temperature monitoring of power lines, integration into the European transmission grid, power storage and management have to be analysed in follow-up studies.

Results:

14 % of national net electricity consumption from wind power by 2015
The study confirms the technical and economic feasibility of the integration of 36 GW wind power – 26 GW offshore and 10 GW onshore – in the German grid by the year 2015 generating 77 TWh or 14 % of national net electricity consumption (552 TWh). By 2020 even 48.3 GW of wind power capacity can be installed in Germany – 27.9 GW offshore and 20.4 GW onshore. The main challenge, given the intermittent character of wind and the relative strong geographical concentration of wind power in the North of Germany, was to determine, how the planning of the grid integration of huge amounts of wind energy can be done most efficiently. In order to enable assessment beyond 2015, more extensive investigations in viable solutions are needed, especially in order to integrate increasing amounts of offshore wind energy from the Baltic Sea and the North Sea. The time horizon of the study had to be limited to the year 2015. The time beyond 2015 until 2025 will be investigated in follow-up studies.

Scenario of wind energy development
The dena study develops a scenario of installed wind power capacity and energy output distributed over Germany for the years 2007, 2010 and 2015, taking into account regional and local planning and adjustments on the spacing rules. A gradual increase in effective wind turbine capacity factors has been accounted for, corresponding with expected wind energy technology improvements and the use of more windy locations, especially offshore. As a result, the effective capacity factor in 2015 is 34% higher than in 2003. The installed wind

power increases from 14.5 GW in 2003 to 36 GW in 2015, of which 27 % offshore. The total annual wind energy output raises from 23.5 TWh in 2003 to 77.2 TWh in 2015, effectively increasing the share of wind power in covering the national electricity demand from 4.3% to 14 %. Offshore wind energy can provide 42 % of the wind energy output in 2015.

	2003	2015
Installed wind power capacity (GW)	14.5	36
Annual wind energy generation (TWh) (*)	23.5	77.2
Effective capacity factor	18 %	25 %
Annual net national electricity consumption (TWh)	545.0	552.3
Wind energy share of net annual electricity consumption	4.3 %	14%

Table 1: Characteristic numbers of wind power capacity and generation in 2003 and 2015 in the scenario of the dena study. (*) Wind energy generation corrected to 'normal' wind year.

Wind energy expansion requires only minor expansion of the grid

The transmission system on land should be reinforced and extended. Until 2015, an additional 850 km of extra high voltage lines should be built, and another 400 km should be upgraded. This corresponds to a share of 5% of the currently existing extra high voltage line tracks. The study gives details about the grid bottlenecks to be solved and desired timescales. The corresponding total investment is estimated to be 1.15 Billion € within ten years. This means on average 115 million € per annum, just 5% of the annual investments of German grid operators. Grid extension alone would increase the electricity cost by 2015 for the consumer by a low 0.025 ct€ per kWh (the equivalent of less than 1 € per household per annum). In less windy periods the additional grid capacity can be used for intensified national and transnational electricity trade, This leads to lower wholesale market prices and may offset and considerable part of the grid extension costs. The grid improvements also cater for the amounts of offshore wind power until 2015. The costs for the sea cable to the grid connection point are born by the wind farm operators and covered by the feed-in remunerations. A concept of four offshore high voltage collectors has been proposed to transport the offshore power after 2015. However this issue has not been examined in the report. This should be investigated in more detail in the future studies.

Wind energy does not require construction of additional 'balancing' power stations

The amount of control and reserve power to balance the increasing amount of wind power has been calculated. The amounts of control energy are strongly depending on the accuracy of the short term wind power forecast, and the deviation between forecast and actual feed in. The quality of the forecasting tools keeps on improving. It is found that the additional required balancing power (positive and negative regulation power, from secondary and hourly reserves) can be provided by the remaining conventional plants. There is no need for new investments in additional power stations for this purpose to meet the balancing needs of the German system with 36 GW of wind power. An overview of the required balancing power capacities is given in table 2. In 2015 on average 3.2 GW positive regulation power representing 9% of the installed wind energy capacity and 2.8 GW negative regulation power representing 8% of the installed wind energy capacity is required.

	2003		**2015**	
	average	**max**	**average**	**max**
Positive regulation capacity (MW)	1.2	2	3.2	7
% of wind power capacity	9	14	9	19
Negative regulation capacity (MW)	0.75	1.9	2.8	5.5
% of wind power capacity	5	14	8	15

Table 2: Overview of required regulation power in 2003 and 2015 as found in the dena study. Installed wind power capacity 14.5 GW in 2003, and 36 GW in 2015.

System security of supply can be maintained with significant amount of wind energy
Out of the 36 GW installed wind power capacity foreseen in 2015, around 2 GW (depending on the season) can be considered as 'firm capacity'. In other words, German wind power by 2015 can diminish 2 GW of conventional base load plant capacity to be maintained as long-term reserve, in order to guarantee a reliable (99%) energy supply. Grid connection codes applicable until 2003 requested wind turbines to disconnect from the grid in cases of minor instabilities of the grid and therefore increased the risk of critical grid situations. Improved grid connection codes issued in 2003 which make use of advanced wind turbine technology, ensure that until 2015 the security of supply can be maintained and supported by the increasing wind power capacity. Remaining risks in some parts of Germany and coping with critical grid situations (strong wind combined with low demand), necessitating power export to neighbour countries, need further investigations.

Wind energy increases only marginally the cost of electricity for the consumers
The study calculated the effects of the wind power expansion on the generation costs of electricity. The total additional cost caused by tripling wind power production up to 77 TWh in 2015 compared to 2003 is estimated to be between 1.6 and 2.3 Billion € depending on the chosen scenario for fuel price developments and emission reduction pricing measures. Despite only very moderate assumed increases of fossil fuel prices between 1,5 and 2,5% in the alternative scenario, the assumed expansion of wind energy until 2015 will halve the total additional wind energy feed-in costs from 6 to 3 ct€/kWh. This expected cost development has taken into account on the one hand feed-in remunerations, grid extension, generation strategy, fuel mix, required energy for balancing, and savings in fuel and capital costs on the other hand. External costs have not been taken into account. The effects of these costs for the end consumer are quite low. The cost per kWh for the so-called non privileged users increases by 2015 only with 0.38 – 0.47 ct€, of which the major part is caused by increased generation costs, and a minor part (6%) by the costs of grid extension. For an average household using 3.5 MWh per year the incremental cost due to higher generation costs and increased grid charges would be in the order of 1 € per month.

In the year 2015 about 20 to 40 million tons of CO_2 per annum can be avoided additionally by the assumed expansion of the use of wind energy, depending on the structure of the entire power plant park. This means that, despite the beginning of the phase-out of nuclear energy, which in 2015 will be one-third complete, the CO_2 emissions can be stabilized or reduced, depending on the scenario. The corresponding CO_2 abatement costs – under a rather conservative fuel price scenario - are calculated to be 41 to 77 €/tonne in 2015. Again, other external benefits have not been taken into account. Rather conservative fuel and certificate price scenarios have been used in the simulations. The basic scenario without any price increases and no allocation of CO_2-emission certificates is already outdated by the development of actual gas prices and emission allocation mechanisms. Even the alternative scenario is already obsolete because of the actual price increases for gas and certificates, which are much higher than the assumed ones. The costs shown by the dena grid study for wind energy and CO_2 abatement are the upper limit of possible costs. With more realistic assumptions for the price development of fossil fuels and certificates wind energy will reach the average market price in the middle of the next decade depending on the level of price increases. CO_2 abatement costs of wind energy will then be much lower than expected by the dena grid study.