Demand Response –
A new Option for Wind Integration

Marian Klobasa, Mario Ragwitz

Fraunhofer Institute Systems and Innovation Research
Breslauer Strasse 48, 76139 Karlsruhe, Germany
M.Klobasa@isi.fraunhofer.de, M.Ragwitz@isi.fraunhofer.de

Abstract:

This paper presents a recent analysis of wind energy integration into the electricity system of Austria and Germany. The main focus was on the interaction of wind power production and flexible demand to improve the total system efficiency. Detailed simulations of wind power production and power plant operation were used to quantify additional reserve power. An assessment of possible demand responses provided first evidence that the costs of additional reserve power could be reduced and that demand response may be a valuable option for integrating wind power into electricity systems. This research was done in cooperation with the Vienna University of Technology, Energy Economics Group (EEG) and was funded by the Austrian Ministry of transport, innovation and technology (BMVIT) under the program "Energy Systems of Tomorrow".

1 Introduction

Recent studies on the integration of wind energy into electricity systems concluded that increased efforts are necessary to balance and control the power system if wind penetration increases. So far, the main strategies looked at to secure a high penetration of wind power generation in an electricity system were driven by the supply side or comprise the introduction of storage options.

The key studies examining additional costs for system operation, especially the issue of balancing power [1, 2] found additional costs per MWh wind power in the range between 1 and 10 €/MWh.

The results of a recent study of the German electricity system, which analysed wind penetration up to 36 GW, showed that extended balancing power is necessary [1]. With the increasing penetration of wind power, a maximum of 19.4 % and an average of 9 % of the installed wind capacity would have to be added to existing positive balancing power. For the maximum negative balancing power, the corresponding values were 15.3 % or 8 % on average. The additional balancing power depended on the next day's wind forecast. Research within the scope of the European project GREENNET calculated the additional costs for balancing power at up to 3 € per MWh wind energy for electricity systems with high wind penetration. Further costs between 0 and 5 € per MWh wind energy are expected for grid extension especially if large offshore wind farms are constructed [2]. Studies by the UCTE[1] [3] emphasize the existing congestion between Germany and the Netherlands during the day as well as congestion between Germany and Denmark at times of high wind power generation.

For the above mentioned reasons, strategies to integrate large scale wind power generation are high on the academic research agenda. One such strategy is the introduction of new large storage options into the electricity system. However, state-of-the-art research has provided evidence that these options will not be economically competitive in the near future compared to existing supply options [4, 5].

Another promising strategy is the intensified introduction of demand response into the electricity system. Experiences with demand response in Nordic countries [6] have already

[1] Union for the Co-ordination of Transmission of Electricity (UCTE)

demonstrated the feasibility of this option to overcome restricted network and generation capacities.

Therefore, our analysis was based upon the expected enormous potential for demand response in the German and Austrian electricity markets that could be used to manage the predicted increase in balancing capacity and restricted network capacity due to increased wind generation.

2 Methods and Data

The method used in this study was a dynamic time based high-resolution simulation model of electricity demand, wind generation and power plant operation. A new approach in this study was the introduction of demand response in the electricity systems of Germany and Austria. The necessary balancing power was also simulated.

A database was developed containing time series of total demand and the potential of flexible demand. Wind power simulation was performed on the basis of over 180 wind speed measurement locations. The necessary balancing power was derived from typical deviations for wind power and demand prognosis. The wind power time series and the demand time series formed the main input to the energy system model next to parameters of the demand and supply side. The model was then used to simulate power plant operation on an hourly basis. Finally, the availability and costs of generation capacity for balancing the system were compared with demand-side options. In the following sections, the main data sources for the different parts of the energy system model are described.

2.1 Demand and demand response (basis for load curve and shift potential)

The description of the electricity demand was based on several studies undertaken at the Fraunhofer Institute for Systems and Innovation Research (FH-ISI) and the TU Vienna (EEG) that covered the industry, commercial and residential sectors (fans, pumps, compressed air, air conditioning and refrigeration). The result was a detailed breakdown of the electricity consumption with regard to sectors and appliances. This consumption data was then projected into the future until the year 2020 taking main structural changes in the sectors into account. For the analysis of the interaction between wind generation and electricity demand, a load curve of the total demand on an hourly basis was developed using publicly available data from the UCTE and E-Control [7, 8] and own investigations of FH-ISI and EEG. Besides the total demand load curve, further load curves of flexible appliances were generated. An overview of the appliances that were considered for load shifting in this study is given in Table 1. Around 48 TWh electricity demand were used in cooling compressors in the year 2000. The main appliances were fridges and freezers in the residential sector, cooling and air conditioning systems in the food retail and food industry sector and gas liquefaction plants in the chemical industry. Other appliances which were suitable for demand response like ventilation appliances or washing machines consumed about 45 TWh in year 2000. A third group suitable for demand response were energy intensive processes in the steel, paper und chlorine industry that consumed about 10 TWh.

Table 1: Appliances and energy demand principal suitable for demand response in different sectors in Germany in 2000

Sector	Appliance	Category	
		Storage	Flexible
Residential	refrigeration washing drying dishwashing	16 TWh	 4 TWh 5 TWh 4 TWh
Tertiary	refrigeration ventilation	10 TWh	 7.8 TWh
Public	refrigeration ventilation	2 TWh	 3.6 TWh
Industry	refrigeration ventilation	20 TWh	 20 TWh
Processes	pulp & paper chlorine-alkali steel (EAF)	1.9 TWh	1.3 TWh 3.8 TWh 3.2 TWh

Source: ISI database, [9]

Depending on economic incentives, only part of this electricity demand can be activated for demand response. It is expected that especially the energy-intensive branches will be willing to participate in demand response programmes in order to lower their electricity costs as first experiences in Norway have already indicated [6].

2.2 Simulation of wind power generation

The wind power generation was simulated using wind speed data from around 180 locations in Germany and 15 locations in Austria. The result was a time series for one year with an interval of ten minutes. The calculation adapted measured temperature and atmospheric pressure changes and used a logarithmic height correction to derive wind speeds at average hub heights of the turbines. The model is described in detail in [10]. An overview of the calculation is given in Figure 1. The derived time series were validated with data of measured wind power generation [11].

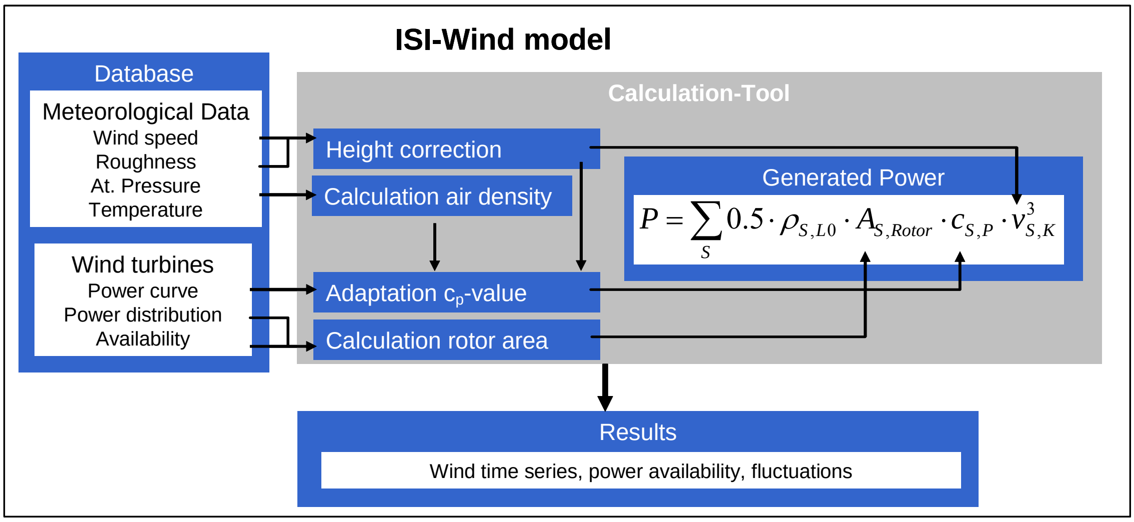

Figure 1: Calculation procedure of the ISI wind model

2.3 Operation of the electricity system (balancing power, load and wind prognosis)

The operation of the electricity system was simulated to derive the impacts of the wind power generation on the remaining power plants. The development of the generation capacities until 2020 is given in the appendix. The conventional power plants were classified by fuel use and short term marginal costs of operation. These costs were used to obtain the operation schedule of the power plants and made it possible to identify which power plant would be substituted by wind power generation.

The amount of balancing power was calculated using the difference between wind power and load prognosis on the one hand and actual wind power production and actual load on the other. The balancing power was then derived from the deviation of the actual values from the prognosis values.

To simulate the wind power prognosis, the persistence prognosis was used which was calibrated by the typical standard deviation and maximum deviation of the prognosis tools used by transmission system operators today. Future improvements of wind power prognosis were simulated by lowering this typical standard deviation of the error. Typical standard deviations of state of the art nationwide prognosis tools for Germany are in the range of 7 % based on total wind power installation [12, 1]. The prognosis horizon is in general 24 hours ahead. Our study used a standard deviation of 6.5 % for Germany and 13 % for Austria in the baseline scenario.

Typical standard deviations of the error of the load forecast on a nationwide level are in the range of 2 % of the peak demand. For the simulation tool, the developed load curve was adapted using a random curve that represented a standard deviation of 2 % with an average value of zero.

2.4 Cost calculation for balancing power

Balancing power can be provided by numerous generation technologies. In our study, hydro storage and pump-storage power plants, conventional power plants in part load and gas turbines were considered to contribute to balancing power. The costs for these technologies were calculated from the short-term marginal costs plus the opportunity costs for not bidding on the spot market. Additional costs due to lower efficiency in part load were also taken into account. The costs for different technologies that supply balancing power are given in Table 2. The opportunity costs plus cost due to efficiency losses provided a coarse estimate of additional costs due to the extended use of balancing power. As can be seen, the best options are pump-storage, combined cycle power plants and gas turbines due to their low opportunity cost. Coal- and lignite-fired power plants have the highest costs for balancing power, because these technologies generate high marginal income and therefore have high opportunity costs.

Table 2: Cost calculation for balancing power

		Pump-storage	**CCGT**	**Coal**	**Lignite**	**Gas-turbine**
Efficiency at full load	%	75	58	47	44	38
SRMC (short-term marginal costs)	€/MWh	30.7	27.2	14.1	9.1	42.6
Emission	tCO_2/MWh(th)	0.279	0.198	0.35	0.374	0.198
Efficiency at 70% part load	%		56.84	46.53	41.8	35.34
Start up factor						1.2
Spot market price	€/MWh	34	32	27	29.1	50
Cost increase due to part load	€/MWh		0.6	0.4	0.7	0
Opportunity costs	€/MWh	3.3	4.8	12.9	20	7.4

2.5 Scenarios for Germany and Austria

To analyse the situation in Germany and Austria, the framework conditions had to be considered. In Germany, the installed wind power capacity is much more evenly distributed than in Austria. Adding the fact that wind power prognosis tools are already widely used in Germany results in a more accurate wind power prognosis here (standard deviation is 6.5 % compared to 13 % in Austria). For the simulation of the balancing power supply, the share of available capacity was given according to installed capacity and typical power plant operation (see Table 3). Wind power capacity was assumed to increase in Germany to 39 GW in 2020 and to 1.4 GW in Austria. Maximum electricity demand load was 92 GW in Germany and 10.5 GW in Austria.

Table 3: Parameters for the baseline scenario

Baseline scenario	Austria	Germany
Wind expansion	Business as usual scenario	
Wind year	average	
Wind prognosis deviation	$\sigma = 13$ %	$\sigma = 6.5$%
Load prognosis deviation	$\sigma = 2$ %	
Share of additional balancing power		
Pump-storage hydro	80	45
Combined cycle gas turbine	10	5
Coal	0	15
Lignite	0	10
Gas turbine	10	25

2.6 Energy system model

The data for the demand and shift potential, the generated time series for wind and demand, the prognosis of the time series and data about the conventional power plants were used as input for the energy system model. This was then used to calculate different scenarios of wind expansion. The flow diagram of the energy system model is given in Figure 2. The first part comprises the calculation of balancing energy and balancing power. The second part is then the cost and CO_2 allocation for additional balancing power and the calculation of the CO2-reduction by substitution of conventional power plants.

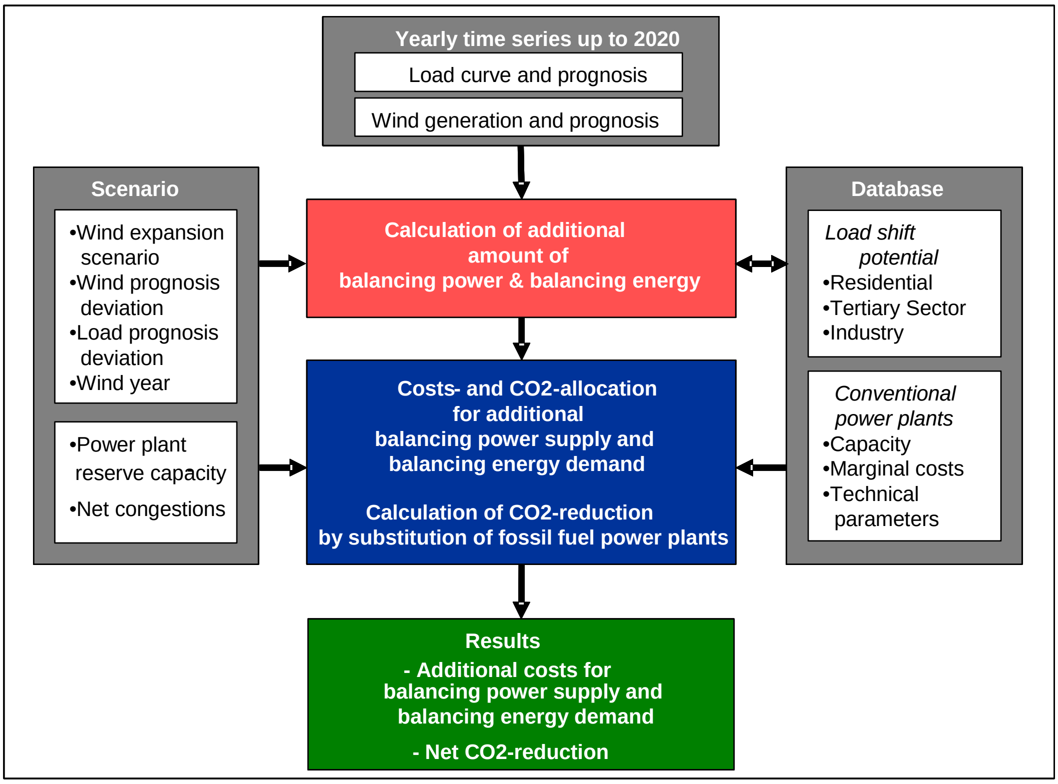

Figure 2: Flow diagram of energy system model

3 Results

The main results comprised the best options for balancing the electricity system. Furthermore the substitution of conventional power plants by wind generation was obtained to calculate the CO_2 benefits that could be achieved by using wind power. Technical potentials for flexible demand were found in all electricity-using sectors. The potentials in industry were the most cost-effective. With low and medium penetration of wind energy, the balancing power had to be increased by less than 50 % of the existing balancing power. This could be handled with the existing system at marginally higher costs of between 1 and 5 €/MWh wind energy. With high penetration, the balancing power would have to be doubled. At this point demand response can become a competitive option.

The comparison of supply- and demand-side options for balancing power showed that flexible demand could play a significant role in balancing the electricity system. It can help to better integrate fluctuating resources like wind power into the Austrian and German systems.

3.1 Demand response potential, best options

The derived results of the demand response potential were given on a theoretical level in the previous section and are disaggregated to the actual appliances in this chapter. The quantification of the technically and economically realisable demand response potential is linked with numerous uncertainties. Much depends on the individual cost-benefit analysis of the electricity consumers. For this reason, the following potentials can only give an overview of appliances that are worth looking at in more detail.

An in-depth analysis was done in the pulp and paper industry, the chlorine industry and the steel industry. The demand response potential for the German pulp & paper industry was found to be around 460 MW (20 % of maximum power demand). A part of this is probably already being contracted by the electricity suppliers. The costs to activate this potential were found to start at 7 Cent/kWh if the load shift was known 24 hours in advance. The demand response could be realised mainly by changed production planning (160 MW). The delay time was expected to be several hours. Shorter times are possible for shifting electricity demand for stock preparation processes (300 MW). The delay time was estimated to be several hours.

In the chlorine industry the electrolysis process was identified to provide demand response up to 900 MW. This power could be provided mainly by the mercury cells process (600 MW) and the membrane cells process (260 MW). Both processes could operate in part load. The delay time was estimated to be between a couple of minutes up to several hours.

In the steel industry the demand response potential was estimated to 400 MW, which could be provided by electric arc furnace. This represented about 50 % of the total power demand for electric arc furnace. The delay time was expected to be a couple of hours. As a typical batch process this potential could be activated on short notice. Costs were found to start at about 10 Cent/kWh.

Further potential in the industry sector was found in the cross cutting technologies of cooling compressors and fans for ventilation. The electricity demand for these appliances was 40 TWh in Germany in the year 2000. Assuming a constant power demand for these appliances, this amounted to 4.5 GW. The demand for cooling compressors is the highest in the food industry followed by the basic chemical industry. The basic chemical industry also has the highest share in the consumption of electricity for ventilation followed by the pulp and paper industry.

In the tertiary sector, demand for cooling amounted to 12 TWh in the year 2000 with almost 6 TWh in the retail sector, mainly food retail. The typical daily power demand ranges between 400 and 1000 MW. The second largest sector with cooling demand was the hotel and restaurant sector.

A huge potential was identified for appliances in the residential sector. The electricity consumption of cooling devices and washing, drying and dishwashing machines lies between 1.8 and 7 GW depending on the time of day. The demand response potential per household was found to be in a range of 50 to 200 W. Additional potentials were found in electrical heating appliances that added up to an electricity demand of over 40 TWh.

3.2 Additional balancing power, additional balancing costs

The simulation showed that the amount of balancing power necessary to operate the electricity system increases with additional wind power. The highest effect was seen in Germany for the year 2020 when penetration reached 39 GW. Our analysis showed that 1,500 MW additional minute reserve power was necessary in 2005 with 17 GW wind power installed. This would increase to more than 6 GW additional minute reserve power in 2020 when 39 GW wind power is assumed to be installed. The figures are shown in Table 4. The additional balancing energy increased from less than 3,404 GWh for the year 2005 to more than 13,310 GWh in 2020. The influence of wind power in the Austrian system was less dominant because the penetration rate here only reached 4 % in 2020 compared to 18.1 % in Germany. Additional balancing costs reached 2.85 € per MWh wind energy in Germany and about 1.29 €/MWh in Austria.

The estimation of additional cost for the changed operation of conventional power plants that were not operated as balancing capacity was found to be between 0.5 € per MWh wind energy and 1 € per MWh. The costs were mainly determined by the amount of substituted lignite and coal power plants which operated with lower load factors. The yearly load factor determined the total efficiencies of the power plants to represent more frequent start ups and part load operation (for details see [13]). The additional costs were then calculated from these efficiency losses and represented mainly higher fuel costs.

The total additional costs for balancing power plants and conventional power plants accumulated then to 3 to 4 € per MWh wind energy in Germany and 1.5 to 2 € per MWh in Austria.

Table 4: Additional balancing power in the Austrian and German electricity systems

		Germany BAU scenario				Austria BAU scenario			
Year	Unit	**2005**	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**
Wind year		average				average			
Wind prognosis deviation	%	6.6%	6.6%	6.9%	7.4%	14.3%	12.8%	12.8%	12.5%
Demand prognosis deviation	%	2%				2%			
Final electricity demand incl. losses	TWh/a	515	533	540	546	57	63	67	71
Wind power capacity	MW	17,000	23,100	29,400	39,000	654	1,162	1,209	1,494
Wind power generation	GWh	29,850	43,915	65,484	98,987	1,226	2,138	2,232	2,760
Wind penetration (MWh-Wind)/(MWh-Load)		5.8%	8.2%	12.1%	18.1%	2.2%	3.4%	3.3%	3.9%
Additional balancing energy	GWh	**3,403**	**5,414**	**8,137**	**13,310**	**189**	**384**	**395**	**513**
Additional balancing power	MW	**1,563**	**2,530**	**3,769**	**6,139**	**90**	**189**	**194**	**255**
Additional minute reserve day-ahead	MW	996	1,530	2,179	3,416	74	145	150	196
Additional yearly costs	1000 €/a	70,903	115,897	173,153	281,858	1,146	2,576	2,635	3,569
Additional costs per MWh wind energy	€/MWh	2.38	2.64	2.64	2.85	0.93	1.20	1.18	1.29
Additional CO_2 emissions	tCO2/a	96,878	157,077	223,166	351,077	142	822	818	1,522
Gross CO_2 reduction	kg/kWh(Wind)	0.862	0.725	0.695	0.669	0.742	0.588	0.570	0.480
CO_2 reduction (cons. part load/start-stop)	kg/kWh(Wind)	0.808	0.698	0.663	0.631	0.693	0.554	0.543	0.461
Total costs	M€/a	**70.90**	**115.90**	**173.15**	**281.86**	**1.15**	**2.58**	**2.63**	**3.57**
Total net CO_2 reduction	MtCO2/a	**24.02**	**30.48**	**43.20**	**62.08**	**0.85**	**1.18**	**1.21**	**1.27**

3.3 Sensitivity of wind prognosis, different capacity for balancing power

The amount of additional minute reserve power and balancing energy was determined by the standard deviation of the wind prognosis error. An improvement of the prognosis accuracy to a standard deviation of 6.5 % for the Austrian system lowered the additional reserve power by almost 66 %. For Germany, an improvement from 6.5 % to 4.5 % reduced the additional minute reserve power by 50 %. The same reductions occurred for the related costs for balancing power.

If cheaper technology options were excluded from the balancing power portfolio, costs increased significantly. If fewer pump storage power plants were able to be used for balancing power, costs increased up to 2.4 €/MWh. In this scenario, pump storage provided only 15 %, but coal and lignite provided 40 % of balancing power. For balancing power in Germany, a shift from pump storage to coal and lignite power plants led to a cost increase of up to 4.0 €/MWh.

3.4 Demand response as regulating power, necessary cost, integration into the system, realisable profits

The first insights into the demand response potentials for the German and Austrian electricity systems showed a number of suitable appliances. The identified available power for demand response in the German industry sector was 6.3 GW. For demand response options, the prices that could be achieved were between 100 and 400 €/MW on the German minute reserve market in 2004 [14]. Part of the identified potential should be competitive at these prices. Taking the pulp and paper industry for example the utilisation of 10 % of the production capacity for demand response could save about 4 % of electricity costs. A communication infrastructure, suitable tariffs and a functioning market are all necessary for the integration of demand side management. Also the other suitable processes should be available for demand response at the given price band.

A technical assessment of available appliances and shift times in the residential sector was done for the Austrian system. The potential was high enough to supply the minute reserve market in 2005. The expected growth of the minute reserve market could still be supplied by the residential sector in daytime in 2020. For the German system for example 60 % of the cooling and ventilation appliances in industry and tertiary sector would be necessary to provide the minute reserve market.

4 Discussion

For the development of balancing power a comparison with the results of [1] showed the additional minute reserve to be in the same range. A main factor for future development is the improvement of wind power prognosis tools that have an important influence on the integration of wind power. Up to a certain amount of wind power penetration (which was found to be between 40 and 50 GW for the German electricity system), balancing can be managed using the existing capacity and structures. The analysis showed furthermore that demand response may be a valuable option competitive with supply side options, especially in the near future when wind power capacity exceeds 25 GW. The technical potential is available.

In general, the additional system costs for wind integration found in this study were at the lower end of the figures published by other international studies [2]. The main costs were the opportunity costs for not selling on the spot market. Not considered were costs due to a different structure of the conventional power plant capacity. This will also play an important role in the future, but was not in the focus of this study.

The best way to integrate demand response into the German and Austrian electricity market is the further development or establishment of balancing pools like the ones established by the German SaarEnergie [15] or the RKOM market in Norway. They already allow customers with flexible demand or supply capacity much lower than 30 MW to participate in the balancing markets. The main barriers to further development are cheap communication infrastructures and market conditions which take into account the hourly and daily changing costs of electricity generation. This should reflect the dependence on actual load and fluctuating generation capacity.

Experiences in the Nordic countries demonstrate the importance of integrating the demand side to cope with fluctuating generation capacities like hydropower plants in Norway or wind generators in Denmark. Coping with increasing balancing capacities seems to be realisable at much lower costs with flexible demand than a system-wide installation of storage technologies or an extension of conventional generation capacity for balancing purpose only.

Acknowledgement

This project was carried out in the framework of the program „Energy Systems of Tomorrow" – an initiative of the Austrian Federal Ministry for Traffic, Innovation and Technology (BMVIT). The program „Energy Systems of Tomorrow" is financed by technology funds of the Austrian Federal Government upon the recommendation of the Council for Research and Technology.

References

[1] Schulz, W. et al. (2005): Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020, Cologne: Energiewirtschaftliches Institut Köln on behalf of Deutsche Energie Agentur (DENA).

[2] Auer, H.; Stadler, M.; Resch, G.; Huber, C.; Schuster, T.; Nielsen, L. H.; Twidell, J.; Swider, D. J. (2004) Pushing A Least Cost Integration Of Green Electricity Into The European Grid (GreenNet) - Cost and Technical Constraints of RES-E Grid Integration, Wien: TU Wien, Energy Economics Group.

[3] Haubrich, H.-J.; Zimmer, C.; Fritz, W.; Schulz, W. (2001) "Analysis of Electricity Network Capacities and Identification of Congestion". Final Report. European Commission; Directorate-General Energy and Transport. IAEW: Institute of Power Systems and Power Economics; CONSENTEC: Consulting für Energiewirtschaft und -technik GmbH.

[4] Junca Vicens, N. (2004): "Wasserstoff als Elektrizitätsspeicher. Ein Vergleich mit Druckluft- und Pumpspeichern", Diploma Thesis, Fraunhofer Institute System and Innovation Research.

[5] Anderson, D.; Leach, M. (2004): Harvesting and redistributing renewable energy: on the role of gas and electricity grids to overcome intermittency through the generation and storage of hydrogen. In: Energy Policy, 32 (14), S. 1603-1614.

[6] Togeby, M. (2005): Newsletter Demand Response in Practice, Ballerup, Oslo: Elkraft System and Nordic Energy Research (Norden)

[7] UCTE: "National electricity consumption and peak load" www.ucte.org visited 21.2.2005

[8] E-Control: "Betriebsstatistik 2003, täglicher Belastungsablauf" www.e-control.at visited 23.12.2005

[9] Fraunhofer Institute Systems and Innovation Research: Demand database developed from several studies.

[10] Sensfuss, F.; Ragwitz, M.; Wietschel, M. (2003) "Fluktuationen der Windenergie und deren Vorhersagbarkeit bei einem verstärkten Ausbau des Offshore Anteils in Deutschland bis 2020", Fraunhofer Institute Systems and Innovation Research, Proceedings IEWT 2003

[11] Durstewitz, M. et. al. (2004) "Wind Energy Report Germany 2004" Kassel: ISET on behalf of Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

[12] Ernst, B. (2003) "Entwicklung eines Windleistungsprognosemodells zur Verbesserung der Kraftwerkseinsatzplanung", ISET, University Kassel, Dissertation

[13] Geiger, B.; Hardi, M.; Brückl, O.; Roth, H.; Tzscheutschler, P. (2004) "CO2 - Vermeidungskosten im Kraftwerksbereich, bei den erneuerbaren Energien sowie bei nachfrageseitigen Energieeffizienzmaßnahmen", Munich: Technical University Munich, ISE Schriftenreihe Issue 47, E&M-Verlag

[14] Wawer, T. "Effiziente Ausgestaltung von Regelenergieauktionen zur Verringerung der Netznutzungsentgelte", Westfälische-Wilhelms-Universität Münster, Proceedings IEWT 2005 – Energiesysteme der Zukunft: Herausforderungen und Lösungspfade

[15] Strese, J. (2003): Pool für dezentrale Regelenergie. In: Energie & Management (E&M), Page 12.

[16] Mantzos L., Capros P., Kouvaritakis N., Zeka-Paschou M., Chesshire J., Guilmot J.F.: „European Energy and Transport Trends to 2030“, Publication by National Technical University of Athens (NTUA) for the Directorate-General for Energy and Transport (DG TREN), Belgium, January 2003.

Appendix

Table 5: Development of generation capacities in the German and Austrian electricity system [16]

	Power Plant Capacities in MW				
Austria	**2000**	**2005**	**2010**	**2015**	**2020**
Hydro, run of river	3,793	3,793	3,793	3,793	3,793
Coal	769	769	769	1,300	1,300
Lignite	256	256	256	256	256
CCGT	427	427	1,000	1,500	2,000
Gas turbine	346	346	700	1,000	1,300
Hydro, storage	4,096	4,096	4,096	4,096	4,096
Germany	**2000**	**2005**	**2010**	**2015**	**2020**
Hydro, run of river	2,603	2,603	2,603	2,603	2,603
Nuclear	19,679	19,679	15,175	12,289	9,868
Lignite	18,070	18,070	17,124	20,359	21,690
Coal	24,007	24,007	27,991	24,736	23,155
CCGT	9,561	9,561	11,107	9,822	9,822
Gas turbine	7,997	7,997	11,900	13,800	17,800