Description of integrated pilots/demonstrations/field tests/existing practices

1. Name of the case

   Integration of wind energy by load management

2. What is integrated with DSM

DG	x
Energy storage	
Smart grid technologies	x

3. What is the level of commercialization

Research project	x
Demonstration	
Field test	
Existing practice	

4. Where to find more information?

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   - Company

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   - web-site

     http://info.tuwien.ac.at/iew

   - references

     http://www.energiesystemederzukunft.at/results.html/id4480

Description of integrated pilots/demonstrations/field tests/existing practices

5. Objectives of the case

   As the amount of wind generation in an electricity network increases, the impacts on power system operation become evident and lead to extra costs and reductions of CO2-emissions. Based on the existing literature it is not clear, to which extent these effects are influenced by the configuration of the power system and whether measures on the demand side allow more efficient integration of this renewable energy source. Answering these questions may help to compare wind power with other conventional as well as renewable energy technologies in a consistent manner and allows to evaluate approaches for an optimised integration of wind energy in power systems with different characteristics.

6. Business rationale/model

7. Technologies used

   Several effects of wind power production on power system operation are analysed for predominantly thermal (Germany) and a hydro-thermal system (Austria) and corresponding costs and CO2-reductions are allocated. Furthermore potentials for demand response are determined for different consumption sectors and technical as well as economical aspects of using power demands to provide reserves are investigated. Extra costs and net-CO2- reductions related to wind power are determined by running simulations with a power system model developed within this project. Basic data for the simulation include hourly time series of wind power and demand as well as capacities, technical and economic parameters of the conventional power plants until 2020.

8. Short description of the case

   Simulation of optimal strategies to integrate wind energy in Austria and Germany, under consideration of load management, to maximize the resulting CO2-savings.

   Wind power production replaces production from fossil fuel fired power plants and therefore reduces CO_2-emissions in the range of 0.75 tCO_2/MWh(wind) for 2005 in Austria. This specific reduction declines by about 20–30 % until the year 2020. In Germany the corresponding numbers are higher due to the higher share of coal units in the system. Additional wind related emissions reduce the CO_2-reduction effect by 8 % for highest wind penetration levels in Germany. Extra costs occur due to impacts on the operation of conventional power plants and because of additional requirements for minute reserve and balancing power. The latter effect is dominant for the current wind penetration and becomes increasingly relevant with a rising share of wind power in the system. According to the baseline-scenario specific total system operation costs rise up to 1.8 €/MWh(wind) for Austria und 3.5 €/MWh(wind) for Germany in 2020. Better wind power forecasts can lower these costs by up to 30 % in a medium term perspective. If the flexibility of the power system decreases due to congestions, balancing costs may rise by 15 % in the worst case.

Description of integrated pilots/demonstrations/field tests/existing practices

Activating demand response is an adequate measure to react on the limited contribution from wind power to system security especially when conventional capacities decline. Potentials on the demand side are available to a considerable extent in different consumption sectors and can be activated anytime which is not the case for building new power capacity. For balancing groups with an increasing share of wind power production flexible loads can be used as an option to limit costs for balancing power.

For the short to medium term better wind prediction is the key aspect for integrating wind power more efficiently. Flexible loads can rise the value of wind power especially when system capacity reaches critical limits. Current approaches for allocating wind related grid extension und connection costs in Austria and Germany do not consider the fundamental unbundling principle. Therefore in Austria a discrimination-free access to the grid cannot be guaranteed. An efficient use of the offshore potential in Germany is only possible if the extension of the coastal grid is coordinated and financed by the grid operator.

9. Achieved/expected results (operational savings, CO_2, efficiency enhancement)

According to the BAU-scenario wind capacity continuously increases in Austria and Germany until 2020 (see table below). The annual wind power production rises up to 2760 GWh in Austria which is equal to 3.9 % of the annual total consumption. In Germany the annual production from wind power increases up to around 100,000 GWh for the year 2020 or 18.1 % respectively.

Baseline-scenario		**2000**	**2005**	**2010**	**2015**	**2020**
AT	Wind capacity in MW	77	654	1.162	1.209	1.494
	Wind power production in GWh/yr	129	1.226	2.138	2.232	2.760
	Full load hours in h/yr	1.675	1.875	1.840	1.846	1.847
DE	Wind capacity in MW	6.039	17.000	23.100	29.400	39.000
	Wind power production in GWh/yr	10.668	29.850	43.915	65.484	98.987
	Full load hours in h/yr	1.767	1.756	1.901	2.227	2.538

Table 1: Assumptions on the development of wind capacity and wind power production for Austria and Germany until 2020

The main objective for promoting energy from renewable sources is to reduce CO_2-emissions. Wind power is replacing production from power plants that operate with fossil fuels, which leads to lower overall emissions of the energy system. The amount of the corresponding reduction is influenced by the wind power production as well as the shares of the production of different technologies that are replaced.

According to the baseline-scenario specific CO_2-reductions of wind power in Austria decline from 0.75 tCO_2/MWh(wind) in 2005 to 0.48 tCO_2/MWh(wind) in 2020. Because of

the higher share of replaced production from coal plants the corresponding numbers for Germany are around 15 % higher. The results show, that the specific reduction of CO_2-emissions declines with higher wind penetrations, because production from power plants with lower emissions is gradually replaced.
Wind power is an intermittent energy source that can be predicted to a limited extent. Current standard deviations of the wind power forecast errors in Austria are around 13.5 % and in Germany around 6.5 % of installed wind capacity. In Germany the fluctuations of wind power production are lower due to higher spatial distribution and better wind forecast tools. The uncertainty of wind power leads to additional requirements for minute reserves and to higher amounts of balancing power.

Costs allocated to additional reserve requirements and balancing power (balancing costs) occur in form of opportunity costs und due to lower efficiencies of thermal power plants when operating part loaded. Specific balancing costs increase with higher wind penetration levels.In the baseline-scenario specific balancing costs rise up to 1.8 €/MWh(wind) in Austria and 3.5 €/MWh(wind) in Germany for the year 2020. The most important parameters that are influencing these costs are the quality of wind power forecasts and the configuration of the power system. Lower forecast errors may lead to a decrease of costs in the range of 30 % until 2020. Because of increasing congestions on the network that lead to a lower availability of flexible production costs may rise up to 15%

Annual extra costs and CO_2-reductions related to wind power are summarised in the following tables. Please note, that there are effects on the operation of the existing power plants considered too.

	Baseline-scenario	**2000**	**2005**	**2010**	**2015**	**2020**
AT	Reserves and balancing power cost in Mio.€/yr	0,0	1,2	2,6	2,6	3,6
	Power plant operation cost in Mio.€/yr	0,1	0,6	1,1	1,1	1,4
	Total system operation cost in Mio€/yr	0,1	1,8	3,7	3,8	5,0
DE	Reserves and balancing power cost in Mio.€/yr	11,2	70,9	115,9	173,2	281,9
	Power plant operation cost in Mio.€/yr	5,3	14,9	22,0	32,7	49,5
	Total system operation cost in Mio€/yr	16,5	85,8	137,9	205,9	331,4

Table 2: Development of additional annual system operation costs related to wind power in Austria and Germany until the 2020 according to the baseline-scenario

	Baseline-scenario	2000	2005	2010	2015	2020
AT	CO2-reduction in MtCO2/yr	0,10	0,91	1,26	1,27	1,32
	CO2-reduction incl. Power Plant operation	0,10	0,86	1,19	1,21	1,28
	CO2-reduction incl. PP operation & reserves	0,10	0,86	1,19	1,21	1,27
DE	CO2-reduction in MtCO2/yr	9,35	25,73	31,84	45,51	66,22
	CO2-reduction incl. Power Plant operation	8,78	23,73	29,99	42,50	61,37
	CO2-reduction incl. PP operation & reserves	8,77	23,61	29,82	42,30	61,07

Table 3: Development of annual CO2-reductions related to wind power w/o consideration of additional system related emissions for Austria and Germany until 2020

The results show that costs for additional balancing costs are dominant for the current wind penetration level and becoming even more relevant with higher penetration. Wind related CO2-reductions are mainly determined by the replacement of fossil fuel production and effects on system operation lower this potential in the range from 4 % (Austria) to 8 % (Germany) in the year 2020.

Fairly new approach to encourage the integration of wind power is to use demand response to balance intermittent production. The main motivation for this approach is not to reduce CO2-emissions, but to provide system security and financial benefits for utilities.

Appliances have to show specific characteristics to be suitable for providing power reserves.

Table 4 gives an overview of the most important responsive appliances and their classification.

Sector	Appliance	Categorie		
		Storage	Flexible	Discetionary
Housholds	Cooling/Freezing	X		
	Washing		X	
	Drying		X	
	Dish washing		X	
	Lightning			X
Commercial sector	Cooling	X		
	Ventilation		X	
Public sector	Cooling	X		
	Ventilation		X	
Industry	Cooling	X		
	Ventilation		X	

Table 4: Overview of responsive loads in different sectors

Potentials for demand response are primarily determined by the aggregated consumption of flexible appliances and are therefore depending on daytime and season. The technical potential is furthermore reduced by the aggregated availability that is in the range of 80 %. Technical constraints (like e.g. temperature limits of cooling appliances) limit the potential of demand response as the duration of the activation increases. The comparison of technical potentials of flexible loads in households with current and future requirements for minute reserves in Austria show that the consumption is able contribute to system balancing to a high extent (see Figure 0.2).

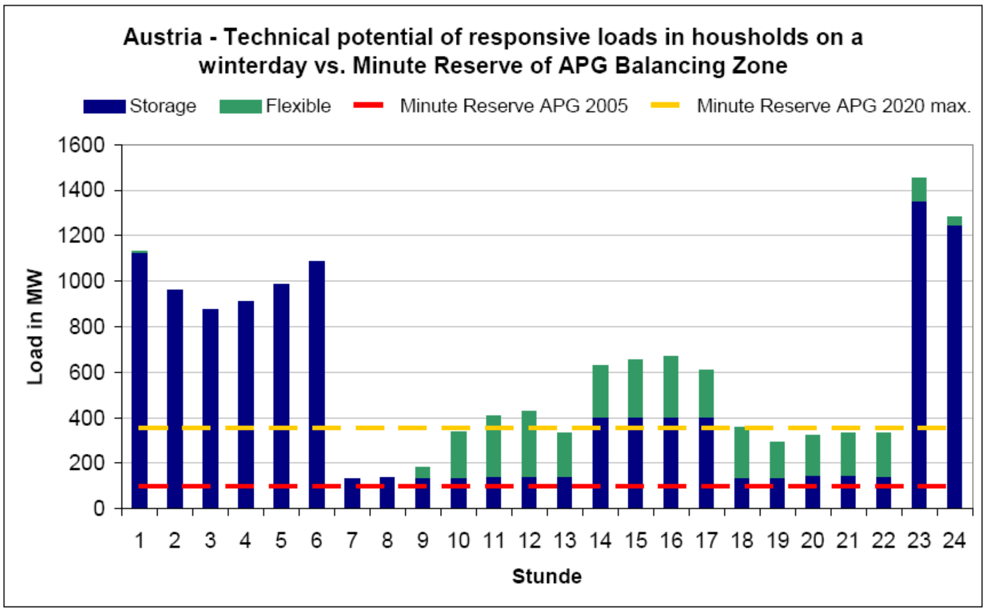

Figure 1: Comparison of the technical potential of responsive loads in households on a winterday with current and future requirements for minute reserve of the APG Balancing Zone. Assumptions: Wind power development according to BEST-scenario, wind forecast error = 13.5% (RMSPE)

10. Lessons learnt

Based on the existing empirical data it is not possible to determine the realisable potential of reserves from consumption. Future trends that provide incentives for the activation of demand response are decreasing conventional power capacities and increasing shares of wind power in the system.

The Norwegian case shows that power reserves from demand response can provide system security especially during peak load events even better than power plants can do. Using loads as power reserves may therefore be an adequate measure to react on the varying contribution of wind power to the system security. In contrast to the installation of new power plants, flexible loads are already available.

The work conducted has shown that on the short to medium term better wind power forecasts may ensure a more effective integration of wind power. The comparison of the Austrian and German system shows that the shares of different power technologies are considerably influencing additional wind related system costs. If the system becomes less flexible because of congestions or a decreasing share of flexible units, wind related costs are rising slightly. Activating demand response is an adequate measure to react on the limited contribution from wind power to system security especially when conventional capacities decline. For balancing groups with an increasing share of wind power, demand response may be an option to limit costs for balancing services in the future. The current allocation of grid related costs to wind power operators is not considering the fundamental principle of unbundling. This leads to discrimination concerning the access to the existing grid in Austria. In Germany the allocation from grid connection costs to wind power producer is the major barrier for the coordinated extension of the existing coastal grid, which is of importance for the future wind power development offshore.

Additional research is needed to identify how current market designs have to be adapted to react on the increasing share of intermittent production from wind power in Europe. One further interesting question is whether integrating demand response to optimise production and consumption can raise dividends for utilities under current conditions.