Increased Electricity Demand Flexibility Enabled by Smart Grid: Impacts on Prices, Security of Supply and Revenues in Northern Europe

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Background

The challenges related to regulation and balancing of energy systems with a high share of renewable intermittent power are well known (e.g. Georgilakis (2008), Franco and Salza (2011), Perez-Arriaga and Batlle (2012)). Increased flexibility on the demand side, in the form of moving electricity consumption from peak to off-peak periods, is seen as one of the options for handling varying power generation from RE sources in future energy systems with high RE shares. Currently, however, this type of short-term flexibility on the demand side, i.e. a consumption pattern with less difference between off-peak and peak periods and that may adjust on an hourly basis to variations in supply, is limited. There are two main reasons for the current lack of demand flexibility: First, most consumers are not exposed to real-time pricing (RTP), implying that they have no incentives to move consumption to periods with low prices. Second, technical solutions for automatic adjustment of consumption are today limited, meaning that flexible - or smart - energy usage requires user's action. Notwithstanding, there are reasons to expect that these obstacles may become less important in the future, due to technical development and restructuring of electricity markets. In this regard, it is of interest to analyze how a development towards more active use of demand side management will affect the power system in terms of need for peak power capacity, technology mix in electricity production, electricity prices and system costs.

Scenarios Analysed

In the current study, we apply country-specific estimates from IEA on potential short term (within day) demand flexibility that are used to define four scenarios regarding future demand flexibility in the North European power market (the Nordic countries, Germany, the Netherlands and the UK). The electricity market impacts of the different demand flexibility levels are then analyzed applying an power market model that has an hourly time resolution, a fine spatial resolution. The power market model applied is based on the Balmorel model structure which is a convex and linear partial equilibrium model simulating generation, transmission and consumption of electricity under the assumption of competitive markets (see e.g. Ravn (2001), Ravn, Hindsberger et al. (2001)). The current model version covers the Nordic countries, Germany, the Netherlands and the UK and is calibrated with updated 2012 power system data for all model countries. The model, which is deterministic in a one year (or one week in the short-term mode) time frame, calculates the electricity production per technology, time unit and region, minimizing total system costs for a given electricity demand and under certain capacity constraints regarding production and transmission.

Three different demand response scenarios are developed and compared to a Baseline scenario where today's level of demand flexibility is assumed: i) a Moderate demand response scenario, where a 50 % realization of the maximum potential found in the IEA publications is assumed, ii) a Full demand response scenario where the maximum potential found in the literature is assumed implemented, and iii) a High demand response scenario, where we assume that strong policy measures combined with a technological development such that the demand response potential is doubled relative to the Full flexibility scenario.

Findings

Results from model simuilation are shown in Table 1 and Figure 1.Table 1 shows average annual production levels for different technologies in the different scenarios while Figure 1 shows the average changes in production mix in the full flexibility scenario relative to the base scenario, at an hourly level.

The model simulation results show that the need for peak power technologies (natural gas, reservoir hydropower and pumped storage) and balancing reserves decreases substantially when demand flexibility increases. At the same time, revenues of all the intermittent renewable energy sources (wind, run-of river and solar power) are found to increase, indicating opportunities for improved utilization of the renewable energy resources if systems for increased short term demand side management are introduced. Coal power

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	Baseline scenario (total production in TWh)	Demand flexibility scenarios (change in GWh)		
		Moderate	Full	High
CHP, biomass and nuclear	417	-3	-40	-121
Natural gas	41	-1996	-3775	-6941
Solids	402	+1328	+2533	+4747
Reservoir hydro and pumped storage	146	-613	-1162	-2079
Run-off river hydro	104	+44	+67	+97
Wind	252	+217	+501	+995
Solar	56	+85	+101	+131

Table 1. Average production levels in the Baseline scenario (GW), and change in production for the different demand response scenarios, all model countries summarized.

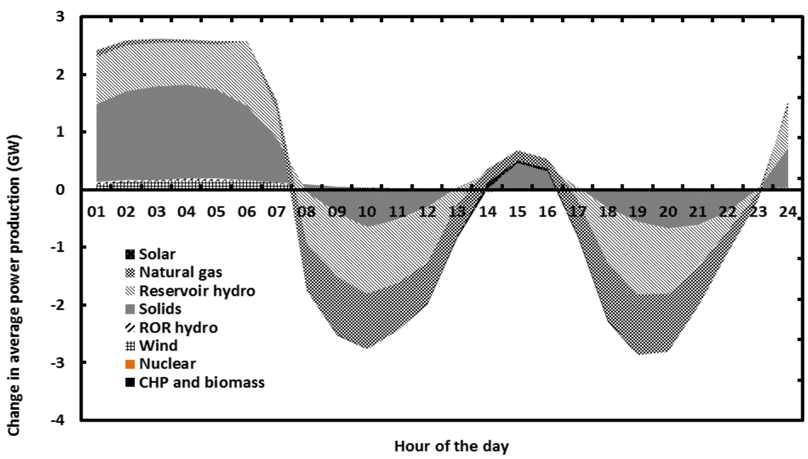

Figure 1. Change in the hourly North European production mix (GWh/h) caused by the increase in demand response, "full" flexibility scenario (all model countries, all-year average)

revenues are found to decrease with increasing demand flexibility, but total coal power production is found to increase significantly. As a consequnece, increased short term demand flexibility caused an increase in greenhouse gas emissions from electricity production . In this study area, increased demand flexibility will in general cause higher night consumption and lower day consumption in the northern, hydro dominated parts. This shift will, in general, also take place in the southern parts (Denmark, Germany, the Netherlands) in the winter season, but variations in wind power generation do to some degree alter the night versus day pattern. In summer months, there is, in the southern parts, a tendency of increasing consumption during day hours in the high flexibility scenarios, due to high levels of solar PV generation. Prices in off-peak hours will as expected increase for increasing short term demand flexibility, while the price in peak hours decrease. The change in average prices is found to be limited, but the change in the daily price profiles is found to be considerable, with a 11-18% reduction in price variation, and the consumption weighted price decreases with increasing demand flexibility.

The North European energy system is in rapid change, with increasing levels of intermittent energy sources entering the market. Increased demand flexibility is likely to play a vital role for realizing system balancing and increased security of supply in energy systems with large shares of intermittent renewable energy. Our results show rather clearly that the system benefits, in terms of reduced residual demand levels, reduced need for peak capacity and increased security of supply, are larger than the economic benefits for the consumers. Therefore, policies stimulating to increased flexibility on the consumer side are likely needed to fully utilize the potential system benefits from increased demand flexibility.

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