An economic assessment of flexible electricity-to-thermal strategies to enable high shares of variable renewable electricity

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Overview

To reach ambitious energy and climate targets the shares of variable renewable energy sources (VRE) is rapidly increasing in international electricity markets. By nature, the temporal supply of VRE is highly variable because it is determined by weather conditions, it is uncertain due to forecasting errors, and it is location specific as the primary energy carrier cannot be transported like coal or biomass [1]. With such characteristics the increased supply of VRE will affect power markets in multiple ways. The average electricity prices reduce since the short term marginal costs of VRE are very low, and the short term price variation increase due to the high short term variation of VRE supply. Due to the merit order effect, hourly spot prices will decline when VRE supply is high [2]. Hirth has shown in [3] that when the share of wind or solar power gets high, the market value (defined as spot market revenues per unit) of these sources drops to levels significantly below the average electricity spot market price, i.e the value factor of VRE drops below 1. Fraunhofer ISE also reports this: for the first 6 months of 2015 the wind power market value was 25.6 €/MWh, compared to an average price of 29.8 €/MWh giving a relative market value of 86 %. For VRE investors and policy makers, the drop in market value and value factor can become a barrier for further deployment as the VRE market shares increase. In addition to the declining market value, affecting VRE competitiveness, there are also challenges realted to security of energy supply in high VRE systems.

As a response to the above mentioned challenges, energy planners are looking for means of increased energy system flexibility that can increase the use of electricity in periods of high VRE supply (and hence low electricity prices) and decrease it when supply is low. Using electricity to produce heat (E2T) in district heating (DH) plants is seen as a promising solution for increased flexibility because the technology is mature and it may also reduce greenhouse gas (GHG) emissions in the heating sector. The flexibility occurs when heat pumps or electric boilers replace other boilers in hours when the VRE supply is high and the electricity prices hence are low, leading to a higher demand in these hours and hence increased VRE market values. At the same time, in periods of low VRE supply, electricity demand is being unchanged since other fuels have lower costs in DH plants under such market conditions. Policies designed to increase deployment of E2T technologies may reduce the need to subsidize VRE and at the same time maintain energy supply security.

In the present study we apply a quantitive model to investigate the impacts on the energy system in general and VRE producers in specific of increased use of flexible electricity in the district heating sector. The Nordic power and heat market is used as an example.

Methods

To analyse the market value impacts of E2T we apply a Nordic power and heat sector model, Balmorel (REFS), with a fine temporal and spatial resolution. The model solution provides market-clearing generation, transmission and prices for each geographical unit and time step, under the assumption of competitive markets. The current model version is updated with 2012 data, and covers the Nordic countries, Germany, the Netherlands and the UK, providing a specifically detailed representation of the hydro dominated Nordic countries, while the rest of the model countries are modeled with one region each. Other interconnected Northern European energy markets are handled as third countries with exogenously given power exchange. The model is applied to simulate the market under different scenarios for installed capacity of electric boilers and heat pumps, and the resulting average power prices and producers' prices of VRE are applied to calculate the market values of VRE under different E2T strategies.

Results

The model simulations confirm that the market value as well as the value factor of wind and run-of-river power plants increase substantially with increasing E2T in DH. Under normal weather conditions, increased E2T can increase the market values for wind and run-of-river power generation by 15-20% if the potential flexible electricity use in the Nordic district heating sector is utilized (fig 1).

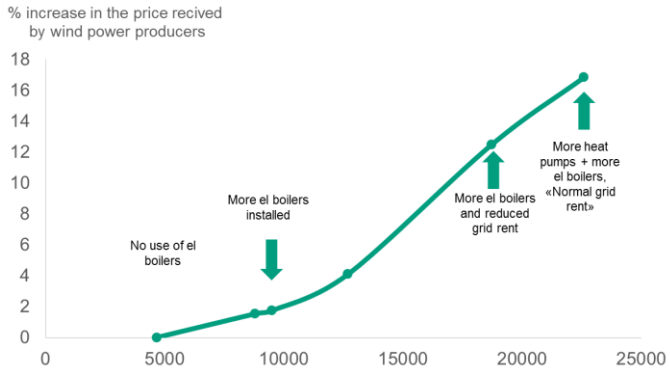

Figure 1. Increase in electricity price recived by wind power generators for different levels of electricity use in the District heating sector.

In a wet year, which causes a significant generation surplus in the Nordic region and hence lower prices, the relative increase in market value is substantially larger. It is also shown that this type of E2T leads to lower GHG emissions in the Nordic region, and that electicity is used to a very limited extent in district heating in periods of high prices.

Conclusions

This study confirms that an E2T strategy can add substantial flexibility to power systems . The E2T strategy reduce the VRE intergration challenges and costs and imply less need for financial support to reach a certain VRE target, without reducing the energy security in the power system. E2T solutions provide more flexibility to the energy system when the electricity grid tariffs are realtivly low, the biomess price is realtivly high and/or the carbon price is low. In line with [4], the results indicate that E2T solutions has a promising benefit-to-cost ratio compared to other flexibility alternatives, but further analyses are needed to be conclusive on this.

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