ANALYSIS OF SEVERAL FLEXIBILITY OPTIONS TO IMPROVE WIND POWER INTEGRATION

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Overview

Variable renewable electricity (VRE) such as wind power plays an important role in future energy scenarios. This will increase the mismatch between power supply and demand, imposing major challenges both for energy systems and markets. To efficiently integrate wind power into energy systems in large scale, effective flexibility measures are needed. In this study, we analyse a large variety of flexibility options for wind power integration. We use Finland as the case study with a Nordic coupling. The main flexibility options considered are sector-coupling such as power-to-heat and power-to-gas, energy storage in the form of thermal and electric storage, and electric vehicles. As the reference case we use Finland's energy strategy for year 2030, which heavily relies on forest biomass and nuclear power as low-carbon energy sources with less focus on VRE. We investigate here to what extent different flexibility measures could cost-effectively be used to integrate wind power in large scale. We employed a national energy system model with hourly resolution incorporating all sectors of an energy system, in order to accurately model the couplings between sectors. In addition to the flexibility options, we considered the possible lock-in effect of combined heat and power (CHP), important for Nordic countries with a cold climate.

Methods

We employed an hourly-level national energy system model, including electricity, heat and fuel sectors and a variety of options for sector coupling. The optimization aimed to minimize the total annual cost of the energy system, while considering the national carbon emission reduction targets. Key input data was based on international and national sources.

Results

Various cases regarding the Finnish energy system and flexibility options were simulated. The results are presented in Fig. 1. Overall, wind production could be increased up to one third of total electricity production, while decreasing annual system costs (up to 10%) and carbon emissions (up to 28%) at the same time. The amount of wind power was mainly limited by the cross-border transmission capacity and the high amount of nuclear baseload. From the different flexibility options, power-to-heat and wind curtailment produced the most cost-effective cases with the lowest CO_2 emissions, whereas power-to-gas and stationary electricity storage were the least favoured flexibility measures. In addition, the cases showed a distinct preference of separate heat and power production over the currently preferred CHP. The amount of wind power could be increased even higher, up to 70% of electricity production, but this would result in 60% higher costs.

Conclusions

The results suggest that wind power could be cost-effectively integrated into the Finnish energy system in 2030, and power-to-heat and wind curtailment would be the most beneficial flexibility options, decreasing annual system costs by 10% and CO_2 emissions by 28% at most. Furthermore, it would seem that combined heat and power might limit the cost-effective wind power integration, as separate heat production and heat pumps are preferred to CHP in the cost-minimizing scenarios. Most of all, the results indicate that viewing the energy system as a whole rather than separately provides valuable insight for wind power integration, and wind power integration with sector coupling could even be done cost-effectively, based on the 10% decrease in annual cost.

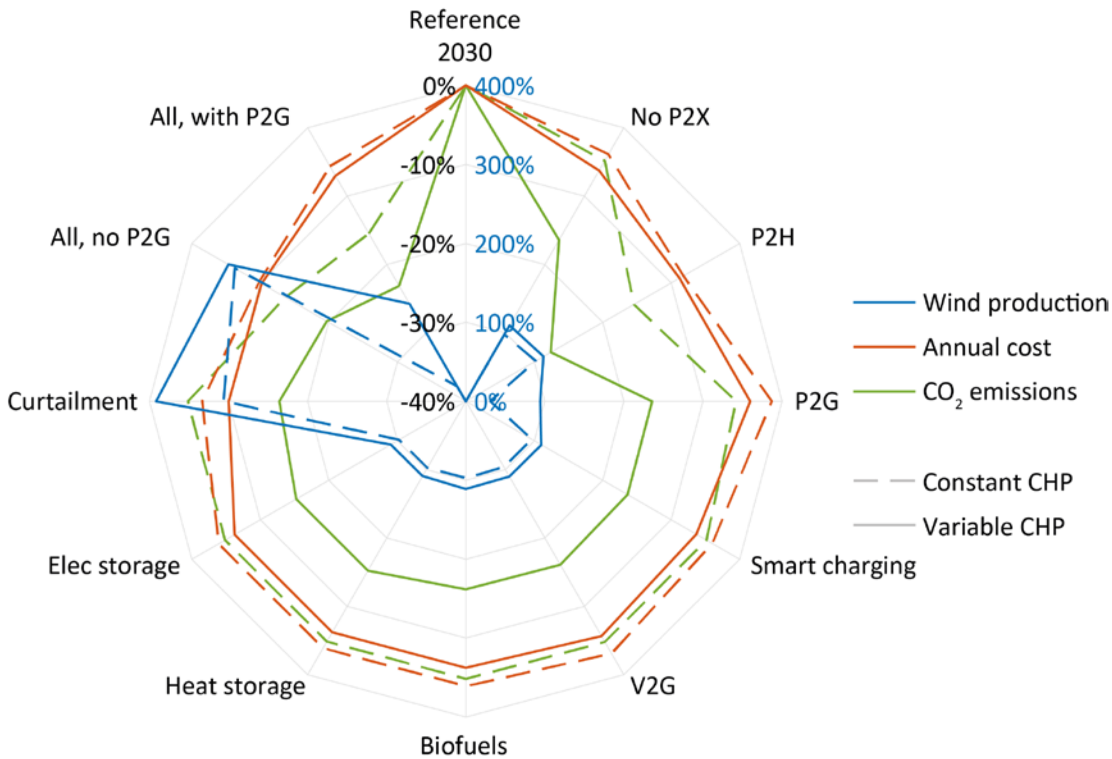

Fig. 1. Effect of the different flexibility measures, presented as change from the reference case. Note the separate scale for wind power (blue). The solid lines represent cases where the amount of CHP remained the same as reference, opposed by the dashed lines with variable amount of CHP. Power-to-heat (P2H) and curtailment are the most effective, though the cost differences are quite small, max. 10% from the reference case.