THE FLEXIBLE USE OF BIOMASS IN THE ELECTRICTY MARKET – A CASE STUDY OF GERMANY

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Overview

The increasing use of renewable energy technologies in the European power sector leads to an energy system, which is mainly dependent on wind and solar energy. This is the case in countries like Germany that has ambitious goals for the energy sector. Biomass is a dispatchable and cross-sectoral applicable renewable energy source and has thus an exceptional position. Within this paper results of a multistage multiperiod linear mixed-integer modelling for the use of regional biomass potentials in the electricity market and in cross-sectoral markets (CHP) is presented. The investment in biomass power plants and thermal power plants with co-firing option for electricity generation and local heat supply (CHP) is optimised endogenously under future framework conditions of the electricity market. Regional potentials of energy crops, wood, waste wood and manure can be upgraded to secondary energy carriers, such as biogas, SNG or woodchips. The use of such energy carriers is subjected to specific regional and intertemporal restrictions, biological and technical flexibility options and is limited by a global upper bound potential. In addition to the model description, a multistage multiperiod method is presented to determine the optimal utilisation pathways of the investigated biomass resources, investment in generation units and the unit commitment considering the impact of local heat supply on the electricity generation with an acceptable calculation time. The analysis focuses on a complementary commitment of biomass units to balance fluctuations of the residual load caused by a volatile feed-in through wind and solar power plants. The results show an increasing need of flexible biomass units with a growing share of wind and solar power plants and additionally further flexibility options such as demand side integration, curtailment, storages and other flexible thermal units using Germany as an example.

Method

The model used for the analysis is based on the stochastic European Electricity Market Model E2M2s, developed and used at the Institute for Energy Economics and the Rational Use of Energy IER, University of Stuttgart. The simultaneous optimisation of power plant investment, technical constraints of thermal plants and the operation of pumped storages are described in [1] and [2]. Fossil Fuels like coal or natural gas are almost unboundedly available whereas biomass is bounded by regional potentials. The focus of the model is to analyse the integration of wind and solar power and complementary flexibility options into the electricity market. For the first time a sharper focus is bent on the flexible use of biomass considering various technical and biological options. The maximum available biomass potential used for power generation in E2M2s is indicated by a predetermined upper bound. A minimum use of biomass, for example caused by ambitions of a state-directed economy, can be adjusted by a lower bound. The optimal share of used biomass is endogenously calculated within the given boundaries. Secondary energy carriers, such as biogas, SNG or woodchips are characterized by economic, ecologic and technical parameters. Each energy carrier is linked with specific investment options for power generating technologies like CHP units. Biomass power plants are divided in biogas plants and wood-fired power plants each with representative size ranges. The dimension and commitment of the biomass units is optimized. The commitment of biogas plants is dependent on the biogas production rate and the biogas storage management. The biogas production rate can be affected by flexible feeding strategies and a specific combination of substrates, therefore influences the required volume of the biogas storage [3]. The variable biogas production rate in the model is indicated by biological parameters and intertemporal restrictions. The biogas storage is indicated as an investment option with variable volume. Biomethane can be transported by the natural gas grid and used irrespective of the regional production and without limitations of a biogas storage [4]. The model also allows the co-firing of upgraded biogas in natural gas power plants like gas turbines or combined-cycle power plants. Focus of the presented analysis is the development of the installed electric capacity and the unit commitment of biomass plants in scenarios with high shares of wind and solar power generation and the allowance of competitive technologies providing flexibility in the electricity market such as demand side integration, curtailment, storages and other flexible thermal units. Assumptions and modelling of demand side integration are based on [5]. Local heat supply, management of biogas and heat storages and partial load operation of thermal units require a precise mixed integer model, that leads to long computing times. A multiperiod method is presented to reduce the computing time without losing the quality of the results. In a first step the aggregated investment of power generation units [2], storages and the import-export saldo are calculated with linear programming. The invested units are fixed in the second step and the unit commitment of biogas plants is calculated with a local heat demand with linear programming to determine the seasonal biogas production rate, the fill level of long-term storages and the investment of heat storages and heat generation technologies. The model is restructured in a multi-period model with sub problems and intermediate time steps, also described in [6]. The second step is formulated as mixed-integer linear program to consider technical constraints like start-up time, minimum operation and shutdown time of thermal power plants and the fuel efficiency change with load variation [1].

Results

In the presented case study of Germany two scenarios with a renewable share of 60 and 80 percent in gross electricity consumption at each case are analysed. A constant amount of biomass used in the future German electricity sector is assumed. The annual electricity production of biomass power plants in each scenario amounts to approx. 50 TWh_{el}. The flexible use of biomass in Germany reduces the installed electric capacity of conventional natural gas power plants up to 25 % referred to a base load operation mode of biomass power plants. High shares of about 80 % of wind and solar power generation lead to an expansion of the installed electric capacity of biomass power plants up to 15 GW and a reduction of the annual full-load hours. The variable biogas production reduces the demand of biogas storages significantly. Considering a local heat supply of biogas CHP-units a seasonal adaption of the raw biogas production is observed. Co-firing of biomethane enhances the average utilization of natural gas power plants.

Conclusions

Integrating high shares of renewable energy technologies in the electricity sector requires new modelling methods to analyse and evaluate the complex interdependencies among the system components and the market. The presented study provides a new modelling method to analyse the optimal use of biomass in the electricity sector. The method can be used for the formulation and implementation of energy and climate policy objectives or scientific research in the field of energy system analysis. The method enables the forecast of the future commitment of biomass power plants and the identification future technical and biological requirements.

References

[1] Sun, N.; Ellersdorfer, I.; Swider, D. J.; Model-Based Long-Therm Electricity Generation System Planning under Uncertainty. In: Thrid International Conference on Electricity Utility Deregulation, Restructuring and Power Technologies, DRPT 2008. 6-9 April 2008, Nanjing, China.

[2] Sun, N.; Model-Based Investigation of the Electricity Market: Unit Commitment and Power Plant Investments. University of Stuttgart, Institute for Energy Economics and the Rational Use of Energy. 2013, Stuttgart.

[3] Mauky, E.; Jacobi, H. F.; Liebetrau, J., Nelles, M.: Flexible biogas production for demand-driven energy supply – Feeding strategies and types of substrates. In: Bioresource Technology 178 (2015), Site 262-269. 2014, Leipzig/Rostock.

[4] Bauer, F.; Persson, T.; Hulteberg, C.; Tamm, D.: Biogas upgrading – technology overview, comparison and perspectives for the future. In: Biofuels Bioproducts and Biorefining 7 (2013), Site 499-511. 2013, Lund/Malmö/Göteborg.

[5] Steurer, M.; Haasz, T.; Fahl, U.; Voß, A.: Analysing Demand Side Management in Energy System Models. In: 14th IAEE European Energy Conference – Sustainable Energy Policy and Strategies for Europe, Conference Paper. October 28-31, 2014, Rome.

[6] Williams, H.P.: Model Building in Mathematical Programming, Fifth Edition. London School of Economics, UK. John Wiley & Sons Ltd.. 2013, London.