The impacts of climate change on Swiss hydropower

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Overview

Climate change has broad consequences for the electricity system both on the demand and supply side (Mideksa & Kallbekken, 2010; Chandramowli & Felder, 2015). On the one hand, consequences affecting electricity production and consumptions stem from gradual, irreversible changes in temperature and precipitation patterns. On the other hand, these consequences are due to more frequent occurance of extreme events. In this paper, our focus is on the impact of climate change on hydropower in Switzerland. Unlike former studies which focus on the quantity effect of changes to total hydropower production potential (e.g., SGHL, 2011), we embed future hydrologic inflows into an hourly electricity market model Swissmod (Schlecht & Weigt, 2014) for a full year with high degree of detail on hydropower operation. This modelling approach enables us to capture not only the possible quantitive effect of changes in water availability and potential generation output but also likely effects on seasonality and market value. Furthermore, we are able to calculate changes in revenue for hydropower operators and assess the feedback effect that changes in hydrologic potential have on electricity market prices. While climate change might lead to an overall reduced total availability in generation potential from hydropower, it is also likely to lead to an increase in winter production. Additionally, reductions and shifts in inflows may free up storage capacities for excess solar generation during summer months, which could overcompensate for revenue shortfalls due to a general reduction in generation.

Methods

For our analysis, we employ the electricity market model Swissmod (Schlecht & Weigt, 2014). Swissmod is a DC load-flow nodal pricing electricity market model of Switzerland and its neighbouring countries. The model framework has been tailored to allow for an in-depth analysis of possible future market designs in Switzerland. As a first step, a yearly nodal pricing model of the Swiss electricity market has been set up (see e.g., Leuthold et al. 2012 or Schlecht and Weigt 2014). Swissmod uses a DC load flow approach linking a detailed representation of the Swiss power system with a focus on hydropower elements on the one hand and a representation of balancing markets on the other with aggregated representations of surrounding regions.As a defining feature of Swissmod, hydropower stations are represented with a high degree of detail; hydrologic interrelations within hydropower cascades are modelled such that the outflow of an upstream power plant ends up as inflow to a downstream power plant. The model captures more than 400 hydro stations in detail, representing around 96 % of Swiss hydro production.

The future energy system is assumed to develop according to the reference scenarios given by the Swiss Federal Office of Energy for Switzerland and by the European Commission for neigbhouring EU countries respectively. The hydrologic inflow data we employ are derived from high resolution climate change inflow scenarios for Switzerland from Speich et al. (2015).

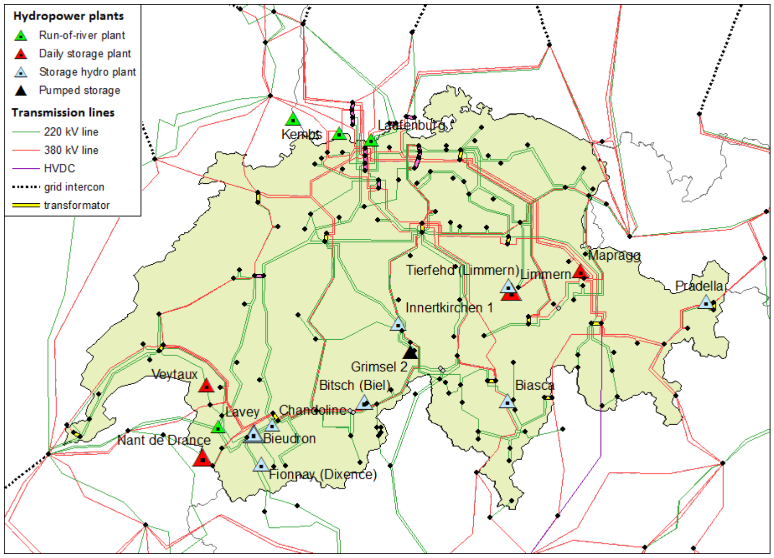

Figure 1: High voltage transmission lines and hydropower stations in the Swissmod model

Results

We are currently in an advanced modelling stage (final calibration of historic inflows in Swissmod), but we cannot present final results to date. These results are expected to be finalized mid to end of March 2018 and will therefore be included in the paper draft to be submitted to the IAEE Groningen conference. As indidcated in the methods section, we expect the scenario results to highlight the potential trade-off between reduced overall production and changes in the seasonality of production which may be benefitial in a solar-wind dominated electricity system. In addition, by performing a cross-comparison of the 2015 and 2050 inflow and market conditions, we will be able to compare the impact of climate change i.e. in inflows to the impact of changes in the market environment (i.e. the increased share of renewables and the reduction in dispatchable fossile generation) on hydropower in Switzerland, its market value and on overall market conditions.

Conclusions

In our paper, we study the effects of climate change on hydropower focusing on Switzerland. While previous literature has looked primarily at quantitative changes in water availability, we employ an electricity market model to also capture the market value of electricity produced by hydropower. Thereby, we are able to evaluate the seasonal changes induced by increased winter runoff and reduced snowmelt in summer. We anticipate this analysis to lead to interesting conclusions regarding the overall revenue impact for hydropower producers as well as the system impacts of changed hydropower patterns.

References

Chandramowli, S. & Felder, F. (2014). Impact of climate change on electricity systems and markets - A review of models and forecasts, In Sustainable Energy Technologies and Assessments, Volume 5, Pages 62-74, doi:10.1016/j.seta.2013.11.003.

Leuthold, F. U., Weigt, H., & Von Hirschhausen, C. (2012). A large-scale spatial optimization model of the european electricity market. Networks and spatial economics, 12(1), 75-107.

Mideksa, T & Kallbekken, S (2010). The impact of climate change on the electricity market: A review, In Energy Policy, Volume 38, Issue 7, 2010, Pages 3579-3585, doi:10.1016/j.enpol.2010.02.035.

Schlecht, I., & Weigt, H. (2014). Linking Europe-The Role of the Swiss Electricity Transmission Grid until 2050.

Speich, M., Bernhard, L., Teuling, A., Zappa, M. (2015). Application of bivariate mapping for hydrological classification and analysis of temporal change and scale effects in Switzerland, In Journal of Hydrology, Volume 523, Pages 804-821, doi:10.1016/j.jhydrol.2015.01.086.

SGHL (2011). Auswirkungen der Klimaänderung auf die Wasserkraftnutzung - Synthesebericht. Beiträge zur Hydrologie der Schweiz I Nr. 38d, Schweizerische Gesellschaft für Hydologie und Limnologie (SGHL) und Hydologische Kommission (CHy) (Hrsg.).