Optimising energy models for hydrothermal generation systems to derive electricity prices

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Abstract. Within this paper, the energy model PERSEUS-HYDRO and its application to Switzerland with a focus on the possibility to provide long-term electricity prices will be presented. Within this model perfect energy markets are assumed and thus electricity prices can be derived from system-marginal-costs. Main features of the plant dispatch within a system with hydro and thermal power will be shown. Also, the integration of energy exchanges (e.g. EEX) are foreseen within the optimising model. As the plant dispatch mainly influences the marginal costs, the important effects and coherences will be highlighted. As prices on the energy exchange have to be set as exogenous input, their influence on the marginal costs will also be discussed.

1 Introduction

The world wide liberalisation of energy markets has far-reaching implications for energy utilities. Competition on national and supranational level leads to a situation in which strategic planning tasks such as capacity expansion and long term production planning become increasingly important for energy utilities. Especially electricity prices get more and more important for investment strategies of energy utilities.
Due to the fact, that water power plants in the Alps have a relevant effect on electricity prices in Europe, it is important to analyse energy systems with a high share of water power in detail. Modelling a generation system with a high share of water power plants (pump storage, reservoir and run-of the river plants) poses additional and different requirements compared to a conventional plant portfolio for the derivation of electricity prices.

Hence, the present paper aims to describe a model application for the analysis of water power plant operation and competitiveness as well as the possibility to derive future electricity prices from a linear optimisation approach. Therefore, the model approach and the specific characteristics of water power plants in an en-

ergy model will be presented. Price information based on system-marginal-costs will be discussed and the influence of the plant dispatch and energy exchanges on the marginal costs will be presented. Furthermore, the application of the developed model to the Swiss energy sector will be shown.

2 A modelling approach to improve the representation of water power plants

The energy and material flow model family PERSEUS (Programme Package for Emission Reduction Strategies in Energy Use and Supply) has been developed at the Institute for Industrial Production (IIP) in order to be able to address questions related to energy systems not only on national, but also on regional and utility level. The modelling approach is based on a detailed representation of energy conversion technologies and the interconnecting flows of energy and material (i. e. primary energy carriers, emissions of pollutants etc.). The structure of the model is equivalent to a directed graph: Energy and material flows are conform with arrows. Conversion technologies and their processes correspond to the nodes of the graph. The models follow linear and mixed integer programming approaches. A detailed description of the entire modelling package can be found in [4].

In the following, this paper will focus on a specific model of the PERSEUS family, the PERSEUS-HYDRO model, which aims at the modelling of energy systems with a large-scale of water power plants and supporting energy utilities by providing information on future electricity prices. Within prior model approaches, the dispatch of water power plants has been set exogenously, while within this approach the dispatch is optimised. Interested readers on further methods of modelling water power systems are referred to [2, 3].

Let us suppose, the energy system to be analysed consists of a set of $units=\{1,...,m\}$ of existing power plants (units) and power plant options, which can be built up in the future. Each of the power plants $unit \in Unit$ contains at least one process $proc \in Proc$ ($Proc=\{1,...,n\}$), which reproduces the operation mode of the power plants. The processes represent the transformation process of the in- and outgoing energy carriers. The typical time horizon (about 30 years) is divided into single periods $t \in T$, where each period is subclassified into time intervals $seas \in Seas$. Time intervals are necessary to draw up the energy demand (load curve) for typical days within one period. Each time interval represents a time range of a typical day (e.g. 9.00 to 12.00 o'clock of a summer working day) for all days with this characteristic. Thus the energy demand within one time interval $seas \in Seas$ and one period $t \in T$ represents an average energy demand, which has to be multiplied with the amount of characteristic days within this period. The exogenous energy demand $D_{t,seas}$ has to be satisfied by the power plants. Variables of the model approach are the process levels $PL_{proc,t,seas}$ of the various operation modes of the energy units and the energy flows $FL_{prod',prod,t,seas}$ between the