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Methodology for forecasting in the Swedish–Norwegian market for el-certificates

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ABSTRACT

In this paper we describe a novel methodology for forecasting in the Swedish–Norwegian el-certificate market, which is a variant of a tradable green certificate scheme. For the forecasting, the el-certificate market is integrated in the electricity-market model EMPS, which has weekly to hourly time-step length, whereas the planning horizon can be several years. Strategies for the certificate inventory are calculated by stochastic dynamic programming, whereas penalty-rates for non-compliance during the annual settlement of certificates are determined endogenously.

In the paper the methodology is described, and we show the performance of the model under different cases that can occur in the el-certificate market. The general results correspond to theoretical findings in previous studies for tradable green certificate markets, in particular that price-scenarios spread out in such a way that the unconditional expected value of certificates is relatively stable throughout the planning period. In addition the presented methodologies allows to assess the actual dynamics of the certificate price due to climatic uncertainty. Finally, special cases are indentified where the certificate price becomes excessively high respectively zero, due the design-specific dynamics of the penalty rate.

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1. Introduction

A variety of support schemes for renewable electricity are in operation in Europe, including market-based instruments such as TGCs (tradable green certificates). In 2006, TGC schemes were in operation in eight EU-countries [1]. Similar SREC (solar renewable energy certificate) markets have emerged in a number of states in USA [2]. The Swedish market for TGCs started in 2003, and from 2012 there is a common market for Sweden and Norway called the el-certificate market. Translations of the Norwegian act and regulations on el-certificates, as well as the Swedish–Norwegian treaty, can be downloaded from Ref. [3].

In the el-certificate market, producers obtain 1 el-certificate on their el-certificate account per MWh electricity produced from renewable sources during the first 15 years of operation. On the other side, power suppliers have to purchase a number of el-certificates given by the certificate share for that year multiplied with the number of MWh electricity supplied to end-users that are included in the el-certificate system. Power-intensive industry and a number of other consumers are exempted from requiring el-certificates. If suppliers have too few certificates on their account during the annual settlement for the previous year at April 1st, they have to pay a penalty for the deficit. The penalty rate is set to 150% of the average certificate price for the previous year. This creates a demand for certificates. Certificates can be stored from one year to the next, which is important for stabilizing prices. The certificate shares for consumers are increased year by year until 2020. Afterwards certificate shares are reduced again till the planned end of the system in 2035.

The certificates traded in the Swedish–Norwegian el-certificate market shall provide an incentive to invest in new generation assets for renewable energy sources. As a result the certificate system are expected to provide annually 26.4 TWh extra electricity from renewable energy sources in sum for Norway and Sweden by 2020. In order to take investment decision for such generation assets, stakeholders need to know respectively estimate the future certificate price. As this price is not set, but determined through a cap and trade system with an inherently set penalty price advanced forecasting methodologies are required.

In this paper we propose a methodology for forecasting in the common el-certificate market for Norway and Sweden. We present an integrated model for electricity markets and el-certificates

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markets where the value of certificates is calculated from stochastic dynamic programming with a weekly time-resolution and with endogenously determined penalty-rates. The objective is to provide a forecast for the el-certificate price for a short to medium-term horizon (a number of years), taking into account climatic uncertainties, such as the annual inflow to the hydropower system or the annual wind speeds. These uncertain values will have a significant impact on the power production from the renewable energy sources as well as the availability of el-certificates.

The proposed methodology is implemented in the existing power market modeling tool EMPS, as it is well suited to determine optimal storage strategies in case of climatic uncertainties. The proposed stochastic dynamic programming methodology is already used in EMPS to address the challenge of calculating water values. Furthermore, EMPS is a well known and applied model throughout the power sector in the Nordic region.

The paper is organized as follows. A literature review is presented in Section 2. In Section 3 we give a brief description of the EMPS model, which is the electricity market model we build upon. The implementation of the el-certificate market is described in Section 4. In Section 5 we show how the model performs for different situations that may occur in the el-certificate market. Conclusions are provided in Section 6.

2. Literature review

There are numerous studies of TGC markets. An early study [4] shows that the equilibrium price for certificates (P^{cert}) will be the production costs for renewable generation (C^{ren}) minus the electricity price (P^{el}).

$$P^{cert} = C^{ren} - P^{el}$$

The cost for renewable generation (C^{ren}) and hence the certificate price will be impacted by the ambition level for renewable generation. Many studies utilize static equilibrium models to derive market equilibrium conditions for TGC schemes. For instance [5], shows that the impact on end-user prices for electricity is ambiguous. The interaction between markets for electricity, TCGs and emission permits is studied in Refs. [6], whereas cost-reductions because of international TCG trade are studied in Ref. [7].

Several numerical energy-system models have been adopted to include TGC markets. In optimization models such as MARKAL [8,9] this is typically done by including the effect of such a market. This mean an extra constraint is implemented, requiring that power generation from renewable energy sources shall be at least a given quantity or a share of electricity consumption. The shadow price of such a constraint can provide a good estimation for a certificate price. However, when such models are run separately for several years in a sequence, prices will not reflect the possibility of storing certificates from one year to the next. In agent-based competitive equilibrium models for a given year such as LIBEMOD [7], a new equilibrium condition for the renewable market can be included. The PRIMES model [10] is a deterministic dynamic model for many years including within-year periods. Since it is deterministic, the TGC price can be calculated, which is sufficient for reaching policy-goals for renewable generation. However, there is no uncertainty in the availability of certificate and hence certificate prices or within-year price variation.

The storage of TGCs from one year to the next is called banking. The possibility of banking TGCs has a major effect on prices, as certificates can be stored in years with ample supply to years with scarcity. Such effects can only be analyzed in dynamic models, and preferably with including the stochastics the generation from renewable energy sources. In Refs. [11], a competitive market equilibrium with and without banking is derived. In the case of banking, the speculation in TGCs as a financial commodity leads to equilibrium prices such that no expected profits can be made by an arbitrage between different time-steps. While certificates that exist today are perfect substitutes for certificates in the future, the opposite is not true. A certificate cannot be utilized in any settlement before it has been issued. Thus, the expected price for certificates can descend. However, if some certificates are banked from one time-step to the next, the competitive certificate price in the current time-step (P_t^{cert}) must equal the discounted (β) expected value in the next time-step$E[P_{t+1}^{cert}]$.

$$P_t^{cert} = \beta E\left[P_{t+1}^{cert}\right]$$

This should not be regarded as a contradiction to the study [4]. Instead one should think of [4] giving the general required certificate price-level for the aggregated market over several years, while [11] provides the expected value for the stochastic price development from one time-step to the next.

Furthermore, the specific design of a TGC market will also influence prices. TGCs have a certain value because there is a probability for certificate deficit and a corresponding penalty during future settlements. If one extra certificate is at disposal in a given settlement-week (s), then the expected avoided penalty during this settlement is the penalty rate (P^{pen}) multiplied with the probability for certificate shortage (q_s). As certificates can be stored to future years, the price of certificates in any given week must be equal to the highest of discounted expected-value for all future settlements, cf [12].

$$P_t^{cert} = \max_s\{\beta_s q_s P^{pen}\}$$

The model in Ref. [12] is developed for the New Jersey SREC market. The interaction with the electricity market is not included as generation from existing solar-power capacity is assumed to be unaffected by electricity prices, and the share of solar-power is small in the electricity market. This, however, is different in the Swedish–Norwegian el-certificate market since production from hydro and bio can be adjusted in response to changes in power prices. Other approaches for analyzing TGC markets include i.a. system-dynamic approaches [13], experiments [14] as well as econometric studies [15].

Resulting from the literature review no numerical simulation model could be found, which analyses the electricity market as well as a green certificate market in an integrated way, including the banking of certificates. In addition, one important feature of the Swedish–Norwegian, the endogenous determined penalty price, has to be addressed. The methodology proposed in this paper should fill this knowledge gap.

3. EMPS model

3.1. General

The EMPS model [16] is a partial model for electricity markets, which is used by producers, regulators and system operators throughout Scandinavia. Especially hydropower is represented in detail, as well as the uncertainty of climatic variables.[1] The model calculates the optimal strategy for the utilization of hydropower reservoirs. Subsequently, the market equilibrium is calculated for each time-step, area and stochastic climate scenario. The model can run in an operational mode, i.e. with predefined capacities for production and transmission, or in investment mode [18]. The el-

[1] In the context of the EMPS model climatic variables comprise the precipitation (inflow to hydro reservoirs), wind speeds, solar radiation as well as temperatures

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