# **ÖGOR** - **IHS** Workshop und ÖGOR-Arbeitskreis

# "MATHEMATISCHE ÖKONOMIE UND OPTIMIERUNG IN DER ENERGIEWIRTSCHAFT"

Sponsorship:

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At September 23rd, 2010, the 6th "Workshop on Mathematical Economics in Energy" will be held at IHS (Institue for Advanced Studies) in Vienna (Stumpergasse 56), from 9 a.m. to 5 p.m.

We shall concentrate on (stochastic and deterministic) optimisation and risk management in power markets.

Conference languages are English and German.

### Homepage: http://www.oegor.at/ihs/

Registration: <u>http://www.oegor.at/oegor.php?oegor=section,1;subsection,44</u>

### Organisation:

Gerold **Petritsch**, **e&t** ENERGIE HANDELSGESELLSCHAFT m.b.H. and **ÖGOR** (Österreichische Gesellschaft für Operations Research)

Isabella Andrej and Wolfgang Polasek, IHS

## Place and Time:

Institue for Advanced Studies, Vienna (Hörsaal II) Stumpergasse 56, A-1060 Vienna (Nähe Westbahnhof)

Thursday, September 23rd, 2010,

9:00 -17:00

# Plan of site



## 9:00 Opening: Wolfgang Polasek (IHS, Vienna):

## 9:05 – 10:30 First morning session

Chairman: Alfred Kalliauer (Verbund-APT, Vienna)

# Valery A. Kholodnyi (VERBUND – Austrian Power Trading AG, Vienna)

# Extracting Risk-Neutral Probabilities from Energy Forwards in the Framework of the Non-Markovian Approach

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Key words: energy forwards, non-Markovian approach

We present and further develop the non-Markovian approach to modeling energy spot prices with spikes proposed earlier by the author. In contrast to other approaches, we model energy prices with spikes as a non-Markovian stochastic process that allows for modeling spikes directly as self-reversing jumps. We use this approach to analytically model energy forwards and extract, by means of an optimization problem, the forwardlooking risk-neutral probability distributions for the energy spot prices with trends, seasonalities and spikes from the related energy forward prices. We consider practically important examples of power, gas, oil and carbon markets. In particular, we show that the annualized risk-neutral mean-reversion rate for the carbon spot prices is approximately equal to 0.01 and, while being relatively small, is not, in fact, equal to zero.

# Andreas Eichhorn (VERBUND – Austrian Power Trading AG, Vienna)

# Stochastic Programming in Energy: Theory vs. Practical Application

In electricity production and sales, mathematical optimization frameworks are widely used in order to support the actual (short-term) scheduling of power plants and in order to get somehow realistic medium-/long-term schedules for planning and hedging issues.

Most available software products for such applications are deterministic, i.e., there is an implicit assumption that all parameters (such as demands and prices) in the future are perfectly known in advance. Incorporating the fact that at each point in time there is only statistical knowledge about the respective future leads to stochastic programming (stochastic optimization). This framework is somewhat more correct and allows, in theory, the direct incorporation of risk management / hedging. However, the increase of complexity for passing from deterministic to stochastic programming is often prohibitive ("curse of dimensionality") and, therefore, fewer software products are available.

After introducing theoretical concepts of stochastic programming such as 2-stage and multi-stage frameworks, scenario (tree) approximation, stochastic dynamic programming, incorporation of risk functionals, we address practical application of stochastic programming to electricity production planning. We present some examples and discuss the question in what situation is it really worth (respectively possible) to use stochastic programming.

## 11:00 – 12:30 Second morning session

Chairman: Alfred Kalliauer (Verbund-APT, Vienna)

# Wolfram Wiesemann (Imperial College of Science, London)

## **Stochastic Programming without Scenario Trees**

Traditionally, operations research has focused on deterministic optimisation models in which all parameter values are assumed to be known precisely. However, many decision problems contain inherently random parameters such as future demand and prices, and it has been shown that replacing these parameters with estimated values can lead to severely suboptimal or even infeasible strategies. To overcome this issue, stochastic programming describes the random parameters by a finite set of possible realisations (scenarios) and constructs deterministic optimisation models that optimise risk measures over these scenarios. While flexible and easy to implement, stochastic programs suffer from the curse of dimensionality: they become computationally cumbersome if the decision problem contains multiple time periods.

In this talk, we survey recent advances in scenario-free stochastic programming, a research area that has attracted significant attention over the past five years. Instead of approximating the realisations of the random variables by scenarios, scenario-free techniques approximate the decision variables by families of decision rules. Decision rules are computationally attractive since the resulting approximate problems avoid the aforementioned curse of dimensionality. We show how to construct hierarchies of increasingly accurate piecewise linear decision rules, and we explain how the incurred approximation error can be estimated by applying decision rules to the dual of the stochastic program. We also present preliminary numerical results that show how decision rules can solve previously intractable optimisation problems.

# Daniel Kuhn (Imperial College of Science, London) Breaking the Curse of Dimensionality in Energy Trading

Stochastic programs are traditionally solved by approximating the uncertain problem parameters by a finite scenario tree. New solution techniques based on functional approximations of the recourse decisions require no scenario tree approximation and can therefore even cope with a continuum of scenarios. Unlike scenario tree-based methods that inherently suffer from the curse of dimensionality, these scenario-free approximations pave the way for polynomial time solutions.

In this talk we demonstrate how scenario-free stochastic programming methods can be used to solve two generic portfolio problems encountered by electricity retailers. Such retailers procure electric energy on the spot market to satisfy their customers' electricity demand and thus face substantial financial risks due to the possibility of sudden price spikes. We formulate a multistage stochastic mean-variance optimization model for the management of a hedging portfolio that facilitates mitigation of these risks. We demonstrate the benefits of using a true multistage model with adaptive decisions as opposed to a static model that assumes precommitment of the decisions. We also show that the scenario-free approach yields implementable conservative solutions, whereas a scenario-tree approach based on conditional sampling results in overoptimistic solutions that may fail to be implementable. In the second part of the talk we develop a related multistage stochastic portfolio model for the hedging of an electricity swing option, that is, an energy delivery contract with volumetric and timing flexibility. We approach the problem from the holder's as well as the seller's perspective and characterize the trade-off between the option premium and the risks faced by both parties.

## 13:40 – 15:00 First afternoon session

Chairman: Gerold Petritsch (e&t, Vienna)

# Ronald Hochreiter (Vienna University of Economics and Business) and David Wozabal: A Multi-Stage Stochastic Programming Model for Managing Risk-Optimal Electricity Portfolios.

Keywords:

# Stochastic programming, multi-stage decision optimization, electricity portfolio management, real option pricing, risk management

We present a multi-stage decision model, which serves as a building block for solving various electricity portfolio management problems. The basic setup consists of a portfolio optimization model for a large energy consumer, that has to decide about its mid-term electricity portfolio composition. The given stochastic demand may be fulfilled by buying energy on the spot or futures market, by signing a supply contract, or by producing electricity in a small plant. We formulate the problem in a dynamic risk management-based stochastic optimization framework, whose flexibility allows for extensive parameter studies and comparative analysis of different types of supply contracts. A number of application examples is presented to outline the possibilities of using the basic multistage stochastic programming model to address a range of issues related to the design of optimal policies. Apart from the question of an optimal energy policy mix for a large energy consumer we investigate the pricing problem for flexible supply contracts from the perspective of an energy trader, demonstrating the wide applicability of the framework.

# David Wozabal, Nils Löhndorf, Stefan Minner (University of Vienna)

# Optimal Day-Ahead Bidding of Electricity Storage using Approximate Dynamic Programming

We model the decision of a storage operator who trades at a wholesale electricity market. The market implements a two-settlement system with a day-ahead and a real-time balancing market. Every day the decisionmaker submits hourly bidding curves to the day-ahead market and has to decide on his operation on the balancing market. We propose a new approximate DP algorithm to solve the Markov decision problem underlying storage operation. Our approach can be used to optimize the bidding strategies by taking stochastic day-ahead prices as well as dynamics of future prices and decisions into account.

## 15:30 – 16:50 Second afternoon session

Chairman: Gerold Petritsch (e&t, Vienna)

# Georg Ostermaier (Decision Trees, St. Gallen)

## Stochastic Programming in Gas Storage and Gas Portfolio Management

The liberalization of gas markets has motivated utilities to invest in gas storage and structured procurement of gas. More and more utilities are not fully supplied by incumbent gas companies anymore but operate their own gas procurement portfolios consisting of storages and multiple flexible supply contracts.

Stochastic modeling in the gas market has recently focused on gas storage valuation. The uncertainty in gas day ahead prices is usually modeled either jump diffusions or regime switching stochastic processes. The path dependency in the decision process of gas storage operation is addressed by least square Monte Carlo approaches.

However, the decision problem under uncertainty that utilities need to solve dos not consist of gas storage only. Portfolios consisting of gas storages and multiple flexible supply contracts with time integral volume restrictions need to be operated with the objective to cover an uncertain future retail demand at minimum costs. In addition to gas price uncertainty, the uncertainties of the retail demand and oil prices that determine the price of flexible contracts need to be considered. Thereby daily decisions on forward and spot gas market trades need to be taken under considerable uncertainty.

We propose a multistage stochastic optimization model for the operation of gas procurement portfolios comprising storages and flexible gas supply contracts with time integral volume constraints. The model considers day ahead gas price uncertainty, retail demand uncertainty and oil price uncertainty. The basic mathematical concepts as well as a brief practical example will be introduced.

#### 16:10

# Christian RedI (Vienna University of Technology), Derek W. Bunn (London Business School)

## Determinants of Forward Premia in Electricity Markets: A Taxonomic Empirical Analysis

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#### Derek W. Bunn: Energy Markets Group, London Business School, United Kingdom

The (current) forward price of a commodity can be split up into a forecast of the future spot price at delivery and a risk premium. This article introduces a taxonomy of electricity forward premia determinants as the understanding of the drivers of the forward premium allows a better regulation of electricity markets and design of corresponding market rules. Specifically, our aim is to extend established concepts of forward premia in electricity markets. We have organised these components into a taxonomy of fundamental influences, behavioural effects, market conduct, dynamic effects and shock effects.

The components of the ex post forward premium are unravelled with the help of an empirical modelling approach. The biggest regional European power market is assessed: the Western European power market with its leading power exchange, the European Energy Exchange (EEX).

Overall, the forward premium in electricity is a rather complex function of fundamental, behavioural, dynamic, market conduct and shock components. It is clearly an oversimplification in practice to analyse it only in terms of the stochastic properties of the spot prices (variance and skewness). Only part of the risk can be attributed to the electricity sector per se, but in that, risk aversion to scarcity, volatility and extreme events, as well as behavioural adaptation and oil sentiment spillovers characterises agent behaviour. Furthermore, market concentration appears to translate market power effects into the risk premium, which may have important market monitoring implications since forward markets have, so far, been considered to be procompetitive. The reserve margin plays a crucial role since increased scarcity increases spot prices (which is amplified in the case of concentrated markets) and, moreover, also the forward premium. Hence, consumers take a "double hit" if the margin reduces. In general, some of the insights presented here suggest that forward premia should be considered key elements of a transaction cost view of market efficiency in power trading.