UNIVERSITÄT DUISBURG ESSEN

LEHRSTUHL FÜR ENERGIEHANDEL UND FINANZDIENSTLEISTUNGEN

LEHRSTUHL FÜR ENERGIEWIRTSCHAFT

# Energy Finance / INREC 2010

*Essen*
*October 6-8, 2010*

*Plenary Speakers*

René Aïd
Markus Burger
René Carmona
Ulrich Horst
Ronald Huisman
Ulf Moslener
Mark O'Malley
Andrea Roncoroni
Marliese Uhrig-Homburg

*Scientific Committee*

Derek Bunn
René Carmona
Dominique Dupont
Wolf Fichtner
Rüdiger Kiesel
Christian Rehtanz
Michael Römmich
Sven-Olaf Stoll
Christoph Weber

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Dear Participants,

Welcome to the 7th Energy & Finance Conference, which takes place jointly with the 2nd International Ruhr Energy Conference (INREC) this year. As usual the conference merges in a unique way academic research on the highest level with practical applications. This year the conference covers a wide range of topics from Emission Certificate Trading to Weather Derivatives. We are proud to be able to feature an impressive list of invited speakers together with high-quality contributed talks, which went through a competitive selection procedure. For the first time in the history of the conference we will have two best paper-awards, which have been sponsored by RWE Supply & Trading.

This entire event would not have been possible without the support of our sponsors and many helping hands within the university and outside. We would like to thank Marlin IT for organizing the energy trading game which emphasizes the practical aspects. Our special thanks go to our main sponsor RWE Supply & Trading for their generous support.

I hope you will enjoy the conference and your stay in Essen. Together we will have stimulating and productive days!

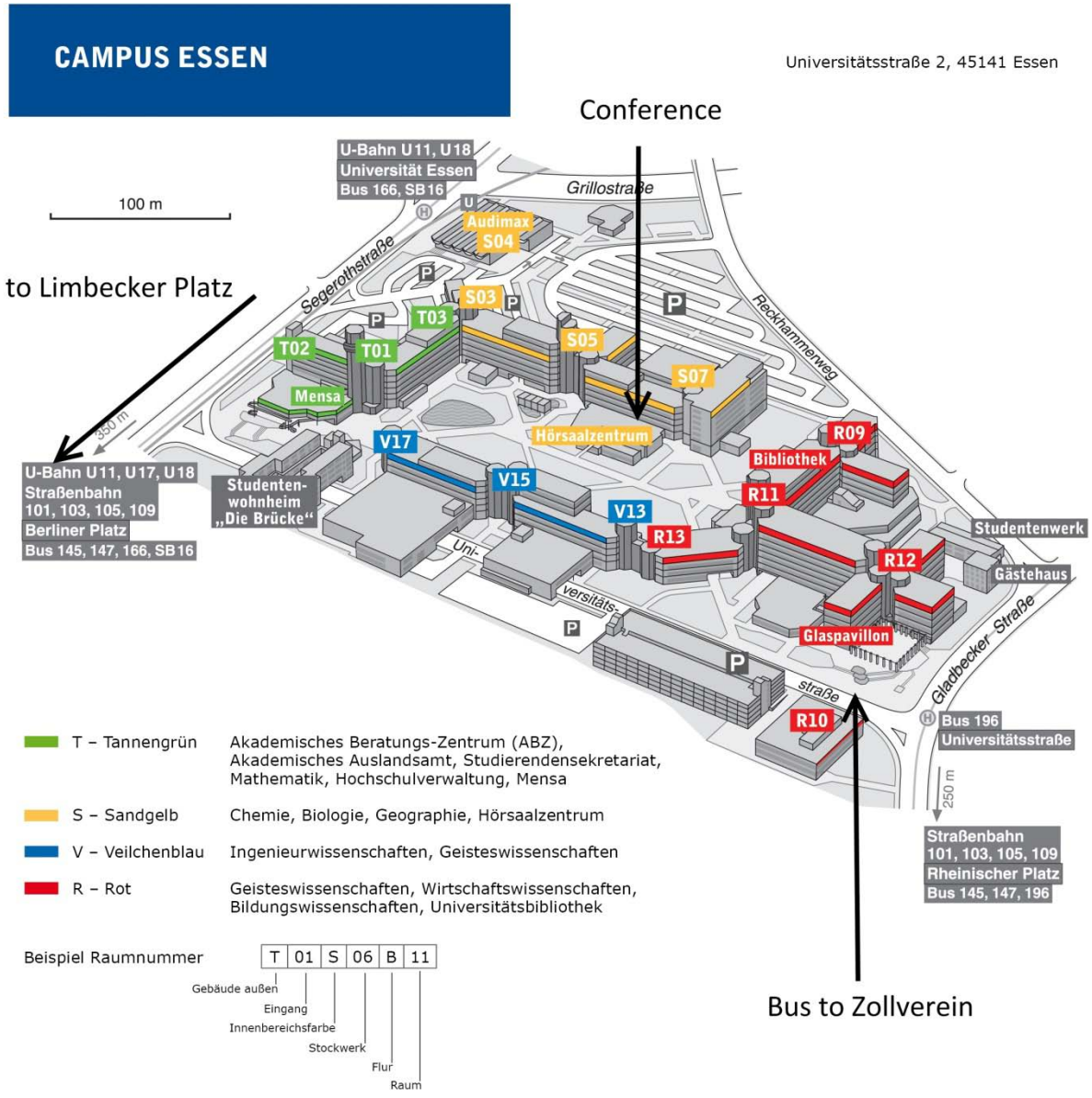
Rüdiger Kiesel

## Conference Venue and Surroundings

The conference takes place in the lecture halls S05 T00 B32 and S05 T00 B42 in the “Hörsaalzentrum” on the Essen campus. Downtown Essen and the shopping center “Limbecker Platz” are within walking distance (see the map below).

You can get to the campus from the main station by taking the underground lines U11 and U17 and exiting at “Universität” or by taking the tram lines 101 or 105 and exiting at “Rheinischer Platz”.

For lunch, you have multiple options: The university cafeterias in buildings R12 and T01, the university canteen (“Mensa”) in building T01, as well as several restaurants at the shopping center Limbecker Platz.




## Using the WLAN

Connect to the network “ecampus” and open your browser. You will be redirected to a logon page where you can enter the user name and password provided in your conference folder.

If you are affiliated with an institution that is part of the DFN (Deutsches Forschungsnetz) and that supports DFN-Roaming, you can use the WLAN with your account from your home institution. Connect to the “eduroam” network, open your browser, and enter your user name in the form “username@domain”, e.g., max.mustemann@uni-koeln.de, together with your password.

UNIVERSITÄT DUISBURG ESSEN



## Wednesday, Oct. 6

| | | | |
|---|---|---|---|
| 10:00 | Registration | | |
| 10:30 | Welcome & Introduction | | |
| 11:00 | Invited Talk: **Marliese Uhrig-Homburg**<br>*Understanding the Price Dynamics of Emission Permits: A Model for Multiple Trading Periods* | | |
| 11:45 | Invited Talk: **René Aïd**<br>*A structural risk-neutral model for pricing and hedging power derivatives* | | |
| 12:30 | Lunch Break | | |
| 13:45 | Invited Talk: **Ulf Moslener**<br>*In the End, it's Investment that Counts - Challenges in Scaling-up Clean Energy* | | |
| 14:30 | Invited Talk: **Andrea Roncoroni**<br>*Energy risk, framework risk, and FloVaR measurement* | | |
| 15:15 | Coffee Break | | |
| 15:45 | 1 Reinhard Madlener<br>*Cost evaluation of credit risk securitization in the electricity industry: credit default acceptance vs. margining costs* | 2 Stelios Kourouvakalis<br>*A lattice-based method for valuing swing option contracts under the Threshold model* | |
| 16:15 | 3 Bernd Tersteegen<br>*Investigations on Factors Influencing the Operational Benefit of Stochastic Optimization in Generation and Trading Planning* | 4 Sjur Westgaard<br>*Covariance estimation using high-frequency data: An Analysis of Nord Pool electricity forward data* | |
| 16:45 | 5 Dogan Keles<br>*A comparison of extended electricity price models considering the impact of wind energy feed-in* | 6 Svetlana Borovkova<br>*Asian basket options and implied correlations* | |
| 17:15 | Coffee Break | | |
| 17:30 | Energy Trading Game (Limited number of participants) | 7 Nina Lange<br>*Seasonality in energy prices: From a term structure model to an affine model* | 8 Joachim Gahungu<br>*Sufficient and necessary conditions for perpetual multi-assets exchange options* |
| 18:00 | | 9 Frowin Schulz<br>*Understanding Time-Varying Risk of Electricity Forwards:* Trading *Activity and News Announcements* | 10 Johannes Müller<br>*On Clearing Coupled Day-Ahead Electricity Markets* |

## Thursday, Oct. 7

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|---|---|---|
| 08:30 | 11 Gauthier de *Maere d'Aertrycke*<br>*Liquidity Risks on Power Exchanges* | 12 Jukka Lempa<br>*On Optimal Exercise Of Swing Options In Electricity Markets* |
| 09:00 | 13 Brenda Lopez Cabrera<br>*Localizing temperature risk* | 14 Peter Schuetterle<br>*Valuation of VPP contracts under a lognormal swap market model* |
| 09:30 | Invited Talk: **René Carmona**<br>*Singular FBSDEs and the option pricing in the EU ETS* | |
| 10:15 | Coffee Break | |
| 10:45 | Invited Talk: **Markus Burger**<br>*Risk-adequate pricing of retail power contracts* | |
| 11:30 | Invited Talk: **Ulrich Horst**<br>*Equilibrium pricing of weather derivatives* | |
| 12:15 | Lunch Break | |
| 13:30 | 15 Christian Redl<br>*Components of the Forward Market Premium in Electricity* | 16 Daniel Schwarz<br>*Risk-Neutral Pricing of Financial Instruments in Emission Markets - A Hybrid Approach* |
| 14:00 | 17 Almut Veraart<br>*Modelling electricity forward markets by ambit fields* | 18 Carlos Pinho<br>*CO2 spot and futures price analysis for EEX and ECX* |
| 14:30 | Coffee Break | |
| 15:00 | 19 Tobias Federico<br>*Interaction of spot and future prices for electricity* | 20 Mara Madaleno<br>*Hedging with CO2 allowances: the ECX market* |
| 15:30 | 21 Richard Biegler-König<br>*The Information Premium in Electricity Markets* | 22 Stefan Giebel, *Martin Rainer*<br>*Stochastic estimation of energy resources and prices*<br>*via neural network* adapted *stable processes* |
| 16:15 | Departure to Zollverein | |
| 17:00 | Guided Tour | |
| 19:00 | Dinner | |

## Conference Dinner and Tour of Zollverein World Heritage

The buses to Zollverein leave at 16:15 from Universitätsstraße in front of the R12 building (see the map on the first page). The Zollverein Coal Mine, opened in 1847 and shutdown in 1986, has been inscribed into the UNESCO list of World Heritage Sites since 2001 and is one of the anchor points of the European Route of Industrial Heritage. We will have a two-hour guided tour (in English or German) of the mine. Afterwards, the dinner takes place at the Casino Zollverein. Situated in the old compressor hall of the mine the restaurant offers a unique and enchanting atmosphere. Its kitchen has been awarded many times and is one of the best-known in the Ruhrgebiet and in North Rhine-Westphalia. After the dinner, the busses leave from Zollverein at 22:00. They can take you back to the Welcome hotel close to campus, to Essen main station and to the BB Hotel in Oberhausen.

## Friday, Oct. 8

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|---|---|---|
| 08:30 | 23 Arne Andresen, Johan Magne Sollie<br>*A Commodity Spot Price Model with Short-, Medium- and Long-Term Components* | 24 Takashi Kanamura<br>*Convenience Yield-Based Pricing of Commodity Futures* |
| 09:00 | 25 Stefan Schneider<br>*Power spot price models with negative prices* | 26 Alexander Boogert<br>*Gas storage valuation using a multi-factor price process* |
| 09:30 | 27 Linda Vos<br>*Modeling electricity prices: spots, forwards and the risk premium* | 28 Dmitry Lesnik<br>*Storage option: an Analytic approach* |
| 10:00 | 29 Carlo Lucheroni<br>A SETARX model for spikes and antispikes in electricity markets | 30 Volker Termath<br>*Hedging and Optimizing Gas Storage from a Trader's Perspective* |
| 10:30 | Coffee Break | |
| 11:00 | Invited Talk: **Mark O'Malley**<br>*Grid Integration of Renewables: Technical issues and impacts on market design* | |
| 11:45 | Invited Talk: **Ronald Huisman**<br>*Risk premia in power forward prices* | |
| 12:30 | Closing Remarks | |

## Invited Talks – Abstracts

**René Aïd** (EDF): *A structural risk-neutral model for pricing and hedging power derivatives*

We develop a structural risk-neutral model for energy market modifying along several directions the approach introduced in [Aïd et al., 2009]. In particular a scarcity function is introduced to allow important deviations of the spot price from the marginal fuel price, explaining price spikes. We focus on pricing and hedging electricity derivatives. The hedging instruments are forward contract on fuels and electricity. The presence of production capacities and electricity demand makes such a market incomplete. We follow a local risk minimization approach to price and hedge energy derivatives. Despite the richness of information included in the spot model, we achieve closed-form formulas for futures prices and semi-explicit formulas for spread options and European options on electricity forward contracts. We show that when far from delivery, electricity futures behave like a basket of futures on fuels.

**Markus Burger** (EnBW Trading): *Risk-adequate pricing of retail power contracts*

For power utilities, pricing of retail contracts is essential.
While wholesale market prices are the same for all utilities, risk premiums and sales margins differentiate the competitors in the power retail market.
The risk premium covers risks from various sources: Validity period of retail offer, balancing power costs, volume risk, credit risk and operational risk. The most significant risk is the volume risk due to the high correlation between load and market prices (expected costs). Furthermore differences between realised customer load and load forecast cause possible losses.
All risks can be classified into systematic and unsystematic risk types. Systematic risks like the validity period of retail offer cause additional costs, while unsystematic risks have zero mean. The risk premium consists of the expected costs from systematic risks and a so-called strict risk premium for the possibility of additional costs from unsystematic risk types. One approach for the calculation of strict risk premiums is the RAROC approach which ensures a certain return on the capital allocated to absorb possible losses. The capital requirement ("economic capital") is determined via a standard risk measure like Value-at-Risk.
For calculating the risk premium for the volume risk a model which generates correlated load and price scenarios (e.g. SMaPS) is used.

**René Carmona** (Princeton University): *Singular FBSDEs and the option pricing in the EU ETS*

We introduce two simple models of forward-backward stochastic differential equations with a singular terminal condition and we explain how and why they appear naturally as models for the valuation of $CO_2$ emission allowances. Single phase cap-and-trade schemes lead readily to terminal conditions given by indicator functions of the forward component, and using fine partial differential equations estimates, we show that the existence theory of these equations, as well as the properties of the candidates for solution, depend strongly upon the characteristics of the forward dynamics. Finally, we give a first order Taylor expansion and show how to numerically calibrate some of these models for the purpose of $CO_2$ option pricing.

**Ulrich Horst** (Humboldt University): *Equilibrium pricing of weather derivatives*

We discuss an incomplete financial market model in discrete time within which to price derivative securities (written on possibly non-tradable underlyings) such as weather derivatives by an equilibrium approach. Under the assumption that investors are sensitive to large losses and evaluate their risk exposures using time-consistent dynamic risk measures, we establish existence and uniqueness of equilibrium results and prove that the dynamic problem of equilibrium pricing can be reduced to a recursive sequence of static one-period equilibrium problems. When the uncertainty is generated by random walks, this allows us to describe the equilibrium dynamics by a coupled system of forward-backward equations. We also discuss a modification of the CAPM in continuous time where the equilibrium dynamics can be given in closed form. This allows us to calibrate our model to market data.
The talk is based on joint work with P. Cheridito, M. Kupper and T. Pirvu

**Ronald Huisman** (Erasmus University Rotterdam): *Risk premia in power forward prices*

The presentation focuses on the pricing of electricity forward contracts. I will discuss some recent findings. The first part discusses how indirect storage of electricity lead to time varying risk premiums in forward prices. The second part discusses the question whether agents in electricity forward markets exhibit heterogeneous expectations. The third part discusses a natural experiment in which the microstructure of day-ahead markets was changed and how that affected the day-ahead prices and their relation to imbalance (spot) prices. All these results shed some light on risk premiums in electricity forward markets and which factors might explain them.

**Ulf Moslener** (KfW Development Bank): *In the End, it's Investment that Counts - Challenges in Scaling-up Clean Energy*

The climate international policy process and national regulatory policies are trying to drive a global structural change sufficient to limiting global warming to two degrees celsius. However, ultimately this structural change means massive investments. Gaps will be highlighted (i) on the way from the international policy process towards creating price signals, ad (ii) in the way the carbon price signal changes the final investment decision.

**Mark O'Malley** (University College Dublin): *Grid Integration of Renewables: Technical issues and impacts on market design*

Driven by maturing and robust technologies and coupled with security of supply and environmental concerns renewable energy deployment is increasing dramatically. Many have expressed doubts about integrating large amounts of variable renewable (e.g. wind and solar) into electricity grids. The presentation will highlight the impacts of variable renewable on electricity grids and show that the doubts are unfounded and there are practical solutions that will allow the integration of large amounts of variable renewable. The impact of variable renewable on markets will be explored in detail and some guidance will be given as to how they should evolve in the future so as they are more suitable for a grid that is dominated by variable renewables. The presentation will be based on real life experience and extensive studies on the topic by the speaker and his colleagues.

**Andrea Roncoroni** (ESSEC Business School): *Energy risk, framework risk, and FloVaR measurement*

We unveil and explore two kinds of risk sources affecting the marked-to-market value of commodity portfolios.
1. It is well known that commodity prices often display seasonal patterns in their trend and volatility, a phenomenon that is particularly evident in energy markets. This fact calls for risk measures exhibiting the time structure of market risk affecting portfolios that include commodity-related positions. FloVaR™ provides the risk manager with a methodology to combine existing risk measures with the seasonal trend displayed by the underlying energy and commodity prices.
2. "Framework risk" generalizes the notion of "Model risk". It refers to the relative effect of using alternative formulations of a common model for the purpose of providing an effective risk assessment of portfolios (Roncoroni (2010)). In the context of commodity markets, this risk source can be unveiled by exploring the relative performance of a spot convenience yield model versus the forward price equivalent at reproducing empirical volatility curves.

**Marliese Uhrig-Homburg** (KIT): *Understanding the Price Dynamics of Emission Permits: A Model for Multiple Trading Periods*

Cap-and-trade systems for greenhouse gases, like the European Union's Emission Trading System (EU ETS), are currently established in many different countries all over the world. Those are characterized by a set of regulatory rules which have shown to be appropriate in the recent past. The regulatory framework clearly impacts the price dynamics in such a market, a dependency not yet fully understood. Although insights into this subject are crucially important for risk management, derivative pricing, and many energy-related operating and investment decisions, there exists no long-term equilibrium model accounting for the trading systems' main stylized facts: the existence of multiple trading periods, the allowance of banking, and the later delivery of lacking permits.
We propose an equilibrium model for emission permit prices under uncertainty taking into account a sequence of consecutive trading periods and show how the additional consideration of consecutive trading periods adds to and changes a finite period view. We characterize equilibrium outcomes in this setting, document numerically how prices and volatilities depend on upcoming trading periods, and identify a value component in today's prices related to each trading period. Moreover, we show that an emission permit is essentially equivalent to a strip of binary options written on net cumulative emissions. We exploit this option analogy to derive several general properties of the price dynamics of emission permits and highlight the crucial difference to financial options. In contrast to the classical view on financial options the dynamics of the underlying is no longer exogenously given but derived endogenously through abatement measures. Differences due to the impact of equilibrium abatement strategies become the more important the more future trading periods are considered. Finally we discuss derivative pricing in our equilibrium model.

## Contributed Talks - Abstracts

**1 Reinhard Madlener** (RWTH Aachen): *Cost evaluation of credit risk securitization in the electricity industry: credit default acceptance vs. margining costs*

Since the worldwide disruptions of the financial markets and the default of many market participants in the recent years, institutions like the European Commission seek to increase the transparency of the derivatives markets. This course of action includes in particular the installation of a centralized clearing and with it the obligation to clear all relevant financial derivatives. Besides the expected securitization of the financial system these steps would also massively influence the electricity industry, as most of the current commodity trading in this sector is still done in the non-cleared OTC markets. Despite the fact that clearing of the OTC contracts in this sector has significantly increased over the last years, still a big part of the credit risk mitigation is done with bilateral netting agreements, standardized contracts, and individual trading limits between partners. This paper explores the impact of margining on the financial costs in comparison to the direct management and the intentional acceptance of credit risk. For this purpose we evaluate the losses due to defaulting business partners with the interest requirements of the cash reserve for an assumed margining account. We compare a scenario that assumes 100% margining with a scenario in which none of the credit risk is collateralized. We test the robustness of our model through the use of sensitivities on commodity prices, partner structure of the sales/purchase portfolios, and the underlying fuel mix.

**2 Stelios Kourouvakalis** (RWE): *A lattice-based method for valuing swing option contracts under the Threshold model*

A Swing Option is a fundamental contract that arises increasingly often in the conduct of business in the energy industry. This presentation concerns a lattice-based method for valuing such contracts, under the Threshold Model (Geman and Roncoroni, 2006), which incorporates both mean reversion and jumps. Monte Carlo simulations under the Longstaff-Schwartz methodology give strong evidence that the pricing with the lattice method is accurate. Due to the serious time and computer memory issues that arise in the usage of the Monte Carlo algorithm, the grid method represents a very promising alternative for pricing of such complicated derivatives.

**3 Bernd Tersteegen** (RWTH Aachen)**:** *Investigations on Factors Influencing the Operational Benefit of Stochastic Optimization in Generation and Trading Planning*

Deriving operational decisions from power generation and trading planning, e.g. the marketing of a power plant at the day-ahead spot market requires the consideration of time-coupling constraints, such as minimum up- and down-times or limited resources, e.g. take-or-pay restrictions on natural gas. Major parameters determining the optimal unit commitment decision are subject to significant uncertainties, in particular spot prices for electrical energy. For such tasks with time-coupling constraints as well as uncertainties, a method based on techniques of stochastic optimization should be preferred and is exemplarily presented in this work. Such methods provide optimal decisions with respect to all developments of the uncertain parameters in consideration.
The monetary benefit of stochastic compared to deterministic optimization in the day-ahead planning process has been shown in the past but has not been investigated in detail. Hence, in this work factors that potentially influence this benefit are identified and their impact is quantified by means of a day-by-day simulation of the day-ahead marketing for the operational year 2009. The resulting annual revenues for both a stochastic as well as a deterministic optimization are compared

with the theoretical optimum, which is the revenue of the ex-post optimal unit commitment based on perfect information with respect to all uncertainties. In particular it is investigated how parameters of the model system, modelling accuracy of the optimization method and the model of the uncertain parameters influence the operational benefit of a stochastic optimization.

**4 Sjur Westgaard** (Norwegian University of Science and Technology)**:** *Covariance estimation using high-frequency data: An Analysis of Nord Pool electricity forward data*

The modeling of volatility and correlation is important in order to calculate hedge ratios, value at risk estimates, CAPM betas, derivate pricing and risk management in general. Recent access to intra-daily high-frequency data for two of the most liquid contracts at the Nord Pool exchange has made it possible to apply new and promising methods for analyzing volatility and correlation. We apply the concepts of realized volatility and realized correlation, and this first study statistically describes the distribution (both distributional properties and temporal dependencies) of electricity forward data from 2005 to 2009. The main findings show that the logarithmic realized volatility is approximately normally distributed, while realized correlation seems not to be. Further, realized volatility and realized correlation have a long-memory feature. There also seems to be a high correlation between realized correlation and volatilities and positive relations between trading volume and realized volatility and between trading volume and realized correlation. These results are to a large extent consistent with earlier studies of stylized facts of other financial and commodity markets.

**5 Dogan Keles** (KIT)**:** *A comparison of extended electricity price models considering the impact of wind energy feed-in*

In liberalized energy markets investments in power storage and generation technologies depend on the future development of electricity prices. Several methods have been developed in the last years to simulate electricity wholesale prices for a future planning time-period. These methods are based on fundamental, equilibrium, financial and time-series models. Whereas fundamental and equilibrium models analyze the structure of the energy market considering future development of techno-economic parameters on the supply and demand side, financial and time-series models analyze the historical price volatilities and simulate them with stochastic processes. These stochastic models can be extended to capture the main price characteristics: seasonality, mean-reversion, price jumps and spikes. In this paper different time-series models and extended mean-reversion processes are analyzed to find the appropriate model for simulating the EEX spot price. Furthermore, the spot price models are extended by a component, which considers the impact of wind electricity feed-in on the electricity price. Therefore the amount of wind electricity feed-in is simulated by an autoregressive model with an hourly solution.
Finally, the results of the different models are compared analyzing the question, whether the price simulation with consideration of wind-electricity feed-in leads to an improvement or not.

**6 Svetlana Borovkova** (Vrije Universiteit Amsterdam)**:** *Asian basket options and implied correlations*

We address the problem of valuation and hedging of Asian basket and spread options - derivatives very common in commodity and especially energy markets. We extend the Generalized LogNormal approach, introduced in Borovkova et al. (2007), to Asian basket options and apply it to energy option markets. We approximate the basket's average value using a generalized family of lognormal distributions. We provide closed form formulae for the option price and the greeks, which is extremely useful for option traders.

We demonstrate the high accuracy of the GLN approach on the basis of simulated and real oil market options data, by comparing GLN option prices to those obtained by an extensive Monte Carlo simulation, and by calculating the costs of hedging the option.
Inverting the option pricing formula allows us to imply the correlation between the assets in the basket or spread from the corresponding option prices. We apply this to the NYMEX crack spread option prices, to reveal implied correlations between crude oil and unleaded gasoline, and show how the structure of the implied correlation resembles well-known features of implied volatility, such as volatility skew.

**7 Nina Lange** (Copenhagen Business School)**:** *Seasonality in Energy Prices: What is the effect on the convenience yield?*

It is well known fact that energy prices exhibit seasonality. The price of a futures contract vary systematically (partly) throughout the year due to the underlying influence of temperature, consumption patterns and the storage issue. A widely used method to model this is by adding a deterministic seasonality component, for example a trigonometric function added to a factor model. An alternative is suggested by Miltersen 2003, who develops a variant of Miltersen & Schwartz 1998's term structure model for commodity prices. In order to capture the seasonality effect, Miltersen 2003 allows a time varying volatility specification in both the spot price and in the future convenience yield. We derive a condition under which the model can be rewritten as an affine model. The benefit of this is that the model can be estimated through a Kalman filter with simultaneous estimation of the parameters. It also doesn't require the underlying price to be available.
The model is fitted to quarterly futures contracts on UK natural gas, which exhibit a strong seasonality. Besides estimating the full model and some nested variations, we discuss the quantitative results on the convenience yield process and show the model-implied futures curves.

**8 Joachim Gahungu** (CORE / Université catholique de Louvain)**:** *Sufficient and necessary conditions for perpetual multi-assets exchange options*

Analytical models of investment under uncertainty usually determine simultaneously the stopping rule and the value of the project via the resolution of optimal stopping problems. For mathematical tractability, they are usually constrained to use a single uncertainty for price modeling. Indeed multi-asset optimal stopping problems are hard to solve. Even for the simplest multi-asset optimal stopping problem (the optimal exercise of a perpetual basket of log-Brownian motions) at best can one give sufficient and necessary conditions for optimal stopping.
This suggests that one should not look for optimal investment rule for multi-asset investment problems: they are out of range. Nevertheless, the determination of sufficient and necessary conditions for optimal investment appears often feasible.
The idea of this paper is the following. Optimal investment in a power plant of state variable $x \in \Re^n$ (the prices and costs) consists in solving successively the two Problems: (1) find the net present value NPV(x) of the plant; (2) find the value of the investment opportunity which supposes a determination of the optimal investment timing i.e. to solve a discounted optimal stopping problem of reward function NPV(x).
We propose the following procedure to solve those two problems:

(i) (Forward) Monte Carlo simulations are used to find an estimator of NPV($x_i$) for a sample $(x_i)_{i=1,\dots,N}$ of x.

(ii) A regression of the NPV function (based on the sample $(x_i)_{i=1,\dots,N}$) is used to solve Problem (2): the reward NPV should be developed in a serie of analytical functions allowing the determination of sufficient or necessary conditions for optimal stopping.

Regression models are proposed and illustrated in various examples.

**9 Frowin Schulz** (University of Cologne)**:** *Understanding Time-Varying Risk of Electricity Forwards: Trading Activity and News Announcements*

In this study, we elaborate economic explanations for times of high (low) risk of month, quarter and year electricity forward contracts traded on the Nord Pool Energy Exchange from January 2006 to March 2010. Daily risk quantities are generated by decomposing realized volatility in its continuous and discontinuous jump component. First, we analyze the relation between volatility and trading activity. Coherent with existing studies we find that the driving factor of the relation between continuous variation and trading activity is the number of trades. New empirical findings are revealed by considering the relation between the jump factor and trading activity. Our results indicate that the number of trades and absolute order imbalance, which can be explicitly measured in our dataset, are positively related to the jump factor. These results are in line with theoretical market microstructure models. The second investigation is to identify unscheduled news announcements which are expected to cause a rise in volatility. For this, we create a unique dataset of urgent market messages (UMMs), published by the Nord Pool Energy Exchange. We extract relevant unscheduled UMMs, here failures, from both transmission system operators (TSOs) and market participants (MPs), and measure their impact over varying time windows. We find that certain unscheduled UMMs from TSOs (MPs) have a significant impact on continuous variation, especially when the UMM is published close to maturity or the contract is a month forward. The jump factor of each contract can be linked to the relevant unscheduled UMMs from TSOs (MPs).

**10 Johannes Müller** (University of Erlangen)**:** *On Clearing Coupled Day-Ahead Electricity Markets*

The European power grid can be divided into several market areas where the price of electricity is determined in a day-ahead auction. Market participants can provide continuous hourly bid curves and combinatorial bids with associated quantities given the prices. The goal of the auction is to determine cross-border flow and market clearing prices. Whereas this can be done rather efficiently in the absence of combinatorial structure, in the case of electricity markets the determination of a market clearing price is hard.

We present and solve a non-discriminatory market model to determine clearing prices that maximize the economic surplus of all participants.

The determined prices are consistent throughout the market areas. At first it would seem that one price for all market areas is appropriate. This however is not true. We will explain these price differentials as consequences of the underlying optimization problem.

**11 Gauthier de Maere d'Aertrycke** (CORE / Université catholique de Louvain)**:** *Liquidity Risks on Power Exchanges*

The extreme volatility of electricity makes its financial derivatives crucial instruments for asset managers. Even if the volume of derivative contracts has been growing since the inception of the restructuring, electricity remains considerably less liquid than other commodity markets. This paper assesses the effect of limited liquidity in power exchanges using an equilibrium model where agents cannot hedge up to their desired level. Mathematically, the problem is formulated as a two stage stochastic Generalized Nash Equilibrium with possibly multiple equilibriums. Computing a large panel of solutions, we show how the risk premium and players' profits are affected by illiquidity.

**12 Jukka Lempa** (CMA, University of Oslo)**:** *On Optimal Exercise Of Swing Options In Electricity Markets*

We study the optimal exercise of a swing option in electricity markets. To this end, we set up a model in terms of a stochastic control problem. In this model, the option can be exercised in continuous time and is subject to a total volume constraint. We analyze some fundamental properties of the model and carry out a numerical analysis. Finally, the results are illustrated numerically.

**13 Brenda Lopez Cabrera** (Humboldt University Berlin)**:** *Localizing temperature risk*

On the temperature derivative market, modelling temperature volatility is an important issue for pricing and hedging. In order to apply financial mathematics, one needs to isolate a Gaussian risk factor. A conventional model for temperature dynamics is a stochastic model with seasonality and inter-temporal autocorrelation. Empirical work based on seasonality and autocorrelation correction reveals that the obtained residuals are heteroscedastic with a periodic pattern. The object of this research is to estimate this heteroscedastic function so that after scale normalization a pure standardized Gaussian variable appears. Earlier work investigated this temperature risk in different locations and showed that neither parametric component functions nor a local linear smoother with constant smoothing parameter are flexible enough to generally describe the volatility process well. Therefore, we consider a local adaptive modelling approach to find at each time point, an optimal smoothing parameter to locally estimate the seasonality and volatility. Our approach provides a more flexible and accurate fitting procedure of temperature risk process by achieving excellent normal risk factors.

**14 Peter Schuetterle** (E.ON)**:** *Valuation of VPP contracts under a lognormal swap market model*

In the wake of increasing liquidity of European power and gas markets we observe a strong interest among market players to push the forward hedging of power generation assets to the next level of sophistication.
Selling VPP (virtual power plants) contracts against their asset parks generators can capture asset value beyond the bare lock-in of the intrinsic levels by also monetising the asset embedded time value reflected by the volatility and correlation structure of the joint dynamics of the underlying fuel and power prices. On the other hand there is also a keen interest in VPP products from speculators and banks as they look to diversify their investment portfolios adding energy exposure without the need for going physical. With the rising interest in these "paper plant" contracts, currently still traded OTC only, we expect a strong liquidity pick up for VPPs even beyond the broker market and see these instruments to increasingly become traded standard products.
In the light of this development we present a transparent approach to the pricing of VPPs under a multifactor swap market model. A given VPP contract is decomposed into strips of daily/hourly

spread options. Following a similar route as taken by the Libor models of the interest world we value the individual spread options in the strip based on tradable forward products with different granularities seen in the current market structure.
We further assume a time dependent, deterministic volatility and correlation structure. The availability of implied volatilities from the forward options market allows us to calibrate the model volatilities consistent with the market implied volatility for each commodity underlying the spread over the life of a respective reference swaption.

**15 Christian Redl** (Vienna University of Technology)**:** *Components of the Forward Market Premium in Electricity*

This paper presents a multifactor empirical analysis of the determinants of the realised premia in forward prices for electricity, when compared to their associated spot prices. Starting from a wide-ranging taxonomy of factors involving fundamental, behavioural, dynamic, market conduct and shock components, a number of propositions are examined econometrically on a long data set from the most liquid of European forward markets, the EEX. We show that much of what is conventionally regarded as the price of electricity market risk is actually that of its underlying fuel commodity, gas; that market power has a double effect on prices, notwithstanding the theoretical precompetitive properties of forward trading, insofar as it increases spot prices and the forward premium; that oil price sentiment spills over and that these premia react in an positive way to scarcity and the higher moments of spot price uncertainty.

**16 Daniel Schwarz** (University of Oxford)**:** *Risk-Neutral Pricing of Financial Instruments in Emission Markets - A Hybrid Approach*

We present a novel approach to the pricing of financial instruments in emission markets, for example, the EU ETS. The proposed hybrid model is positioned between existing complex full equilibrium models and pure risk-neutral models. Using an exogenously specified demand for a polluting good it gives a causal explanation for the accumulation of $CO_2$ emissions and takes into account the feedback effect from the cost of carbon to the rate at which the market emits $CO_2$. We derive forward-backward stochastic differential equations for the price processes of allowance certificates and derivatives written on them and solve the associated semilinear partial differential equations numerically. The model is extended to emission markets with multiple compliance periods and we analyze the impact different intertemporal connecting mechanisms, such as borrowing, banking and withdrawal, have on the allowance price.

**17 Almut Veraart** (Aarhus University)**:** *Modelling electricity forward markets by ambit fields*

This paper proposes a new modelling framework for electricity forward markets, which is based on ambit fields. The new model can capture many of the stylised facts observed in energy markets. One of the main differences to the traditional models lies in the fact that we do not model the dynamics, but the forward price directly, where we focus on models which are *stationary* in time. We give a detailed account on the probabilistic properties of the new model and we discuss martingale conditions and change of measure within the new model class. Also, we derive a model for the spot price which is obtained from the forward model through a limiting argument.
This is joint work with Ole E. Barndorff-Nielsen (Aarhus University) and Fred Espen Benth (University of Oslo).

**18 Carlos Pinho** (Universidade de Aveiro)**:** *$CO_2$ spot and futures price analysis for EEX and ECX*

In this work we analyze, explore and measure two of the most important concepts for the theory of storable commodity markets. After analyzing the statistical properties of spot and futures EU ETS allowances for Germany and France, we model and test the risk premium and convenience yield for $CO_2$ contracts accordingly to previous economic theories, for the period 2005-2009. Results indicate that convenience yields are positively related to the spot $CO_2$ return while being negatively influenced by the spot volatility. This negative impact of spot volatility is also verified for the risk premium, with the latter varying positively with time to maturity. Contradicting previous empirical findings, we found only a positive influence of the convenience yield on the risk premium for the ECX French market and for Phase II contracts, leading us to conclude that results are Phase, market and data span dependent. Moreover, results are independent on the volatility forecast used and important for risk management purposes for allowances markets participants. Moreover, day-ahead markets for $CO_2$ are in "normal contango" for the entire data period under analysis, contrary to previous empirical findings for the allowances market.

**19 Tobias Federico** (Energy Brainpool)**:** *Interaction of spot and future prices for electricity*

The most common expression regarding power price forecast in the market is “the best forecast of future electricity prices is the today’s future derivative price”. This sentence is referring to the potential development of the yearly average spot price in the future in comparison to the today’s traded derivative prices of a yearly delivery of electricity for the same period. But how good has the forecast been and what type of models can be used in the electricity market to describe these interactions?
Deviations between future prices and today’s spot prices beside the interest rate and the storage cost of energy commodities, which can be stored, are very often described with the convenience yield. The convenience yield is the premium of having the physical commodity in hand in comparison to a future potential delivery contract. In electricity trading the convenience yield is not applicable, because electricity cannot be stored efficiently. The today’s future price is therefore the expectation value of future spot market prices and strongly dependent on the supply and demand situation in the future. Nevertheless, today’s future price is seen as a good forecast of spot prices. Describing the fair value of future spot market delivery and addition premium for risks and securities is one of the big challenges in modeling electricity prices.
The presentation will show that first the future prices are not very good forecaster and second in practice two main parameters are influencing the future derivative prices. One parameter seems to be the historical spot prices of the last 12 month and the other parameter are technical support and resistance lines which cannot be reflected by fundamental parameters. The settlement prices of the Phelix Future Base Year (F1BY) contract of delivery Jan 10 and Jan 11 at the EEX and the EPEX hourly market clearing prices of the delivery area 1 (Germany and Austria) as underlying of the Phelix future will be the showcase.

**20 Mara Madaleno** (Universidade de Aveiro)**:** *Hedging with $CO_2$ allowances: the ECX market*

We investigate and empirically estimate optimal hedge ratios, for the first time, in the EU ETS carbon market. Minimum variance hedge ratios are conditionally estimated with multivariate GARCH models and unconditionally by OLS and the naïve strategy for the European Climate Exchange (ECX) market in the period 2005-2009. Also, utility gains are considered in order to take into account risk-return considerations. Empirical results indicate that dynamic hedging provides superior gains (in reducing

the variance portfolio) compared to those obtained from static hedging, when adjustment costs are not taken into account. Moreover, results improve when the leptokurtic characteristics of the data are into consideration through distributions. Results are always compared in and out of sample, suggesting also that utility gains increase with investor's increased preference over risk.

**21 Richard Biegler-König** (Ulm University)**:** *The Information Premium in Electricity Markets*

In order to explain the relationship between spot and forward prices, i.e. the risk premium, we introduce the notion of the information premium. This premium is defined to be the influence of future information not incorporated in spot prices but taken into consideration when pricing forwards. Considering electricity as the underlying the existence of the information premium can be justified by the invalidity of the Efficient Markets Hypothesis and thus the breaking down of the usual spot-forward relationship. It is possible to deduce some nice analytical properties of the premium making good use of the theory of initial enlargement of filtrations. In this talk, though, we will bring forward an exhaustive empirical demonstration of the existence of the information premium. The properties of the premium are verified by means of a new and specially designed method. As a reference market situation the beginning of 2008 on the German EEX is considered exhibiting a significant information premium due to the introduction of $CO_2$ certificates. Additionally, we will provide an estimate of the value and an analysis of the properties of the information premium. Generally, we argue that this method is also applicable to traditional underlyings and contributes to the ongoing discussion about the nature of the risk premium.

**22 Stefan Giebel / Martin Rainer** (University of Luxembourg / ENAMEC)**:** *Stochastic estimation of energy resources and prices via neural network adapted stable processes*

A neural network calibrated stochastic model including a stable process is applied to predict day ahead values of energy resources and prices. We use a fixed memory horizon (e.g. 10 business days). The model is training neural perceptron layers to learn the weights of historical time series points within a past horizon equal to the the memory depth (e.g. previous 10 business days). With this weights, the parameters of the stochastic model are optimized, and the day ahead gas price and the velocity of wind are computed. Iterating these steps, we obtain forecasts, which demonstrate the learning efficiency of our method on gas prices and the velocity of wind, which essentially corresponds to a stochastic process with time-dependent parameters, the dynamics of the parameters being themselves learned continuously by the neural network. The back propagation in training the previous weights is limited by the memory depth. The latter is the analogue of the maximal time lag of an autoregressive processes.
This is joint work with Chitro Majumdar.

**23 Arne Andresen, Johan Magne Sollie** (Norwegian University of Science and Technology)**:** *A Commodity Spot Price Model with Short-, Medium- and Long-Term Components*

We present a multivariate commodity spot price model and demonstrate the calibration process by fitting the model to data from the Nordic power market and the price of ICE Brent oil. The model is in the spirit of Schwartz and Smith (2000), where we allow the short-term factor to be a multivariate Ornstein-Uhlenbeck process. This implies that the equilibrium level of the short term factor evolves as the sum of possibly correlated Ornstein-Uhlenbeck processes. The structure of the process allows for separation of short-, medium- and long-term effects on the spot price. We show how the model can be fitted to data by a simple Kalman filter procedure. Our model outperforms the two factor

model by Schwartz and Smith (2000) as it provides better out of sample and in sample fit for both the Nord Pool and ICE data.

**24 Takashi Kanamura** (J-POWER)**:** *Convenience Yield-Based Pricing of Commodity Futures*

This paper proposes a convenience yield-based pricing for commodity futures, which embeds the incompleteness of commodity futures markets in convenience yield. By using the pricing method, we conduct empirical analyses of crude oil, heating oil, and natural gas futures traded on the NYMEX in order to assess the incompleteness of energy futures markets. We show that the fluctuation from incompleteness is partly owed to the fluctuation from convenience yield. In addition, it is shown that the additional Sharpe ratio, which represents the degree of market incompleteness and is also used for derivative pricing written on energy prices, is obtained from the NYMEX data. Then, we apply the implied market price of risk to the pricing of Asian call option on crude oil futures. As an empirical example, we try to compute the call option price using the parameters estimated from crude oil futures prices.

**25 Stefan Schneider** (E.ON Energy Trading)**:** *Power spot price models with negative prices*

Negative prices for electricity are a novelty in European power markets. At EEX negative hourly prices have since occurred frequently, down to values as extreme as minus several hundred €/MWh. However, in some non-European markets as USA, Australia and Canada, negative prices are a characteristic for a longer period already. Negative prices are in fact natural for electricity spot: plant flexibility is limited, thus, incurring negative price for an hour can nevertheless be economically optimal overall.
Negative prices pose a basic problem to stochastic price modelling: going from prices to log-prices is not possible. So far, this has been “fixed” by workarounds. However, I advocate a thorough approach, based on the area hyperbolic sine transformation. I apply the transformation to spot modelling of the German EEX and the ERCOT West Texas market and the exemplary valuation of an option.
Conclusion: The area hyperbolic sine transform is well and naturally suited as a starting point for modelling negative power prices. It can be integrated in common stochastic price models without adding much complexity. Moreover, this transformation might be in general more appropriate for power prices than the log transformation, considering fundamentals of power price formation. Eventually, a thorough treatment of negative prices is indispensable since they significantly affect business.

**26 Alexander Boogert** (University of London / KYOS Energy Consulting)**:** *Gas storage valuation using a multi-factor price process*

In this paper we discuss an extension to a popular gas storage valuation method called the spot approach. Least-Squares Monte Carlo, which is the basis for the spot approach, allows for multi-factor price processes. Such price processes can capture more realistically the actual price behavior present in energy markets. In this paper we demonstrate the application of multi-factor Least-Squares Monte Carlo to gas storage valuation. We study the impact of using multi-factor price processes on different aspects of the valuation such as convergence, average storage value and distribution of storage values in a numerical example. We find a counter example to the idea that an increase in market volatility leads to an increase in storage value. As well, we find a counter example to the idea that the natural hedging strategy of the spot approach is no hedge: a simple static

financial hedge can reduce the inherent risk of the spot approach. Finally, we find that in case not the complete forward curve dynamics is taken into account in the optimization, a suboptimal trading strategy is derived.

**27 Linda Vos** (CMA, University of Oslo)**:** *Modeling electricity prices: spots, forwards and the risk premium*

Since the liberalization of the energy market questions have popped up, about the modeling of the observed price curves. In this talk I will present a reasonable model in order to model the spot curve and the forward dynamics and describes a proper relationship between them.
We work with an alpha-stable CARMA-process (contimuous time ARMA process). When working with stable processes the second moment does not exist which creates a challenge in estimating and pricing.
We introduce a non-stationary term which in the description of the trend. This leads to a precise description of the risk-premium. From an empirical analysis of the risk-premium we conclude that the risk-premium is negative and linearly decaying towards maturity. This implies that the market is dominated by electricity producers.

**28 Dmitry Lesnik** (RWE)**:** *Storage option: an Analytic approach*

In our work we provide an approximate analytic solution for the storage problem. Though not exact, this solution provides a deep insight into the problem, revealing the most significant of its characteristic peculiarities. In particular we investigate the storage option time value and its dependency on the price process parameters.
The approach is based on the formulation of the optimisation problem in terms of variational analysis. First we give a solution of an intrinsic problem, and discuss how the solution depends on the different operational and financial constraints. Then we develop a perturbation analysis to solve the stochastic problem. We derive an analytic expression for the time value of storage and swing options, and conduct an example evaluation of a simple storage and swing contracts with one-factor price process. We demonstrate a difference between storage and swing options and identify the range of parameters, where the difference is significant. We also perform a comparison of analytical formula with a numerical simulation which reveals a satisfactory agreement.

**29 Carlo Lucheroni** (University of Camerino)**:** *A SETARX model for spikes and antispikes in electricity markets*

In this talk, two threshold nonlinear hybrid models for electricity prices will be presented, that use a Hopf critical point stochastic dynamics to generate price spikes, and that are able to include in their degrees of freedom typical and more general tight markets behavior. The models will be presented in the frame of TARX (Threshold AutoRegressive eXternally driven) and switching regime modelling of electricity time series and they will be shown to take into account some basic but essential microeconomic features of real power markets.
The major microeconomic feature considered is the presence in the electricity market of some factors, like capacity constraints and the effect of power grid congestions that can act on prices at varying levels of demand. These factors introduce a demand threshold in the price formation mechanism. Below the threshold prices react smoothly to demand variations, above the threshold prices can react in a non-smooth way, with spike-like patterns.
In a three-regimes SETARX (Self-Excited TARX) model, whereas one ARX sector is set in the usual stable regime, two other sectors are set respectively in unstable and metastable regimes in a specific

sequence. These two not-stable regimes together allow for nonlinear deviations from the stable regime, allowing of spikes. TARX self-excitation avoids linking the regime thresholds to data different from the prices themselves, and demand data are unnecessary to calibration as far as a sinusoidal driver is embedded in the model. If desired, real world demand data can be used as an external driver process in substitution of the embedded driver. Grid effects, capacity constraints and the presence of a forward market can be assumed at the origin of threshold effect and spikes. Antispikes can be modeled using a five-regimes SETARX.

**30 Volker Termath** (24/7 Trading)**:** *Hedging and Optimizing Gas Storage from a Trader's Perspective*

Theory and development of a fast optimization and hedging framework for gas storage assets based on energy trading strategies is presented. The following aspects are considered

- physical constraints of gas storage
- forward curve models: static and dynamic
- intrinsic hedge
- rolling intrinsic hedge
- stochastics and time value of storage
- algorithm and implementation
- market value of storage