Energy Trading

Lecture - Summer 2014

Professor Dr. Rüdiger Kiesel | Chair for Energy Trading and Finance | University of Duisburg-Essen

Agenda

Markets and Objects

- Energy Markets and Basic Objects
- Energy Trading
- Specific Derivatives

Liberalisation

The German Electricity market went into Liberalization in April 1998.
The Pre - Liberalisation system was based on calculatory costs: the price was according to the 'cost-plus' rule

- Integrated value-chain: production, grid, distribution
- Electricity production to secure supply within a regional monopole
- Long-term supply contracts
- No liquid market on the whole sale market
- Regulated consumer prices, regulated investments

Liberalisation

Post - Liberalisation system based on forces of market: higher volatility of prices, flexibility has value.

- Unbundling of value-chain
- Power plants are used optimally – no obligation to secure supply
- New players and products
- Trading in Long- and Short-positions on a liquid whole sale market
- Investments based on market expectations

Forwards and Futures

- A *forward contract* is an agreement to buy or sell an asset S at a certain future date T for a certain price K.
- The agent who agrees to buy the underlying asset is said to have a *long* position, the other agent assumes a *short* position.
- The settlement date is called *delivery date* and the specified price is referred to as *delivery price*.

Forwards

- The *forward price* $F(t, T)$ is the delivery price which would make the contract have zero value at time t.
- At the time the contract is set up, $t = 0$, the forward price therefore equals the delivery price, hence $F(0, T) = K$.
- The forward prices $F(t, T)$ need not (and will not) necessarily be equal to the delivery price K during the life-time of the contract.

Forwards

- The payoff from a long position in a forward contract on one unit of an asset with price $S(T)$ at the maturity of the contract is
$$S(T) - K.$$
- The investor now faces a downside risk as well as an upside opportunity. He has the obligation to buy the asset for price K.

Futures

- Futures can be defined as standardized forward contracts traded at exchanges where a clearing house acts as a central counterparty for all transactions.
- Usually an initial margin is paid as a guarantee.
- Each trading day a settlement price is determined and gains or losses are immediately realized at a margin account.
- Thus credit risk is eliminated, but there is exposure to interest rate risk.

Options

- An option is a financial instrument giving one the *right but not the obligation* to make a specified transaction at (or by) a specified date at a specified price.
- *Call* options give one the right to buy an underlying. *Put* options give one the right to sell.
- *European* options give one the right to buy/sell on the specified date, the expiry date, on which the option expires or matures. *American* options give one the right to buy/sell at any time prior to or at expiry.

European Call Price

For a European call $X = (S(T) - K)^+$ with a spot underlying S we have in the Black-Scholes model the explicit price process of a European call given by

$$
\begin{aligned}
C^S(t) &= S(t)\Phi(d_1(S(t), T-t)) \\
&\quad -Ke^{-r(T-t)}\Phi(d_2(S(t), T-t)).
\end{aligned}
$$

The functions $d_1(s, \tau)$ and $d_2(s, \tau)$ are given by

$$
\begin{aligned}
d_1(s, \tau) &= \frac{\log(s/K) + (r + \frac{\sigma^2}{2})\tau}{\sigma\sqrt{\tau}}, \\
d_2(s, \tau) &= \frac{\log(s/K) + (r - \frac{\sigma^2}{2})\tau}{\sigma\sqrt{\tau}}
\end{aligned}
$$

Φ is the standard normal distribution function.

Black's Formula

In Black's futures model the price C^f of a European call option with a futures (forward) as underlying is given by Black's futures options formula:

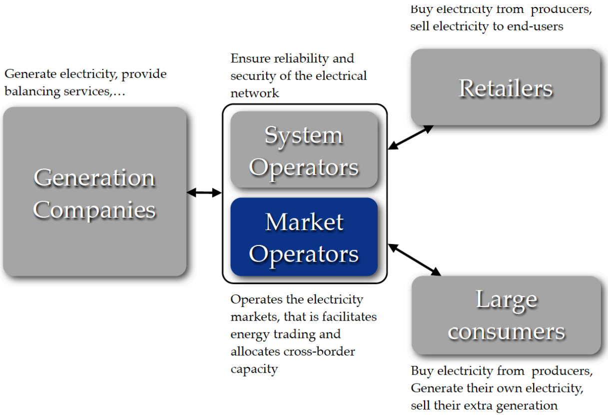
$$C^f(f, T-t) = e^{-r(T-t)}(f\Phi(d_1^f(f, T-t)) - K\Phi(d_2^f(f, T-t))),$$

where

$$d_{1,2}^f(f, \tau) := \frac{\log(f/K) \pm \frac{1}{2}\sigma^2\tau}{\sigma\sqrt{\tau}}.$$

We may use $C_{\mathrm{BS}}(S, K, \sigma_S, \tau)$ as a general reference for the Black-Scholes formula.

Organisation of the Power System



System Balancing

- The transmission system operator (TSO) has the task to match demand and supply (to balance the system).
- The TSO defines a balancing period (15 minutes in Germany), which is the granularity of the measured electric energy supply and during which a constant power supply takes place (by the energy merchant).
- The power balancing during the balancing period (not smaller than the granularity, in Germany an hour) is the task of the TSO.
- The TSO usually has no own generation capacities and has to act on the reserve market to compensate imbalances.

Balancing and Reserve Markets

We use the following definitions

- Reserve Market: allows the TSO to purchase the products needed for compensating imbalances between supply and demand
- Balancing Market: allows merchants to purchase or sell additional energy for balancing their accounting grid. Typically, the only market partner is the TSO.

Balancing and Reserve Markets

In Europe, the *European Network of Transmission System Operators for Electricity,(ENTSO-E)* coordinates overarching grid topics. The main task of a TSO is to ensure a constant power frequency in the transmission system. The following control actions are applied

- *Primary Reserve* starts within seconds as a joined action of all TSOs in the system.
- *Secondary Reserve* replaces the primary reserve after a few minutes and is put into action by the responsible TSOs only.
- *Tertiary Reserve* frees secondary reserves by rescheduling generation by the responsible TSOs.

The TSO tenders the required products for fulfilling these functions. Reserve products may involve payments for the availability of the reserved capacity.

Market Coupling

- Neighbouring electricity markets are typically coupled via transmission capacities owned by the TSOs.
- Transmission capacities can be integrated in the price finding algorithm of cooperating exchanges via implicit auctioning.
- With implicit auctions players do not receive allocations of cross-border capacity themselves but bid for energy on their Exchange. The Exchanges then use the available cross-border transmission capacity to minimize the price difference between two or more areas.
- Currently, the Central Western Europe (CWE) initiative couples Belgium, France, the Netherlands, Germany and Luxemburg.

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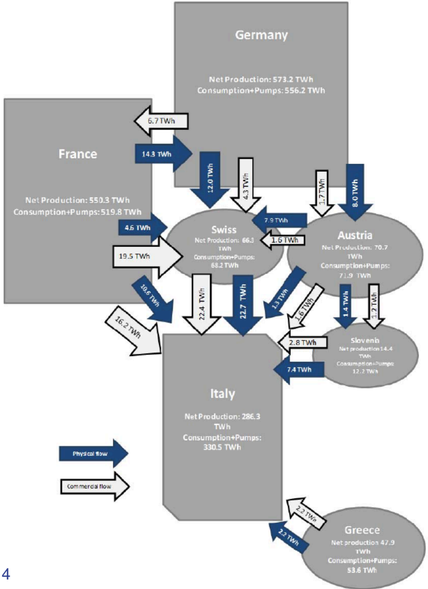
Market Coupling



MARKET COUPLING
TOWARDS THE UNITED DAY-AHEAD MARKETS OF EUROPE

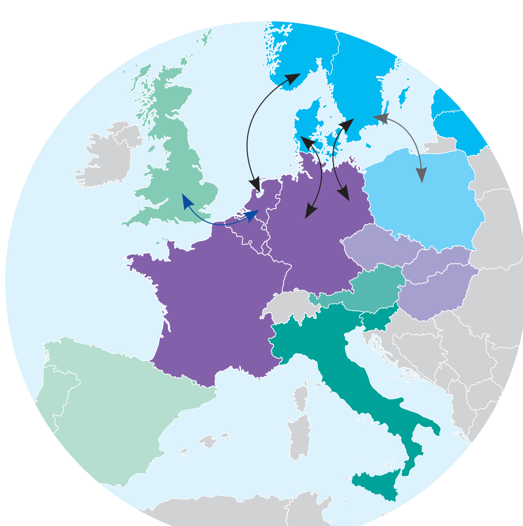
EUROPE'S POWER SECTOR IS ABOUT TO BENEFIT FROM AN UNPRECEDENTED SOLUTION. NATIONAL, ONCE ISOLATED POWER MARKETS ARE BEING COUPLED. THIS INTEGRATION WILL LEAD TO A NETWORK OF INTERDEPENDENT DAY-AHEAD MARKETS. EPEX SPOT FINDS ITSELF AT THE HEART OF THE PROCESS.

The integration of the European power market is a project of prestige and significance. Yet, its first step is somewhat unspectacular: pressing a grey button. Every day at noon, in an office in France or Germany, an EPEX SPOT operator sits in front of two screens, monitors the automated calculation of power market results and then, at 12h40 p.m., clicks this grey button on the screen. This click takes place after a highly complex auction mechanism at the Power Exchanges collecting orders from trading members within Central Western Europe. It might only be a tiny button; yet pushing it has an impact on hundreds of power traders, thousands of people in the European power sector and the lives of millions of Europeans.

Clicking this very button publishes wholesale power prices on German, French and Austrian markets for the following day. These three countries, together with EPEX SPOT's Swiss market calculated one hour sooner, account for more than one third of total European power consumption.

The prices calculated on EPEX SPOT's market provide the orientation and basis for the negotiation of power trading contracts across Europe.

MARKET COUPLING: CURRENT STATUS



Regional implicit auctions

CWE	Price Coupling
Austria	1 AT Power Exchange price coupled to DE (no congestion)
Great Britain	1 GB Power Exchange price coupled to NL via BritNed only
Nordics	Price Coupling (Latvia included as own area in 2013)
Poland	Volume Coupling with Nordics via SwePol
ITVC + NorNed	Volume Coupling CWE-Nordics
Italy-Slovenia	Price Coupling
Spain-Portugal	Price Coupling
Czech Republic-Slovakia-Hungary	Price Coupling

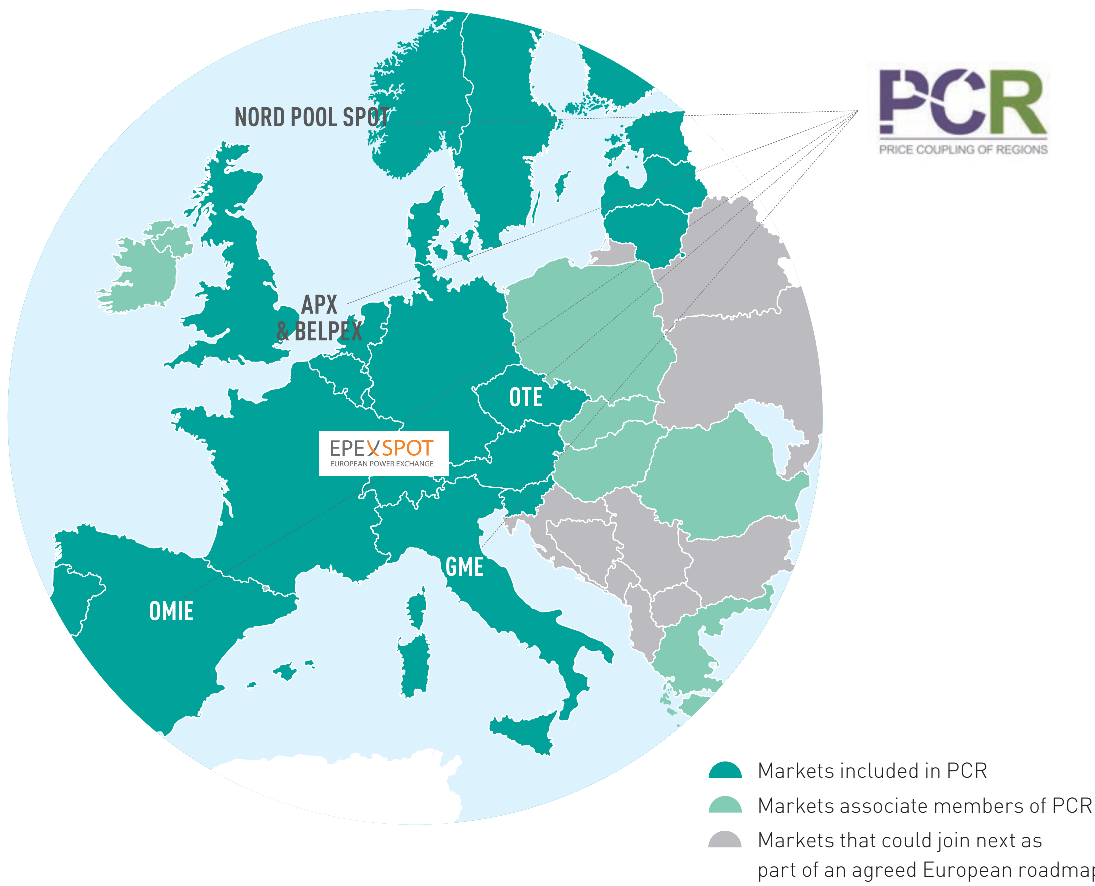
Simultaneously, prices on the German and French markets interact extensively with those in Belgium and the Netherlands, as these four markets are coupled. They were the first power markets in Europe to do so, and they are a blueprint for the whole of Europe: Market Coupling in Central Western Europe, involving Germany, France and the Benelux countries, is the first step of integrating the European power market, to put national, isolated markets together like pieces of a puzzle.

For the time being, most power markets in Europe are organized on national level. They are lone parts of the European puzzle, not yet integrated with their neighboring markets. Offer and demand are limited to capacity and consumption of the country. In tense situations, such as when consumption peaks or when too much power from fluctuating renewables like wind or sun is produced prices can rise quite high or fall below zero. In the latter case, producers have to pay the buyer of energy, instead of getting paid. In such exceptional situations, negative prices are nonetheless a functioning price signal, reflecting market fundamentals.

Market Coupling broadens offer and demand competition by extending it to a vaster territory. In order to achieve this, the available power transfer capacity between countries, a limited resource, is determined by transmission grid operators every morning. This cross-border capacity is then taken into account in the price calculation of the Power Exchange: Generally speaking, power will flow from low-price markets to with higher prices, until cross-border capacity is used a hundred per cent or prices between markets converge.

Buyers and sellers both benefit from this development – we call this the "social welfare". It consists of the overall sum of gains and losses both parties experience compared to isolated markets – they are always well above zero. In addition, extreme price fluctuations in one market tend to be softened by neighbouring markets as interdependence between markets rises by Market Coupling. For instance, Price peaks in case of a cold spell in thermo-sensitive France can be buffered by high wind input in Germany; vice versa, French nuclear power plants can help out on the German market when the wind is not blowing and the sun isn't shining.

TOWARDS THE SINGLE EUROPEAN MARKET: NEXT STEPS



Market Coupling in Central Western Europe was launched on 9 November 2010. It has proven to be robust and reliable. Trading participants as well as politics and regulators have approved this unprecedented achievement. In September 2012, EPEX SPOT helped coupled the power markets of the Czech Republic, Hungary and Slovakia by making available its state of the art technology, the price coupling solution used for France, Germany and Benelux, a second grey-button being clicked by an EPEX SPOT operator.

The pan-European integration of power markets, however, is a much bigger task. It necessitates a lot of energy, manpower and spirit of cooperation. The European Commission has declared 2014 to be the target date for pan-European Market Coupling. Power Exchanges, transmission system operators and national regulators from each country involved have to find common ground and collaborate closely – across borders, across languages, across sectors, across Europe. Ultimately, this means dozens of parties around the table, lots of discussions and more cumbersome decision-making proesses.

The Price Coupling of Regions (PCR) was designed to ease this integration process. Six major Power Exchanges, amongst them EPEX SPOT, teamed up to create a single price coupling solution which is compatible with the different European markets and respects most of their specific characteristics. After the concept was proven in 2010 and intensive design work was carried out in the last two years, PCR will deliver the technical solution in 2013. They will then be extensively tested and implemented step by step between groups of countries, starting in North Western Europe by the end of 2013.

Several of these so-called regional implementations of PCR, for example in North Western Europe – coupling the Nordic-Baltic countries and Central Western Europe plus Great Britain – or South Western Europe, integrating the Iberian Peninsula with France, are on their way. Some of them, like Price Coupling in North Western Europe, will go live in 2013. EPEX SPOT is involved in every single of these regional implementation projects, as our markets share borders or lie within the regions.

2013 is a decisive year for the integration of the European power market. One year from now, the power trading landscape in Europe will have profoundly changed. The day-ahead integration process enters the final stage. Soon, European integration, today best visible in the common currency and open borders, will have reached the power sector – and the united power markets of Europe will emerge.

Electricity Markets

A centralized platform where participants can exchange electricity transparently according to the price they are will to pay or receive, and according to the capacity of the electrical network.

- Fixed Gate Auction
  - Participants submit sell or buy orders for several areas, several hours,
  - the submissions are closed at a pre-specified time (closure)
  - the market is cleared.
  - Example: day-ahead.
- Continuous-time Auction
  - Participants continuously submit orders. Orders are stored,
  - Each time a deal is feasible, it is executed,
  - Example: intra-day.

Electricity Exchanges

Electricity related contracts can be traded at exchanges such as

- the Nord Pool, mainly Northern European countries, `http://www.nordpoolspot.com/`
- the European Energy Exchange (EEX), `http://www.eex.com/en`
- EPEX, located in Paris, founded by EEX and Powernext (French Energy Exchange); Electricity spot market for Germany, Austria, France and Switzerland; `http://www.epexspot.com/en/`
- Amsterdam Power Exchange (APX), covers the Netherlands, Belgium and the UK, `http://www.apxgroup.com`

EPEX SPOT: THE EUROPEAN POWER EXCHANGE

Europe is closing ranks in many ways, energy being one of the main drivers of the European integration process since its start in the 1950s. Today, organized market places like the European Power Exchange are facilitating the next wave of European energy integration.

At this very moment, Power Exchanges are **imagining** new contours for the future European Internal Energy Market, where electricity flows freely across borders, following precise price signals.

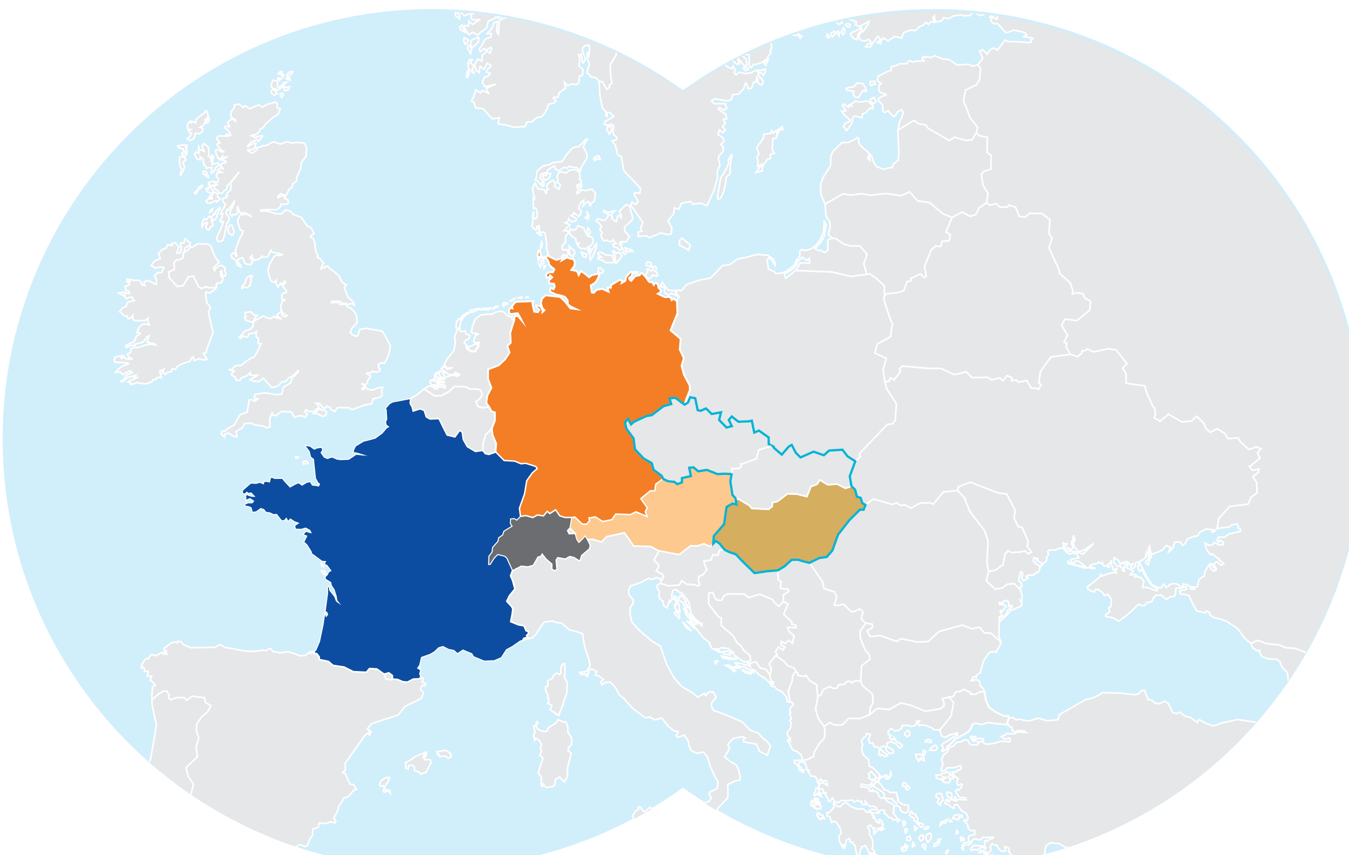
They are **building** transnational trading systems for Day-Ahead and Intraday markets as well as pan-European Market Coupling solutions, unprecedented and one of a kind achievements.

They are **answering** the needs of power producers, suppliers, transmission system operators, commercial consumers and other power trading companies by providing relevant price signals and innovative power trading products.

EPEX SPOT operates the Day-Ahead and Intraday power markets in Germany, France, Austria and Switzerland. One third of the total consumption of these countries is traded on our platforms. We provide our know-how in setting up and operating power trading systems to Power Exchanges around the world.

Energy markets in Europe are closing ranks – and we are at the core of this process.

KEY FACTS & FIGURES
THE EUROPEAN POWER EXCHANGE



EPEX SPOT MARKETS

Germany
Day-Ahead & Intraday

France
Day-Ahead & Intraday

Austria
Day-Ahead & Intraday

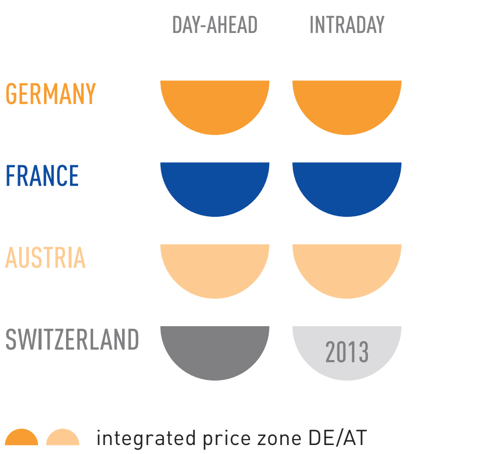
Switzerland
Day-Ahead (& Intraday 2013)

SERVICING OTHER EXCHANGES

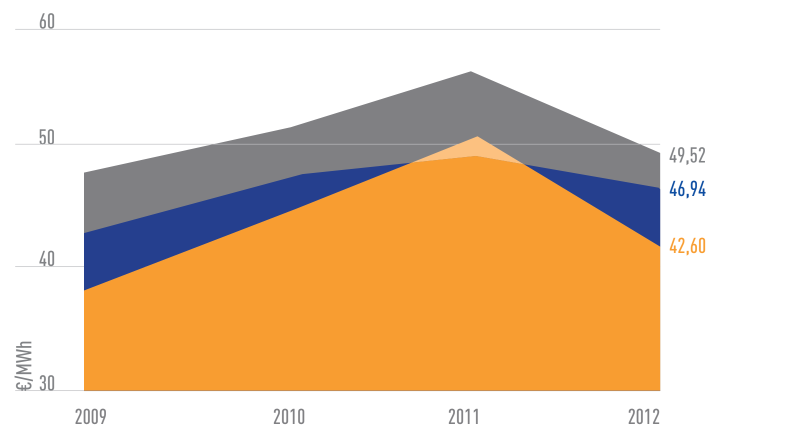
Market operation services for the Hungarian Power Exchange HUPX

Market coupling services for the Czech Power Exchange OTE, Slovakian OKTE and HUPX

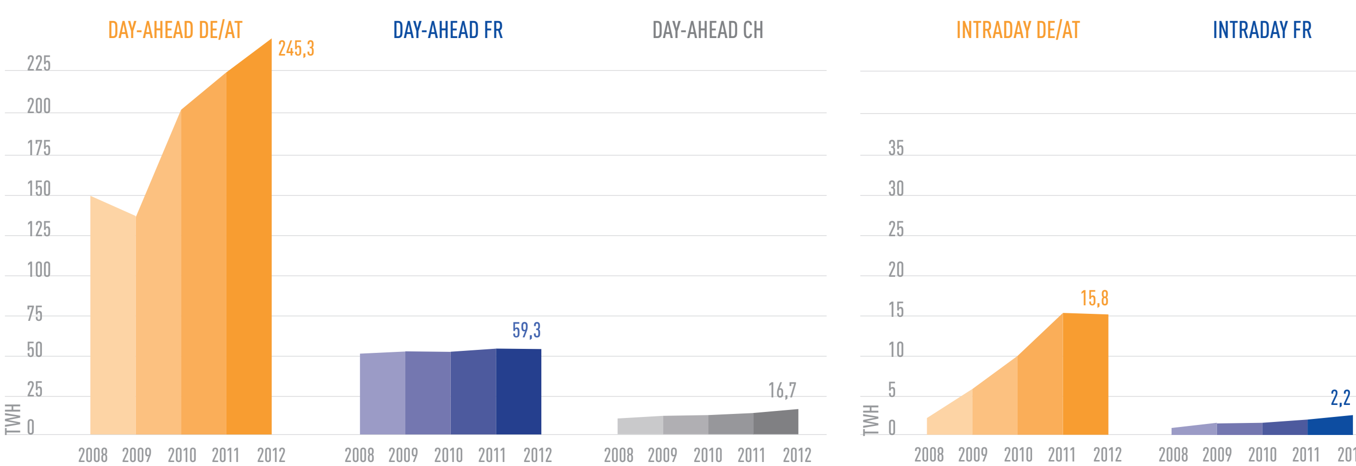
EPEX SPOT'S MARKETS: OVERVIEW



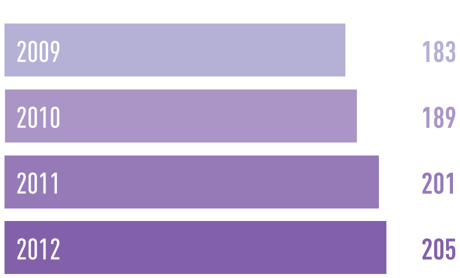
RELIABLE PRICES



339 TWH OF TRADED VOLUME IN 2012



205 EXCHANGE MEMBERS



EPEX – traded products

- Auction day-ahead and continuous intra-day market.
- Products are individual hours, baseload, peakload, blocks of contiguous hours.
- Intraday market is open 24 hours a day, 7 days a week and products can be traded until 45 minutes before delivery.
- in Germany 15 minutes contracts can be traded.

EEX – traded products

- Futures contracts for Germany and France with delivery periods week, month, quarter, year.
- For Germany single days and weekends are available.
- European style options on futures.

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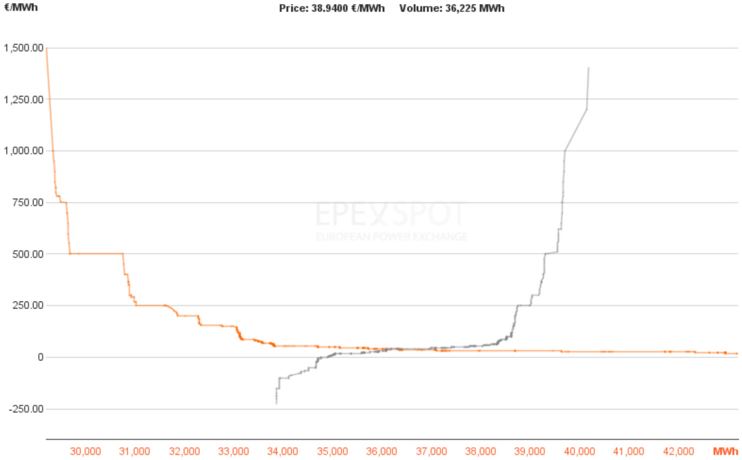
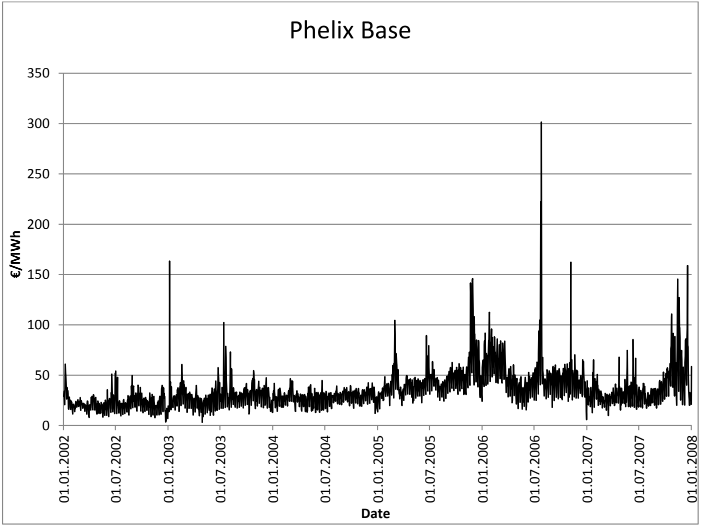
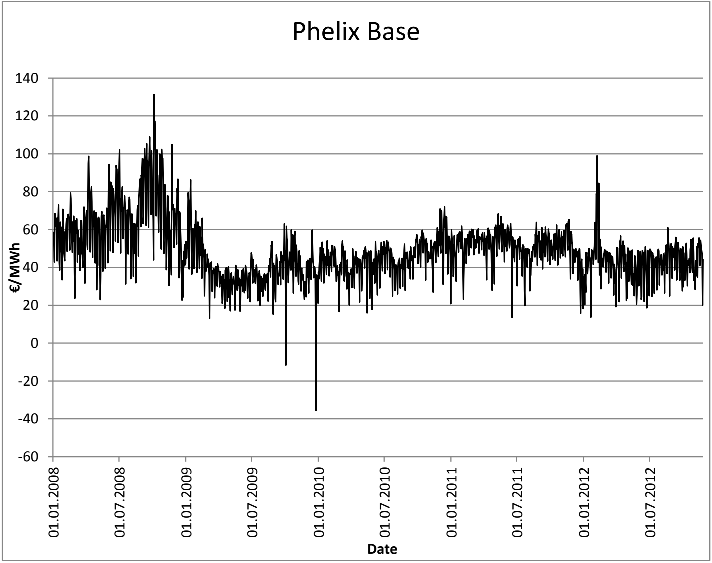
Auction EPEX



Spot prices


Phelix Base
350
300
250
200
150
100
50
0
€/MWh
01.01.2002
01.07.2002
01.01.2003
01.07.2003
01.01.2004
01.07.2004
01.01.2005
01.07.2005
01.01.2006
01.07.2006
01.01.2007
01.07.2007
01.01.2008
Date

Spot prices


Phelix Base
140
120
100
80
60
40
20
0
-20
-40
-60
€/MWh
01.01.2008
01.07.2008
01.01.2009
01.07.2009
01.01.2010
01.07.2010
01.01.2011
01.07.2011
01.01.2012
01.07.2012
Date

Swaps

- A *swap* is an agreement whereby two parties undertake to exchange, at known dates in the future, various financial assets (or cash flows) according to a prearranged formula that depends on the value of one or more underlying assets or a (commodity price) index.
- Swaps are very popular instruments and often offered by banks with a high liquidity for many commodities.
- If used for hedging the underlying index should have a close relation to the actual price of a physical commodity in question to keep the basis risk small.

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Example: Fixed for Floating Swap

Consider the case of a *forward swap settled in arrears* characterized by:

- a fixed time t, the contract time,
- dates $T_0 < T_1 < \ldots < T_n$, equally distanced $T_{i+1} - T_i = \delta$,
- R, a prespecified fixed price,
- K, a nominal amount.

Example: Fixed for Floating Swap

A swap contract S with K and R fixed for the period $T_0, \dots T_n$ is a sequence of payments, where the amount of money paid out at $T_{i+1},\ i = 0, \dots, n-1$ is defined by

$$X_{i+1} = K\delta(L(T_i, T_{i+1}) - R).$$

$L(T_i, T_{i+1})$ is the value of the index over $[T_i, T_{i+1}]$ observed at T_i.

Spread Options

Spread options can be used by owners of corresponding plants to manage market risk.
The pay off of a typical spread is

$$C^{(T)}_{\text{spread}} = \max(S_1(T) - S_2(T) - K, 0)$$

with S_i the underlyings, K the strike.

Spread Options

For $K = 0$ (exchange option) there is an analytic formula due to Margrabe (1978).

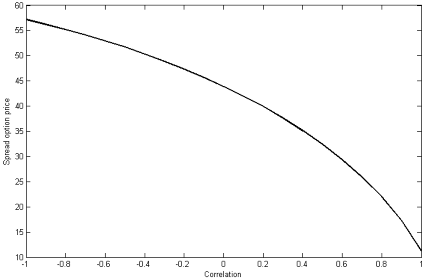
$$
\begin{aligned}
C_{\text{spread}}(t) &= e^{-r(T-t)}(S_1(t)\Phi(d_1) - S_2(t)\Phi(d_2)) \\
\text{where} \quad d_1 &= \frac{\log(S_1(t)/S_2(t)) + \sigma^2(T-t)/2}{\sqrt{\sigma^2(T-t)}} \quad , d_2 = d_1 - \sqrt{\sigma^2(T-t)} \\
\text{and} \quad \sigma &= \sqrt{\sigma_1^2 - 2\rho\sigma_1\sigma_2 + \sigma_2^2}
\end{aligned}
$$

where ρ is the correlation between the two underlyings.
For $K \neq 0$ no easy analytic formula is available.

Spread Option Value and Correlation

The value of a spread option depends strongly on the correlation between the two underlyings.

$S_1 = S_2 = 100$, $T = 3$, $r = 0.02$, $\sigma_1 = 0.6$, $\sigma_2 = 0.4$.



- The higher the correlation between the two underlyings the lower is the volatility of the spread and hence the value of the spread option.

Approximation by Kirk's Formula (3 Assets)

An accurate approximation formula for the three asset case is also given in E.Alos, A.Eydeland and P.Laurence, Energy Risk, (2011). Again for $r = 0$ we have for τ small the formula

$$C_{K3}(S_1(t), S_2(t), S_3(t), K, \tau) \approx C_{BS}(S_1(t), S_2(t) + S_3(t) + K, \sigma_S, \tau) \tag{1}$$

with

$$\sigma_S = \sqrt{\sigma_1^2 + b_2^2\sigma_2^2 + b_3^2\sigma_3^2 - 2\rho_{12}\sigma_1\sigma_2 b_2 - 2\rho_{13}\sigma_1\sigma_3 b_3 + 2\rho_{23}\sigma_2\sigma_3 b_2 b_3}$$

$$b_2 = \frac{S_2(t)}{S_2(t)+S_3(t)+K} \quad \text{and} \quad b_3 = \frac{S_3(t)}{S_2(t)+S_3(t)+K}$$

and ρ_{ij} is the correlation between the underlying i, j.

Basket Options

Assume underlyings

$$dS_i(t) = \mu_i S_i(t)dt + \sigma_i S_i(t)dW_i(t)$$

with $dW_i(t)dW_j(t) = \rho_{ij}dt$.
Here a basket of commodities is the underlying

$$B(t) = \sum_{i=1}^{m} w_i S_i(t).$$

In this model the forward price can be calculated as $F_i(0,T) = \mathbb{E}(S(T))$.

Basket Options – Example

Basket of energy prices related to power production

$$B(t) = 100 \times \left(30\% \frac{\mathrm{oil}(t)}{\mathrm{oil}(0)} + 30\% \frac{\mathrm{coal}(t)}{\mathrm{coal}(0)} + 40\% \frac{\mathrm{CO_2}(T)}{\mathrm{CO_2}(0)}\right).$$

At time 0 the basket is nomalized to 100. If the oil price increases by 100% the basket value increases by 30% to 130.

Basket Options

Pricing is not straightforward even in a BS-framework, since the sum of lognormals is not lognormal.
Typically a lognormal approximation is used, i.e.

$$\tilde{B}(T) = F_B \cdot \exp\left\{-\frac{1}{2}\beta^2 + \beta N)\right\} \quad N \sim \mathcal{N}(0,1).$$

Now

$$\begin{aligned}
\mathbb{E}(B(T)) &= \sum_{i=1}^{n} w_i F_i(0,T) \\
\mathbb{E}[B^2(T)] &= \sum_{i,j=1}^{n} w_i w_j F_i(0,T) F_j(0,T) \exp\{\rho_{ij}\sigma_i\sigma_j T\}
\end{aligned}$$

Basket Options

On the other hand

$$\mathbb{E}(\tilde{B}(T)) = F_B \quad \mathbb{E}(\tilde{B}^2(T)) = F_B^2 \exp(\beta^2).$$

Setting the first two moments equal

$$\begin{aligned} F_B &= \sum_{i=1}^{n} w_i F_i(0, T) \\ \beta^2 &= \log\left(\frac{\sum_{i,j=1}^{n} w_i w_j F_i(0,T) F_j(o,T) \exp\{\rho_{ij}\sigma_i\sigma_j T\}}{F_B^2} \right) \end{aligned}$$

Now Black's formula can be use on $\tilde{B}$.

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Basket Options- Example(continued)

With volatilities 0.3, 0.2 and 0.4 for Oil, Coal, CO2 and correlations $\varphi_{0C} = 0.1$, $\varphi_{0CO_2} = 0.6$, $\varphi_{CCO_2} = -0.2$ one gets for one year at the money calls

	price	imp vol.
MC	8,81	22.85%
Approx	8,95	23.16%

This implies a small pricing error, which s acceptable given the parameter uncertainty for σ_i and ρ_{ij}.