10th Winter School– Energy Markets

Lecture 1
An Introduction to Energy Markets

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Agenda

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, grit, 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

Markets

Since the deregulation of electricity markets at the end of the 1990s, power can be traded at exchanges like the Nordpool, http://www.nordpoolspot.com/ or the European Energy Exchange (EEX), http://www.eex.com/en. All exchanges have established spot and futures markets.

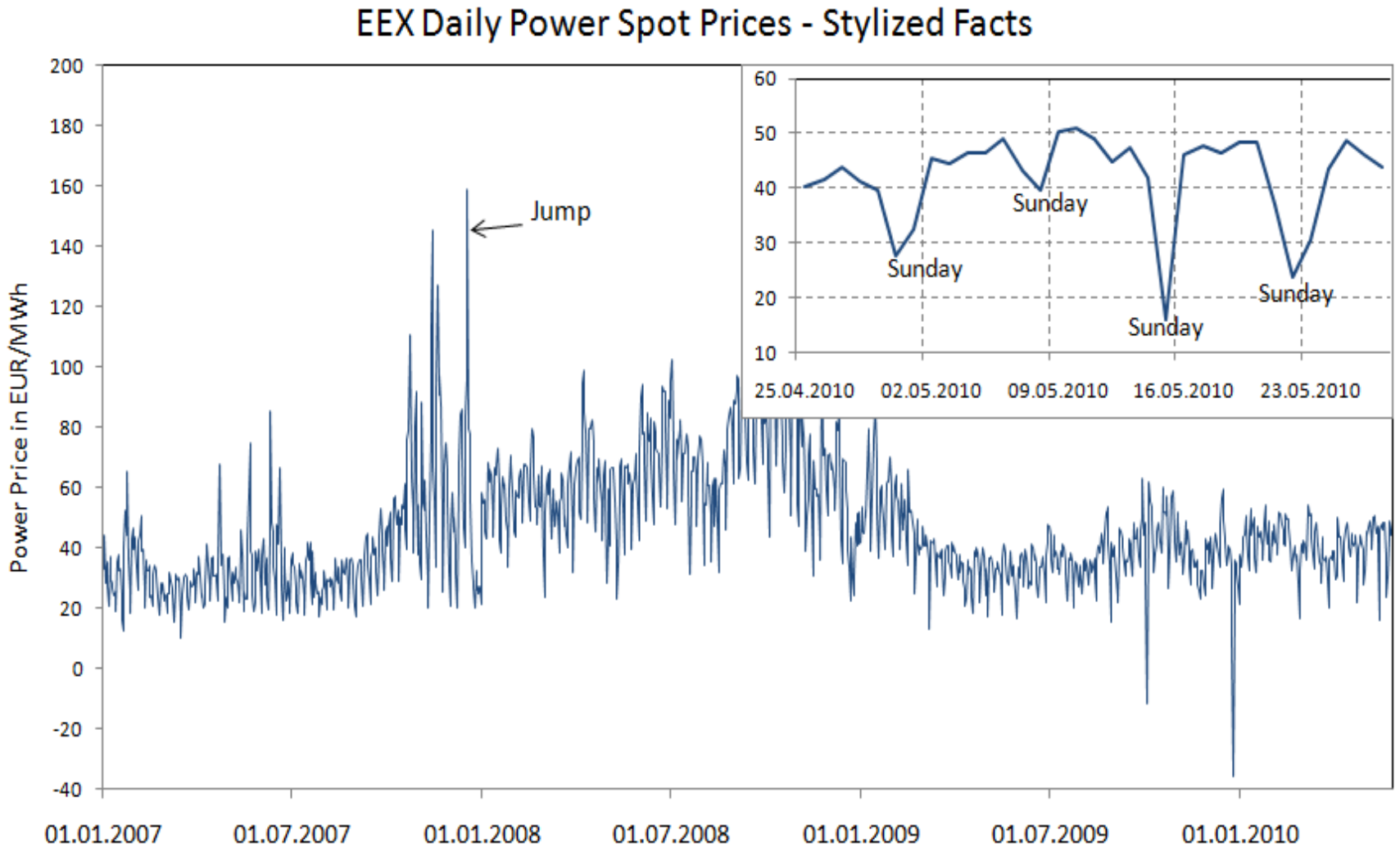
EEX Spot Market

- Trading in Power, Natural Gas and CO_2 Emission Rights.
- Power day-ahead auctions for Germany, Austria, France and Switzerland 7 days a week, including holidays. The 24 hours of the respective next day can be traded in one-hour intervals or block orders (e.g. Baseload: 1-24h, Peakload: 9-20h, Night: 1-6, Rush Hour: 17-20h, Business: 9-16h, etc.).
- Continuous day-ahead block trading for France 7:30 am to 11:30 am, 7 days a week, including holidays.
- Continuous Power intraday trading for Germany and France until 75 minutes before the beginning of delivery with delivery on the same or the following day in single hours or blocks.

EEX Spot Market

- Participants submit their price offer/bit curves. The EEX system prices are equilibrium prices that clear the market.
- EEX day prices are the average of the 24-single hours.
- Similar structures can be found on other power exchanges (Nord Pool, APX, etc.).

EEX Spot Market Price Processes



Electricity is special

- it is not storable
- it is homogeneous
- it can be produced in different ways
- it has to be produced when it is needed
- there is a high fluctuation in demand
- there is no short-term elasticity in demand

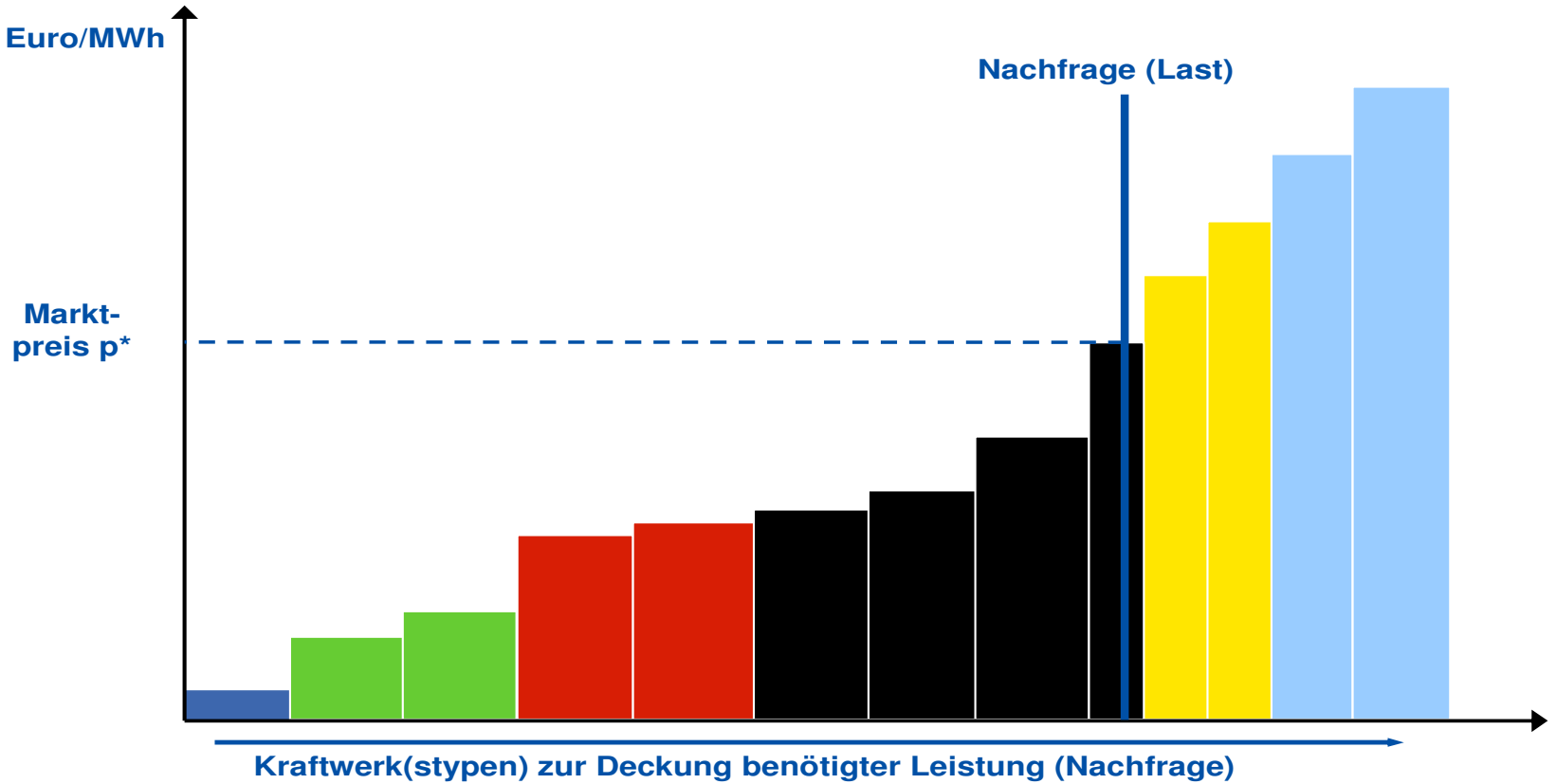
Basic Economics

- A producer produces only if marginal cost are met
- There is only one price for a homogeneous product
- Only producers with marginal costs below the market price will produce
- Production which only meets marginal costs does not cover the fixed costs

Economics of Electricity Production

- Marginal costs for power plants are basically prices of fuel and of CO2 certificates
- The order of power plant use is (increasing costs)
  - wind
  - water
  - nuclear
  - coal
  - gas
  - oil
- To meet demand power plants are added in order of increasing marginal costs (merit order)
- The last needed plant (the marginal power plant) fixes the market price – for all plants in use!

Merit Order



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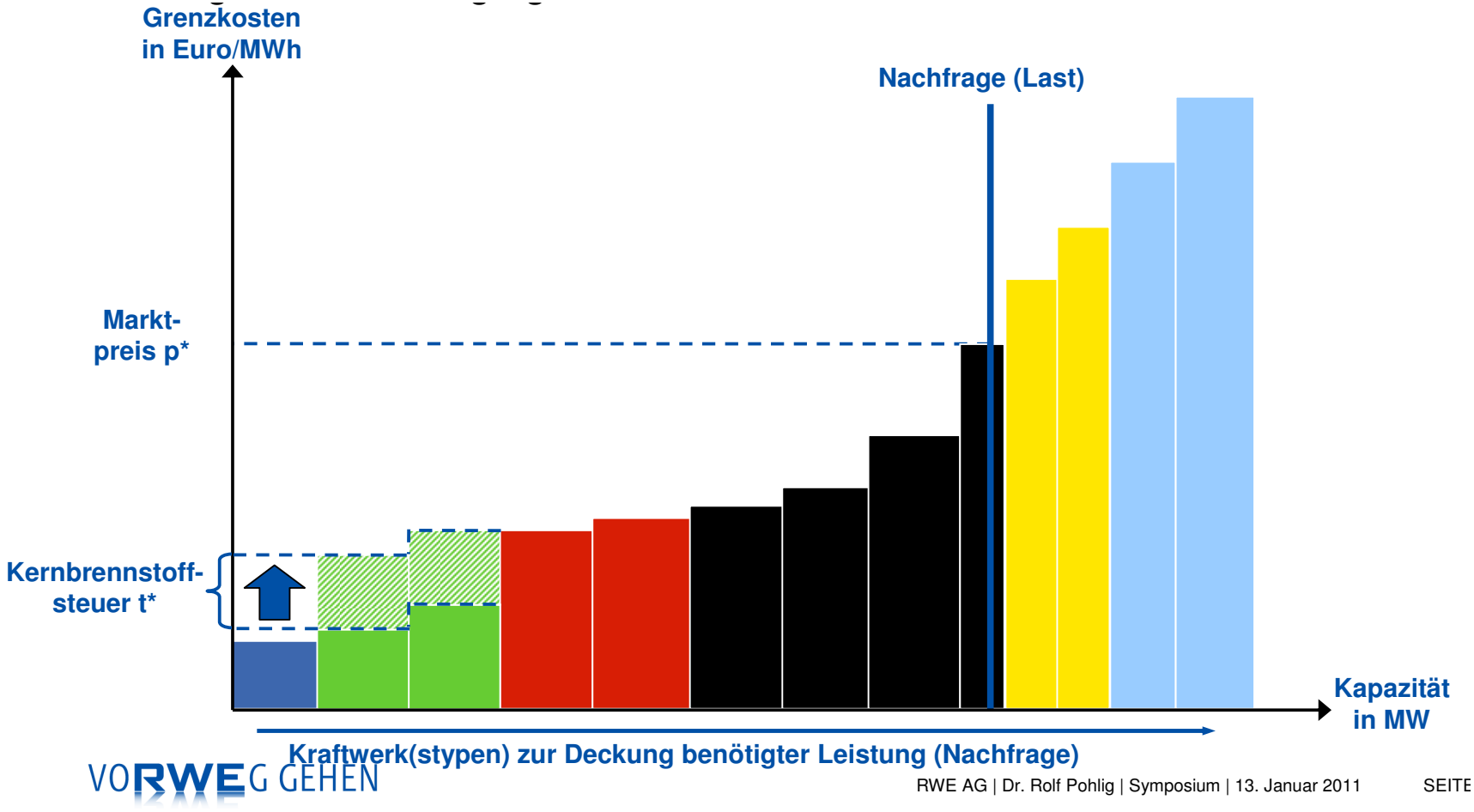
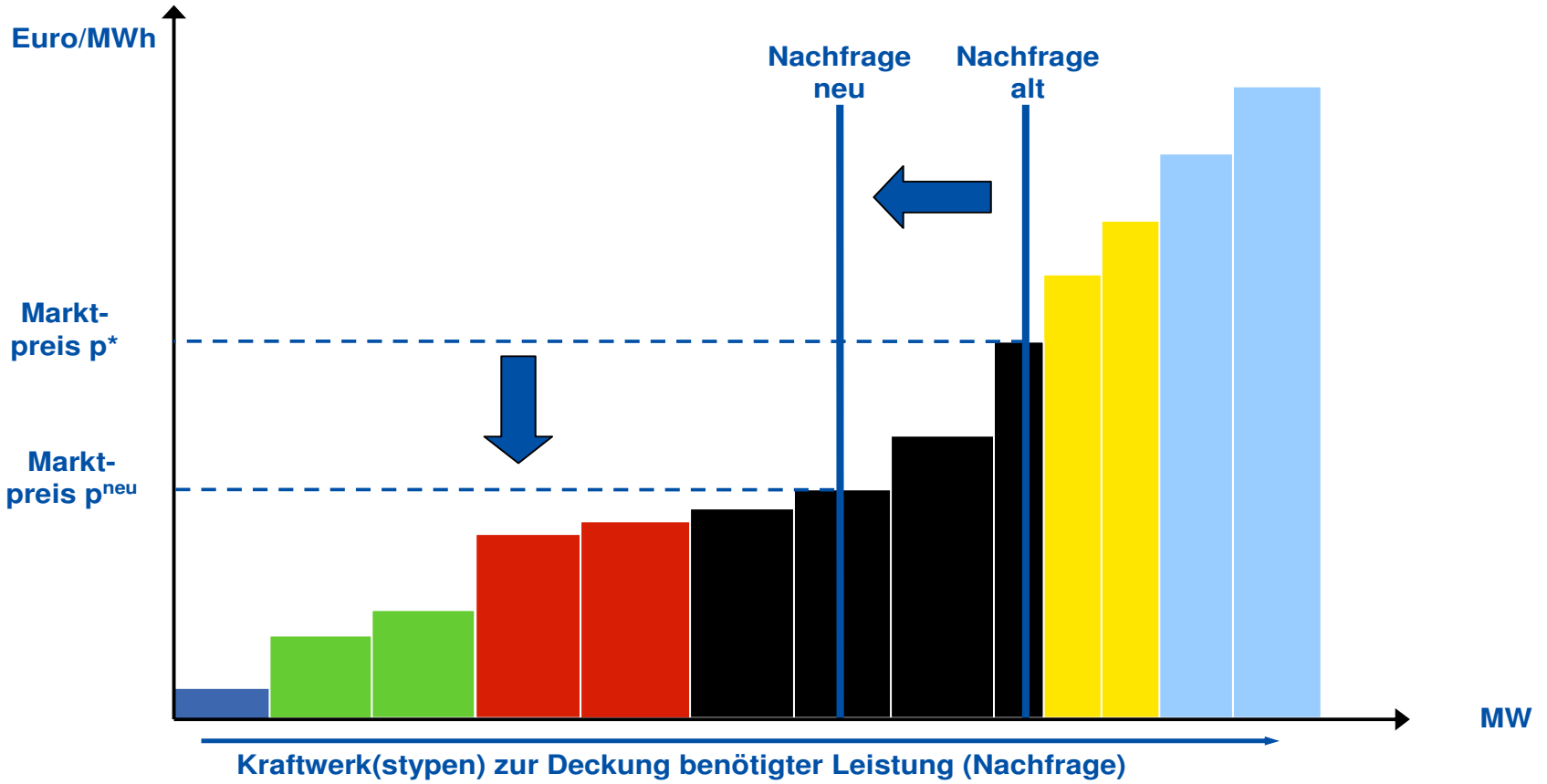
Merit Order – Nuclear Fuel Elements Tax



Merit Order – Changing Demand



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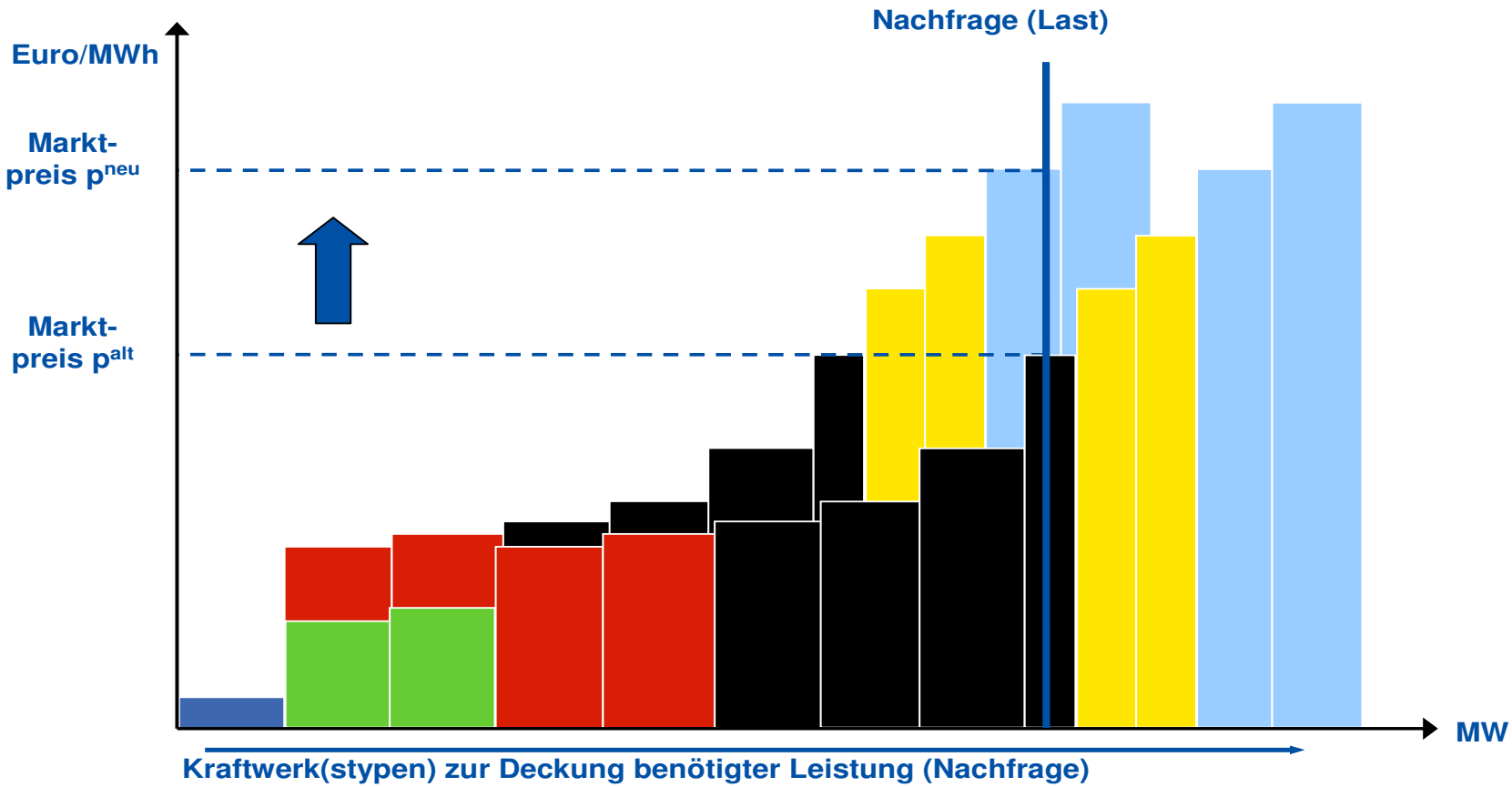
Merit Order – Changing supply



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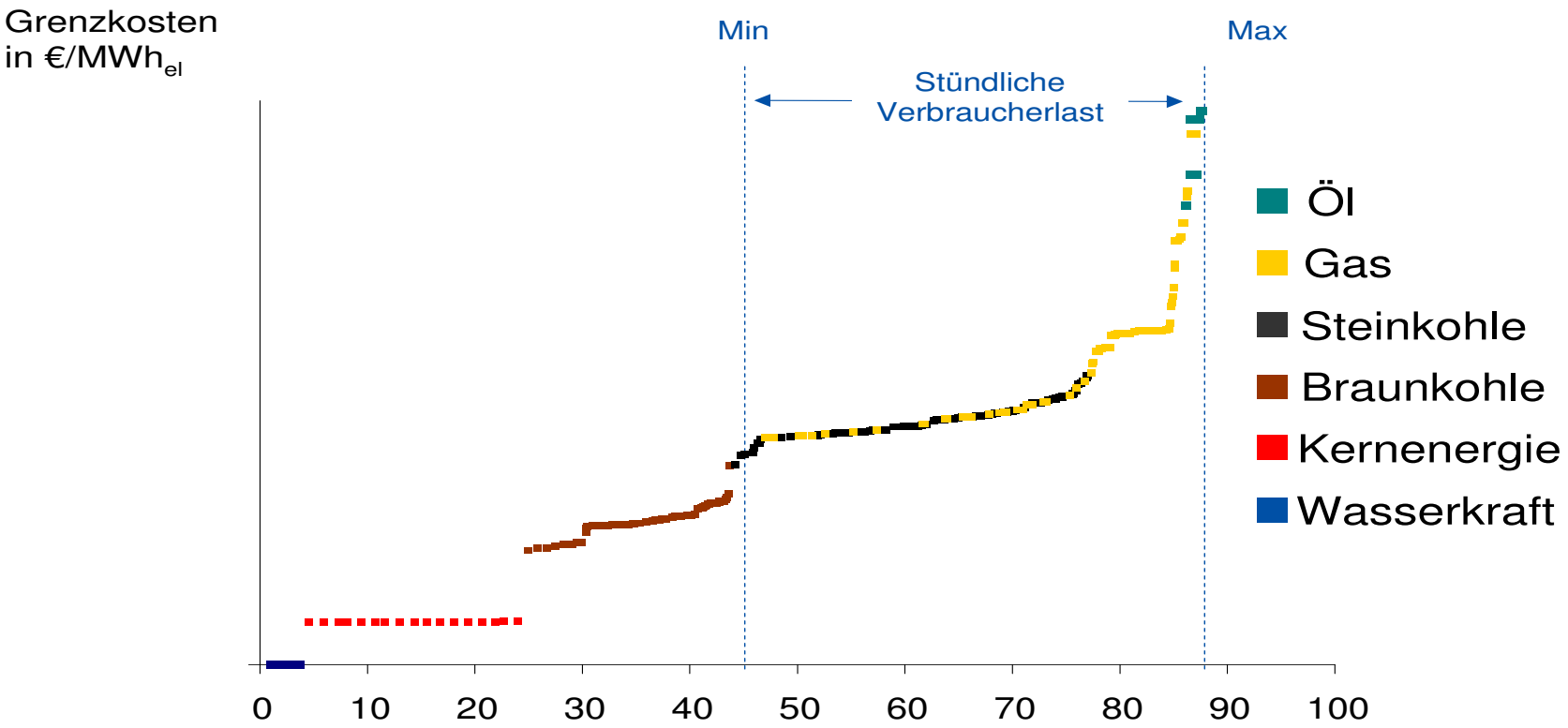
Merit Order – Germany

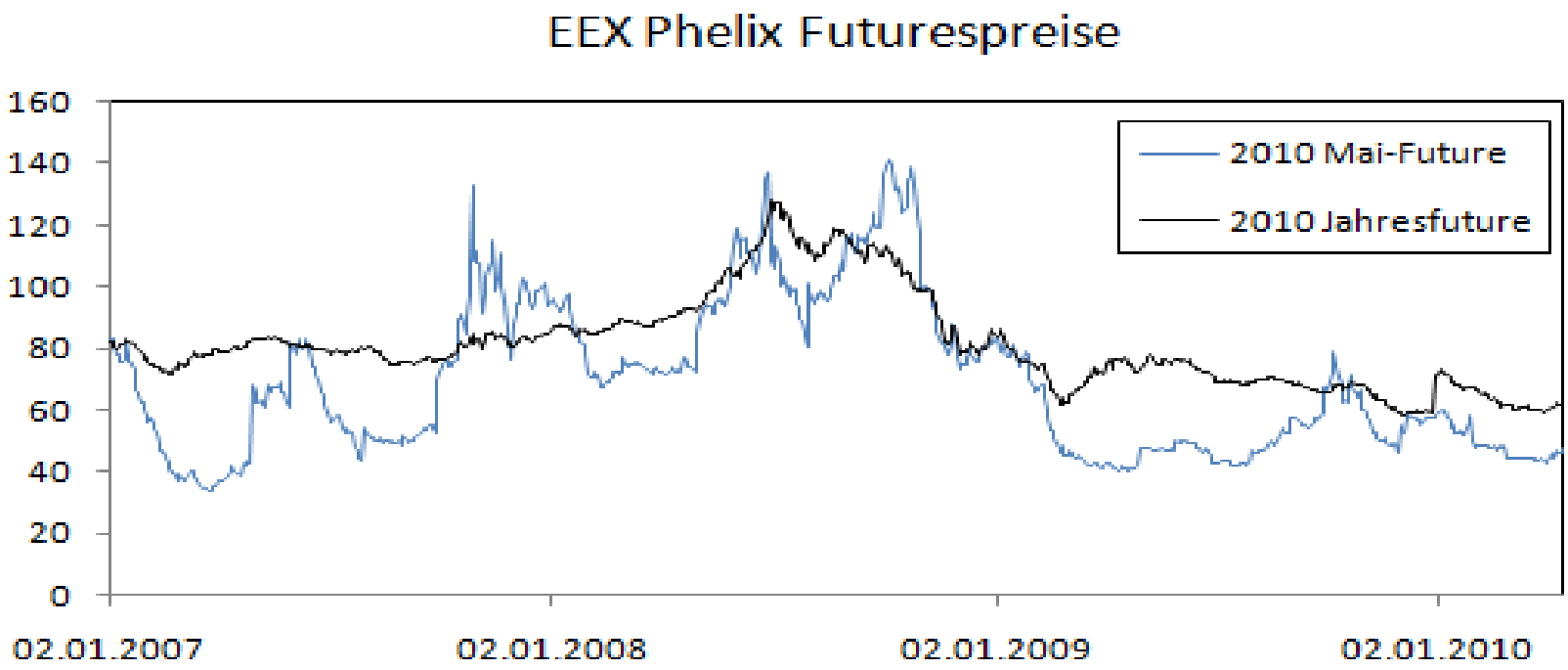


EEX Futures Market

Traded products are

- Futures contracts for Power, Natural Gas, Emissions and Coal.
- Phelix Futures on Phelix Baseload or Peakload monthly power index for the current month, the next nine months, eleven quarters and six years with cash settlement.
- Baseload and Peakload French/German Power Futures for the current month, the next six months, seven quarters and six years with physical settlement, obliging for continuous delivery of 1MW during a month, quarter or a year.
- Actively exchange traded are the next 7 months, 5 quarters and 2-3 years.
- In addition, OTC transactions.

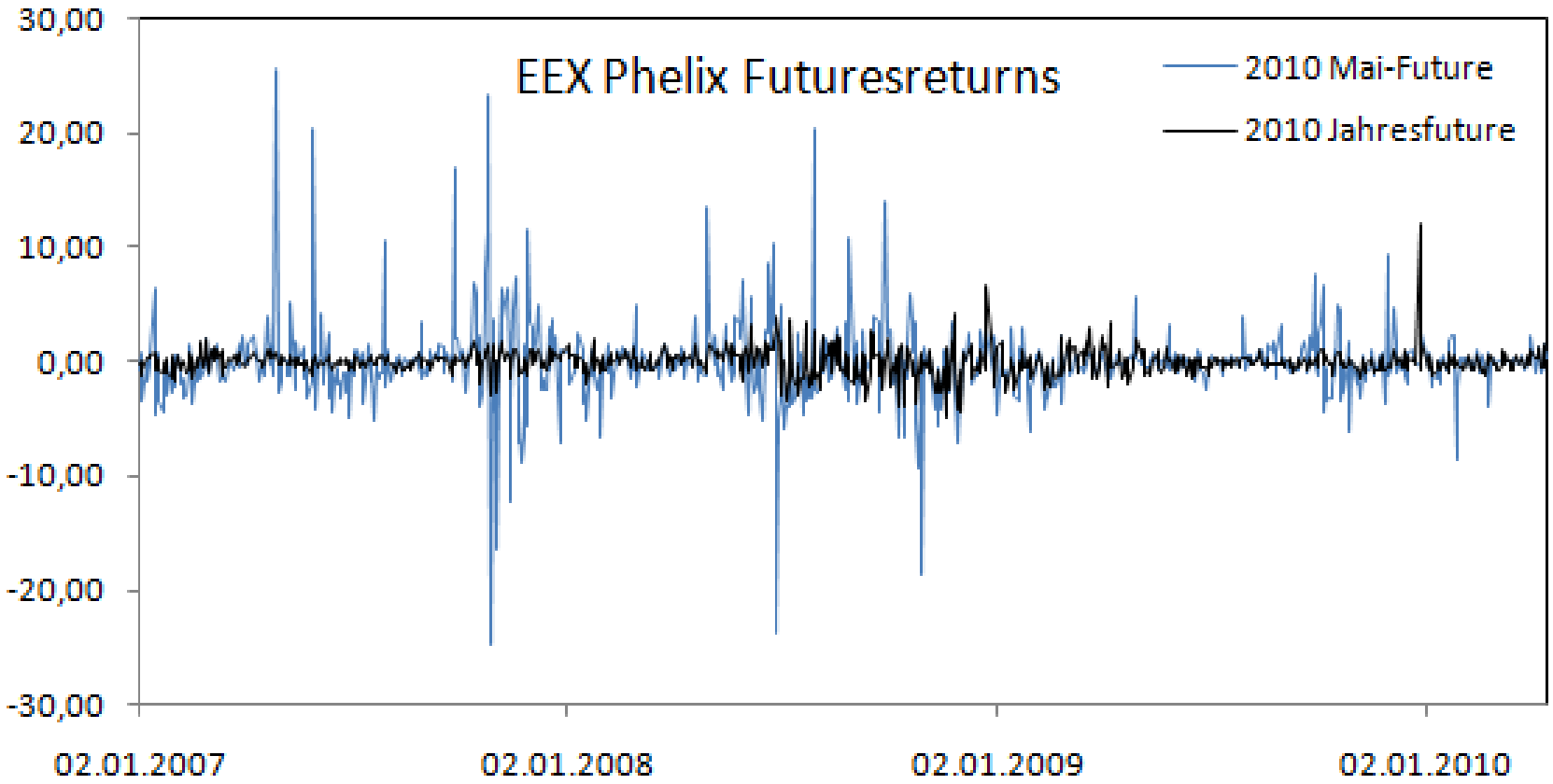
EEX Futures Market Price Processes



2010 Mai-Future: Actual 1-month future contract; the future prices are the quotations of the rolling contracts, i.e. the prices of the actual monthly contract (with delivery in the next month).

EEX Futures Market Price Processes

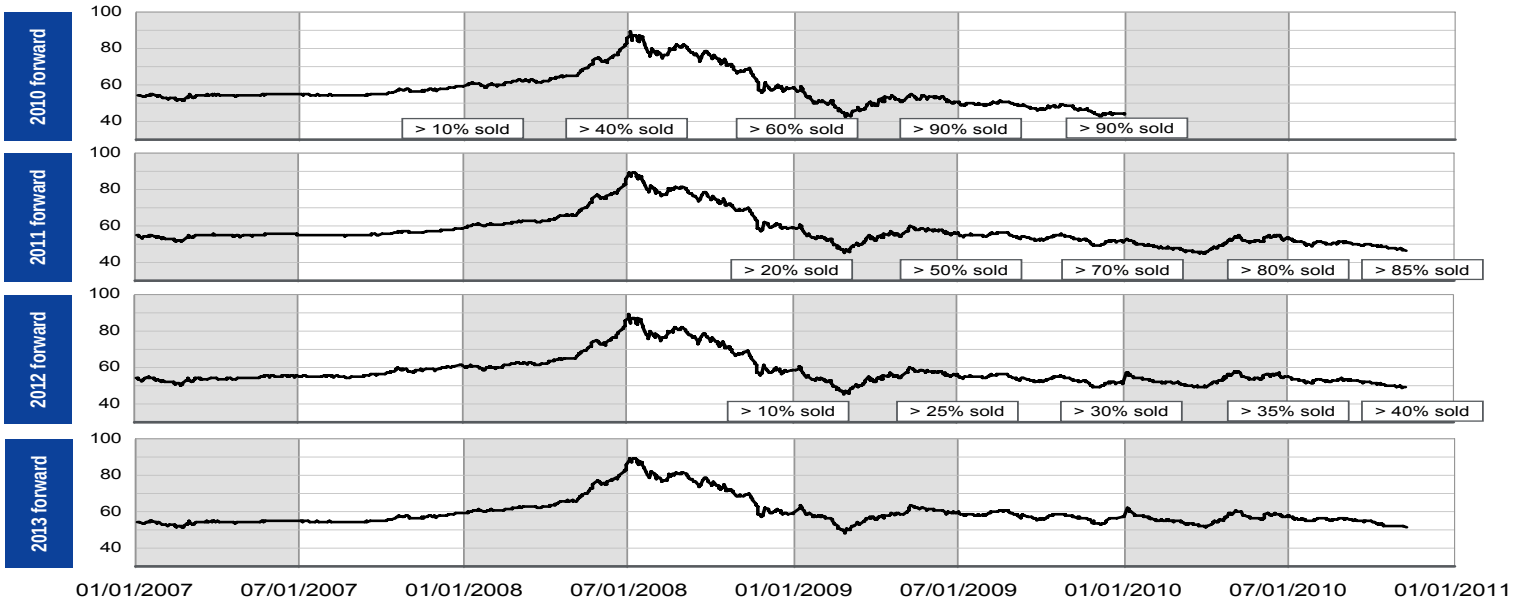
Returns seem to be stationary, no seasonality.



Forward Selling Activity

Forward selling[1] by RWE Power in the German market

(Base-load forwards in €/MWh)



(average realised price for 2008 forward: €58/MWh, for 2009 forward: €70/MWh)
[1] Forward prices until November 8, 2010; hedge ratio as of Sept. 30, 2010.

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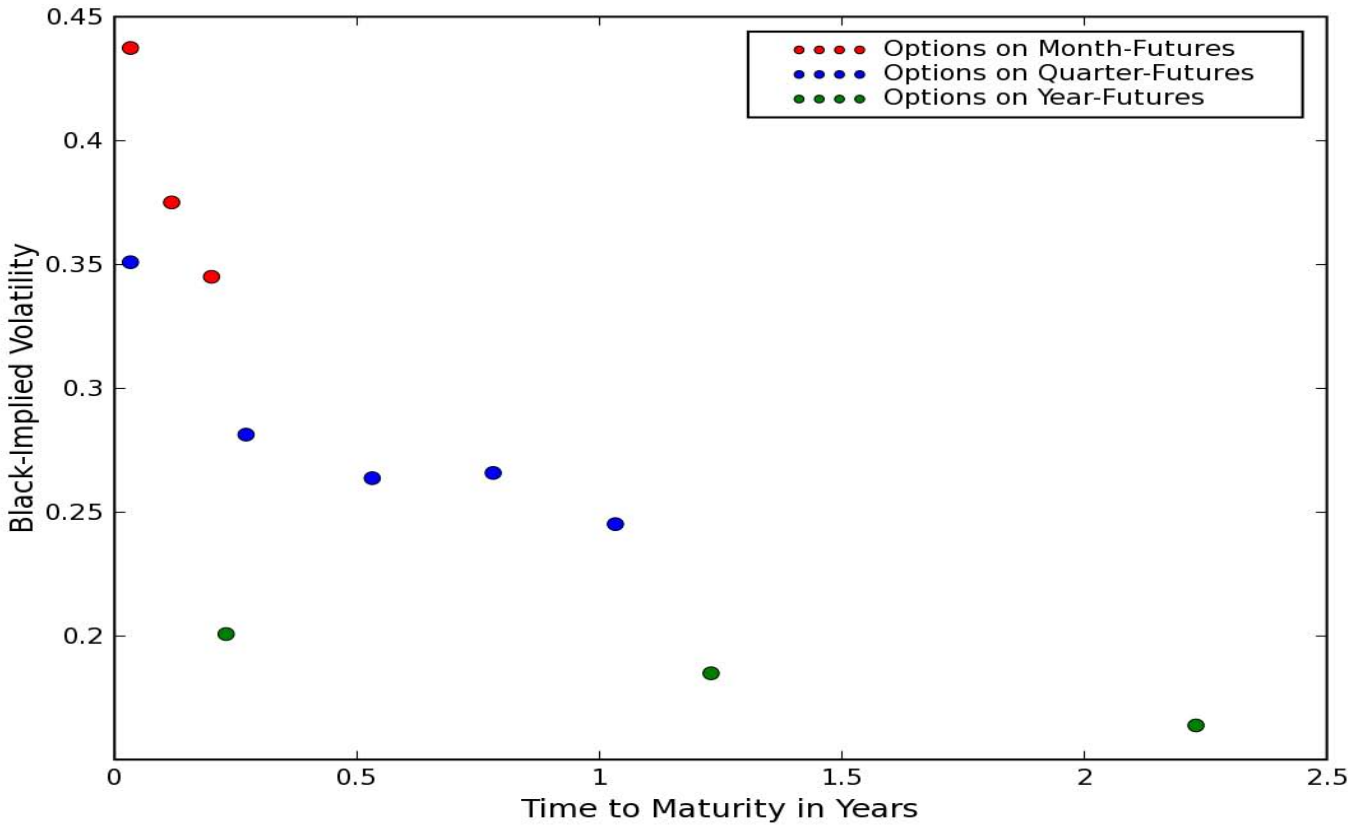
EEX Options on Futures

Traded products are

- European-style Phelix Options which lead to opening of the corresponding Phelix Futures position if exercised.
- Maturities are the next 5 months, 6 quarters and 3 years.
- Physical or financial settlement.
- Option maturity is between 1 and 6 days before start of underlying's delivery.
- In addition, options on second period European Carbon Futures are traded.

Volatilities



Agenda

SME Group Energy Derivatives

CME Group Energy Futures and Options

PHYSICALLY SETTLED CONTRACTS

- Light Sweet Crude Oil
- Natural Gas
- Heating Oil
- RBOB Gasoline
- Singapore 380cst Fuel Oil
- Gulf Coast Gasoline
- Gulf Coast Ultra Low Sulfur Diesel (ULSD)
- New York Harbor Ultra Low Sulfur Diesel (ULSD)
- Russian Export Blend Crude Oil (REBCO)
- Ethanol

CASH SETTLED CONTRACTS

- Light Sweet Crude Oil
- Natural Gas Last-day
- Natural Gas Penultimate
- Heating Oil
- RBOB Gasoline
- Brent Crude Oil Penultimate
- Brent Crude Oil Last-day
- Propane
- Heating Oil and Gasoline Crack Spread
- Electricity
- Uranium
- E-mini Crude Oil
- E-mini Natural Gas
- E-mini RBOB Gasoline
- E-mini Heating Oil

CME Group Energy Derivatives

CME Group is built on heritage of CME, CBOT and NYMEX.

- World's largest and most diverse derivatives exchange
- Average daily volume of 1.25 million energy contracts
- Year-on-year volume growth – up 19 percent in 2008 alone

Size of Derivative Markets: NYMEX

Energy Futures on NYMEX:

NYMEX ENERGY FUTURES VOLUMES & OPEN INTEREST PAGE

DATED: 13-May POSTED: 14-May TIME: 14:00

MONTH	RIC	VOLUME	OP INT		CHANGE	EXPIRY
DEC13	<QLZ3>	0	5	=		26NOV13
TOTAL		1255	7940	⬇	315	

NYMEX ENERGY FUTURES CONTRACTS VOLUME & OPEN INTEREST - TOTAL

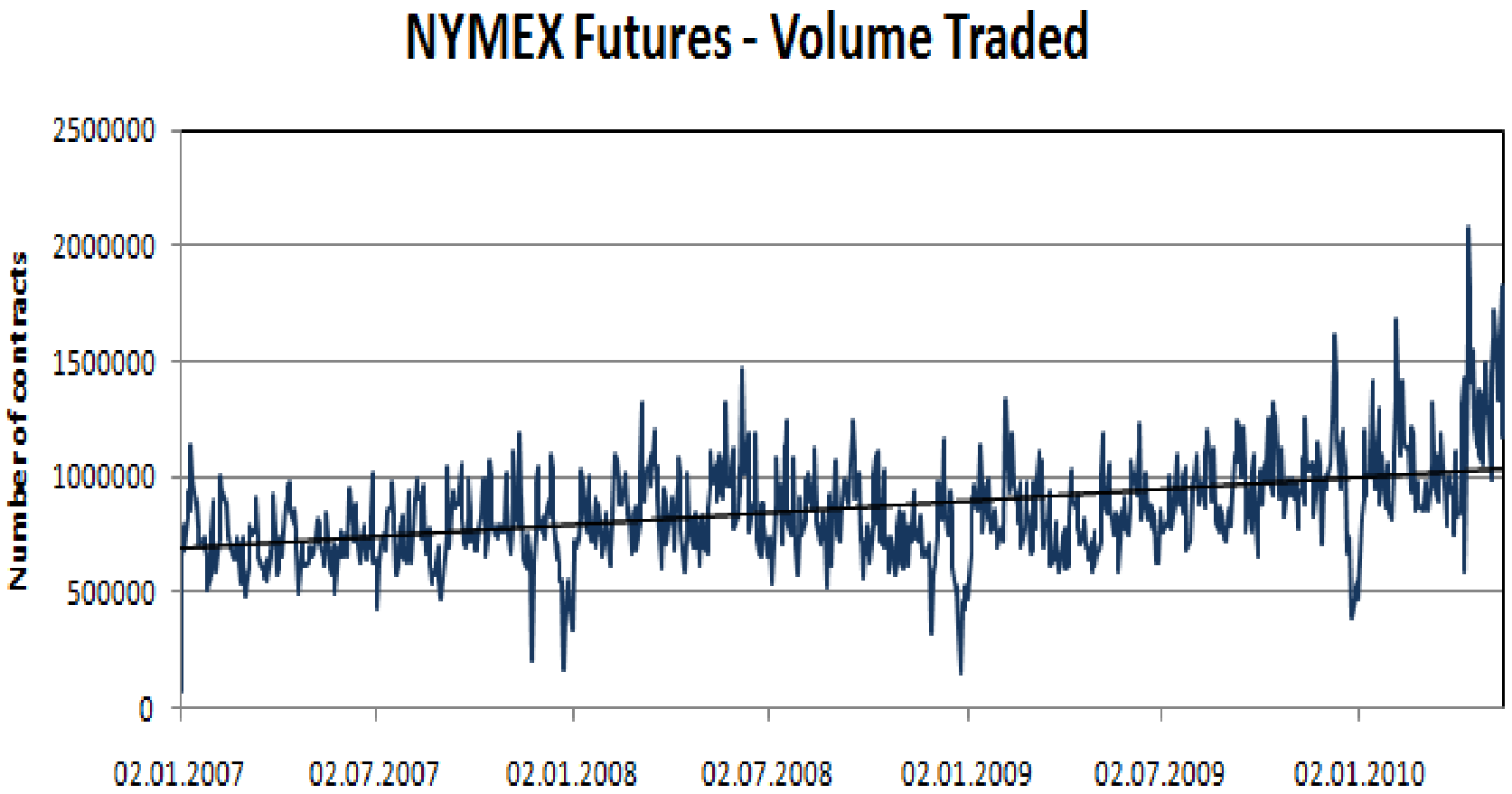
Name & Chain	RIC	VOLUME	OI		Net Change
LIGHT SWEET CRUDE <0#CL:>	<CL-TOT>	1169169	1482103	⬆	12258
HEATING OIL <0#HO:>	<HO-TOT>	132425	320756	⬆	452
RBOB GASOLINE <0#RB:>	<RB-TOT>	122025	278693	⬇	2070
Natural Gas <0#NG:>	<NG-TOT>	402506	870095	⬇	3662
BRENT LAST DAY <0#BZ:>	<BZ-TOT>	35	7504	⬆	7
HENRY HUB <0#NN:>	<NN-TOT>	97764	2857819	⬆	5539
BRENT FINANCIAL <0#B:>	<B-TOT>	2637	39752	⬆	1121
CAPP COAL <0#QL:>	<QL-TOT>	1255	7940	⬇	315

page above contains Volumes and Open Interest for contracts traded on NYMEX
Some of the Contracts may be expired, however they are still displayed by NYMEX
as they have Open Interest.

NYMEX GUIDE .....<NYM/FUTEX1> COMMODITIES MAIN GUIDE ..<COMMOD>

Source: Reuters

Size of Derivative Markets: NYMEX

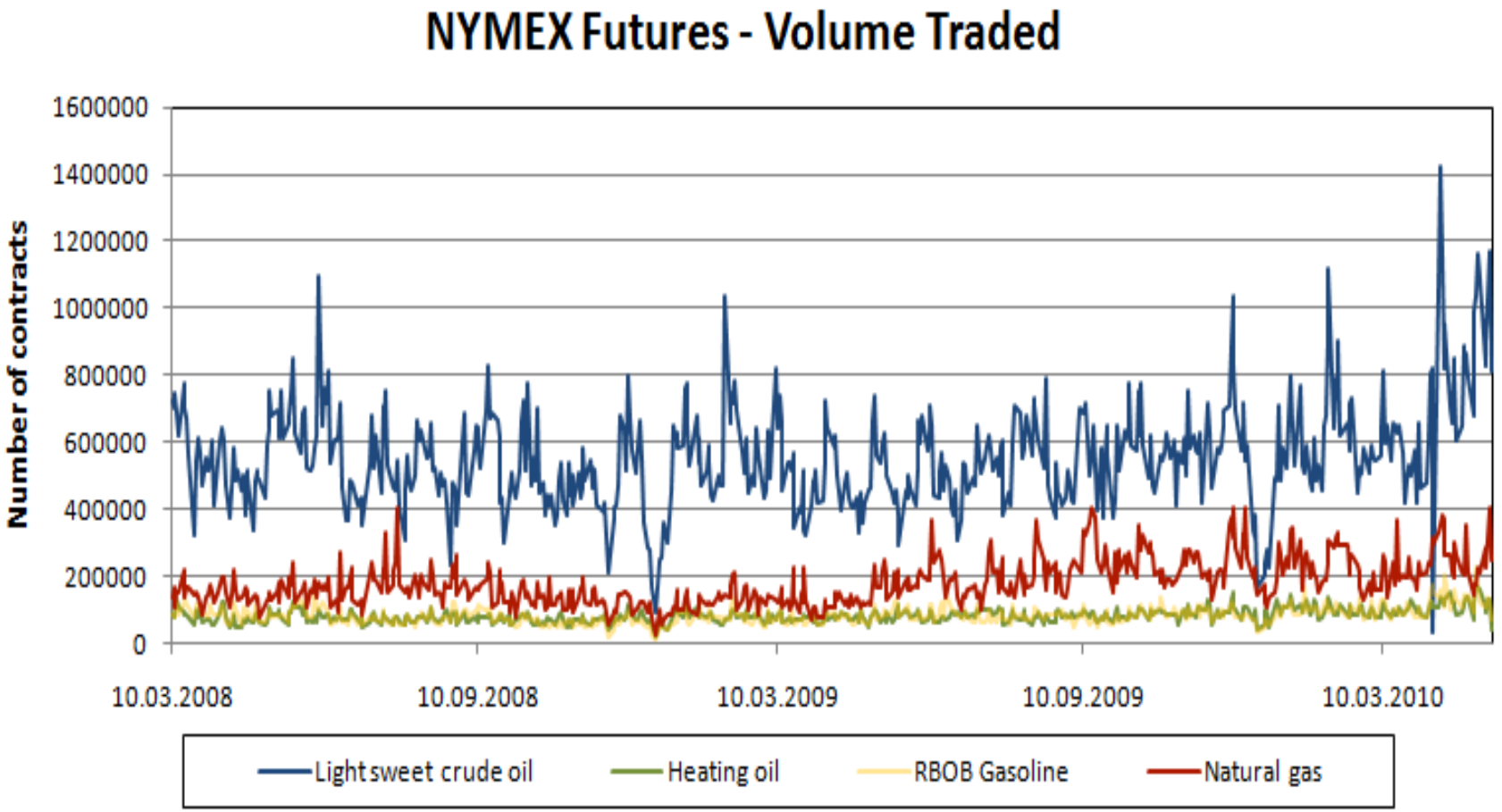


Size of Derivative Markets: NYMEX

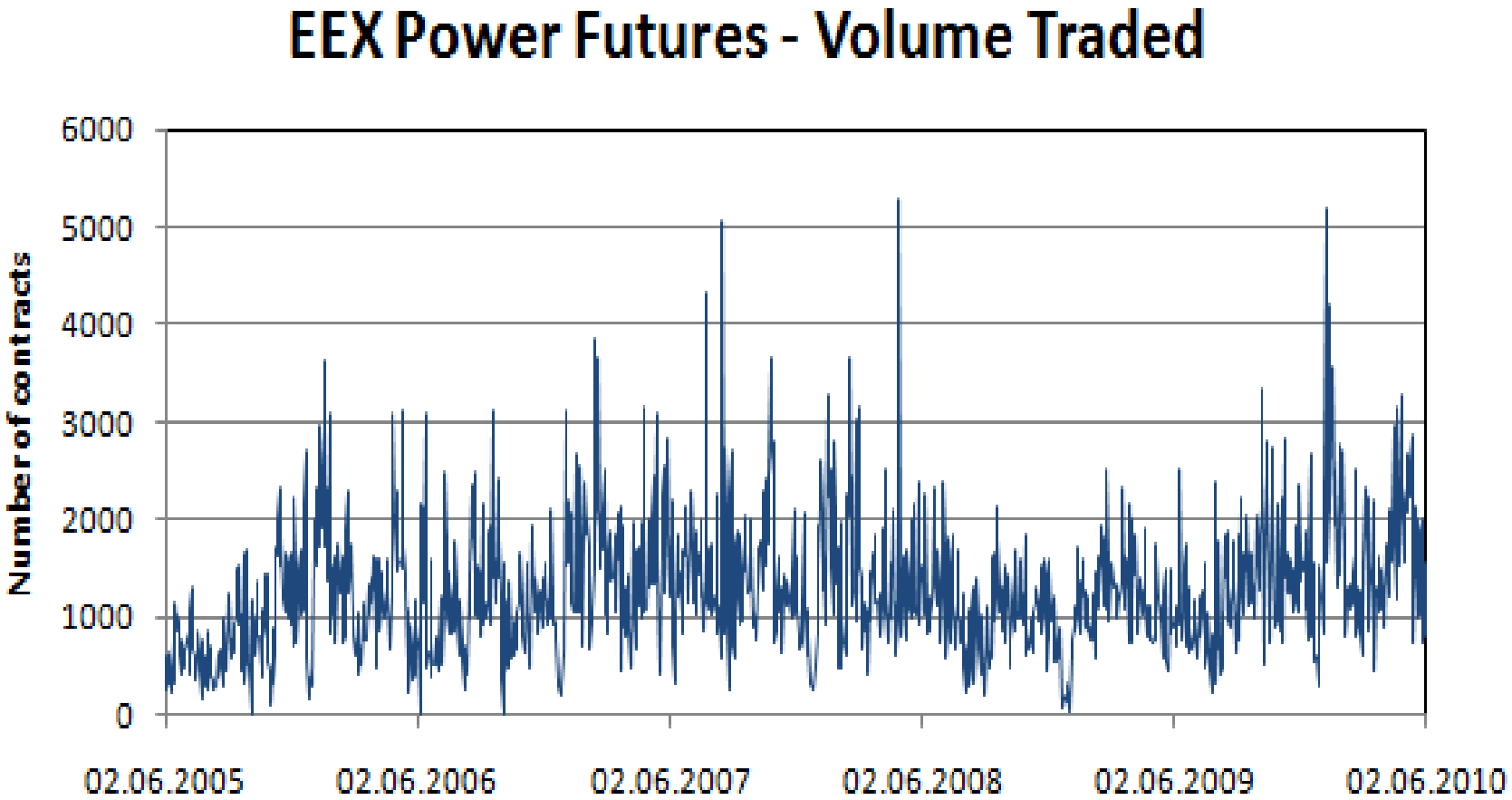
In practice, most futures contracts on NYMEX are liquidated via offset, so that physical delivery of the underlying commodity is relatively rare.

Futures trading volume data display strong seasonality due to the 'rolling over' of positions close to the expiry date of the near contract.

Size of Derivative Markets: NYMEX



Size of Derivative Markets: EEX

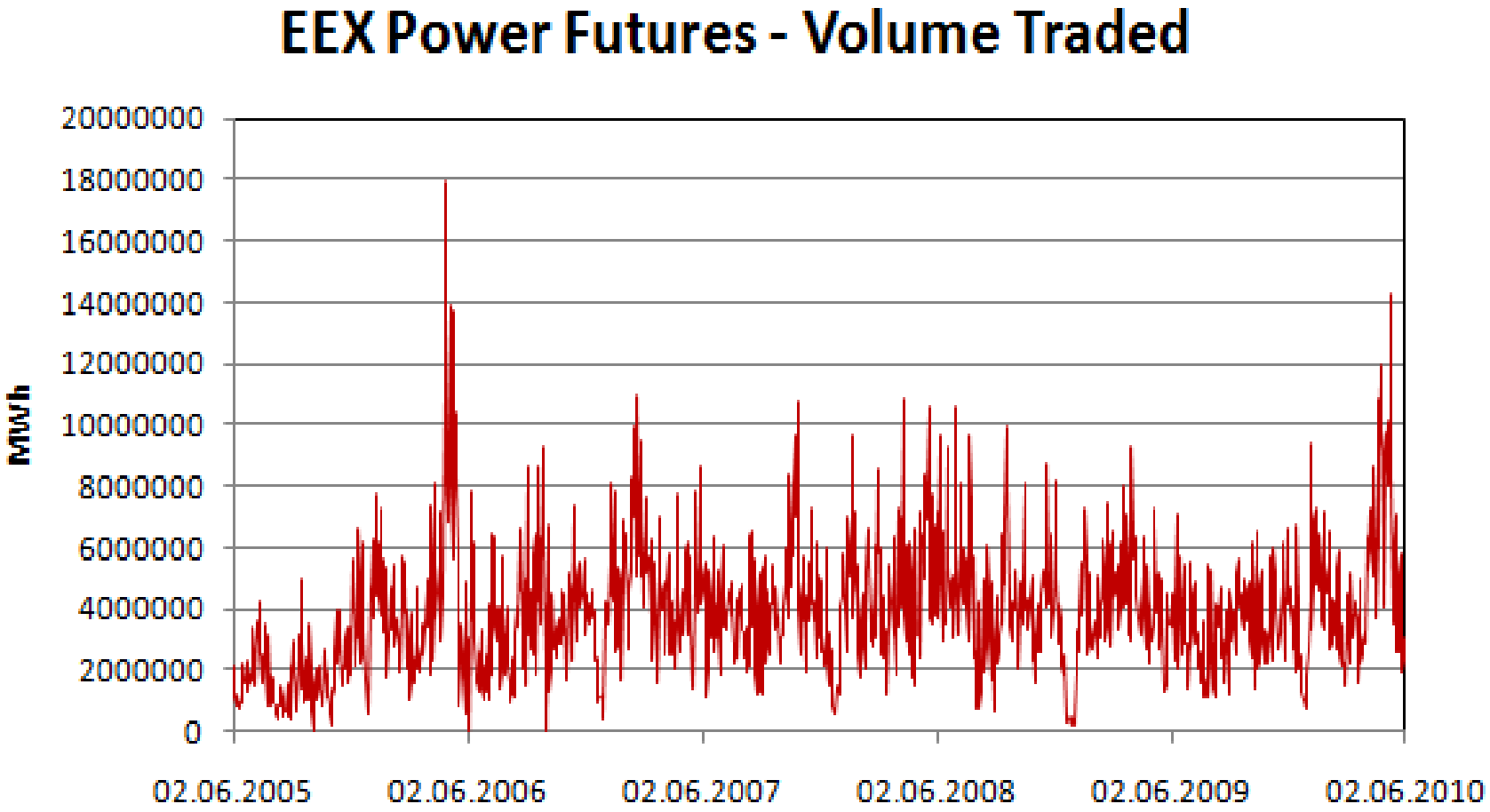


Size of Derivative Markets: EEX

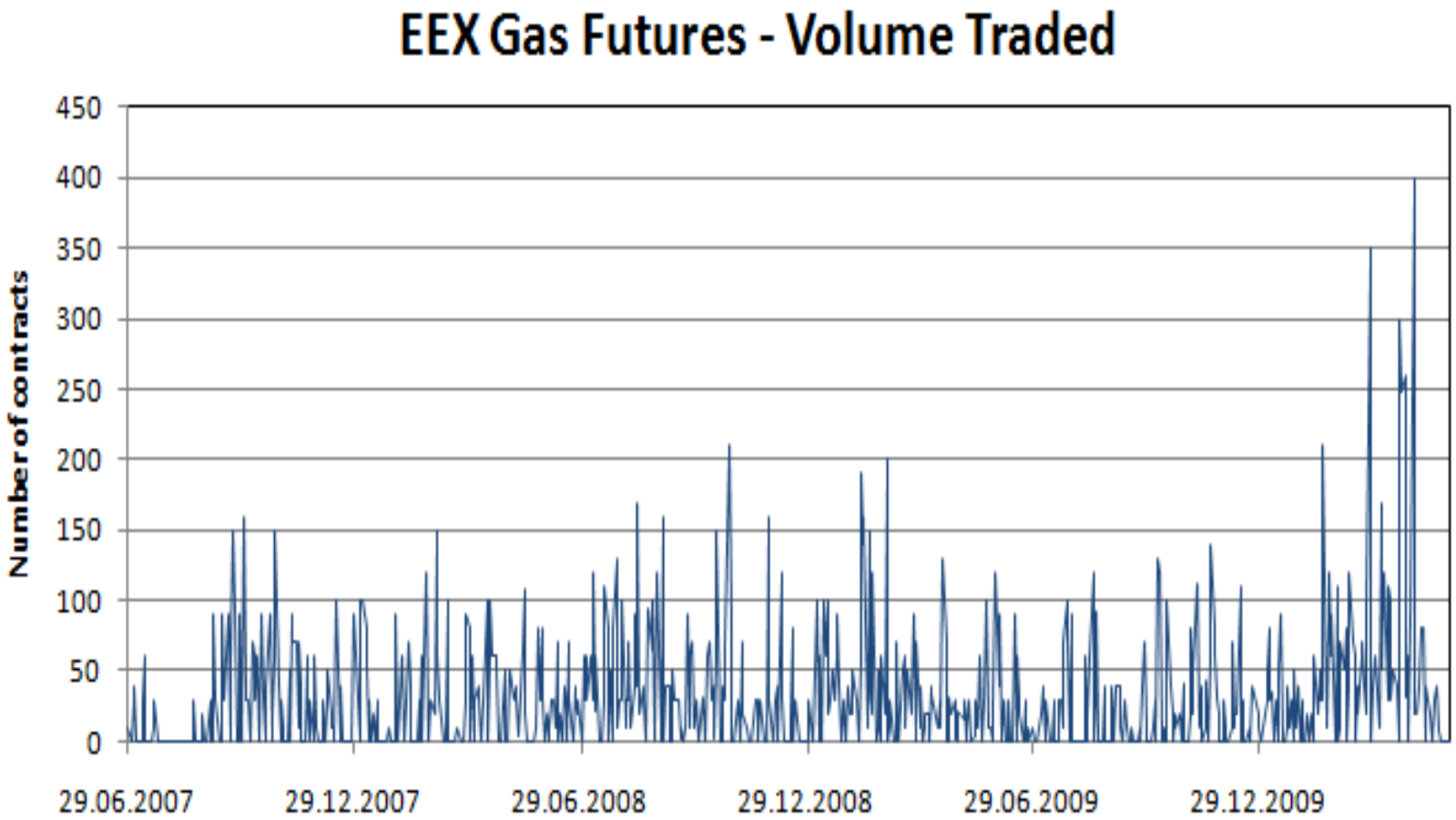
Number of contracts reflects the total number of all power futures contracts traded on a particular day on EEX.

EEX power futures are available as base load and peak load contracts each with month, quarter and year futures. The contract volumes range from 240MWh for the smallest peak load month contract to up to 8 784MWh for the biggest base load year contract. The delivery rate amounts to 1MWh pro contract.

Size of Derivative Markets: EEX



Size of Derivative Markets: EEX

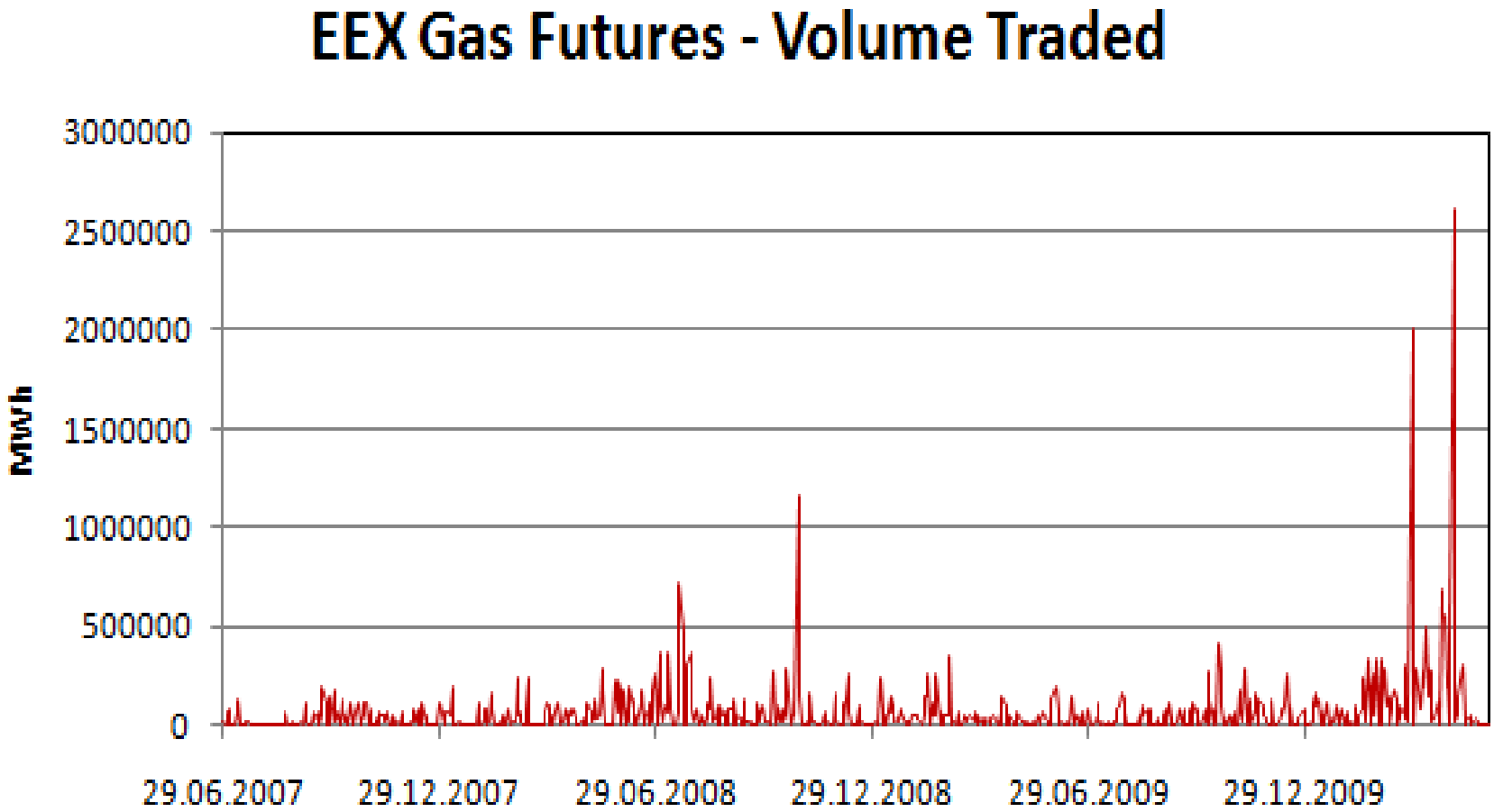


Size of Derivative Markets: EEX

Number of contracts reflects the total number of all natural gas futures contracts traded on a particular day on EEX.

The tradable delivery periods are the balance of month, the following six month, seven quarters, four seasons and six calender years. All prices are quoted in €/MWh. The contract volumes range from 720MWh for the month contract to up to 8 760MWh for the year contract. The delivery rate amounts to 1MWh pro contract.

Size of Derivative Markets: EEX



Spread Options

Some market participants are exposed to the difference of commodity prices. Examples are

- the dark spread between power and coal (model for a coal-fired power plant)
- the spark spread between power and gas (model for a gas-fired power plant)
- the crack spread between different refinements of oil (model for a refinement plant)

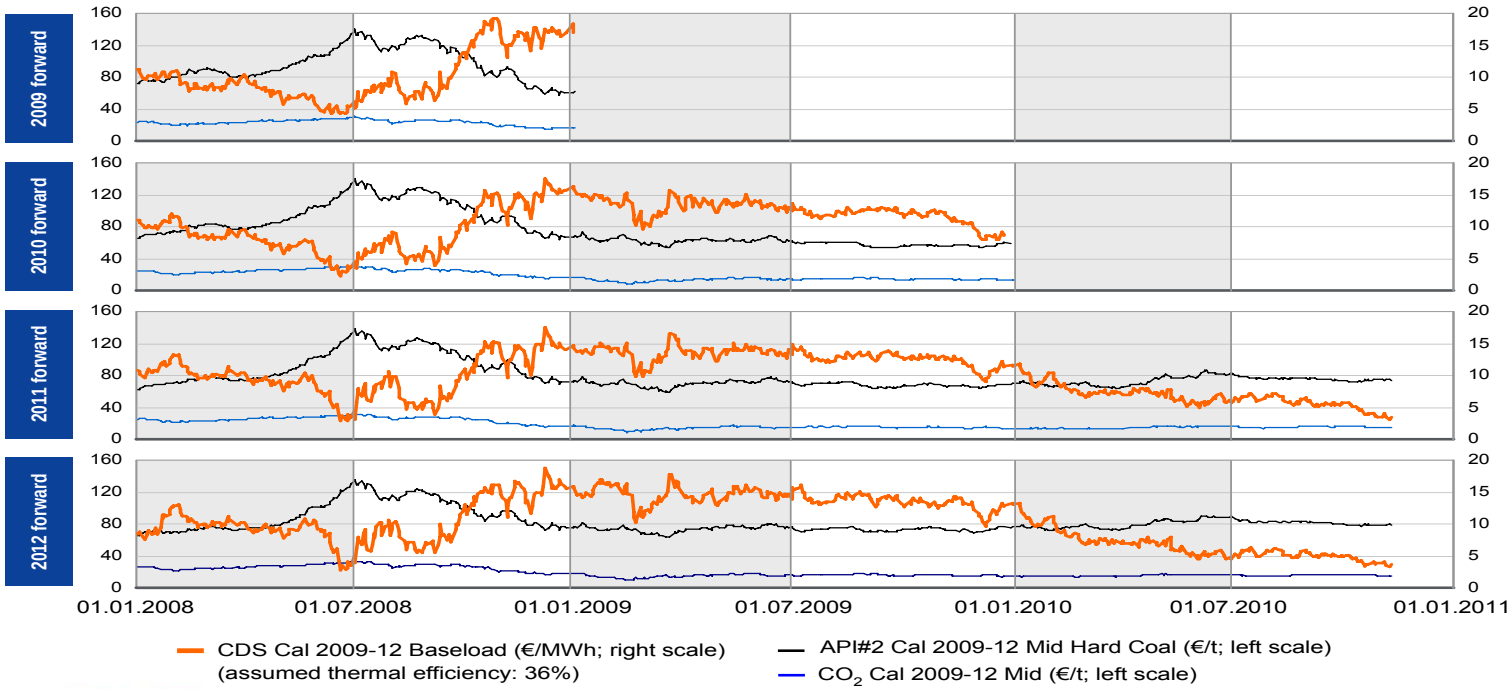
Clean Spreads

In countries covered by the European Union Emissions Trading Scheme, utilities have to consider also the cost of carbon dioxide emission allowances. Emission trading has started in the EU in January 2005.

- Clean spark spread represents the net revenue a gas-fired power plant makes from selling power, having bought gas and the required number of carbon allowances.
- Clean dark spread represents the net revenue a coal-fired power plant makes from selling power, having bought coal and the required number of carbon allowances.
- The difference between the clean dark spread and the clean spark spread is known as the climate spread.

Darks Spreads

Germany: Clean Dark Spread (CDS) versus hard coal and CO_2 prices



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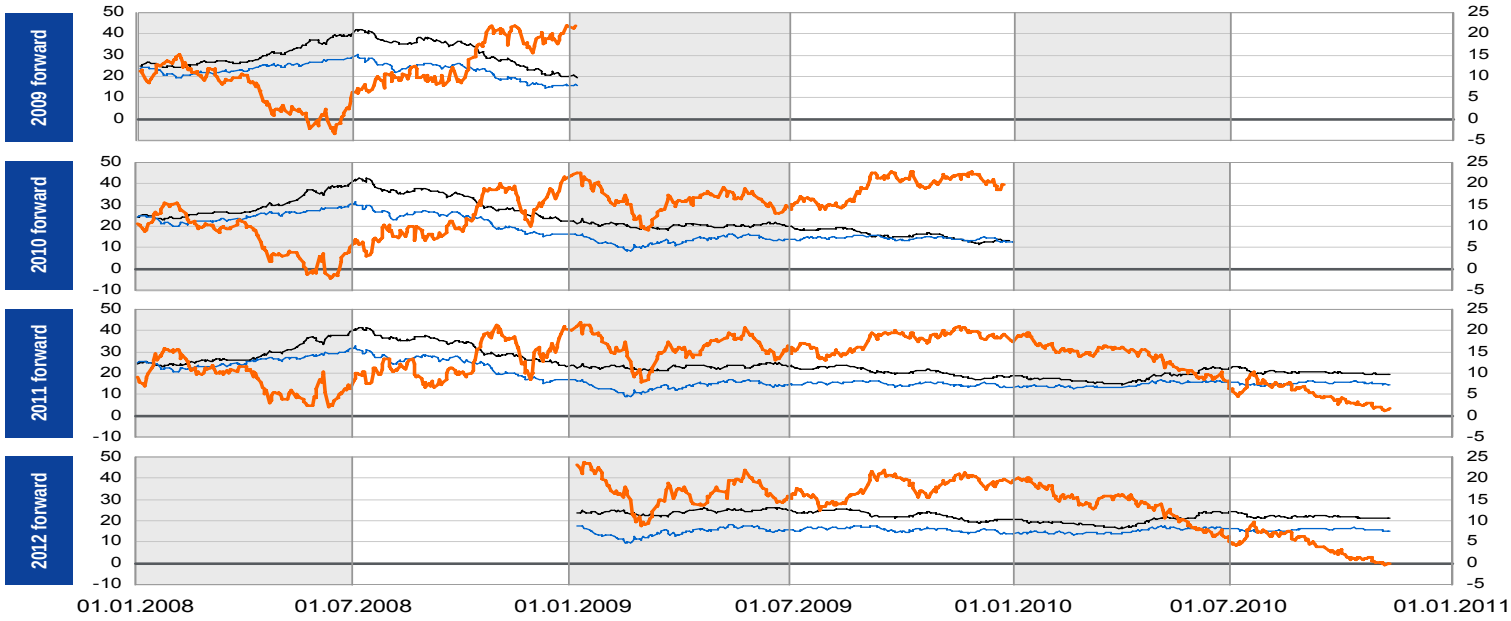
Spark Spreads

Germany: Clean Spark Spread (CSS) versus natural gas and CO_2 prices



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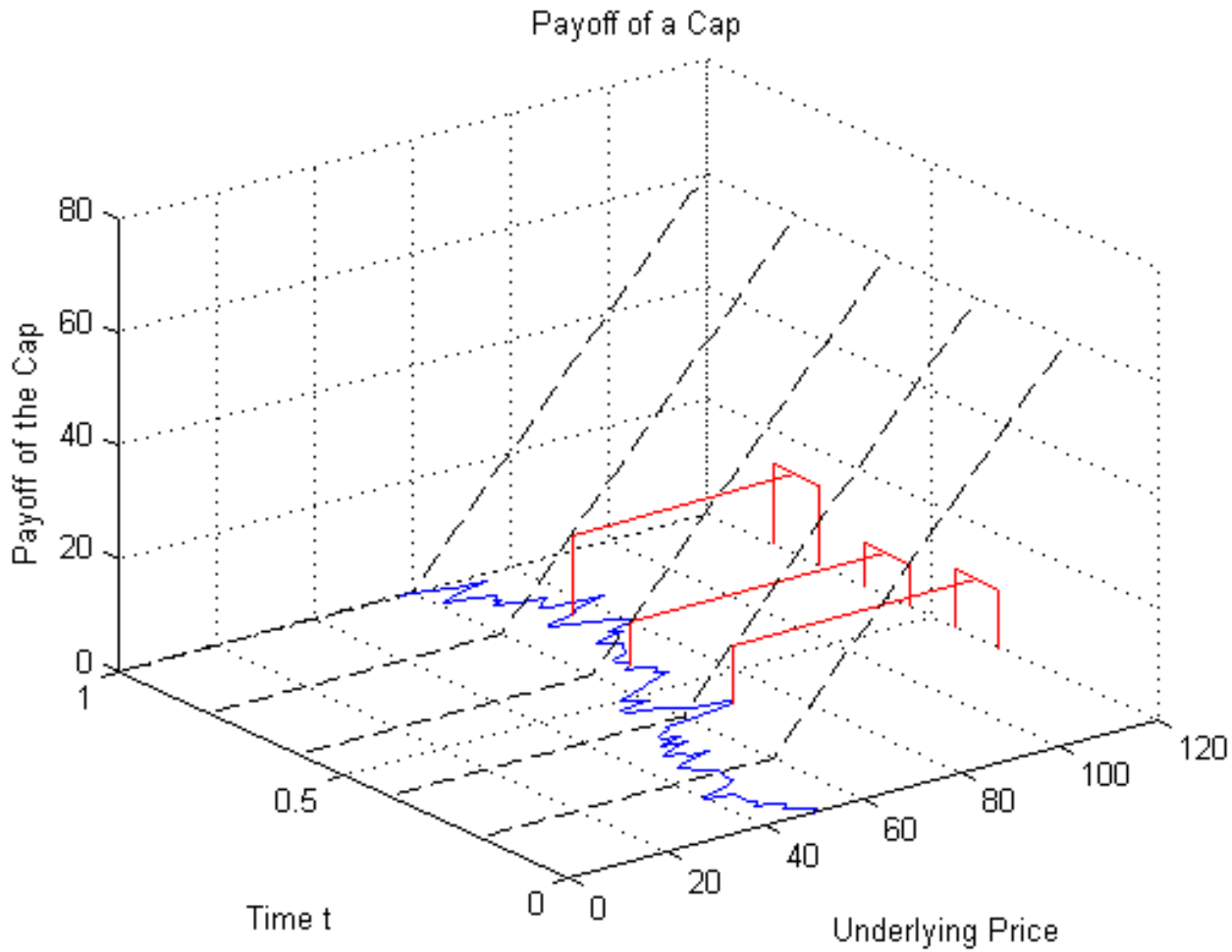
RWE AG | Q1-Q3 2010 Conference Call | November 11, 2010 21

Caps

- Buying a cap, the option holder has the right (but not the obligation) to buy a certain amount of energy at stipulated times $t_1, \ldots, t_N$ during the delivery period at a fixed strike price K.
- It can be viewed as a strip of independent call options, for each time t_i the holder of the cap holds call options with maturity t_i and strike K.
- The static factors describing the cap are:
  - times $t_1, \ldots, t_N$ (how often? when?)
  - strike K (price?)
  - amount of the underlying (how much?)

Cap - Payoff


Payoff of a Cap
Payoff of the Cap
80
60
40
20
0
1
0.5
0
Time t
0
20
40
60
80
100
120
Underlying Price

Caps - Pricing

- Whenever the price of the underlying exceeds the strike K at one of the dates $t_1, \ldots, t_N$, the seller of the cap pays the holder of the cap the difference between the price of the underlying and the strike K or - in case one agreed on physical delivery - the underlying is delivered for the price K.
- Typically, the price of a cap is quoted as price per delivery hours to make different delivery periods comparable. In this case we get a price per MWh.
- The formula is

$$U_c(t) = \frac{1}{N} \sum_{i=1}^{N} e^{-r(t_i - t)} \mathbb{E}[\max(S(t_i) - K, 0)].$$

Caps - Hedging

- The strike price K secures a maximum price for which the option holder is able to buy energy.
- A cap is used to cover a short position in the underlying (energy) against increasing market prices not only at a certain point in time but over the whole period covered by the exercising times $t_1, \ldots, t_N$.
- On the other hand, the option holder is still able to profit from low energy prices as he has the right but not the obligation to exercise the option at each time point.

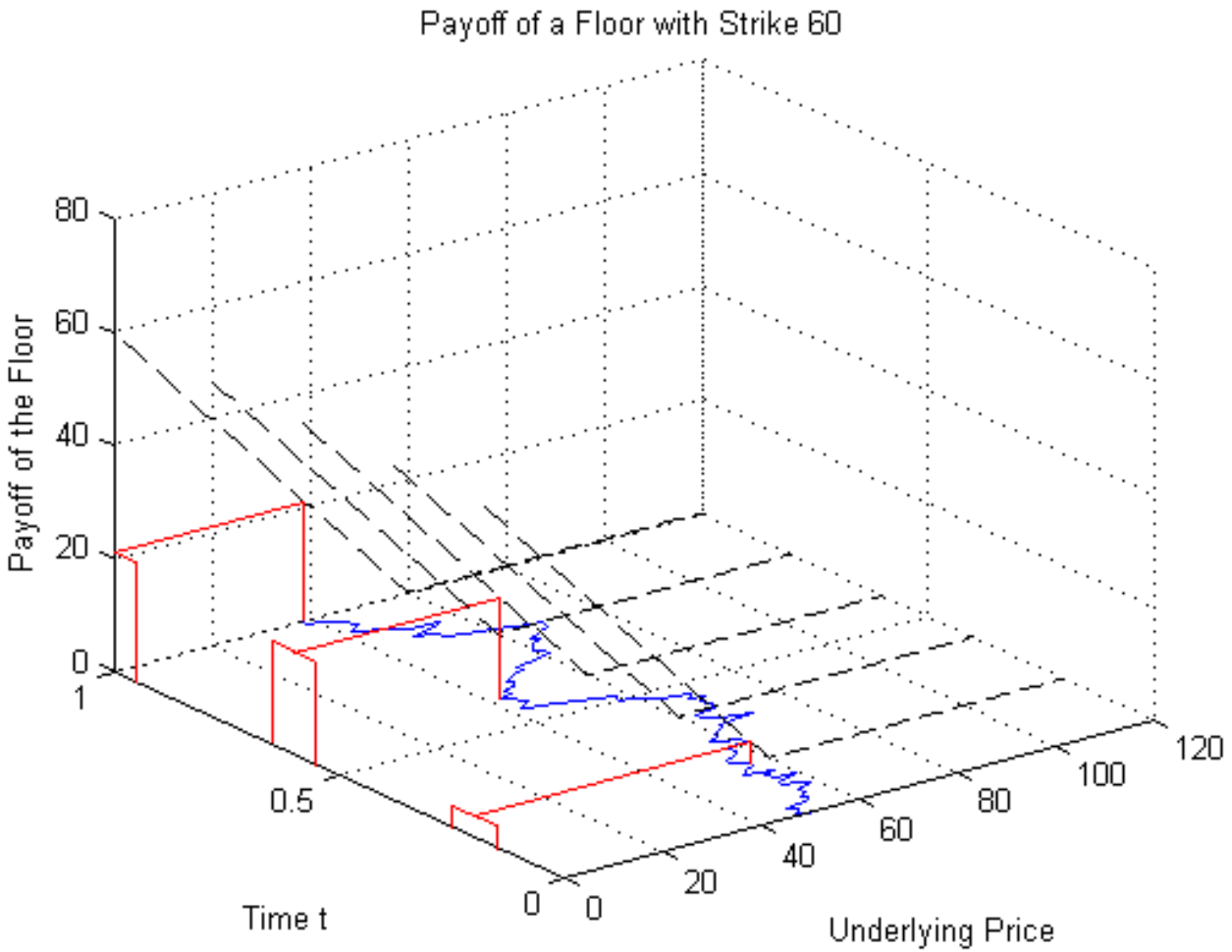
Floors

- Buying a floor, the option holder has the right (but not the obligation) to sell a certain amount of energy at stipulated times $t_1, \ldots, t_N$ during the delivery period at a fixed strike price K.
- It can be viewed as a strip of independent put options, for each time t_i the holder of the floor holds put options with maturity t_i and strike K.
- Similar to the case of a cap, the pricing formula is

$$U_f(t) = \frac{1}{N} \sum_{i=1}^{N} e^{-r(t_i - t)} \mathbb{E}[\max(K - S(t_i), 0)].$$

As with the cap, the price is quoted in Euro/MWh.

Floor - Payoff



Floors - Hedging

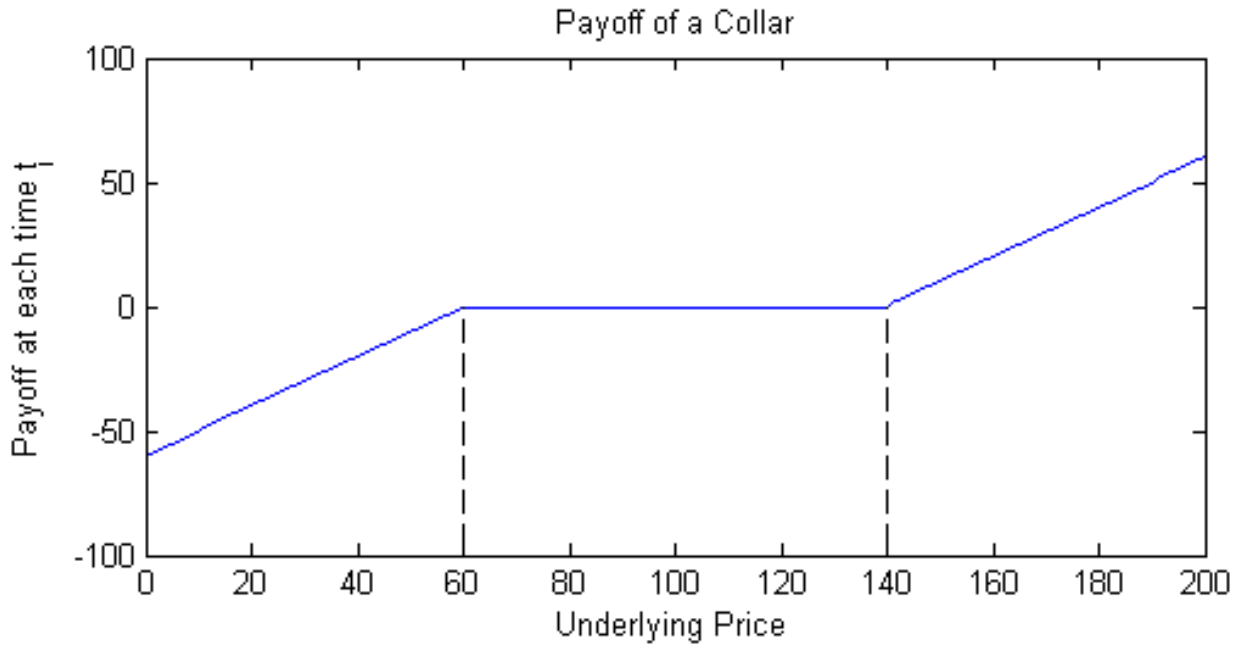
- The strike price K secures a minimum price for which the option holder is able to sell energy.
- A floor is used to cover a long position in the underlying (energy) against decreasing market prices not only at a certain point in time but over the whole period covered by the exercising times $t_1, \ldots, t_N$.
- On the other hand, the option holder is still able to profit from high energy prices as he has the right but not the obligation to exercise the option at each time point.
- The holder of a short position might write a floor to produce liquidity upfront. The maximum gain from the short position is then limited to the strike K.

Collars

- A collar is a combination of a cap and a floor such that variable prices are limited to a certain corridor.
- A long collar position consists of long one cap (with high strike K_2) and short one floor (with low strike K_1) - a short collar position is short one cap and long one floor.
- As long as the price of the underlying is between K_1 and K_2 at one of the dates t_i, no cash flows are exchanged.
- If the underlying is above K_2, the holder of the long collar position receives the difference of the actual price and K_2. If the underlying is below K_1, the short collar position receives the difference between K_1 and the actual price.

Collar - Payoff

As a long collar position is a strip of call options minus a strip of put options, the payoff of a collar at each time point t_i is the following:



Collar - Pricing

- Collars might be seen as a strip of bear/bull spreads, or as a strip of call options minus a strip of put options in the case of a long collar position.
- Consequently, the pricing formula is just the combination of the formulas for the cap and the floor:

$$\begin{aligned} U_{collar}^{K_1,K_2}(t) &= U_{cap}^{K_2}(t) - U_{floor}^{K_1}(t) \\ &= \frac{1}{N}\sum_{i=1}^{N} e^{-r(t_i-t)}\mathbb{E}[(S(t_i)-K_2)^+ - (K_1 - S(t_i))^+] \end{aligned}$$

- The price of a collar might be positive or negative - or even zero. In case the price is zero, the collar is called zero-cost collar.

Collars - Hedging

- The holder of a long position in a collar is protected against increases in the underlying price above K_2, but does not profit from falling underlying prices below K_1. Thus he is protected against rising prices with limited participation on downside prices.
- Having a short position in the underlying, a long collar ensures the ability to cover the short position for prices in the range of $[K_1, K_2]$.
- A short collar protects against falling prices. At the same time, the ability to participate on rising prices is limited to K_2.
- Having a long position in the underlying, a short collar ensures that the position can be closed for prices in the range of $[K_1, K_2]$.

Collars - 3-way-collars

- A long collar is short one floor with strike K_1, long one cap with higher strike K_2.
- A possible extension is to include a short position in one cap with strike $K_3 >> K_2$ in order to reduce the cost of the collar. This extension is called 3-way-collar.
- The price of a 3-way-collar is thus:

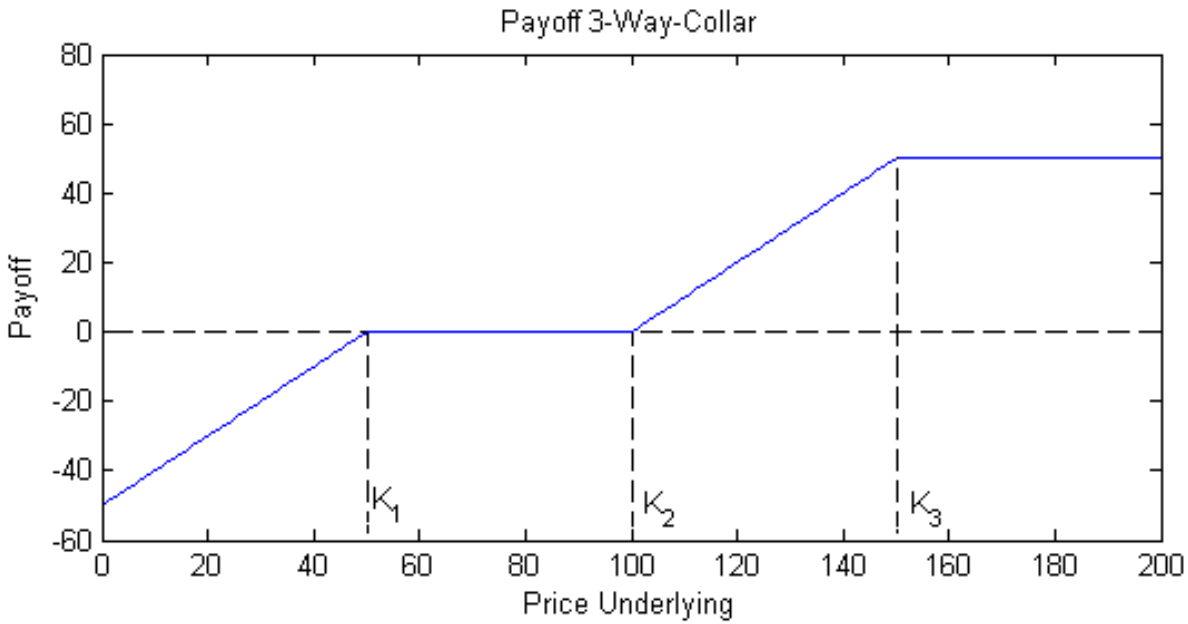
$$\begin{aligned} U_{3-way}^{K_1,K_2,K_3}(t) &= U_{cap}^{K_2}(t) - U_{cap}^{K_3}(t) - U_{floor}^{K_1}(t) \\ &= \frac{1}{N}\sum_{i=1}^{N} e^{-r(t_i-t)}\mathbb{E}[(S(t_i)-K_2)^+ \\ &\quad - (S(t_i)-K_3)^+ - (K_1 - S(t_i))^+] \end{aligned}$$

3-Way-Collar - Payoff

- The holder of the 3-way-collar is protected against increases in the underlying price above K_2, but only till K_3. Afterwards, no protection exists anymore.
- This strategy might be a good choice if one wants to protect its buying costs but is able to stop its business if prices rally unexpectedly high (above K_3).

3-Way-Collar - Payoff

The payoff is



Swing Options

- A swing option is similar to a cap or floor except that we have additional restrictions on the number of option exercises.
- Let $\phi_i \in \{0, 1\}$ be the decision whether to exercise ($\phi_i = 1$) or not to exercise ($\phi_i = 0$) the option at time t_i.
- The option's payoff at time t_i is given by

$$\phi_i(S(t_i) - K) \quad \text{call resp.} \quad \phi_i(K - S(t_i)) \quad \text{put.}$$

- We may also require that the number of exercises is between $E_{\min}$ and $E_{\max}$.

Swing Options

To determine the swing option value, we have to find an optimal exercise strategy $\Phi = (\phi_1, \ldots, \phi_N)$ maximising the expected payoff

$$\sum_{i=1}^{N} e^{-r(t_i - t)} \mathbb{E}[\phi_i (S(t_i) - K)] \quad \rightarrow \max$$

subject to

$$E_{\min} \leq \sum_{i=1}^{N} \phi_i \leq E_{\max}.$$