



Modeling Power Prices

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What is the Influence of Wind Power Feed-in?

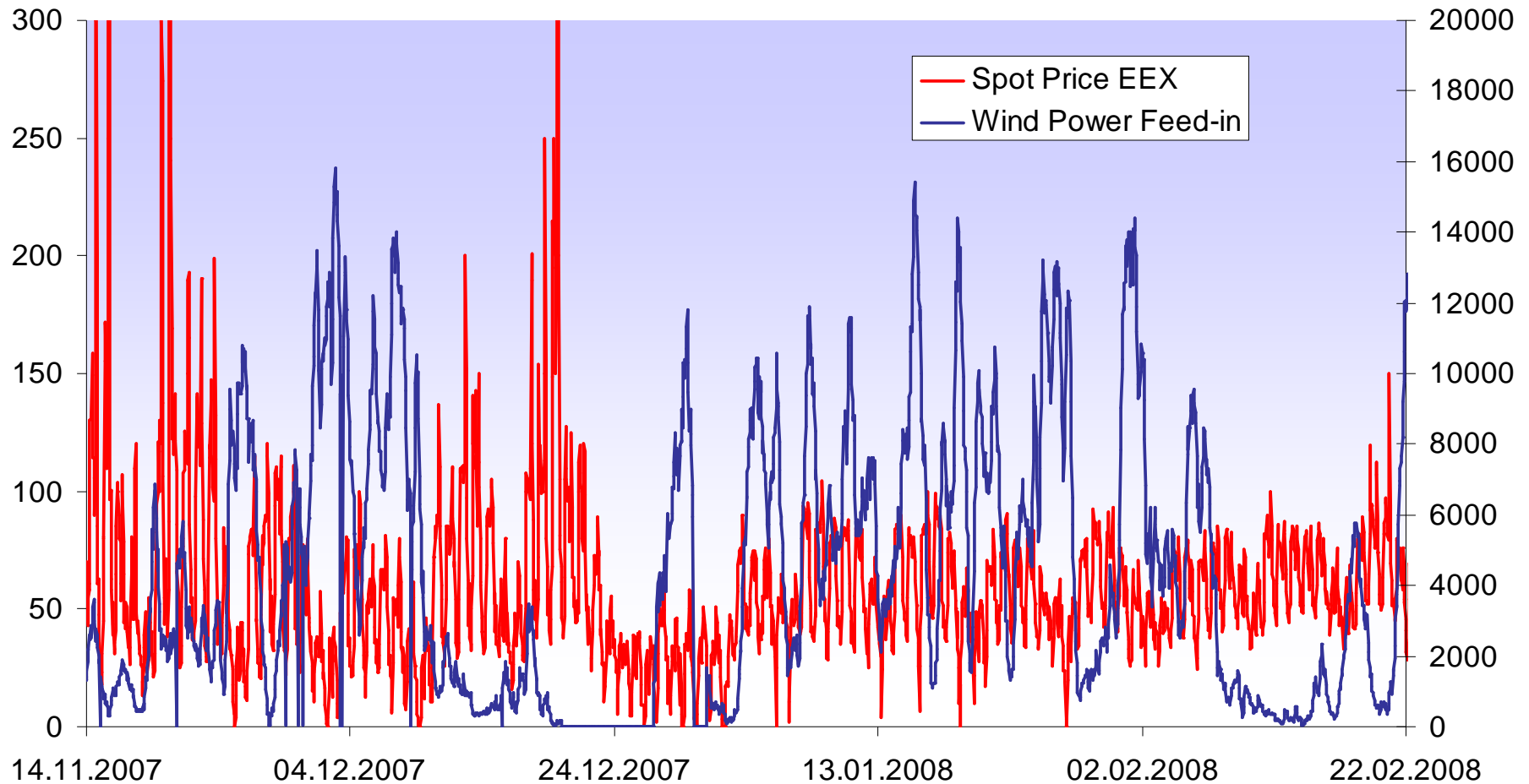
Steffen Sacharowitz

GTZ Workshop

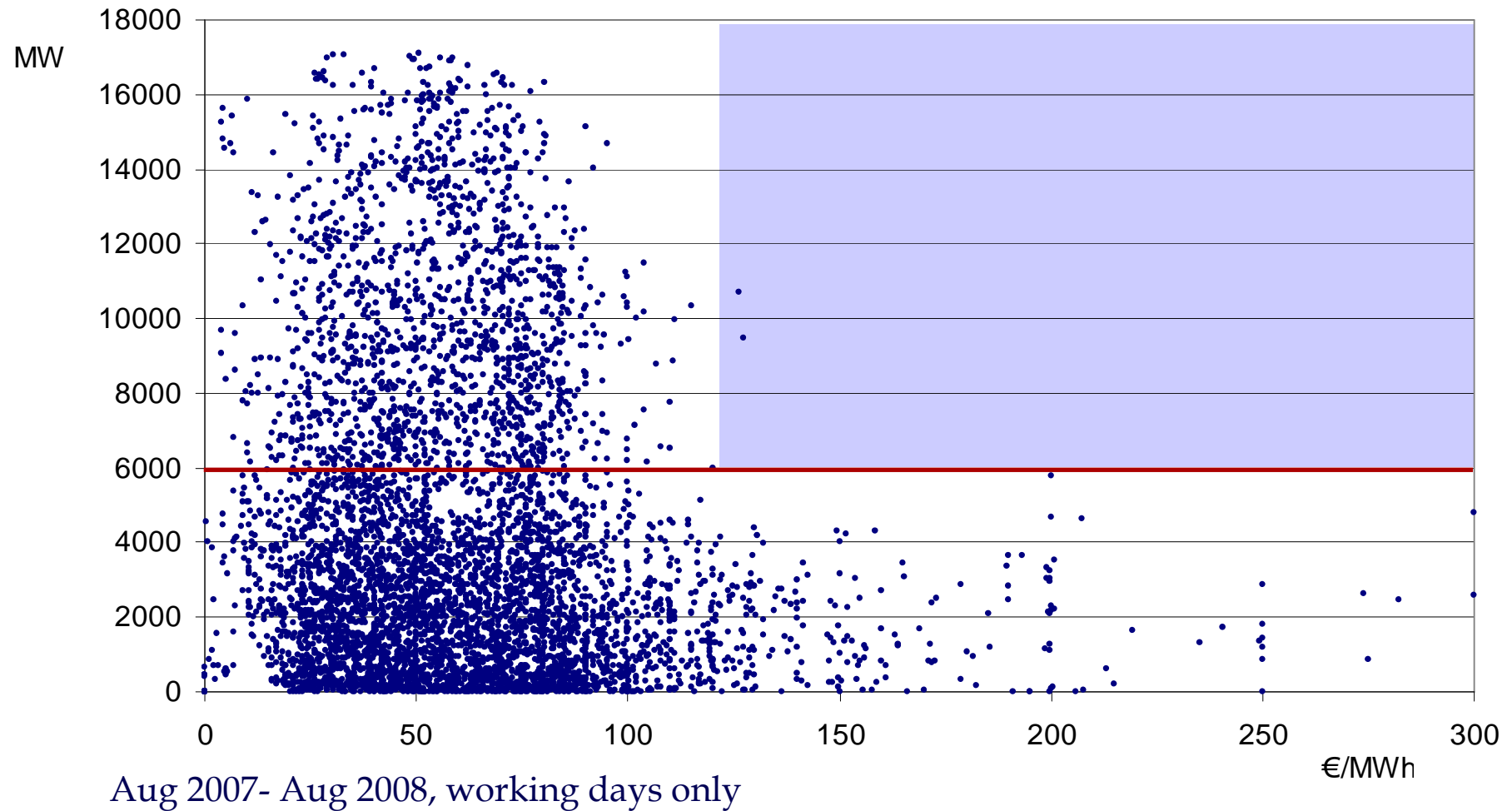
Grid and System Integration of Wind Energy

Berlin, 17 September 2008

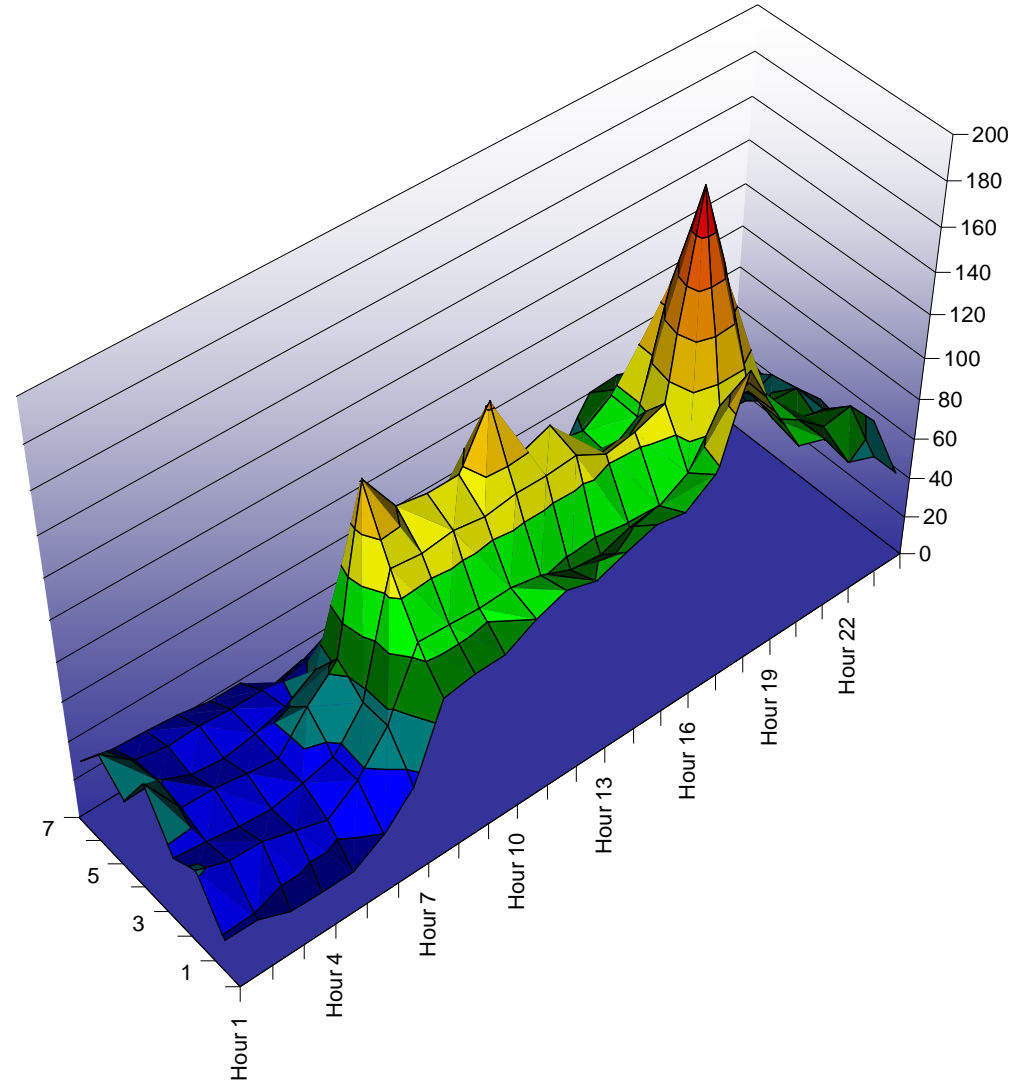
German Power Prices and Wind Power Feed-in



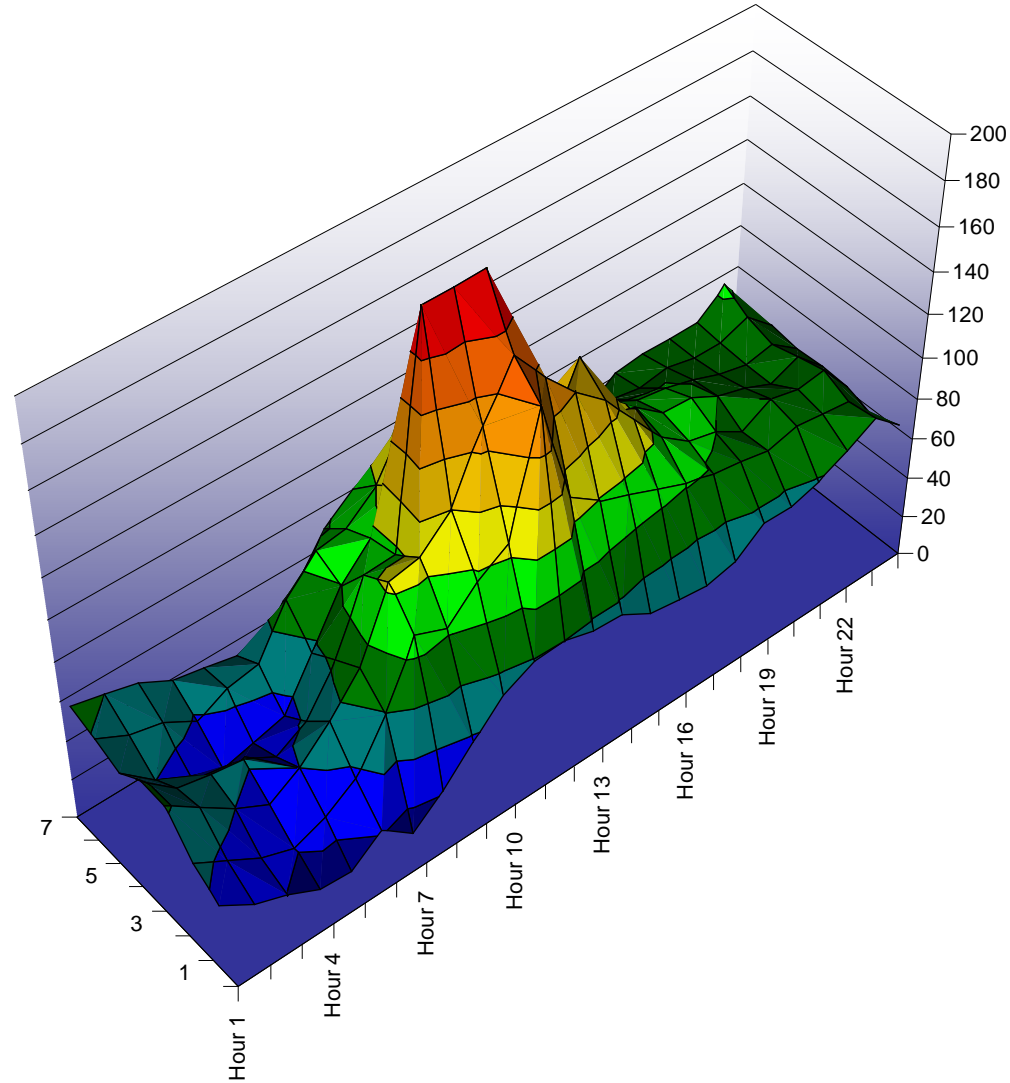
Hourly Power Price vs. Wind Power Forecast



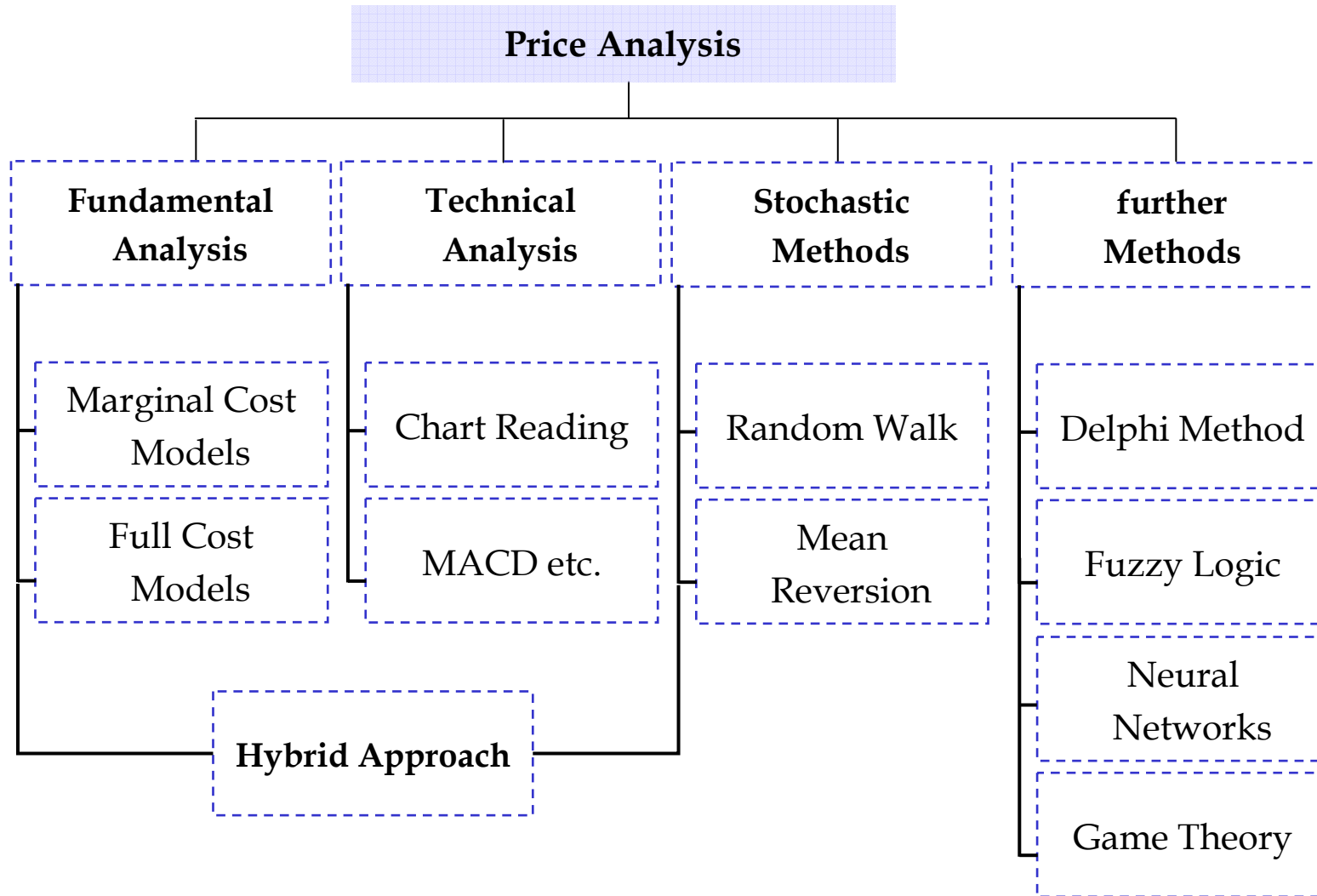
EEX Spot Price Power December 2007



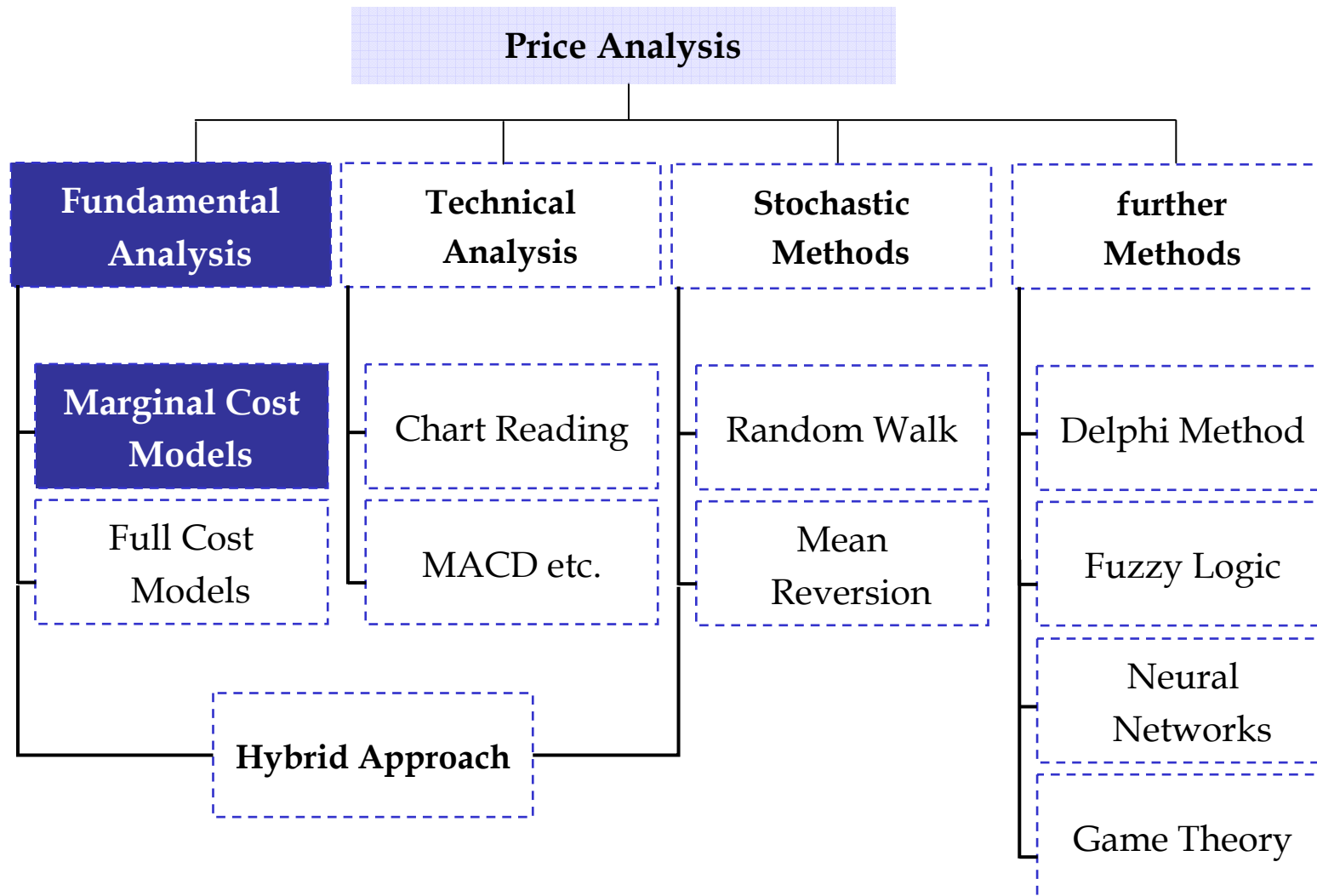
EEX Spot Price Power June 2008



Price Analysis Approaches



Price Analysis Approaches



Fundamental Modeling Approach

- Rational bidding behavior
- Power plant dispatch for power prices above short term marginal generation costs (STMGC)
- STMGC: marginal costs of next dispatched unit

$$STMGC = \frac{P_{PE}}{\eta_{PP,PE}} + \varepsilon_{PP} \cdot P_{EUA}$$

P: price; η : electric efficiency; PP: power plant; ε : specific emission coefficient;
EUA: EU allowance (CO₂)

- Merit Order modeling approach: power plant capacities sorted according to STMGC

Modeling Power Plant Dispatch

Merit Order

- availability renewables
- power plant DB
- efficiencies according to year of construction
- STMGC according to commodity prices

Power Demand

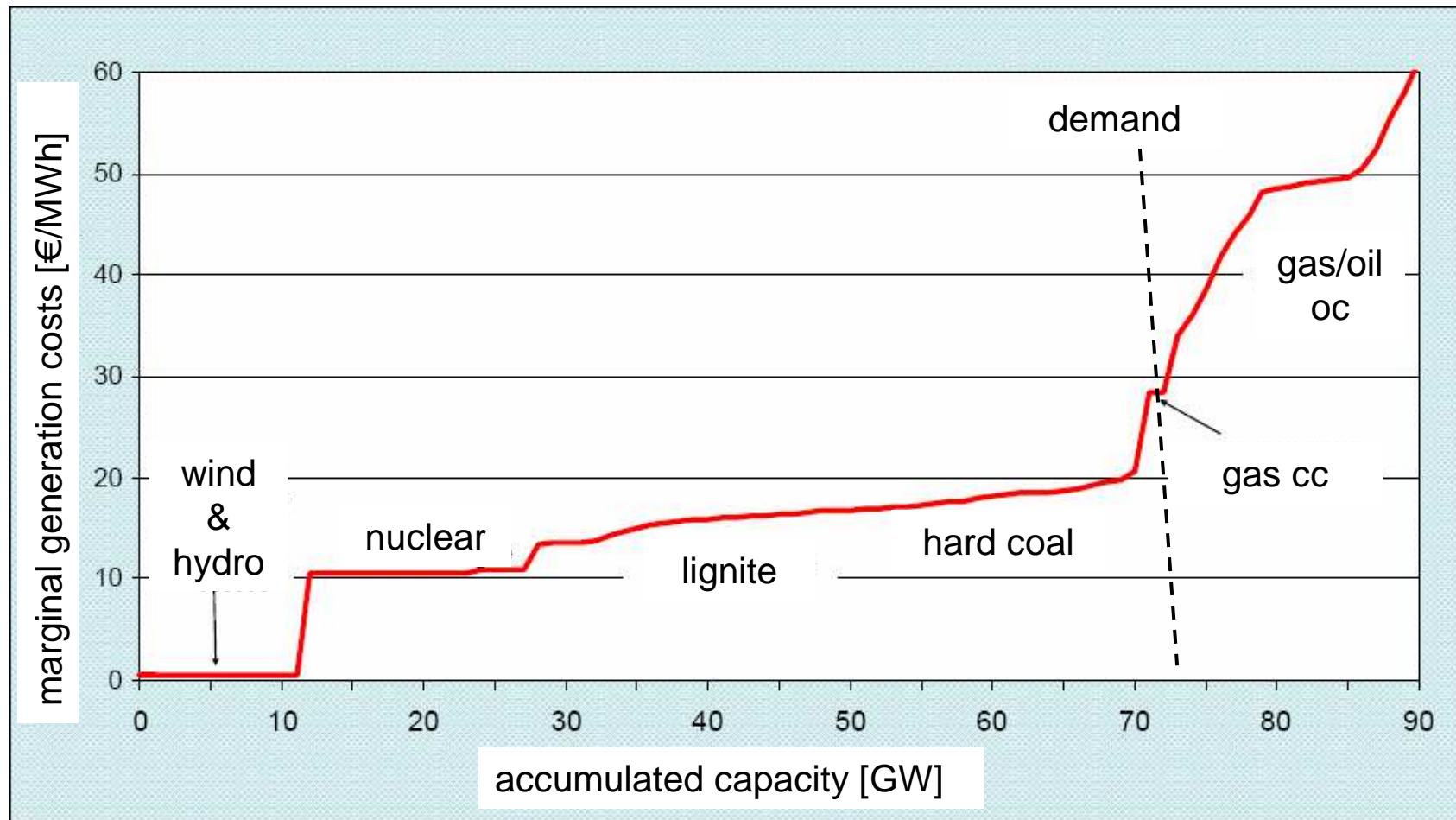
- regression analysis of daily average demand
- parameters: calendar and temperature data
- hourly load profile according to monthly day type



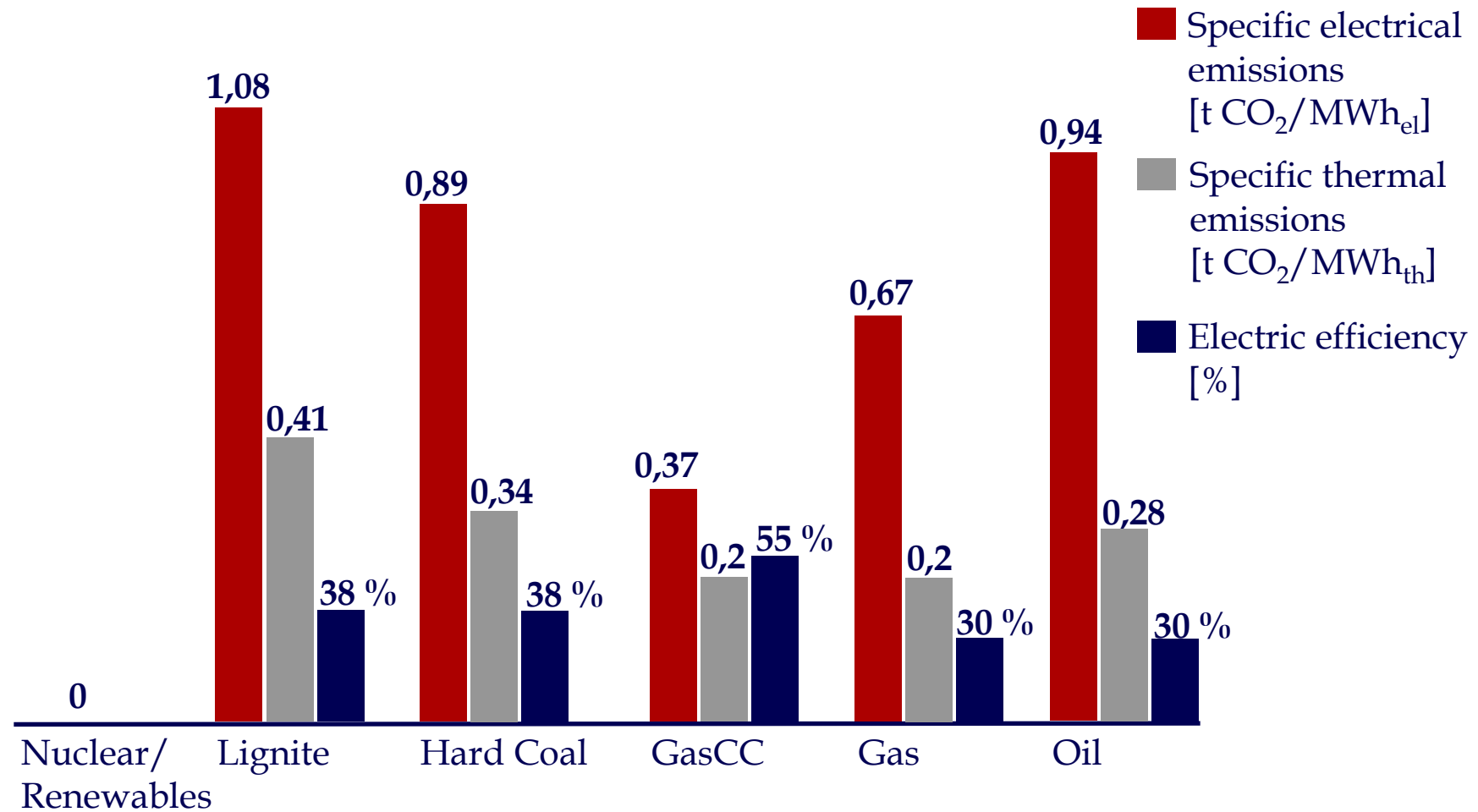
Power Plant Dispatch

hourly power plant dispatch with according market clearing price

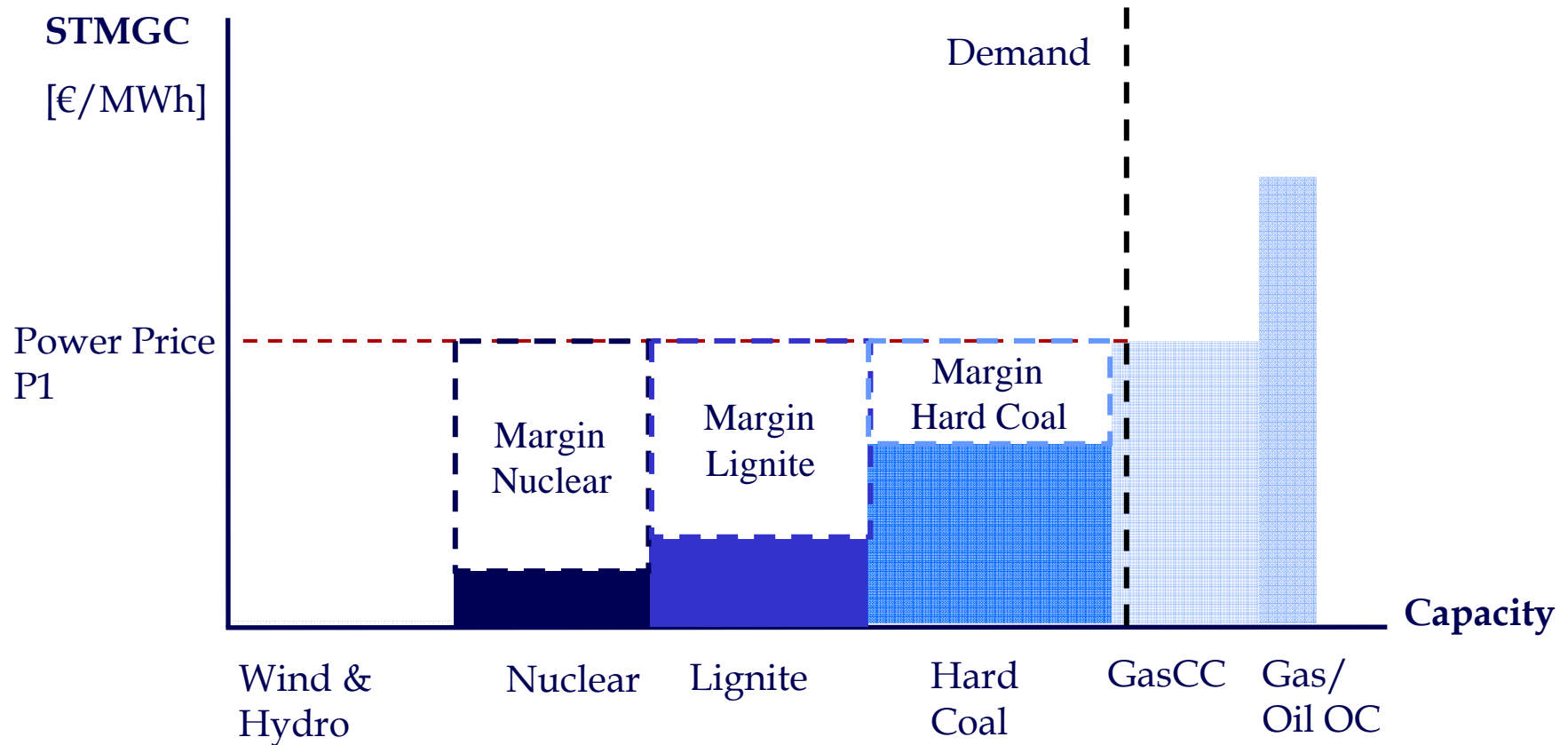
Merit Order without CO₂ Price



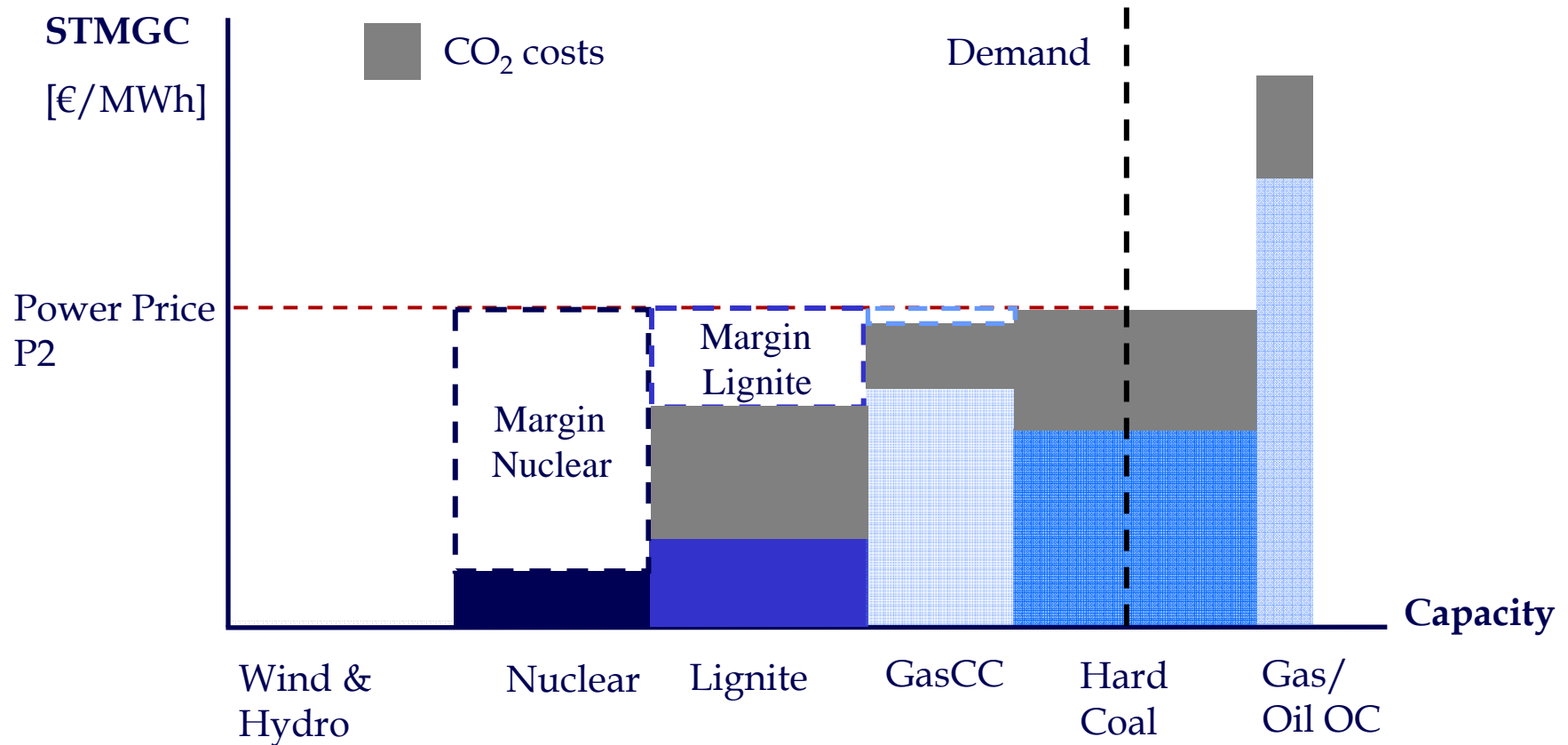
CO₂ Emissions of Power Plant Technologies



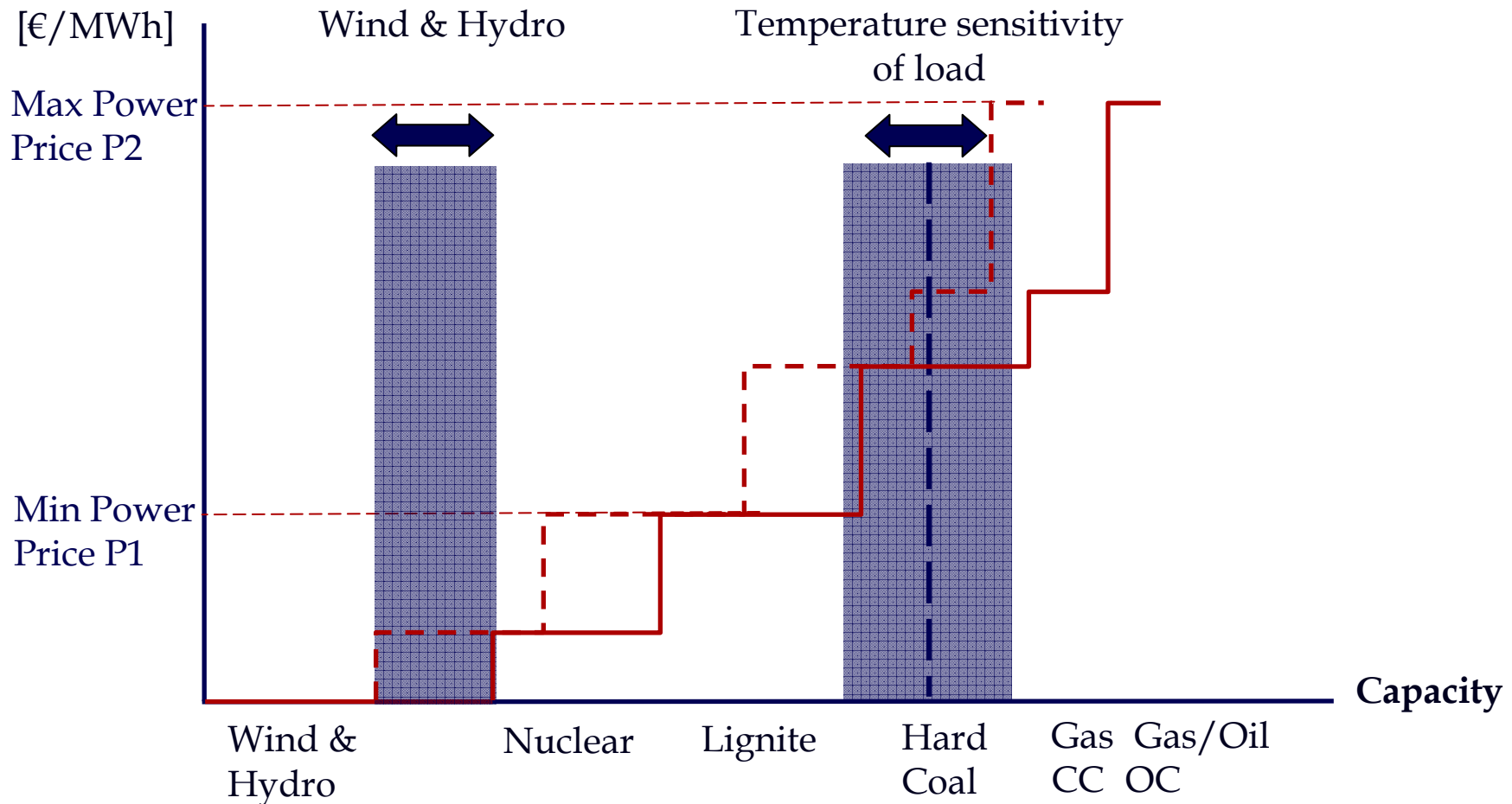
Schematic Merit Order without CO₂ Price



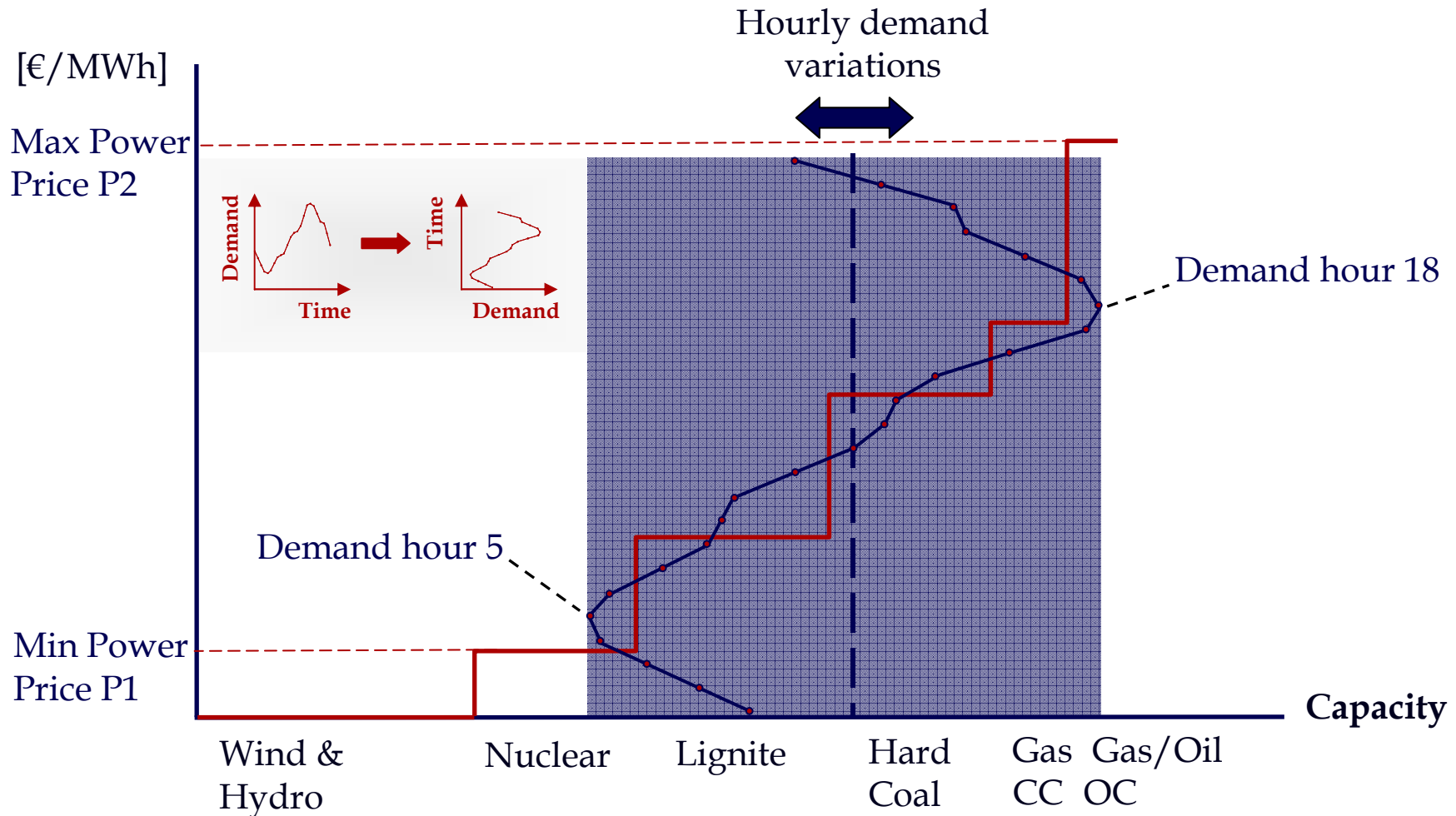
Schematic Merit Order Including CO₂ Price



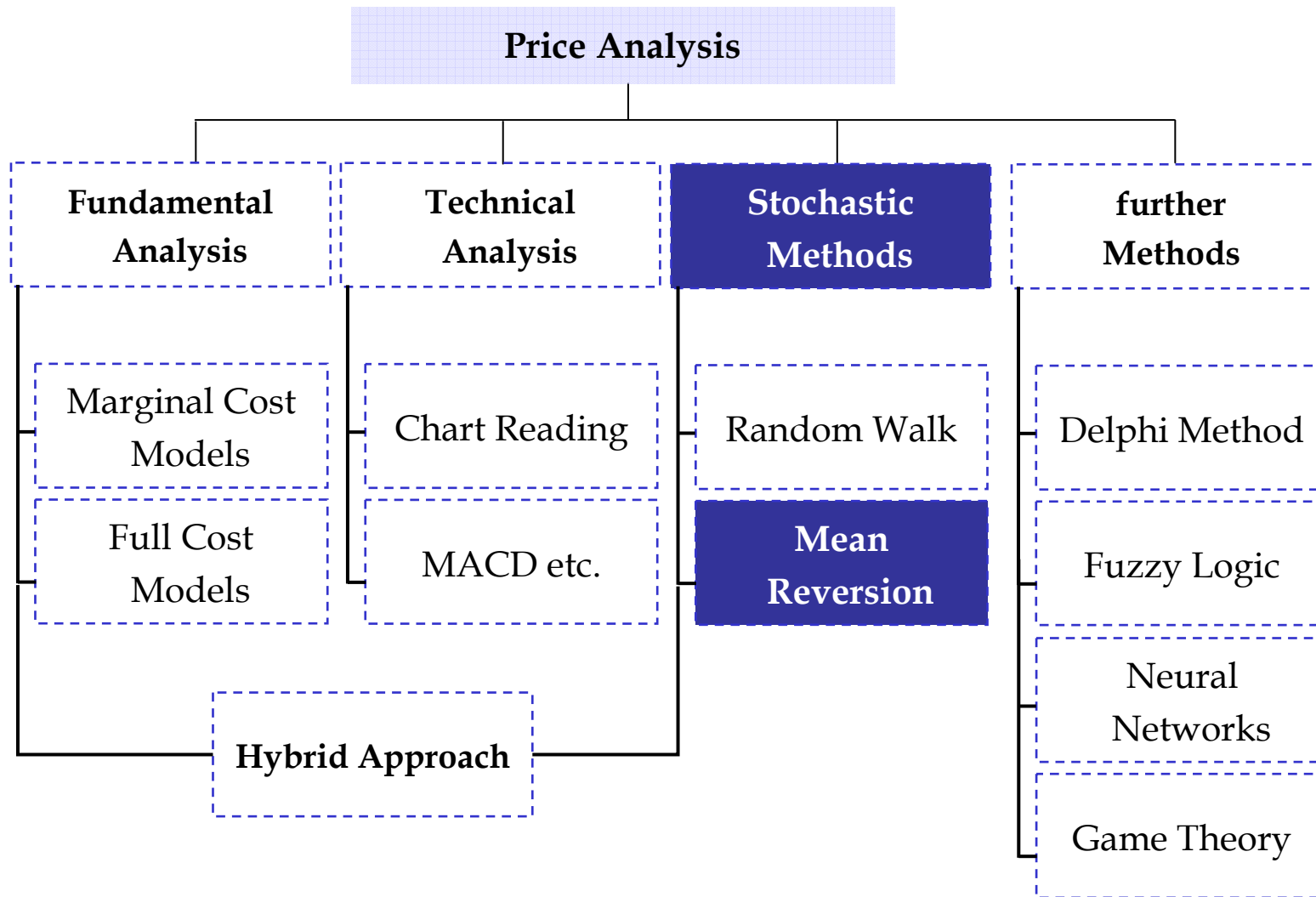
Weather Dependency of Power Prices



Hourly Variation of Power Prices



Price Analysis Approaches



Linear Regression

- Stochastic analysis of historical prices
- Movement of dependent variable (price) contains information of independent variables (calendar data, temperatures etc.)

$$p_j = c_0 + c_1 x_1 + c_2 x_2 + c_3 x_3 + \dots + \varepsilon_j$$

p : price (dependent variable); c_i : correlation coefficient;
 x_i : independent variables; ε_j error term

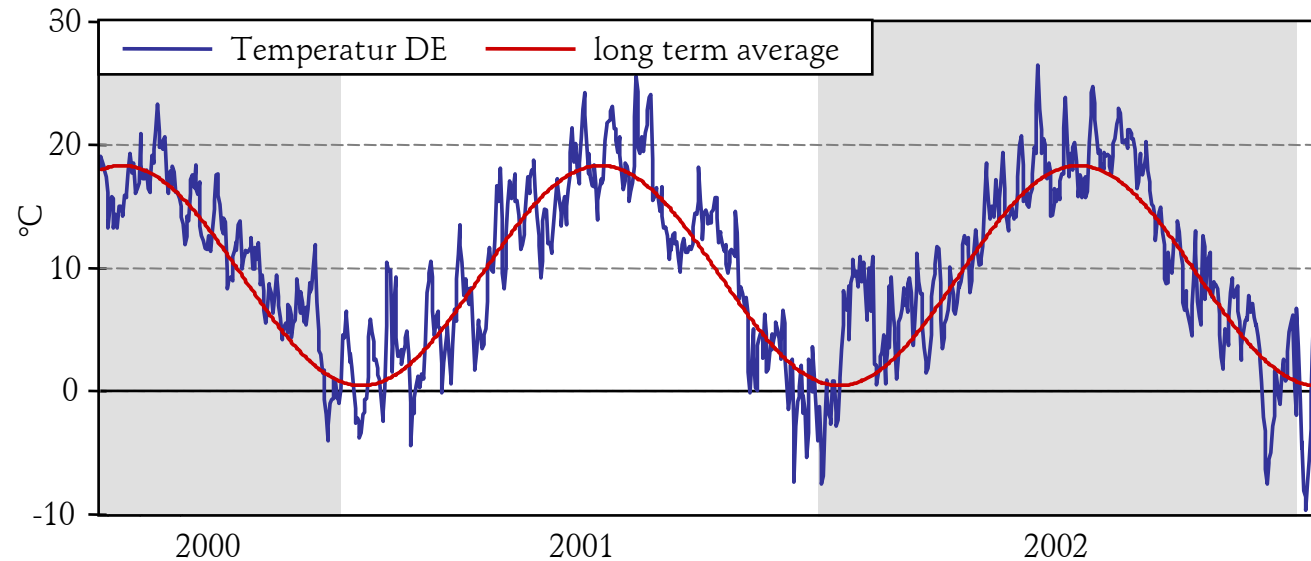
- Least-squares analysis: deriving best fit by minimizing S :

$$S = \sum_{j=1}^n \varepsilon_j^2 \quad S: \text{sum of squared residuals}$$

Example of Linear Regression Modeling Approach

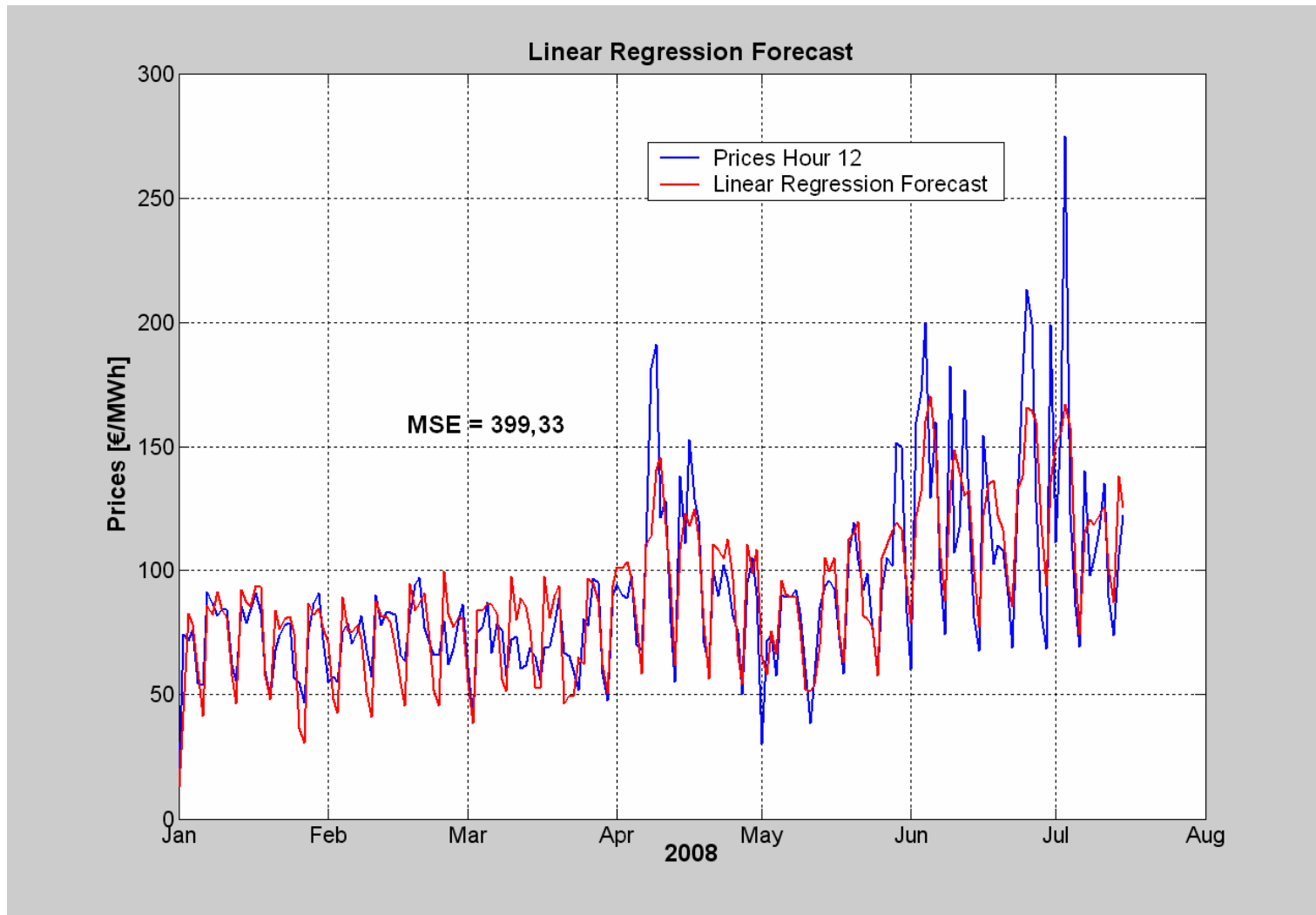
- Basis: mean reversion model
- Modeling a time-dependent mean:
 - identifying seasonal and temperature dependencies
 - influence of calendar data
- Examples of other influencing factors:
 - wind and hydro power generation
 - power price France
 - availability of power plant capacities

Finding the Mean: Long Term Average Temperatur

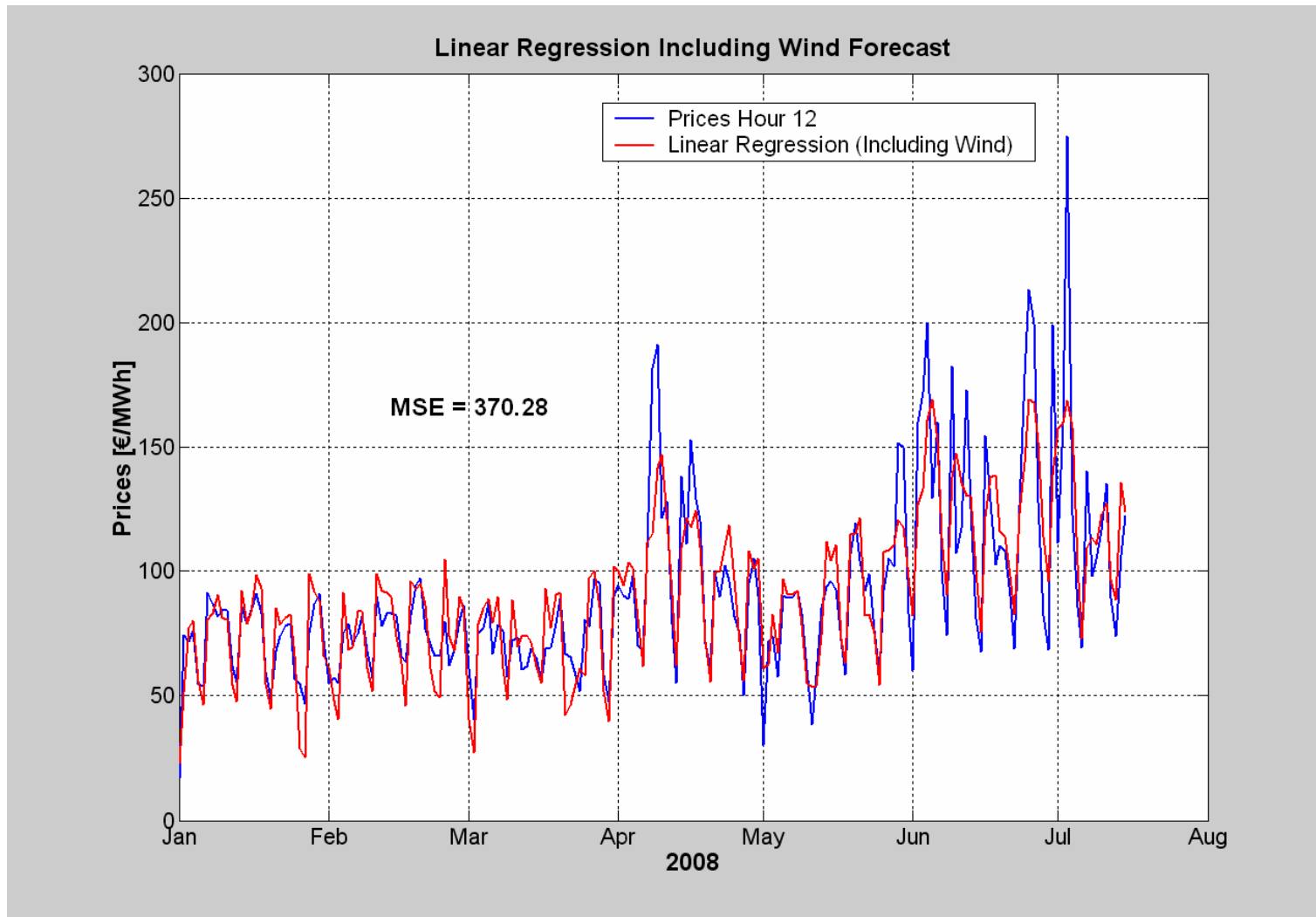


- Distinct long term average
- Deviations from mean with periods of unusual cold and warm temperatures
- Distinct reversion to mean
- Significant influence on spot power prices

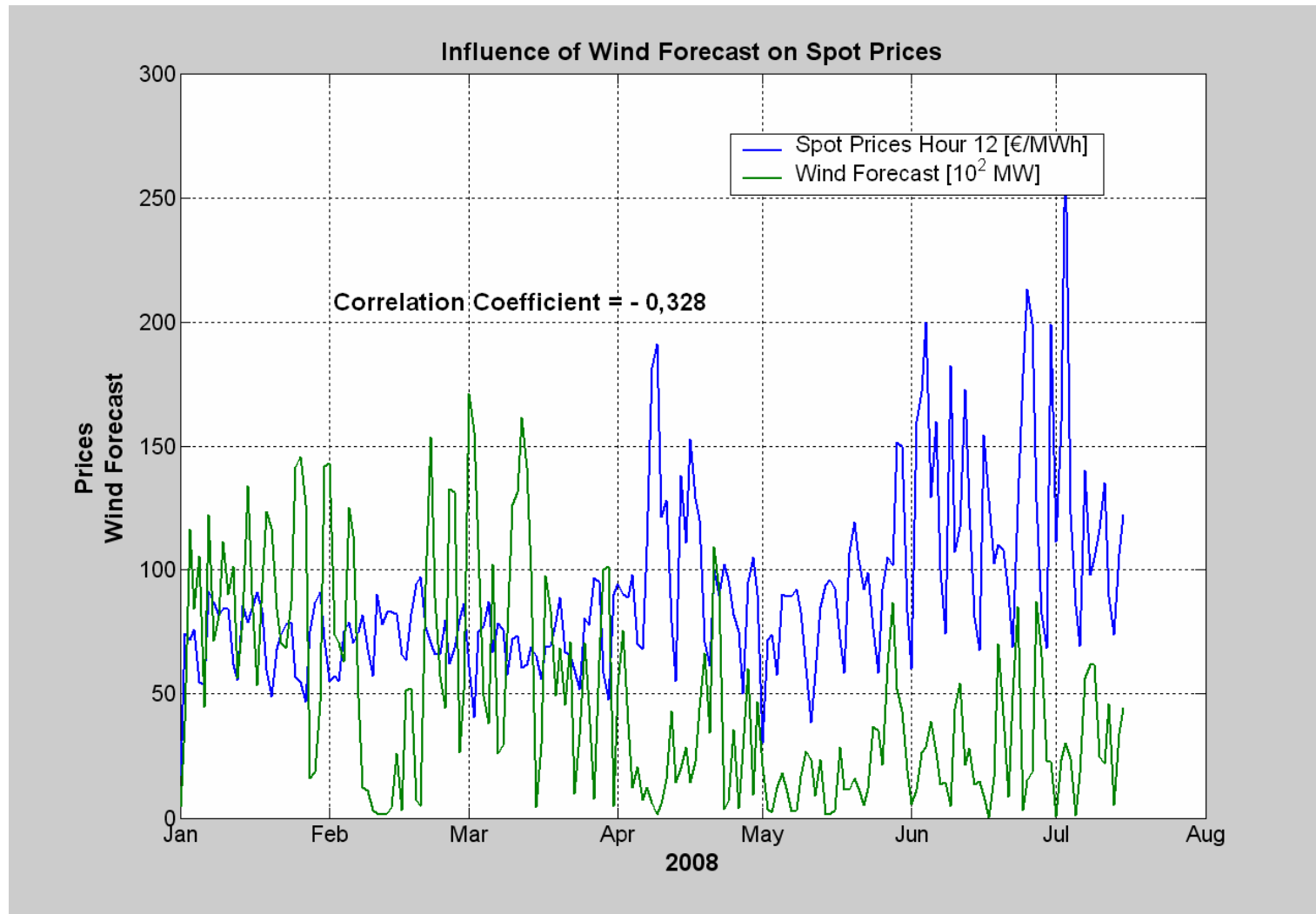
Linear Regression of Spot Prices without Wind



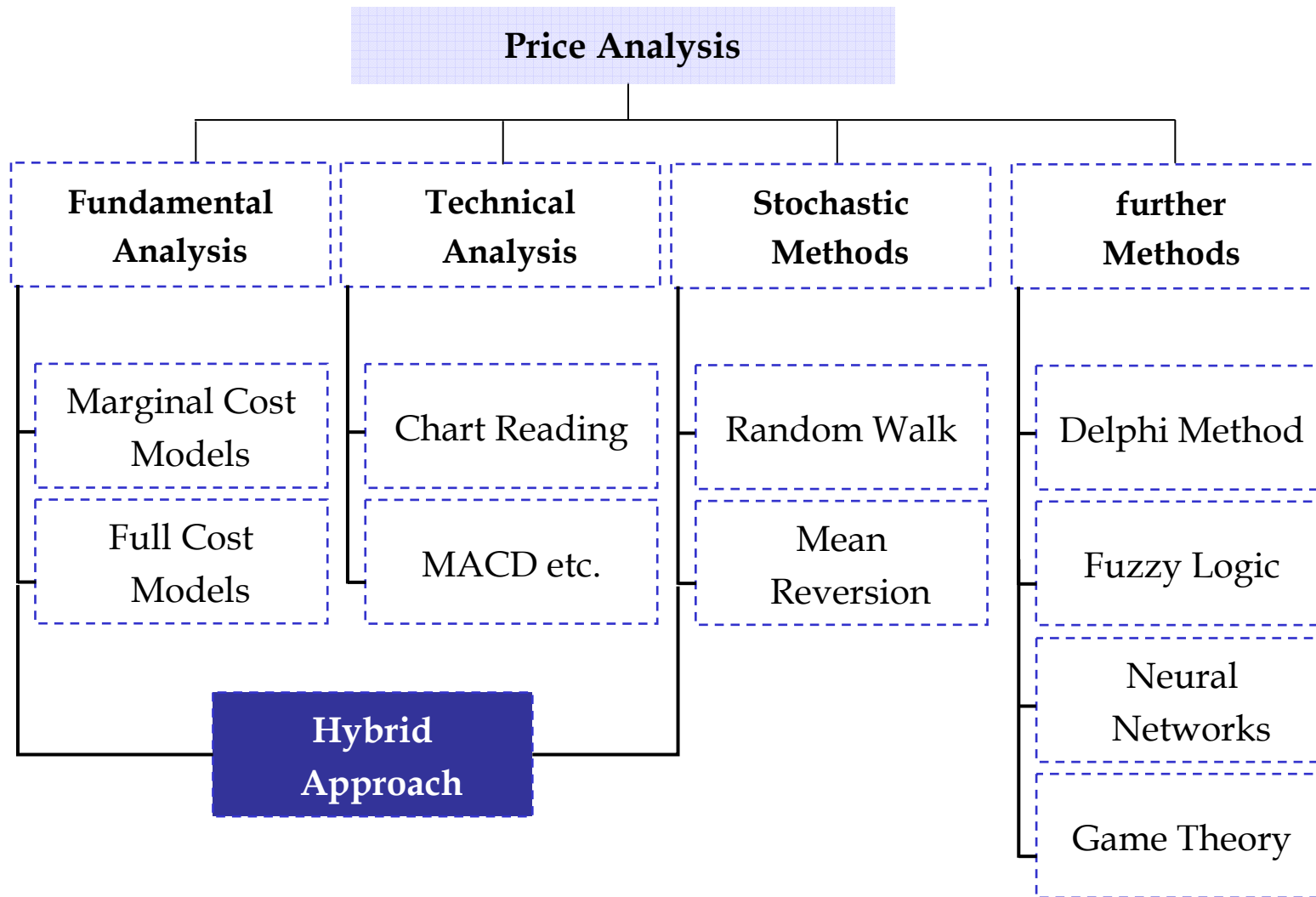
Linear Regression of Prices Considering Wind Power



Influence of Wind Power Forecast



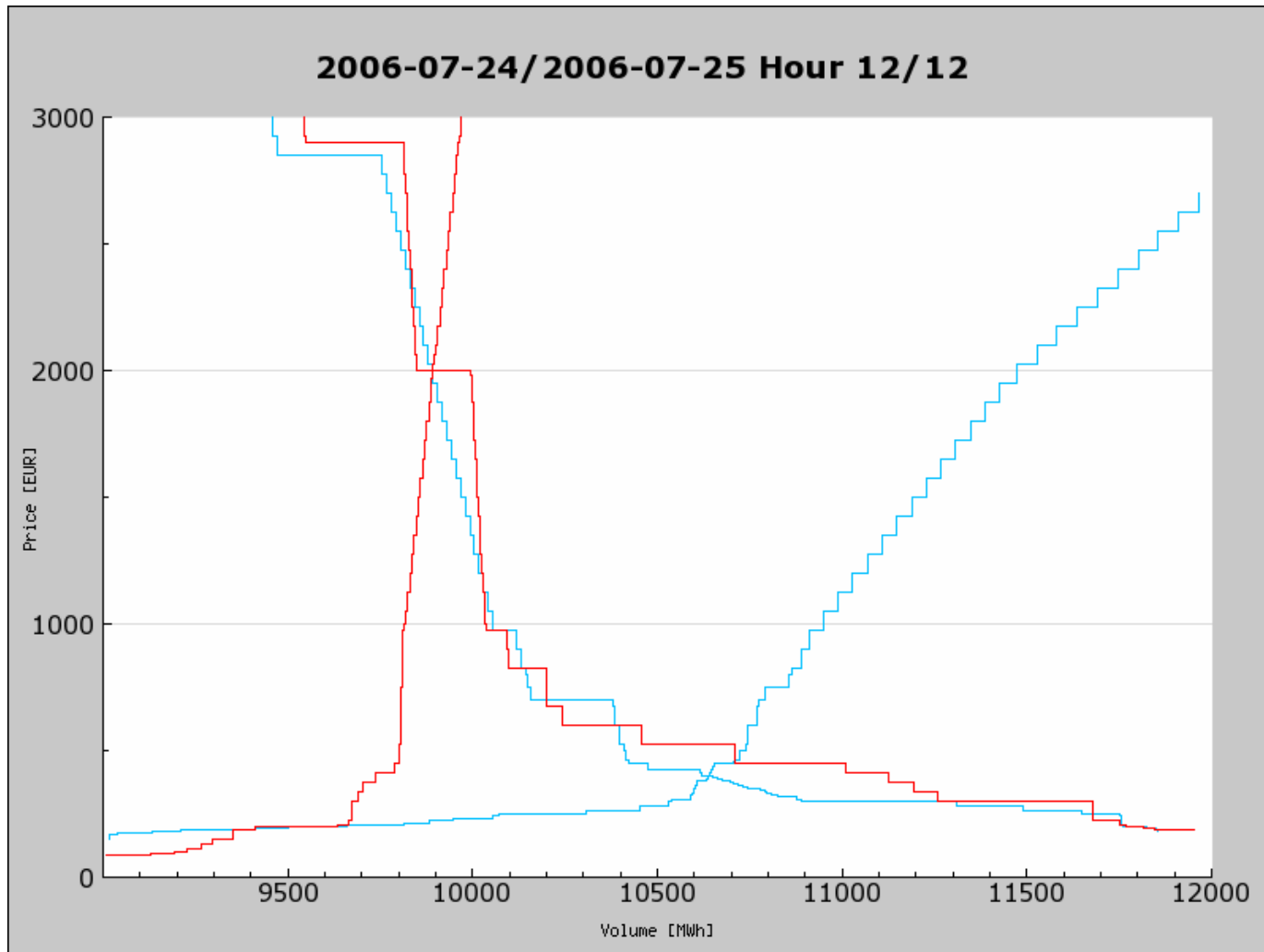
Price Analysis Approaches



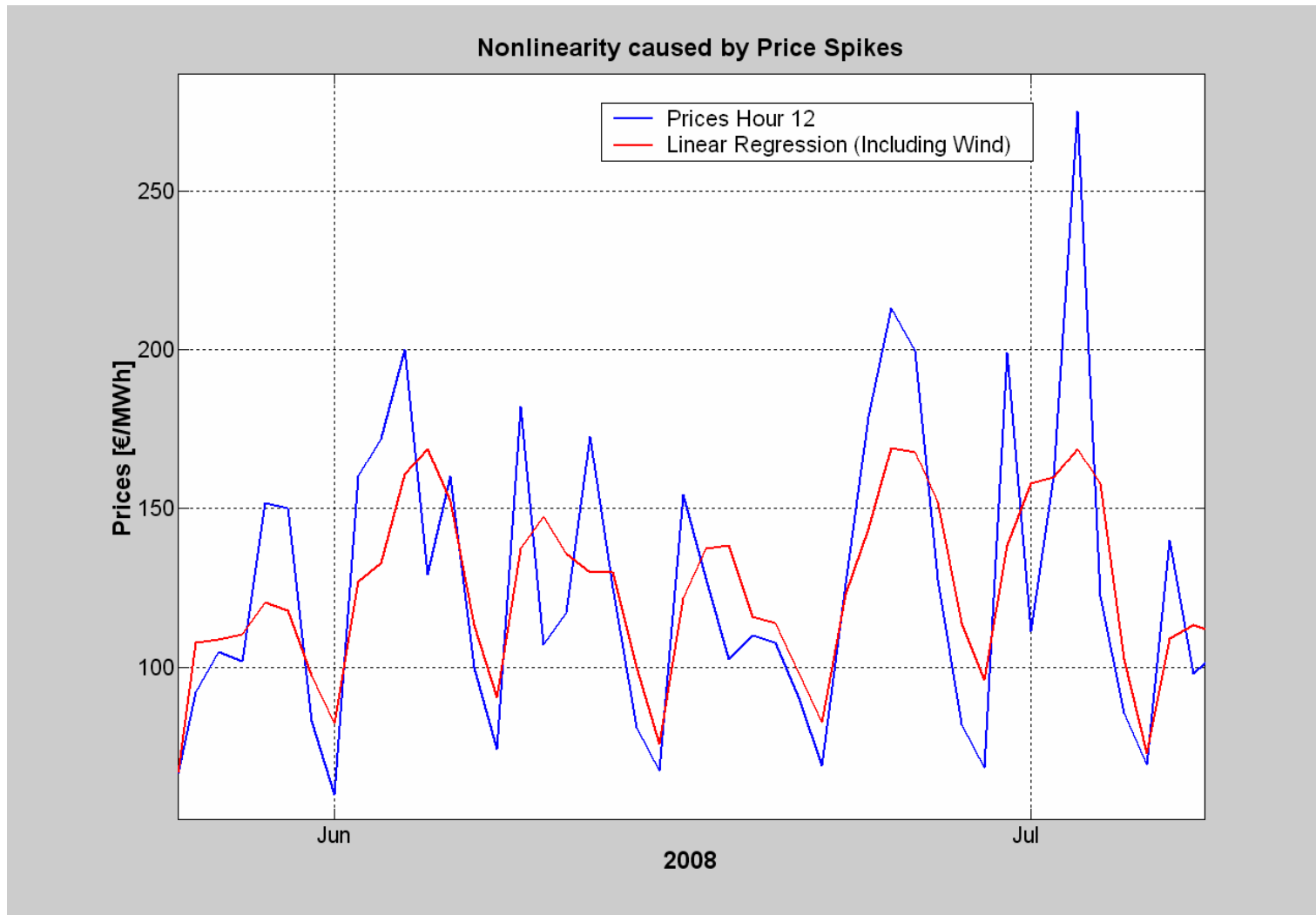
Principles of Hybrid Approach

- Combination of fundamental and stochastic approaches
- Parts of the market are modeled by a modular fundamental approach to represent underlying factors
- Output of fundamental model modules is correlated with price information
- Non-linear behavior is addressed by fundamental model modules

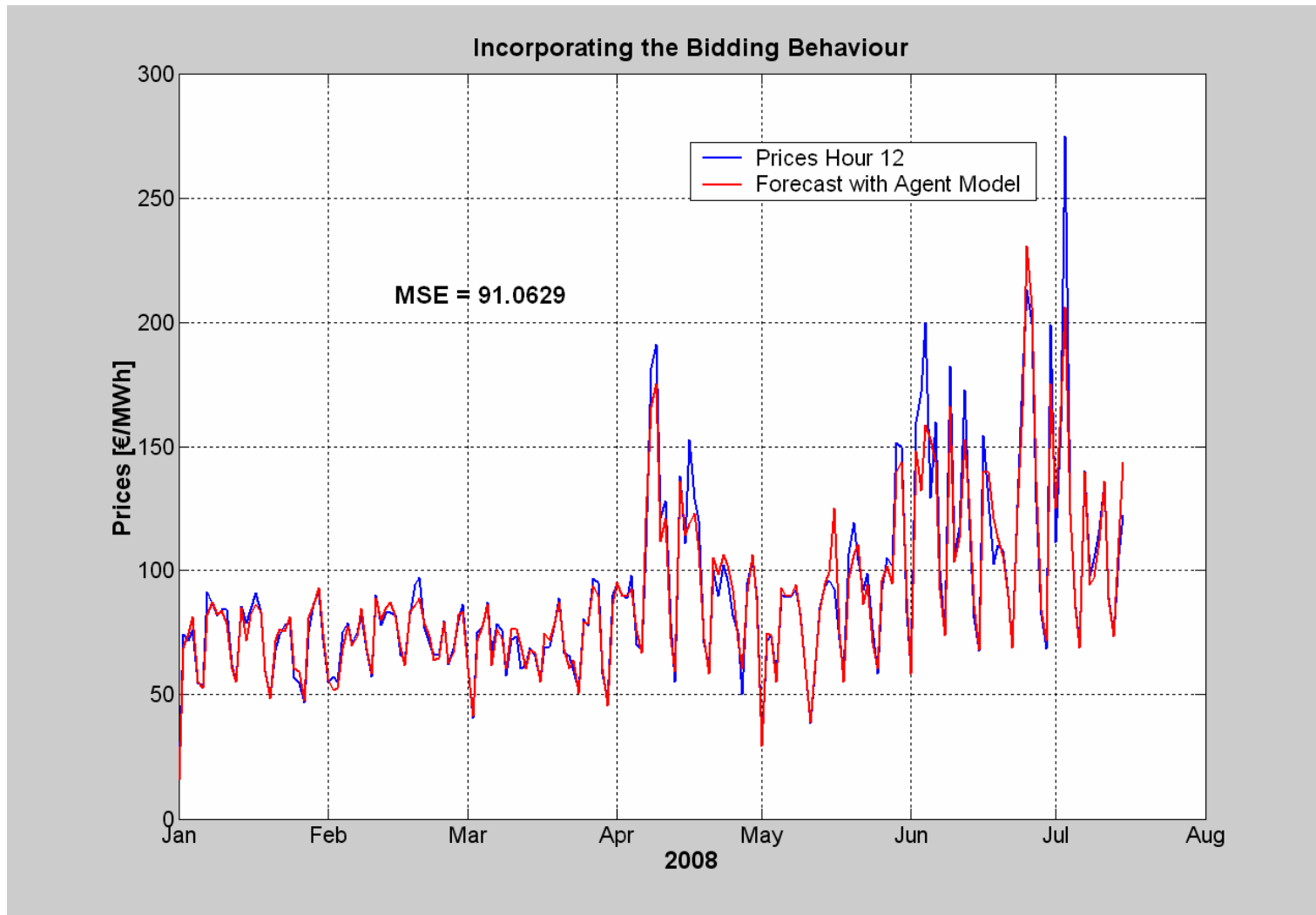
Non-linear Bidding Behavior in Spot Price Auction

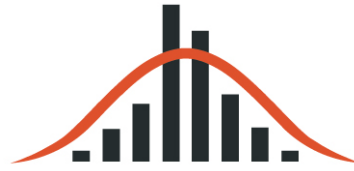


Price Spikes Caused by Non-linearity



Improved Model Incorporating Bidding Behavior





Energy Brainpool

Analysis - Modelling - Consultancy

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