

Energy Economics: Electricity Markets

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- Theory of Efficient Power Dispatch
- Implementation and Market Results

- Problem 1: Possible Price Manipulation
- Problem 2: Free GHG Allowances
- Problem 3: Regulation and Balancing Power
- Problem 4: Clearing of Electricity Futures
- Problem 5: Lack of Power Plant Investments
- Problem 6: New Market Design



Theory of Efficient Power Dispatch

Generation Decision in a Competitive Market

Profit $\Pi = p \cdot Q - C_f - c_v \cdot Q$

p	Price
Q	Generation (Quantity)
c_v	Variable unit cost
C_f	Fixed costs

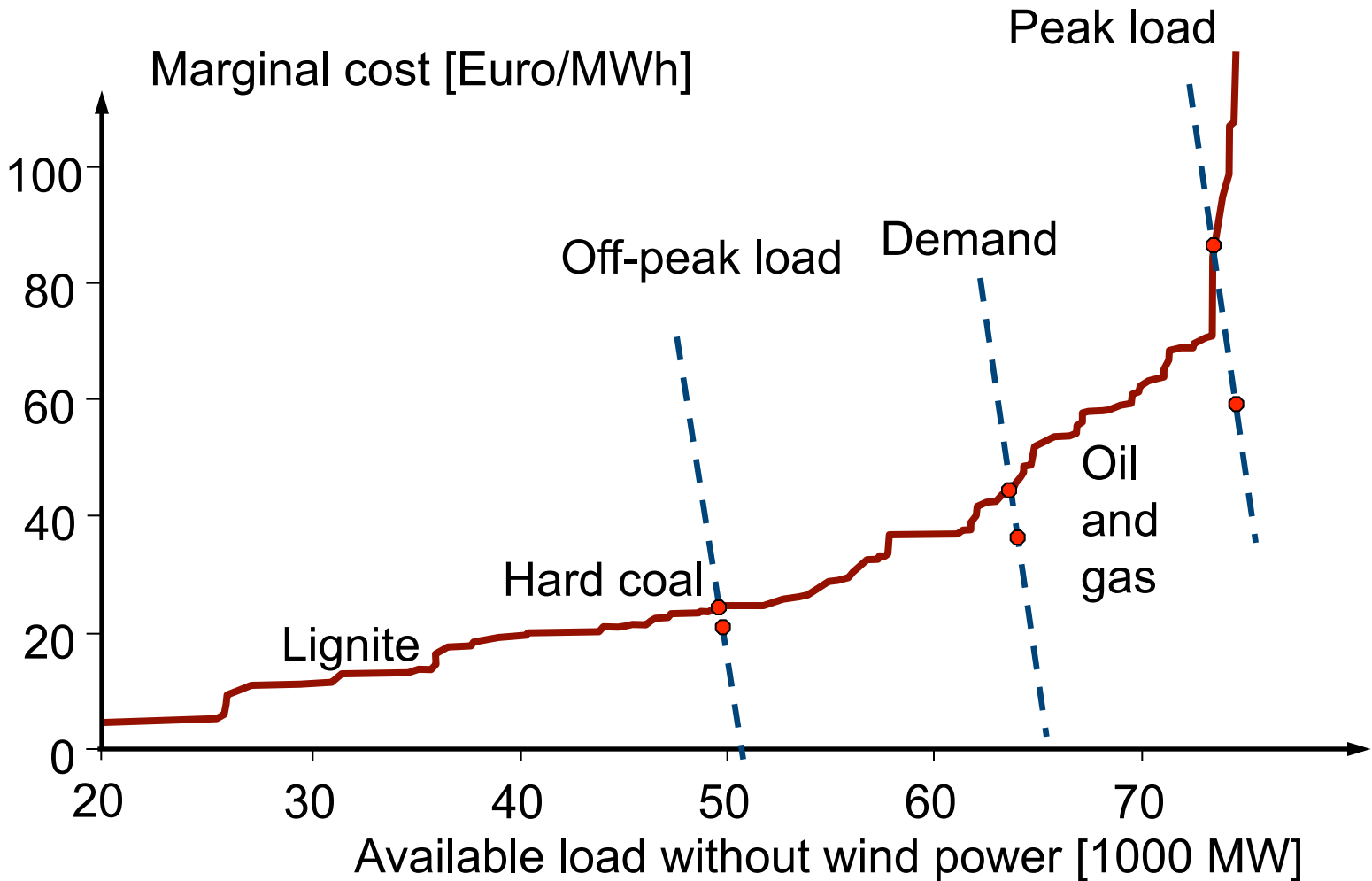
Profit maximizing under atomistic competition:

$$\frac{d\Pi}{dQ} = p \frac{dQ}{dQ} + \underbrace{Q \frac{dp}{dQ}}_{=0} - \underbrace{\frac{dC_f}{dQ}}_{=0} - \frac{d(c_v \cdot Q)}{dQ} = 0 \quad \Rightarrow \quad p = \frac{dC}{dQ} = c_v$$

Sales price must exceed the variable costs, otherwise no offer

Merit Order Curve Germany

[without CO₂ cost; Source: EU Sector Enquiry 2007, p. 260]





Implementation and Market Results

European Power Exchanges



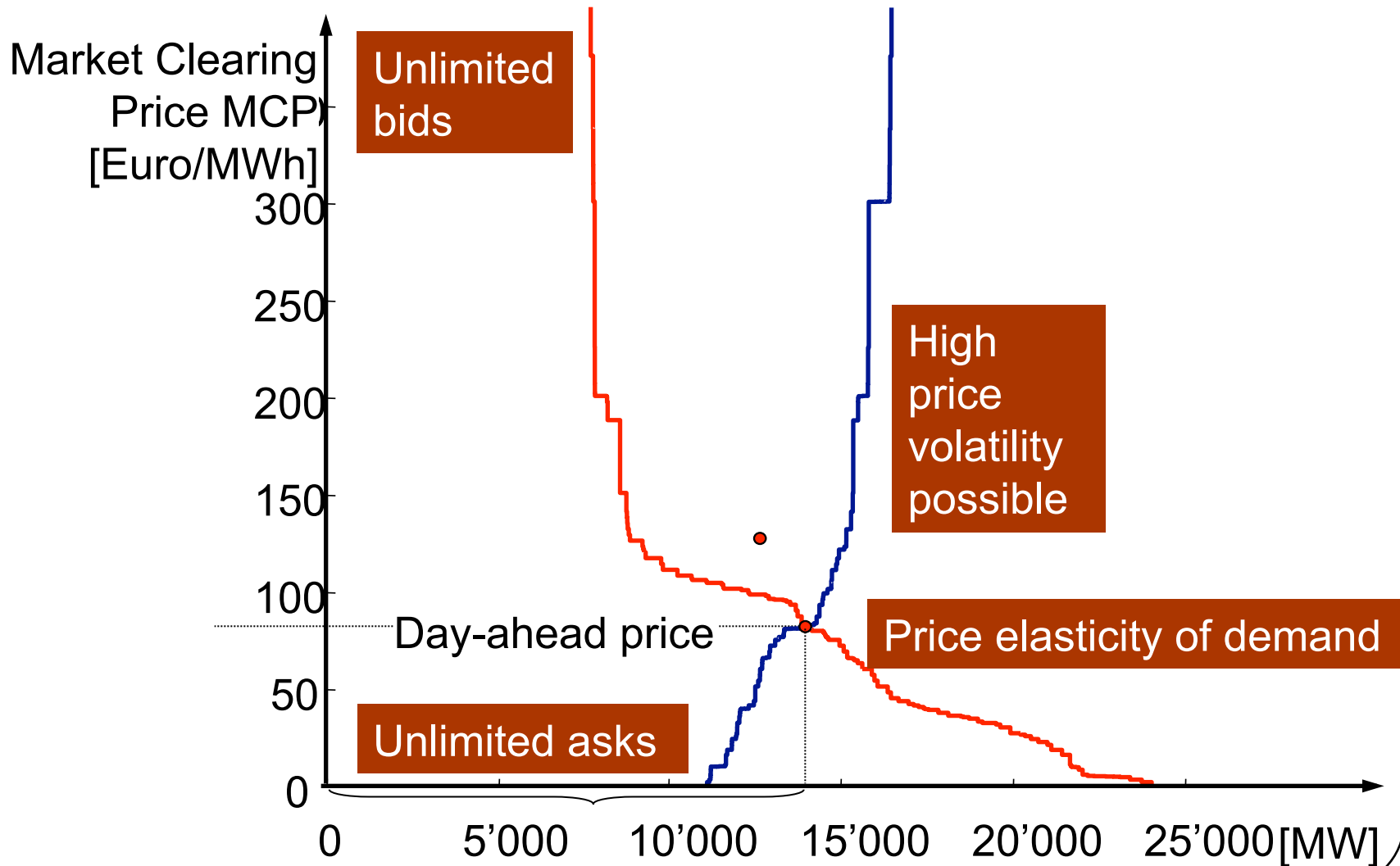
EEX Day-ahead Auction [24 hourly products]

- Double sided auction (bid and ask order book)
- Multi unit auction (share auction; transaction volume and price caps can be included in the order book)
- Sealed bid market (participants don't see the offers of other traders)
- Single round auction (no continuous trade)
- Uniform price auction (MCP instead of pay-as-bid)
- Combinational auction (block orders are possible)
- Gate closure 12:00 noon
- Before 15:00 h the resulting $\frac{1}{4}$ h schedules are submitted to the TSOs

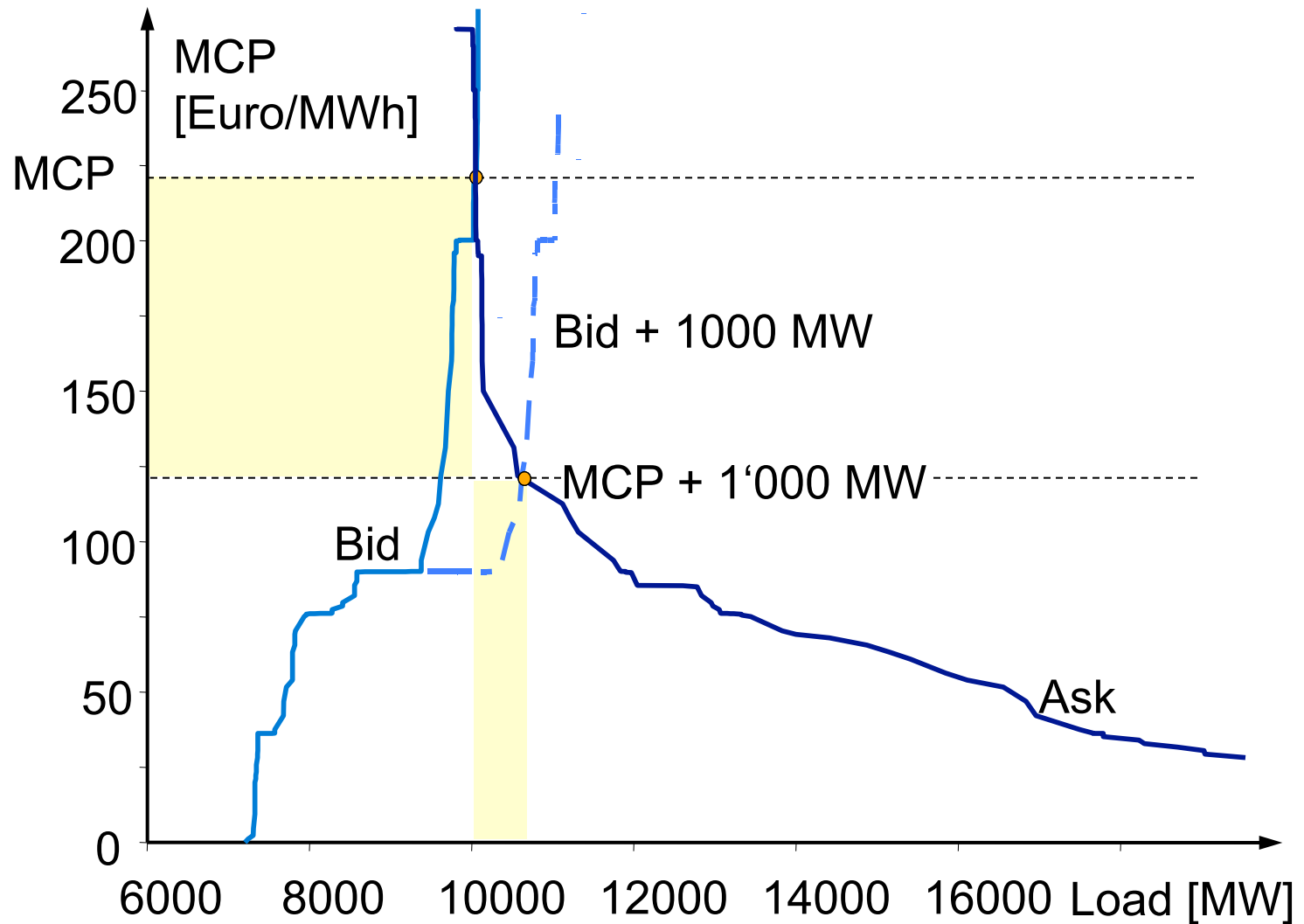
Tasks of the Balancing Group Management

Day-ahead	The balancing group manager (BGM) provides a
before 12:00 h	$\frac{1}{4}$ -h load schedule and an hourly price forecast
until 12:00 h	Based on a trading strategy, bid and ask orders are submitted to the energy exchange (EPEX)
12:30 h	EPEX informs traders on trading results
until 15:00 h	BGM submits the day ahead schedule ($\frac{1}{4}$ -h) to the Transmission System Operator TSO
Delivery day	
00-24:00 h	Deviations from the schedule are covered by the TSO in form of balancing power (or covered by intra day trading)
Following day	Financial settlement of trades

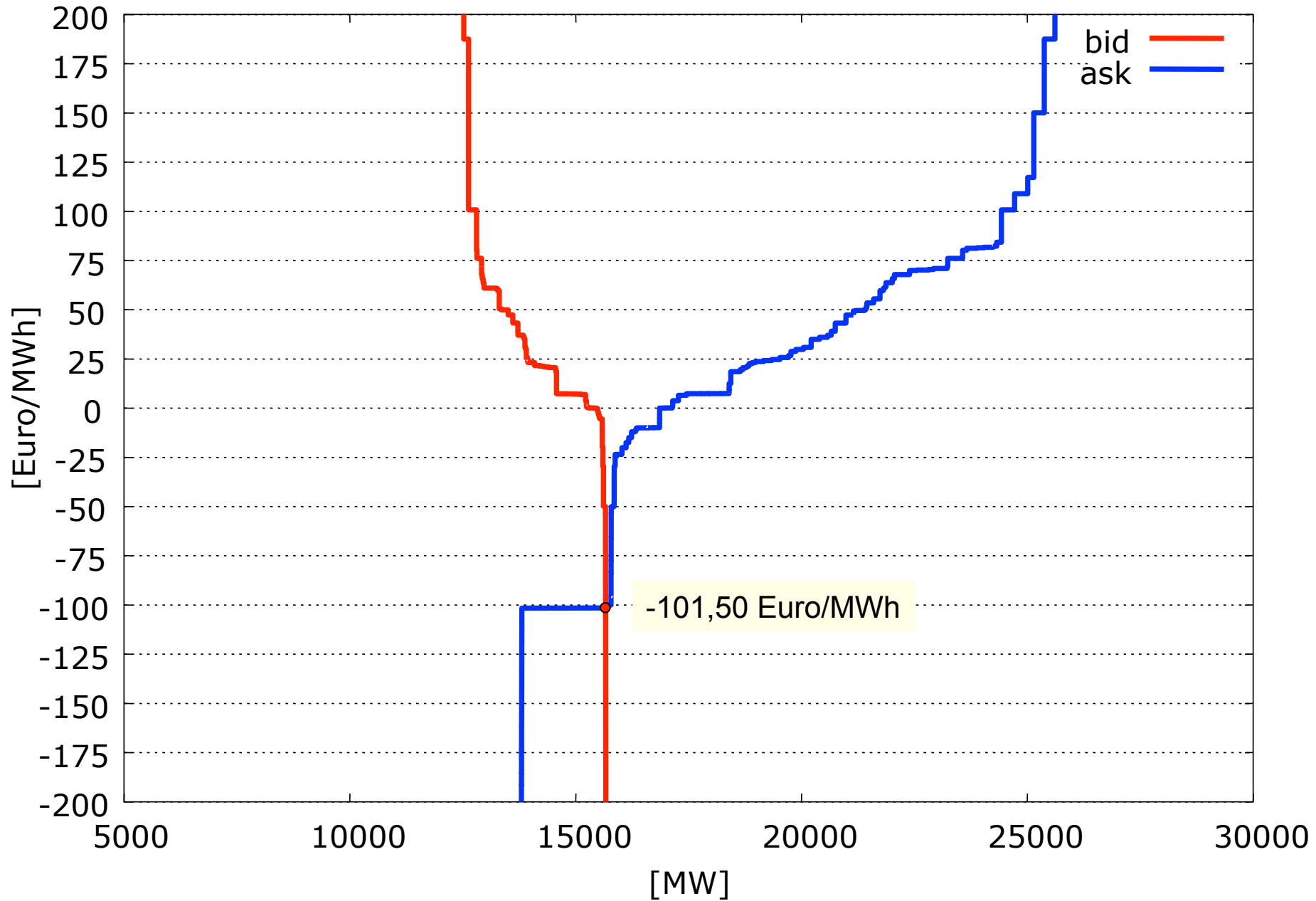
Day-ahead Market [Wednesday, 31 October 2007, 18-19 h]



Merit-order Effect of Wind Power *[15.1.2007, 18-19 Uhr; German EEX]*

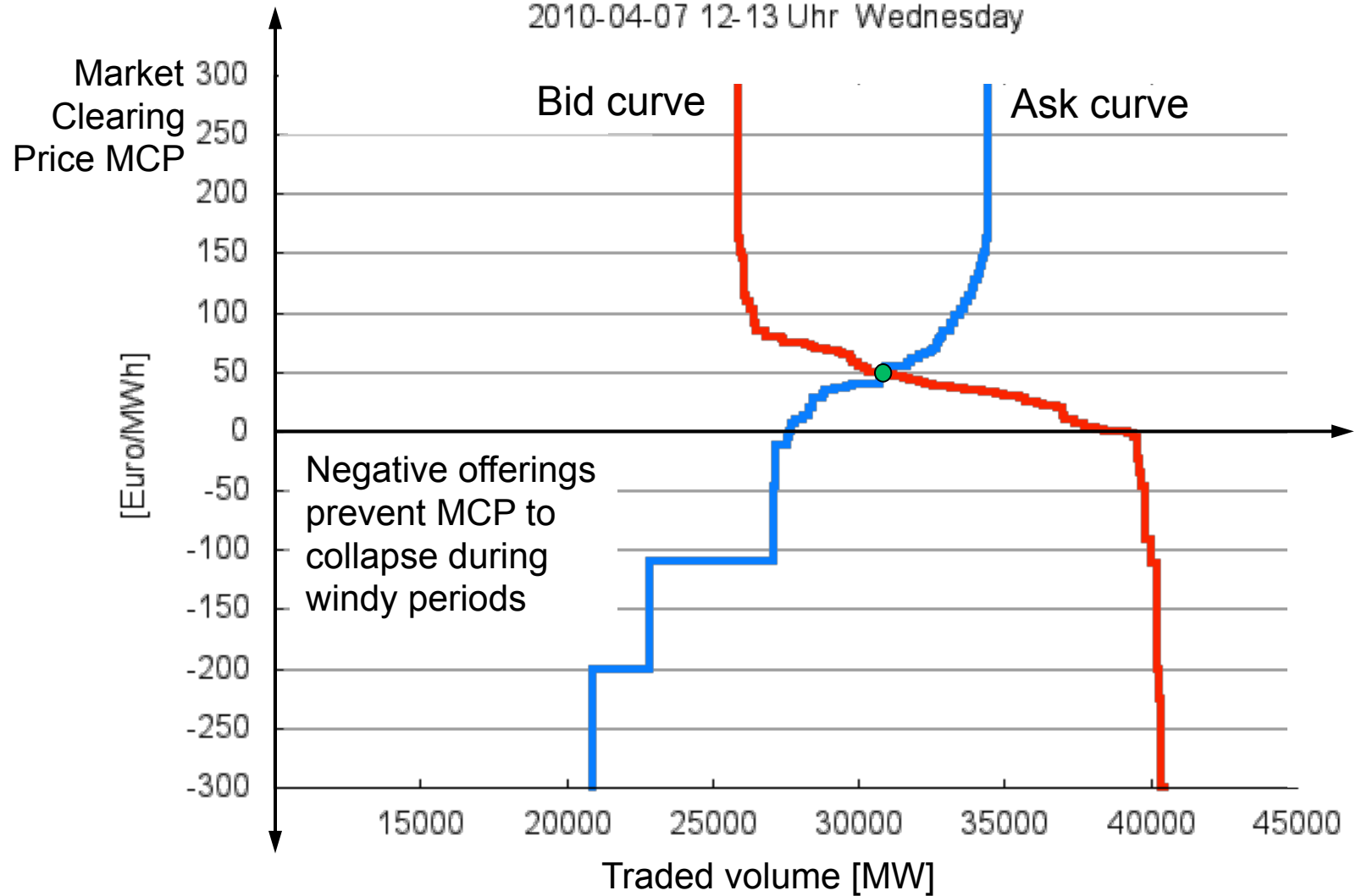


2008-12-22 4-5 Uhr Monday



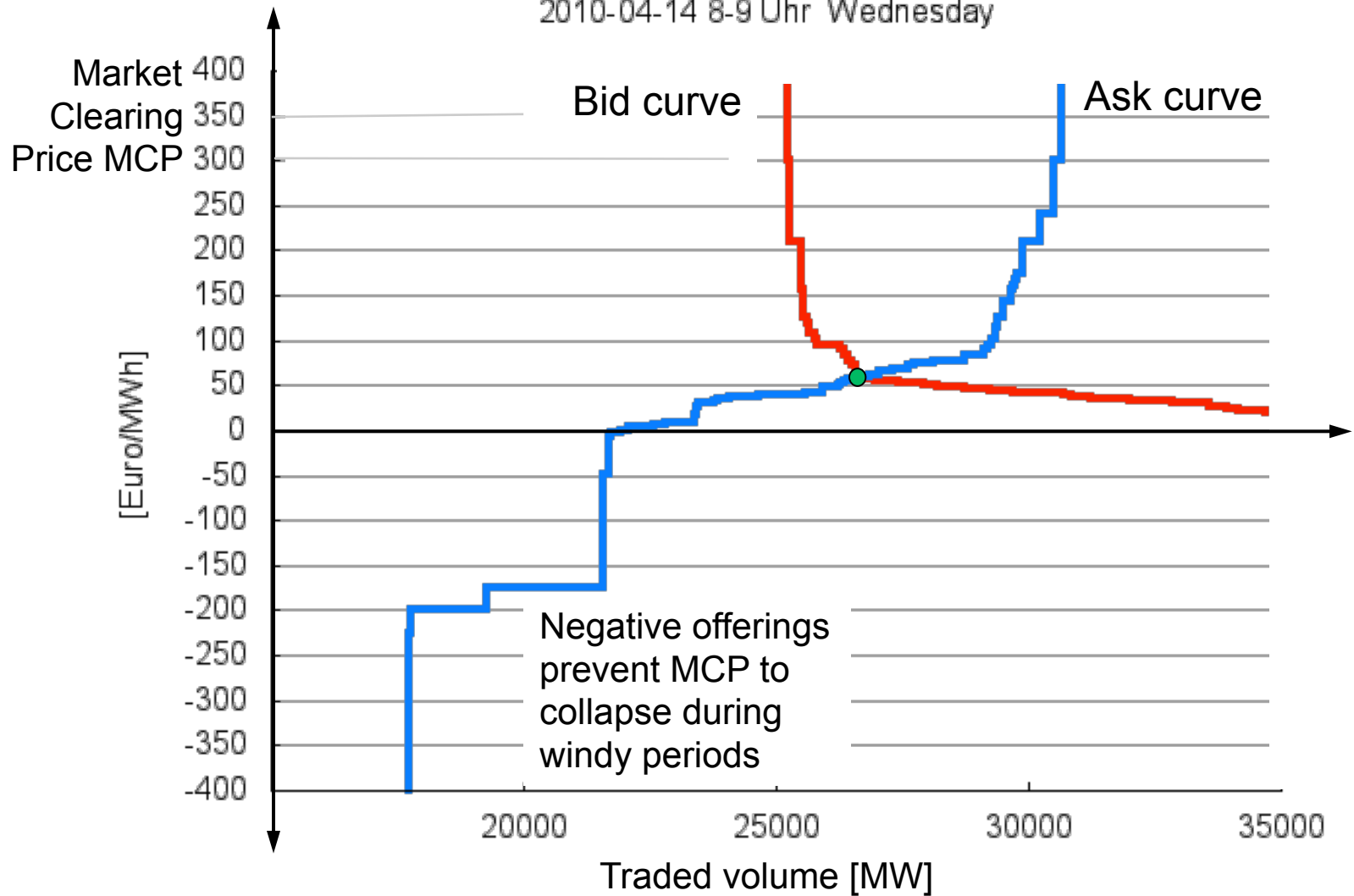
Day-ahead Bid and Ask Curves

2010-04-07 12-13 Uhr Wednesday



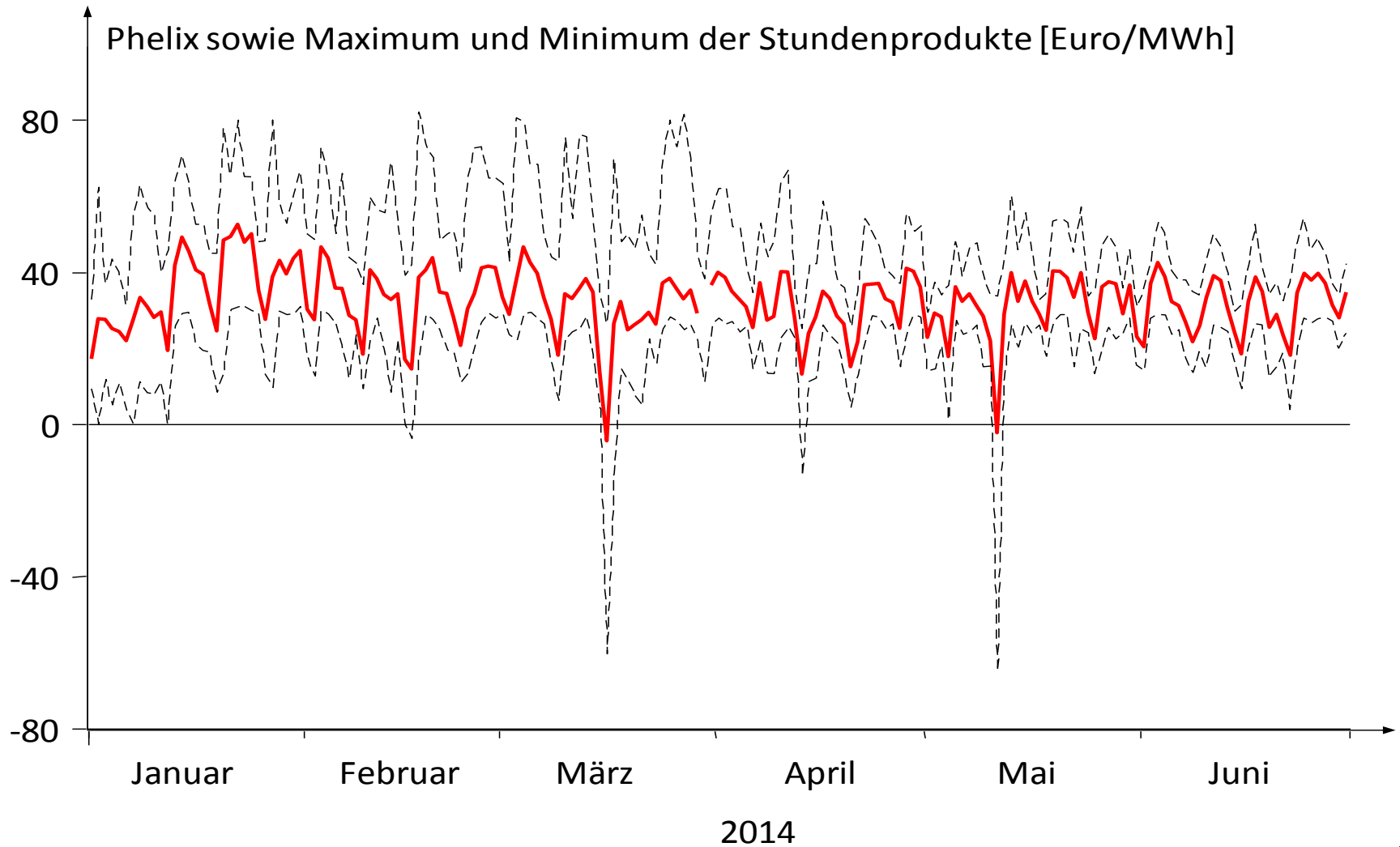
Day-ahead Bid and Ask Curves

2010-04-14 8-9 Uhr Wednesday



Day-ahead Power Prices [Source: EPEX]

15



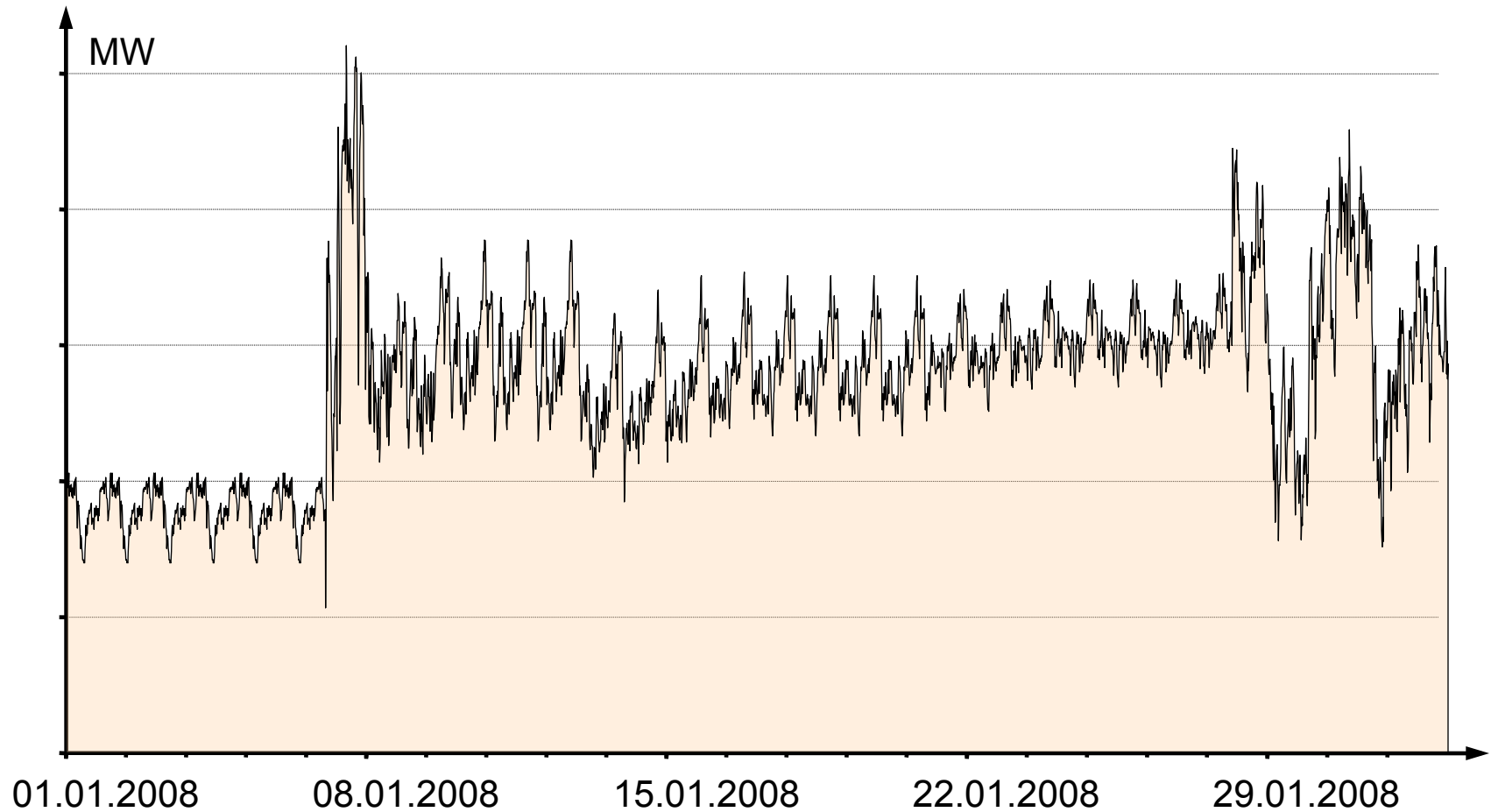


Day-ahead Electricity Market Products

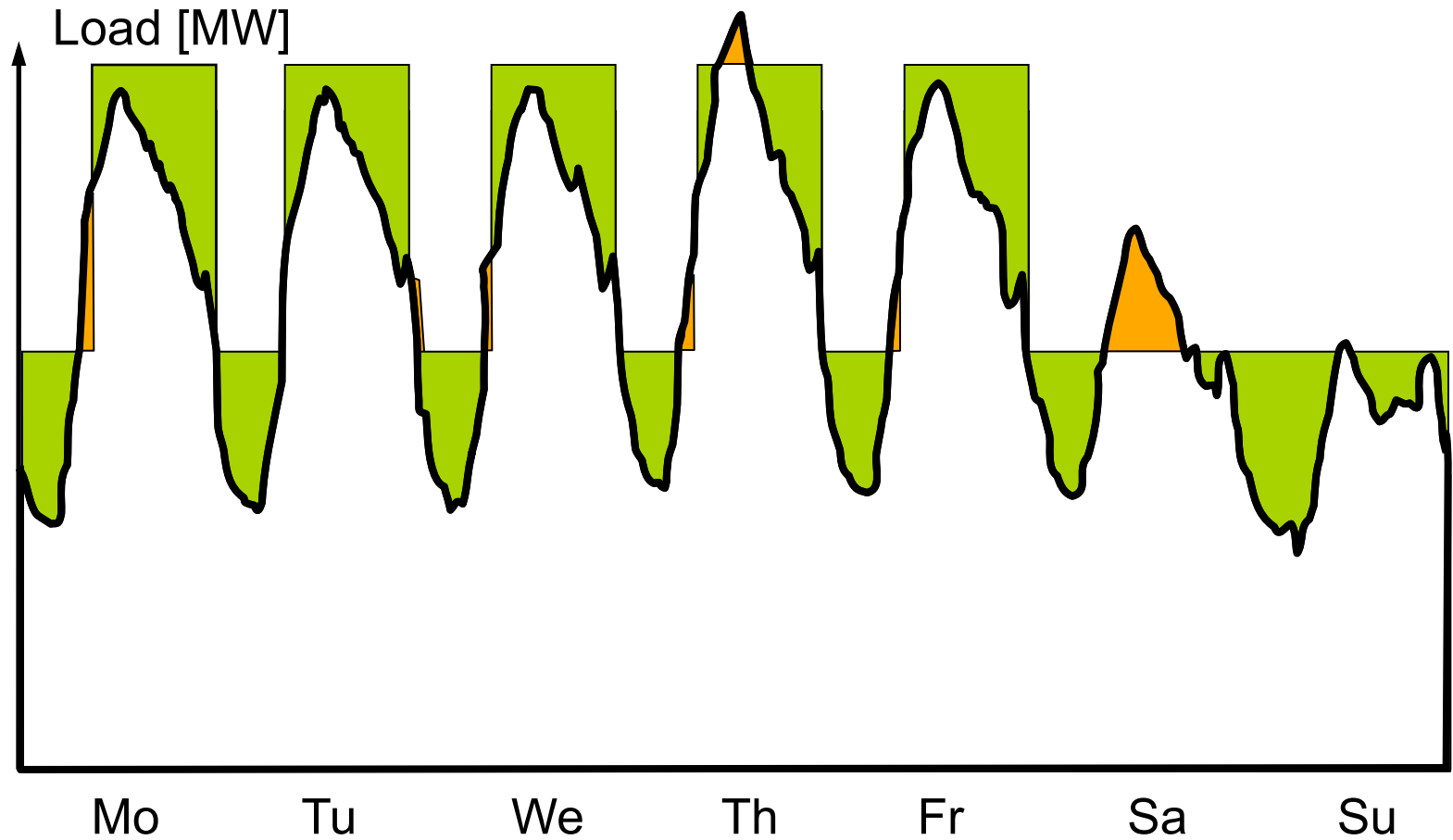
Uhrzeit	Sonntag	Montag	Dienstag	Mittwoch	Donnerst	Freitag	Samstag
0-2							
2-4							
4-6							
6-8							
8-10							
10-12							
12-14							
14-16							
16-18							
18-20							
20-22							
22-24							

Peak Load

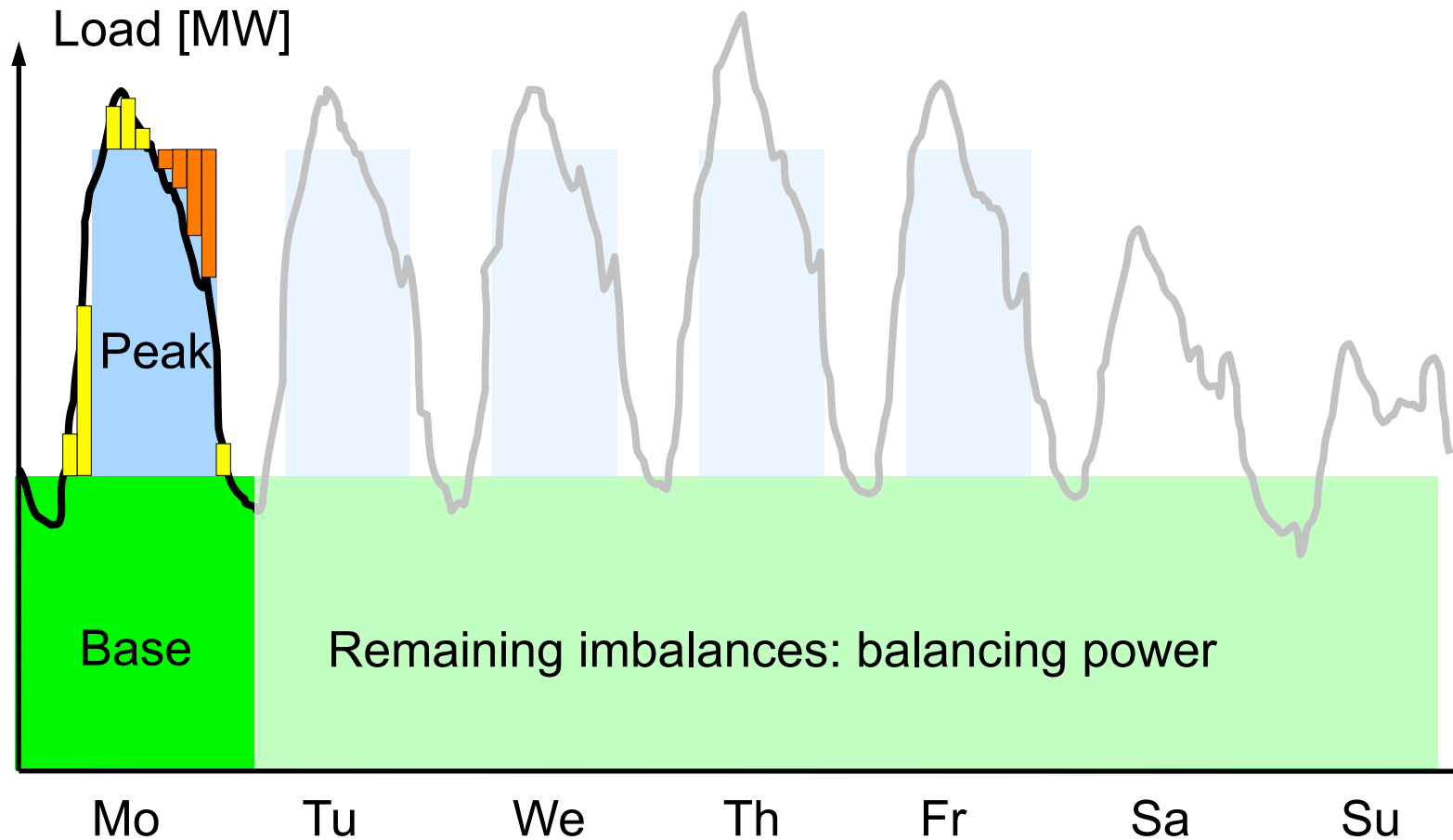
Sample Power Purchase Schedule



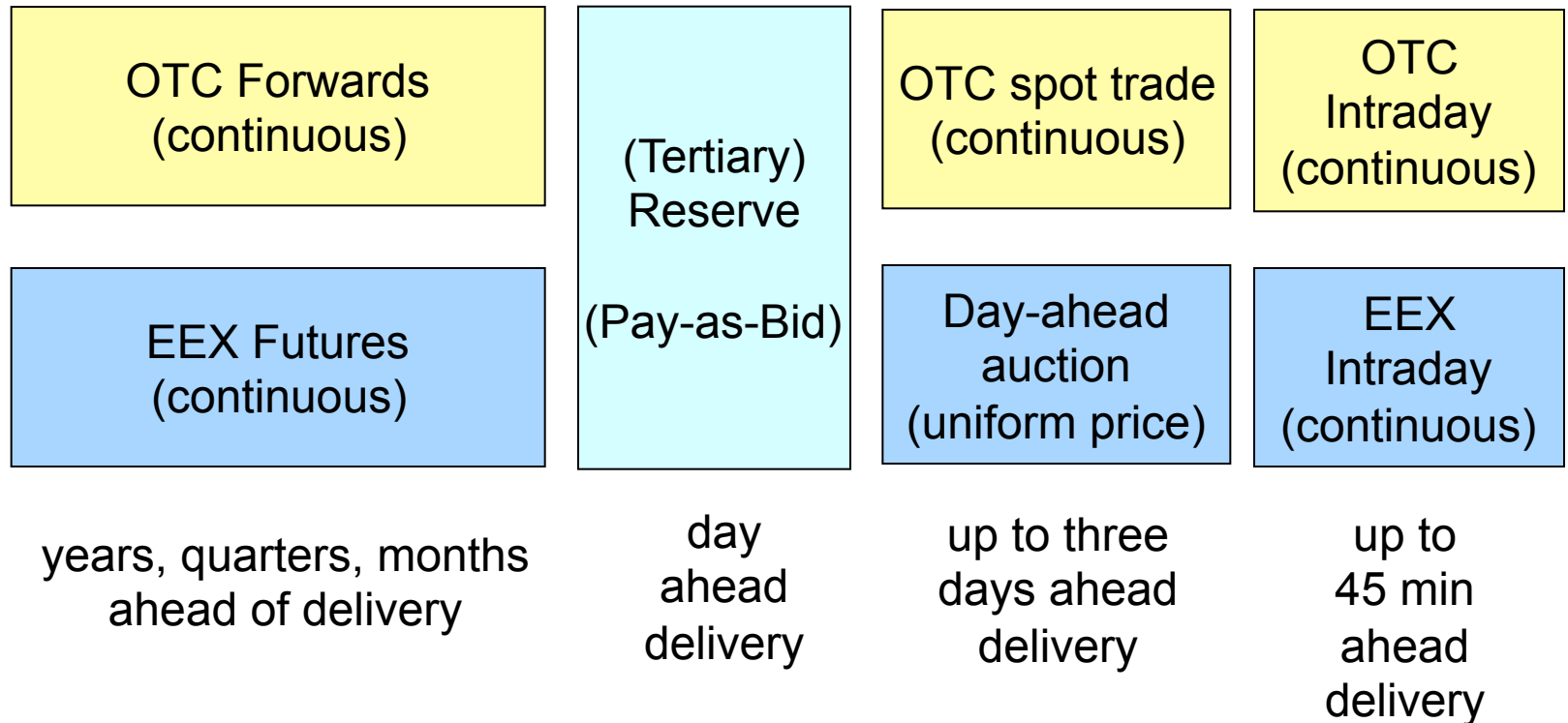
Portfolio Management of a Power Retailer



Day-ahead Contracts for Singular Hours

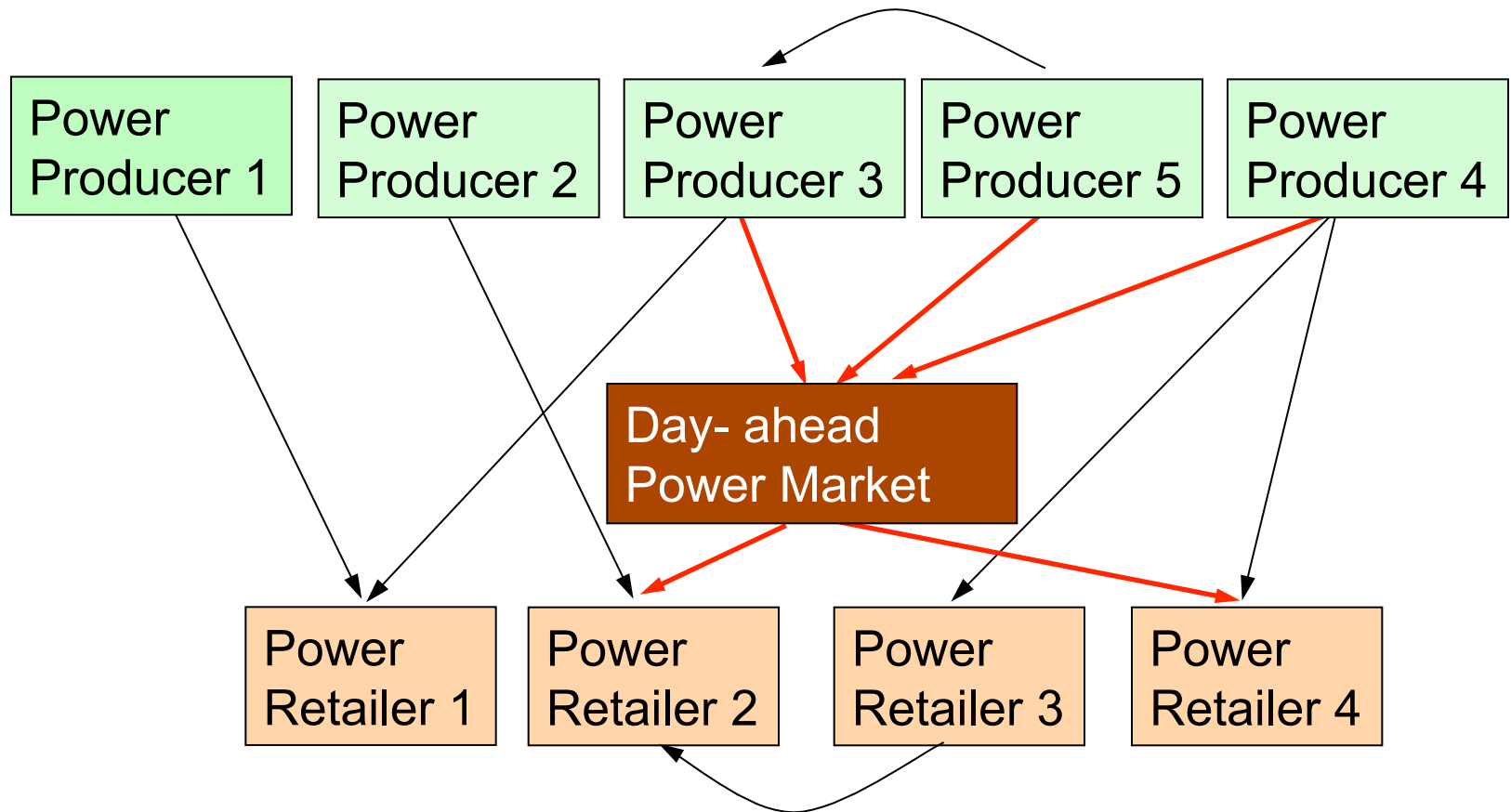


Connected Chain of Power Markets



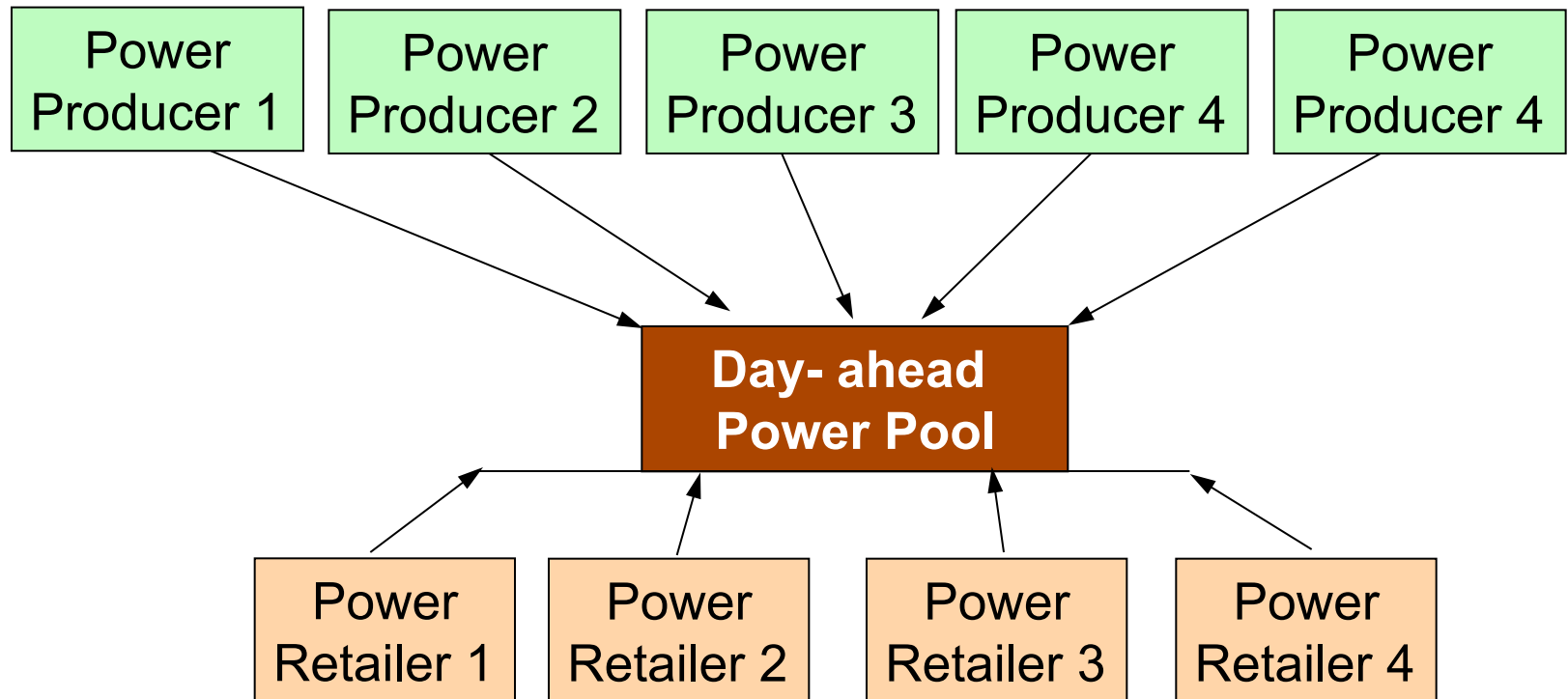
OTC: Over the Counter

Bilateral Power Trade (OTC)



The two systems “power exchange” and “OTC trade” can coexist

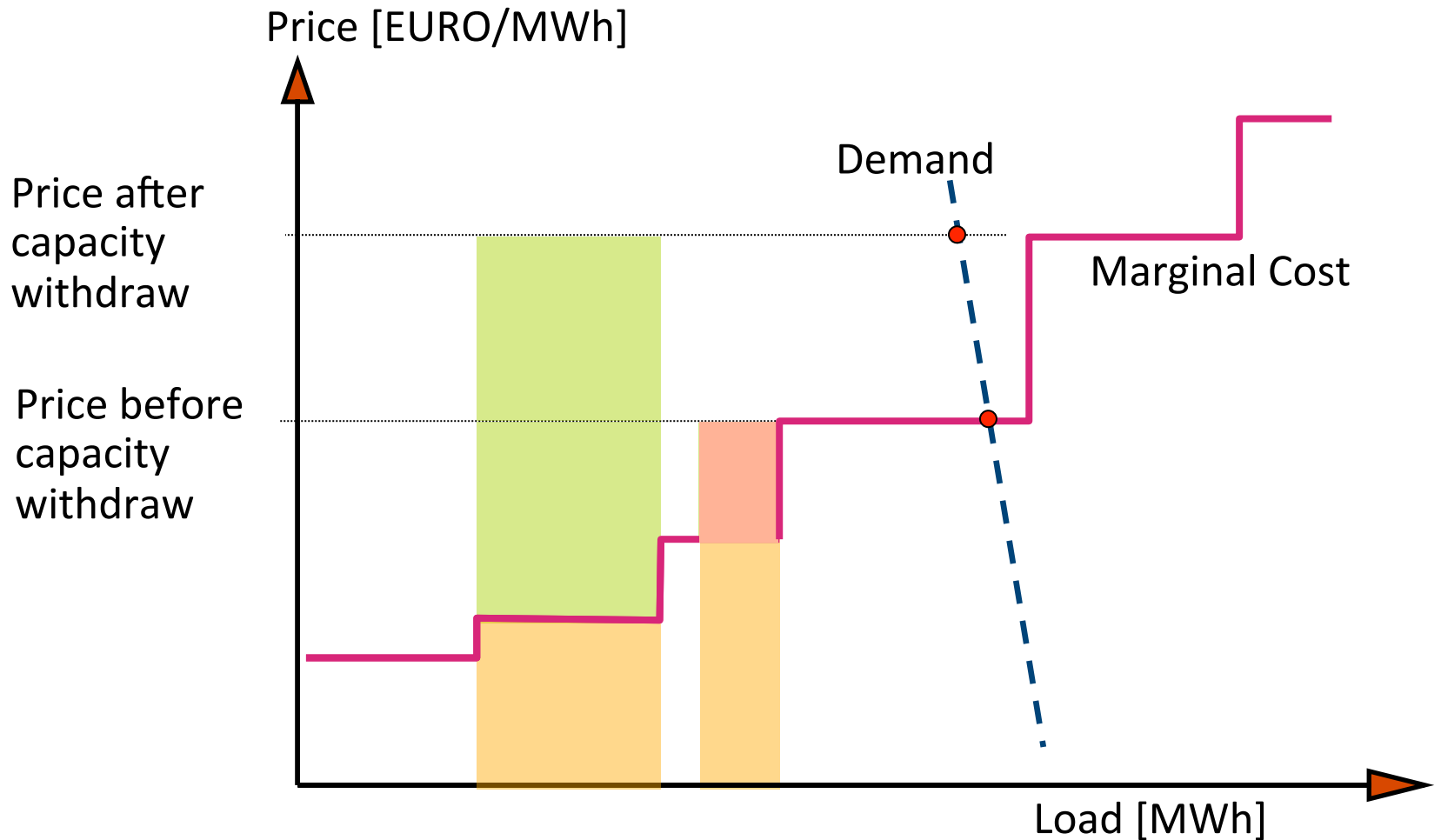
Power Trade in a Pool Model





Problem 1: Possible Price Manipulation

„Cournot-Game“ under Merit Order





Problem 2: Free GHG Allowances

EUA Allocation and Power Prices

$$\Pi(Q, Em) = p \cdot Q - C(Q, Em) - p_{em} \cdot (Em - g(\overline{Em}))$$

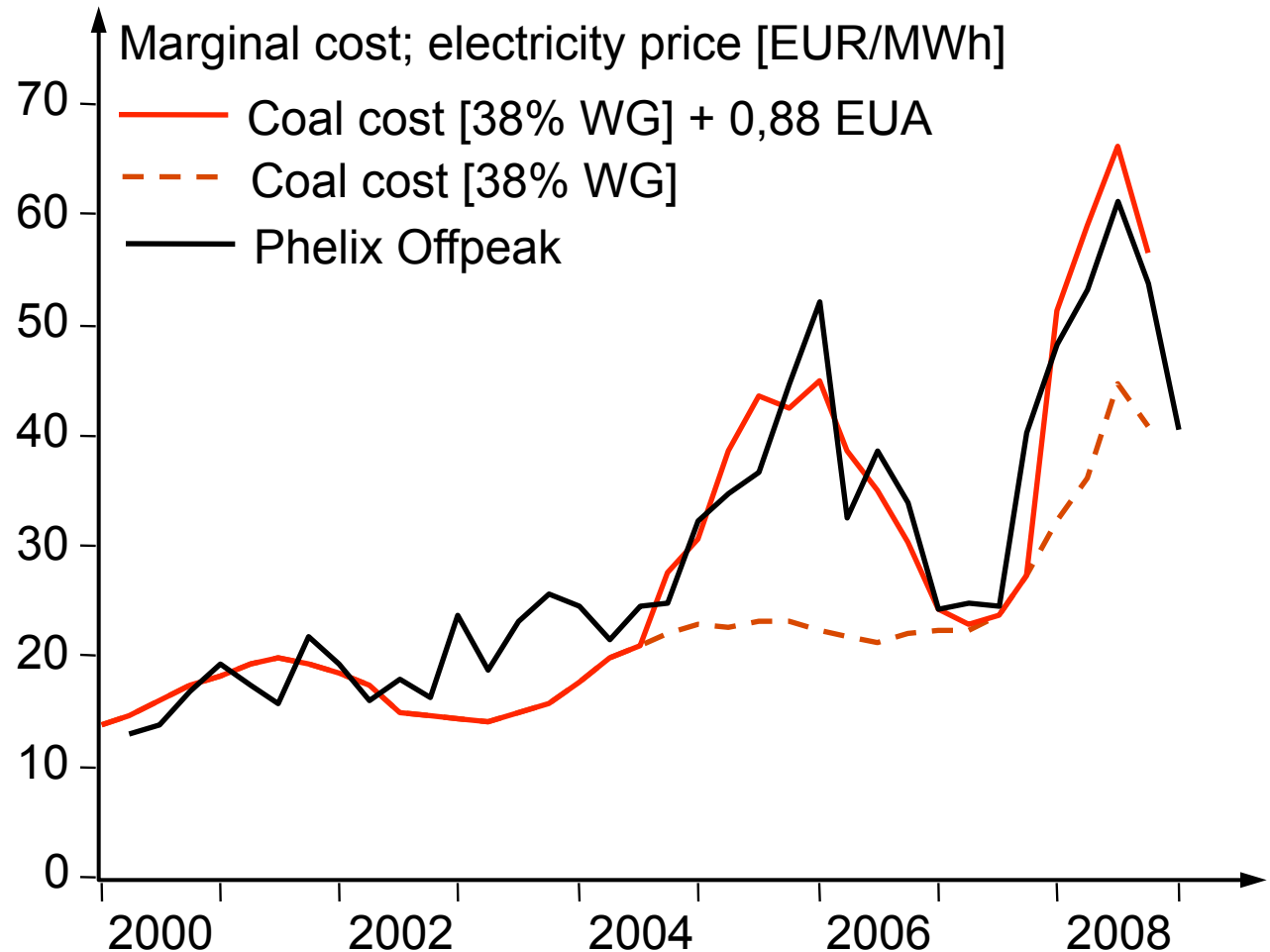
First order optimality conditions

$$\frac{\partial C}{\partial Em} = -p_{em} \quad p = \frac{\partial C}{\partial Q} + p_{em} \cdot \frac{Em}{Q}$$

Em	Total emissions of a facility [t CO ₂]
$g(Em)$	Free allocation of EUA [t CO ₂]
C	Cost function [Euro]
p	Power price [Euro/MW]
p_{em}	Emission price [Euro/t CO ₂]
Π	Profit [Euro]
Q	Output [MWh]

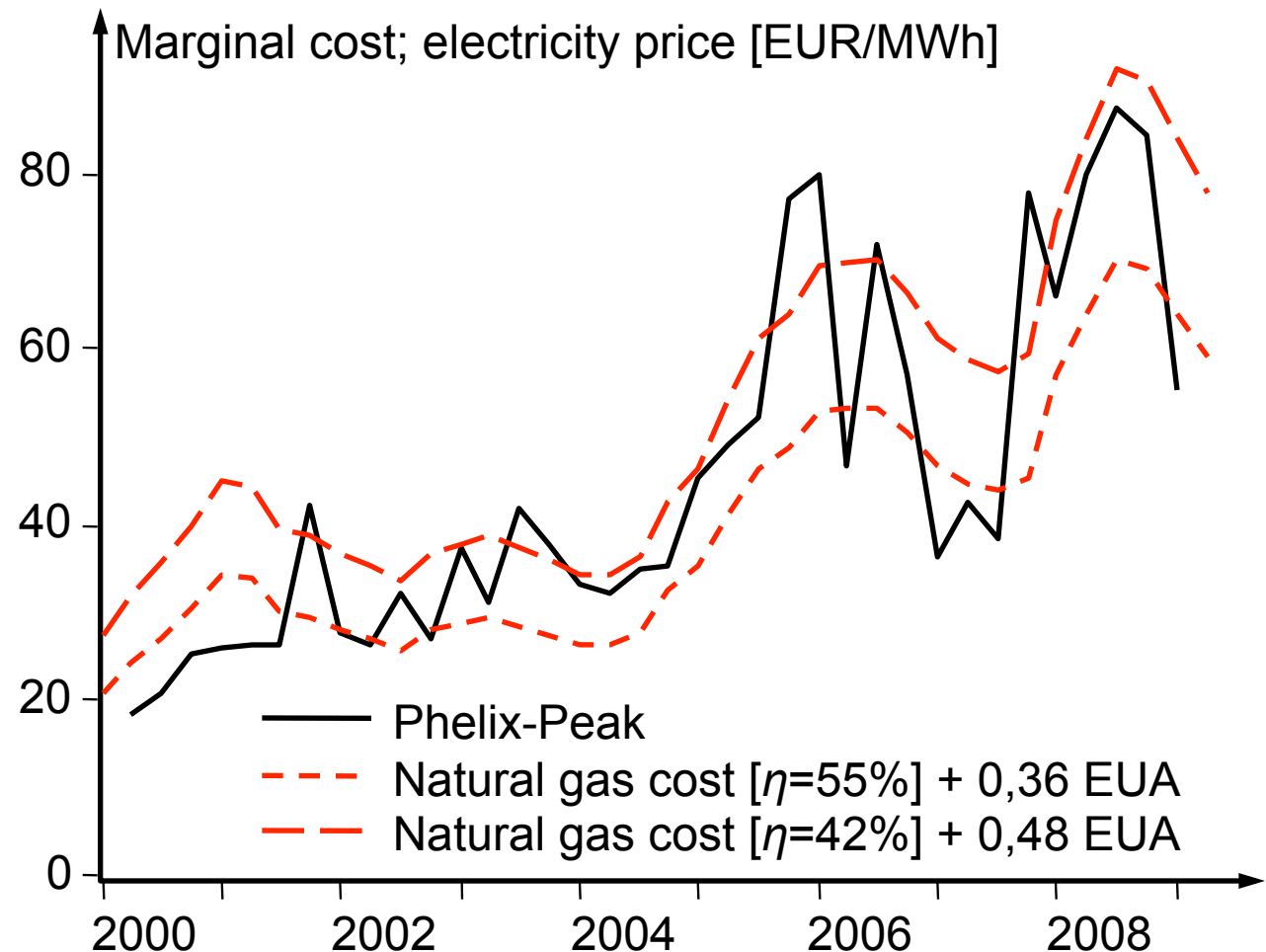
(Clean) Dark Spread in the Day-ahead Market

[Quarterly average; Germany; Source: BAFA; EEX]



(Clean) Spark Spread in the EEX Market

[Quarterly average; German Day-ahead-market; Source: BAFA; EEX]





Problem 3: Regulation and Balancing Power

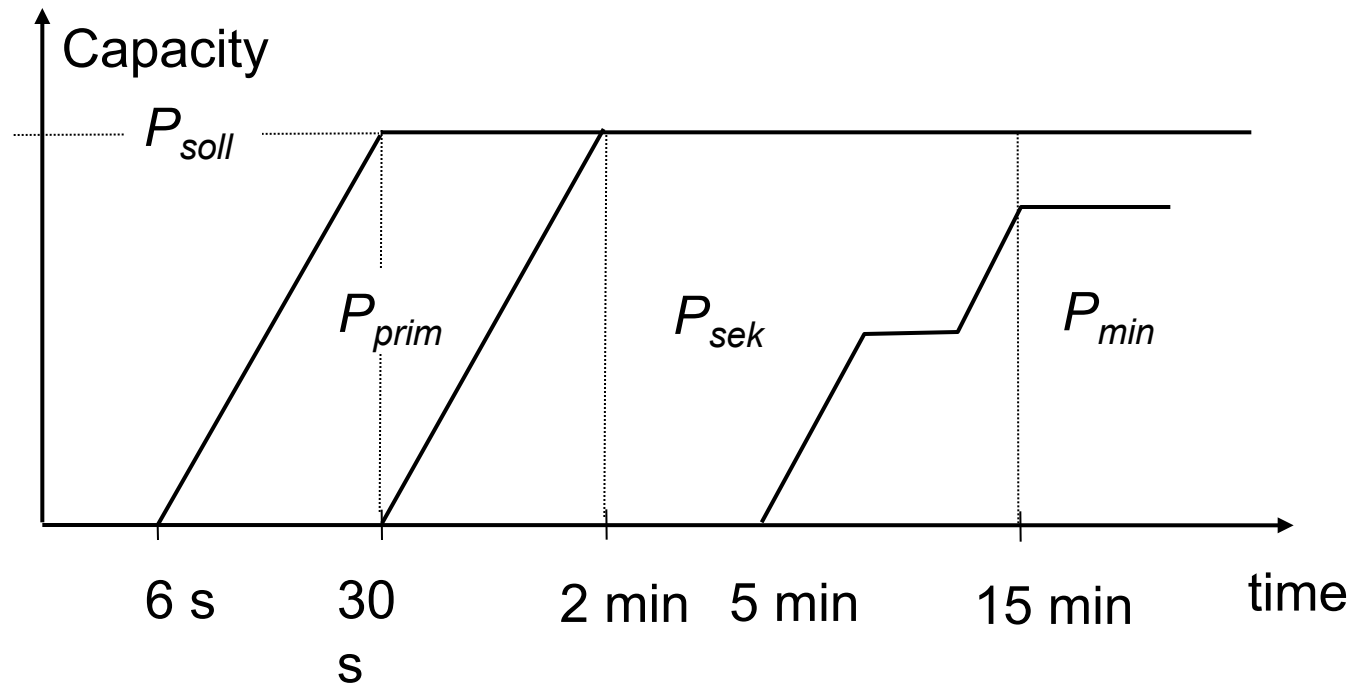


Regulation
Power

Balancing
Power

Pay-as-bid
auction

Types of Regulation Power in Germany

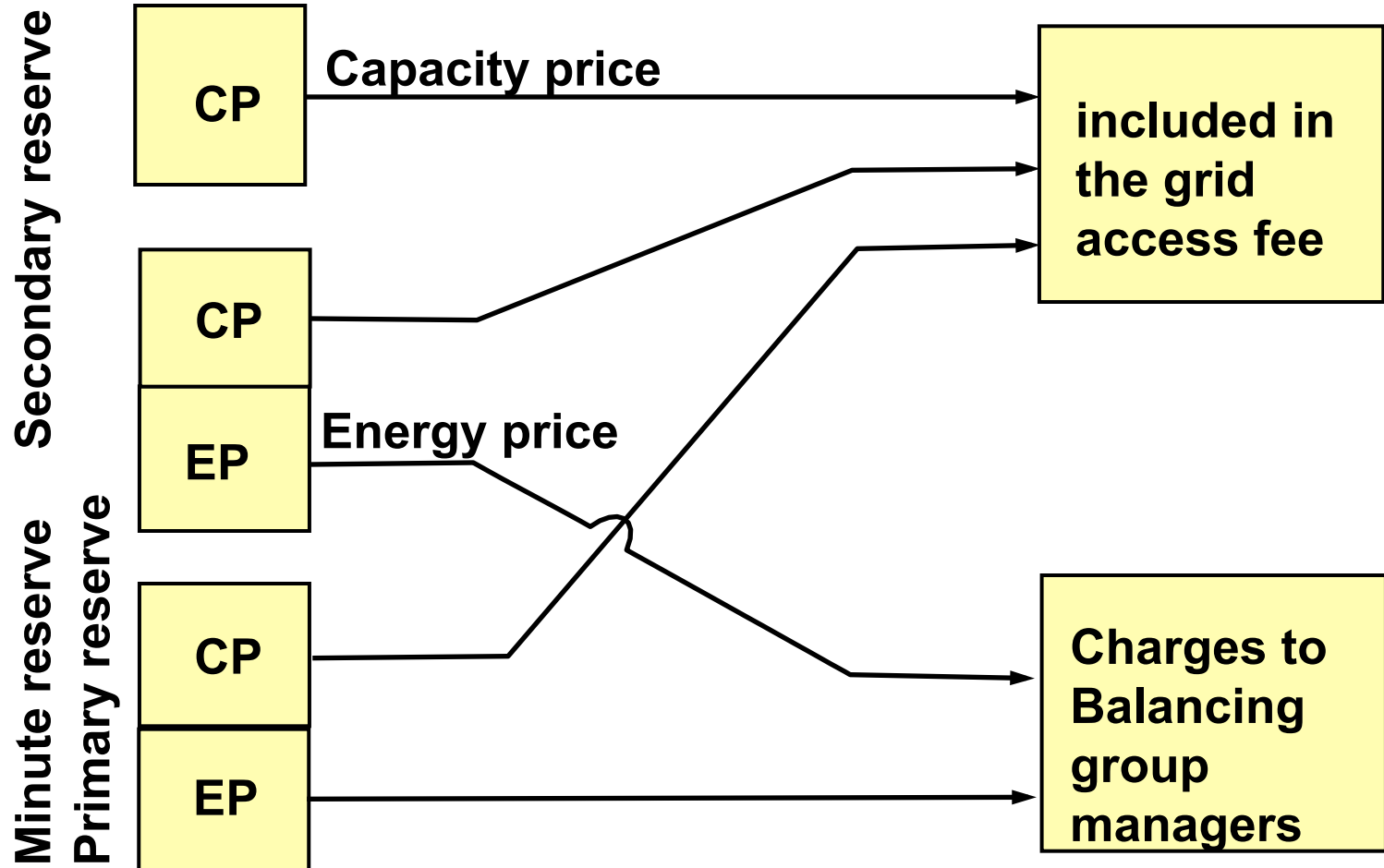


P_{prim} Primary reserve

P_{sek} Secondary reserve

P_{min} Tertiary reserve (Minute reserve)

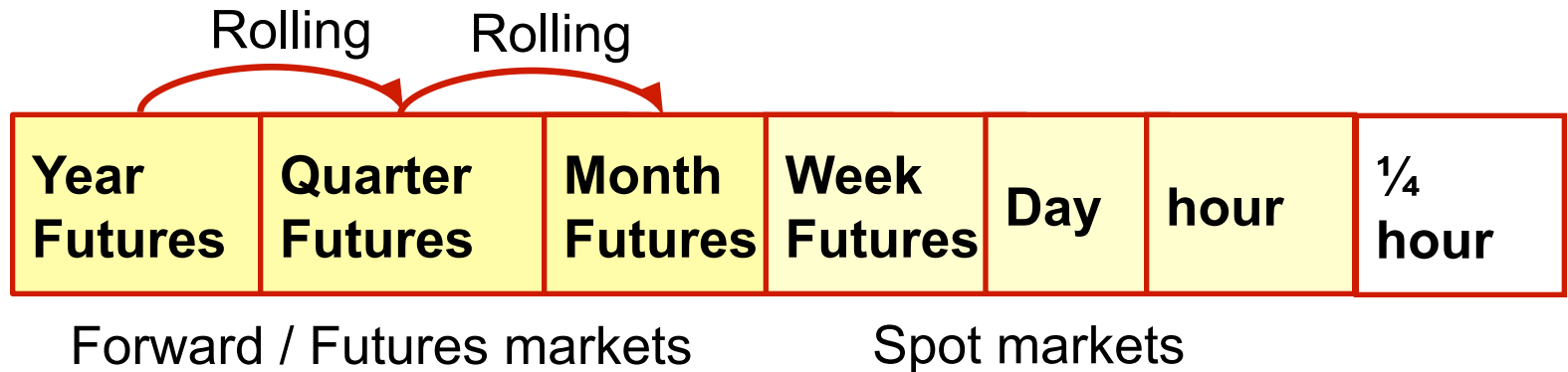
Allocation of Regulation Cost





Problem 4: Clearing of Electricity Futures

Continuous Trading of Power Futures

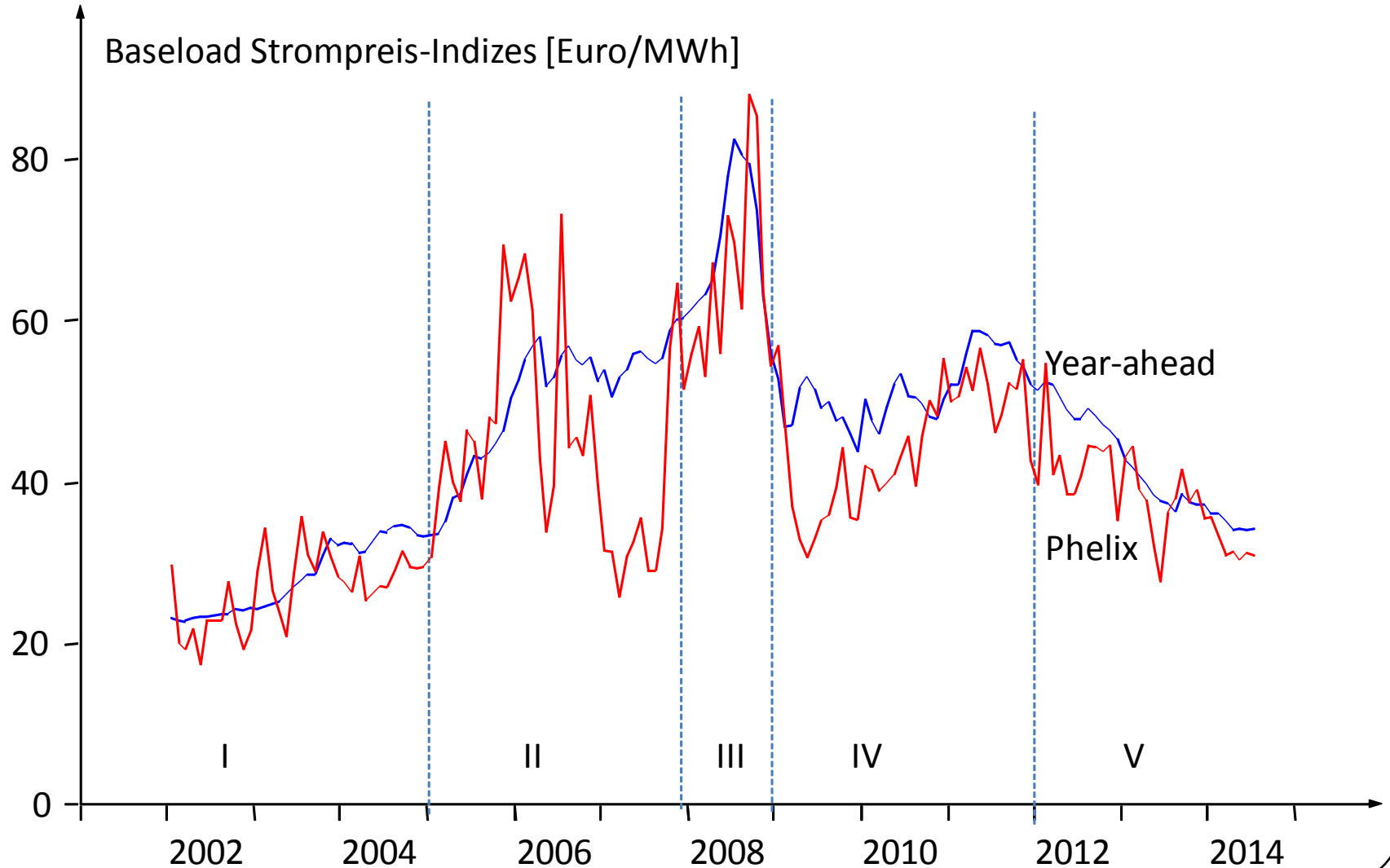


Standardized Futures don't match with typical load schedules. Open positions must be closed on the day-ahead market or with balancing power (supplied by the TSO)

Rolling: When delivery period of a year ahead future begins, the contract splits into

- 3 monthly futures M_0 , M_1 and M_2 ,
- 3 quarterly futures Q_1 , Q_2 and Q_3

Wholesale Power Prices [Source EEX]





Types of Bilateral Trade Contracts

Cash trade

- Spot trade: Delivery and payment follow immediately after the conclusion of the trade contract

Forward trade

- Forwards: Conditions of the deal (quantity, quality, price, delivery and payment conditions, ...) are fixed in the contract, but the contract is physically settled at a later date

Derivative trade

- Futures: like Forwards, but financial settlement with Clearing (Interest → Future prices exceed Forward prices)
- Call-Option: like Forward, but the buyer can withdraw from the contract
- Put-Option: like Forward, but the seller can withdraw

Clearing of open positions

To cover the counterparty risk, each trader is obliged to sustain a margin account at the energy exchange (or the clearing house). In addition, the trader has to open a maintenance account and to transfer an initial margin that depends, among others, on the expected volume of his open positions

If a trader holds an open position and the futures price exceeds the contracted price, the clearing house transfers the price difference times contract size from the maintenance account to the margin account of the seller and from the margin account to the maintenance account of the buyer.

Debits and credits are adjusted at the end of each trading day according to the market price at closure

If the maintenance account drops below a maintenance margin, the trader has to remargin the maintenance accounts within short time. Otherwise all open positions of the trader are closed by the clearing house at market conditions

Types of Trades

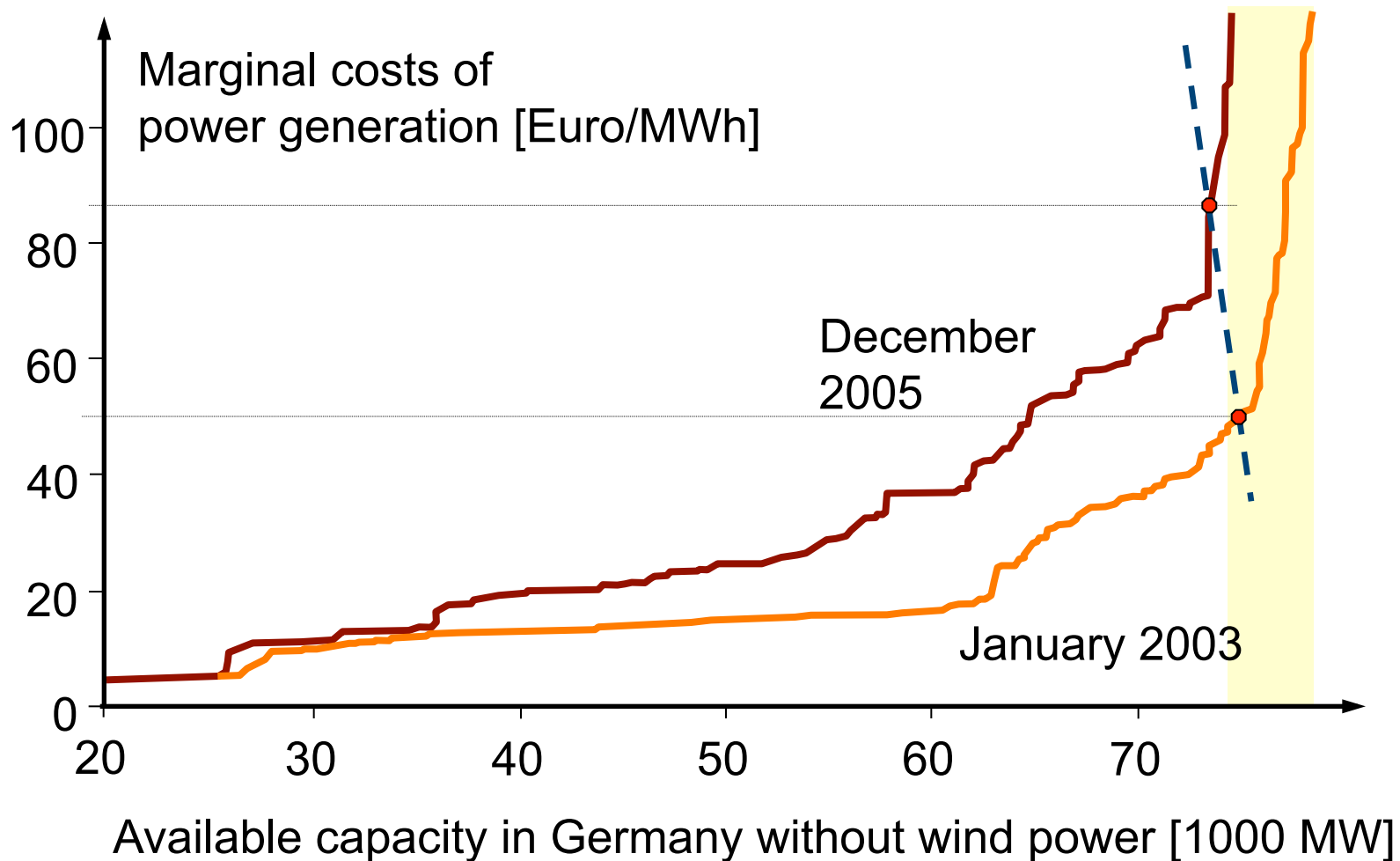
- **Hedging:** the aim of hedging is to ensure price risks. Hedgers are prepared to pay a risk premium
- **Speculation:** Speculation is based on price expectations that may turn to be right or wrong. Speculators ensure the hedgers and thereby earn the risk premium
- **Arbitrage:** the aim is to use price differences for achieving a risk free trade profit
- Markets that offer no arbitrage are said to be in equilibrium



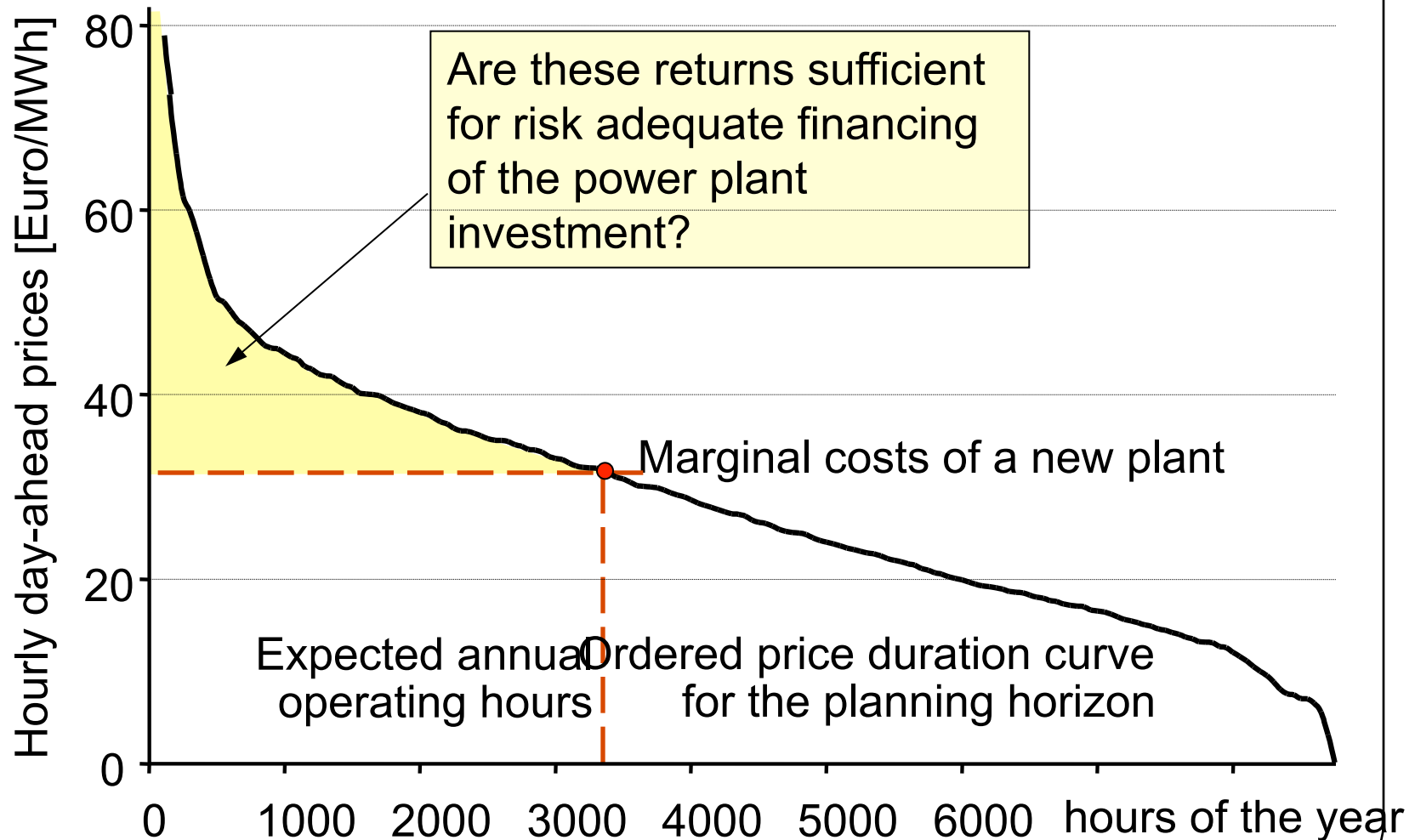
Problem 5: Lack of Power Plant Investments

Estimated Merit Order for Germany

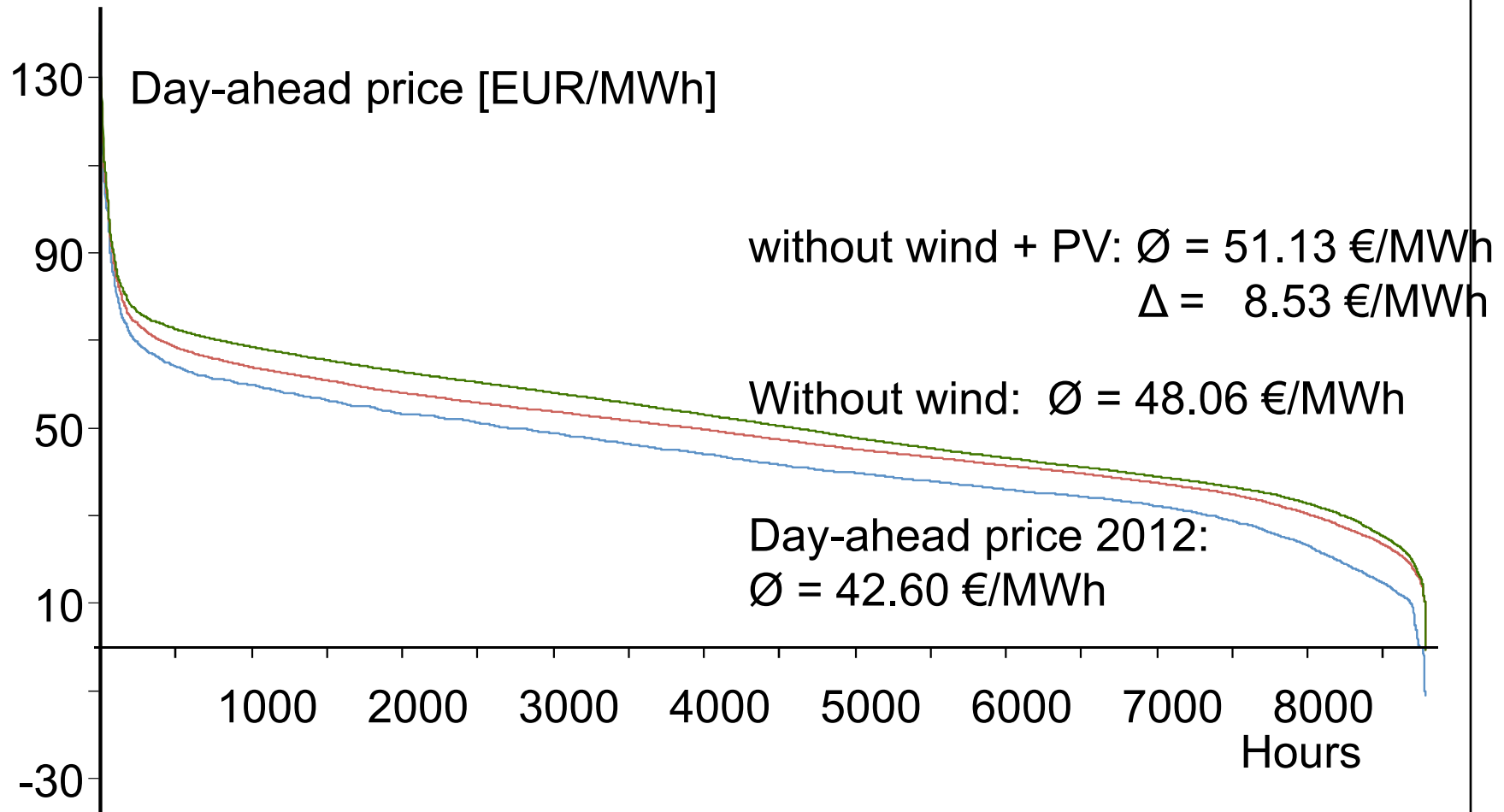
[without CO₂ costs; Source: London Economics 2007]



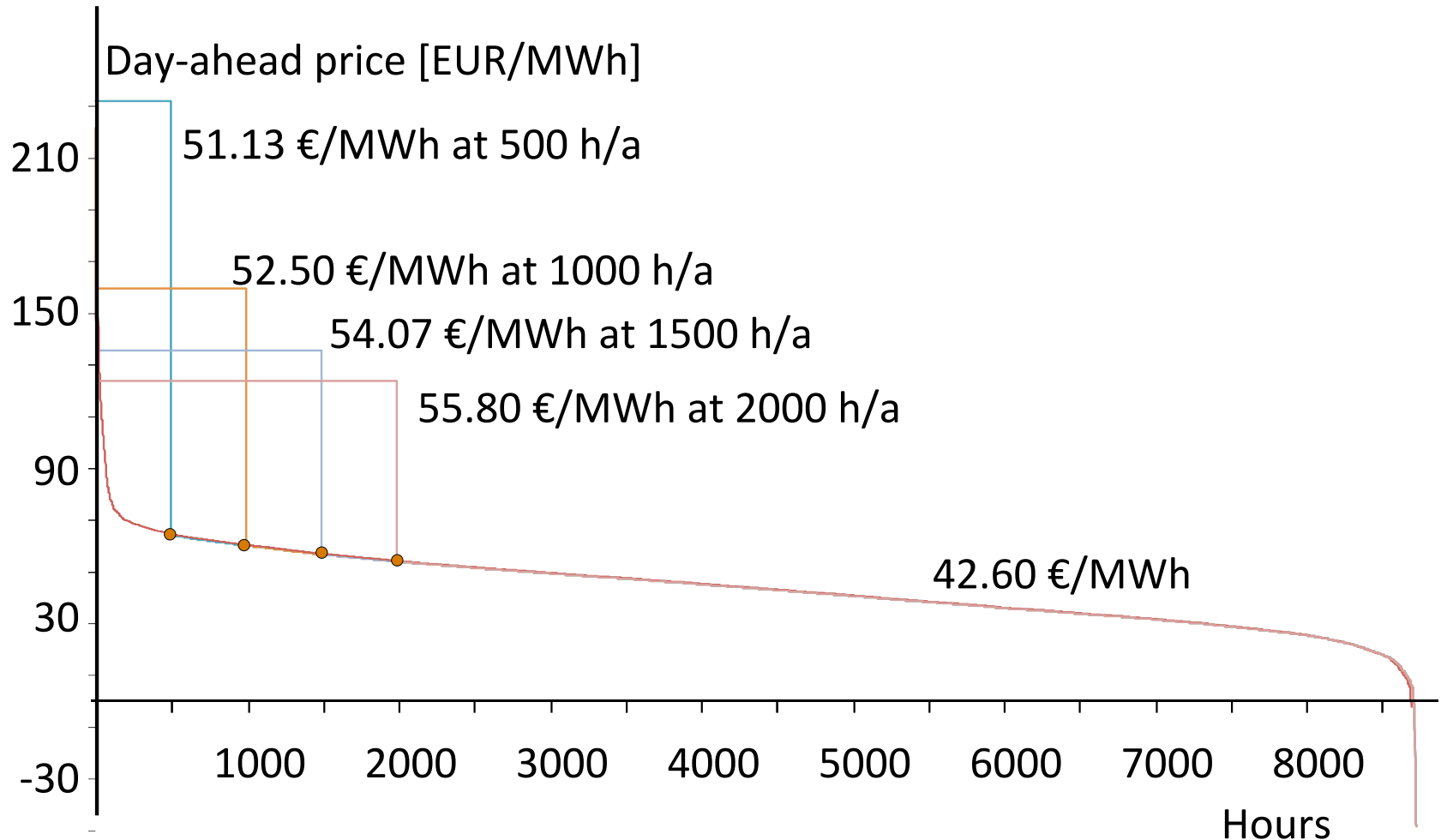
Power Plant Investments on Competitive Markets



Ordered Day-ahead Prices in 2012



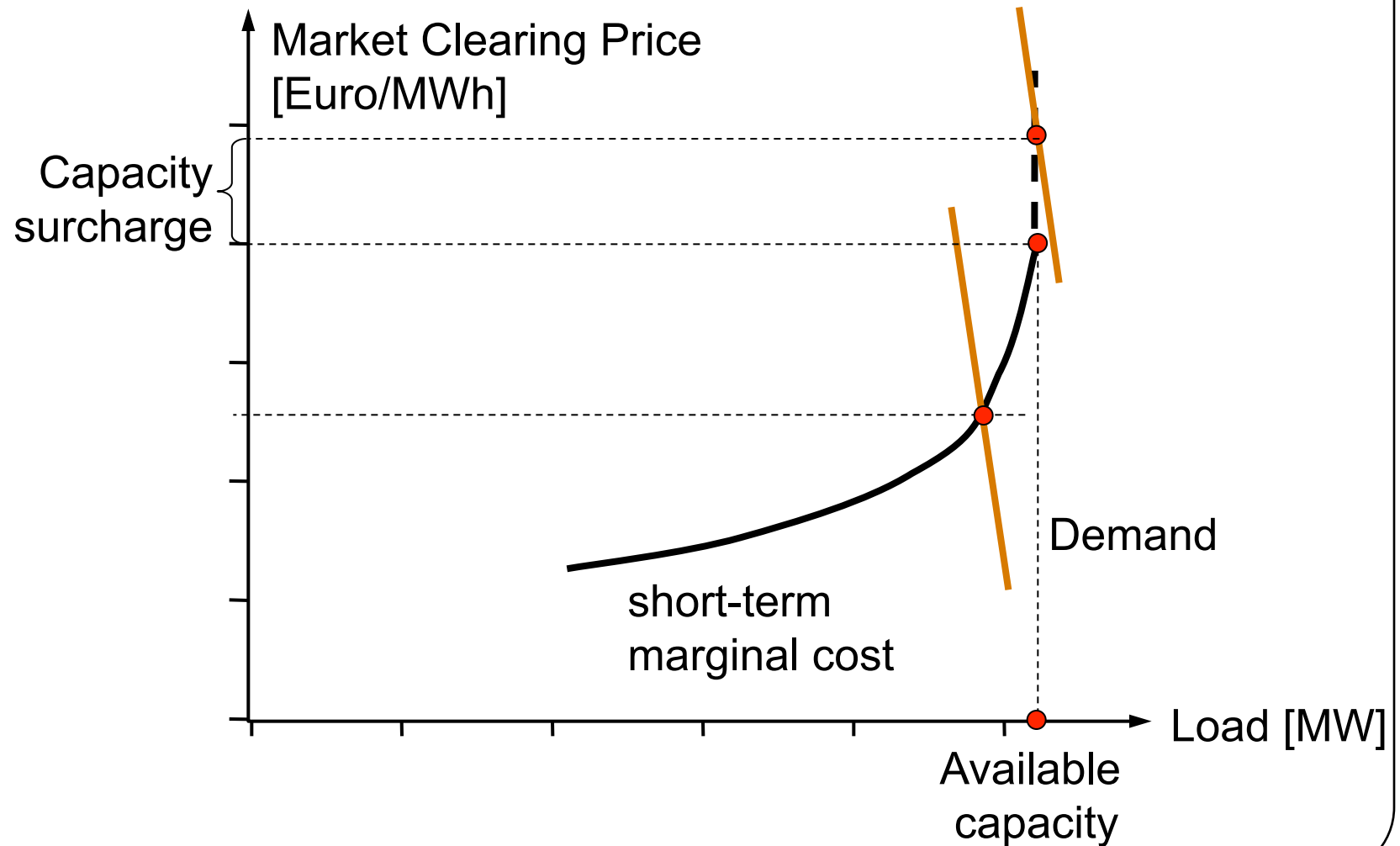
Ordered Day-ahead Price Level Necessary for Financing new GT





Problem 6: New Market Design

MCP with Capacity Shortages



Strategic Reserve

- Similar to the strategic petroleum reserve: Some (new or old) gas turbines or coal plants are taken out of the normal market supply and scheduled according to the order of the regulator
- Power capacity surplus shrinks in normal periods and increases in critical periods. Who decides about what periods are critical?
- The plants in the strategic reserve receive a capacity payment financed through the grid fees
- Who decides and according to what rules about which plants should be allocated to the strategic reserve?

Decentralized Capacity Market

- No market participant shall withdraw power from the grid without a capacity allowance which has to be purchased
- PJM Market: Distributed power (such as wind power) can be fed-in and taken out from the distribution grid so that no capacity allowance is necessary
- Alternative: Any power generator that feeds-in electricity must be in the possession of the appropriated number of fed-in allowances
- How to prevent the capacity market from not being manipulated (market power issue)?
- How to control?

Other Capacity Market Design Options

- Comprehensive capacity markets: All plants that can be dispatched according to the demand receive a capacity premium (cash flow to existent and new plants)
- Focused capacity markets: Certain new plants that have been selected through a competitive bidding receive a capacity premium (cash flow to new plants)

Price Elasticity of Demand

