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Identifying Market Power in the EEX Electricity Market

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Background and Purpose of Study

- We study the European Energy Exchange (EEX) day-ahead hourly prices
  - EEX is the biggest power exchange in the area
  - Availability of data (prices, loads, generators etc.)

- EEX prices have increased substantially in the last several years
  - Can the increase be explained by fuel and emission costs?

- We investigate the prices in EEX by simulating the market in January 2006 with the Electricity Market Complex Adaptive System (EMCAS)
  - Can a model come close to reproducing the historical prices?
  - Are the historical prices close to production cost?
  - Study potential strategic interaction between generators

Why Agent-Based Modeling and Simulation (ABMS)?

- Standard simulation/optimization models assume
  - Single decision-maker often with 1 objective (least cost), or myopic decision-making
  - Often concerned about the “end-state” with systems in equilibrium

- In game-theory approaches, several simplifying assumptions necessary to solve equilibrium models
  - Physical laws (e.g. transmission network, inter-temporal constraints)
  - Market rules (bid format, multiple markets, congestion management, settlements rules, market power mitigation etc.)

- Markets are rarely in a state of equilibrium

- ABMS offers an interesting alternative
  - Allows to simulate markets with more real-world assumptions (physical constraints, market rules)
  - Out-of-equilibrium

Specifically, Agent Modeling Allows us to Address the Following

- Agent diversity
  - Agents may have different characteristics, different rules of behavior
    - *Risk preferences, strategies, and (multiple) objectives*
- Each stakeholder maximizes own objectives (profit) or utility function, and not public welfare (least cost)
- Objectives across agents may be conflicting
- Information may be asymetric and imperfect (uncertainty)
- Stakeholders learn and adapt their behavior based on their observations
- Analyze transitory behavior in addition to long-run equilibrium state

Agent-based Simulation: A Field Grounded in the Biological, Social, and Other Sciences

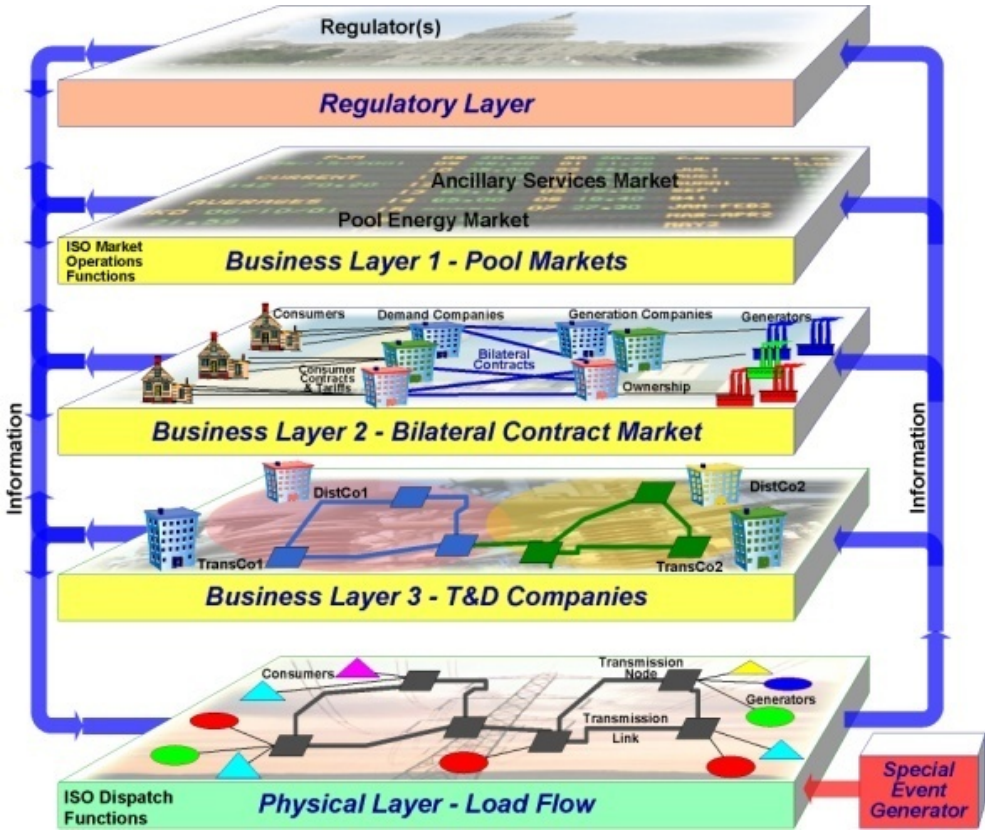
- What is an agent-based system?
  - An agent-based system is made up of agents that interact, adapt, and sustain themselves while interacting with other agents and adapting to a changing environment
  - Agent-based Modeling and Simulation (ABMS) is grounded in the theory of Complex Adaptive Systems (CAS)

- What is an agent?
  - A discrete entity with its own goals and behaviors
  - Autonomous (most important) and able to act independently
  - Possibly has the capability to adapt and modify its behaviors

- Key Assumptions
  - Some key aspect of agent behaviors can be credibly described
  - The mechanisms by which agents interact can be credibly described
  - Complex social processes can be built “from the bottom up”

EMCAS Agents are Bounded by Constraints in the Physical World

- EMCAS combines the modeling of the individual business entities (agents) with the modeling of the physical infrastructure in which they operate
  - Generator constraints: capacities, ramp rates, minimum downtimes, etc.
  - Transmission constraints: line flows
- Estimates prices by hour and node using a DC-OPF algorithm
  - Short-term simulation mode develops hourly prices for 1 to several years
  - Long-term simulation mode develops long-term expansion and price forecasts (20-30 years)



Simulated Market Operation in EMCAS

- Different generation technologies
  - Thermal, hydro, wind, etc.

- Hourly chronological simulations
  - Bid-based scheduling (day-ahead) and dispatch (real-time) based on DC-OPF
  - Planned and forced generator outages

- Calculation of prices and profits based on “two-settlement system”
  - Day-ahead (DA) schedule at DA price
  - Deviations from DA at real-time (RT) price

- EMCAS can simulate the electricity market under different assumptions about agent behavior and market rules, e.g.:
  - Congestion management; price and bid caps
  - GenCo strategic bidding; demand response

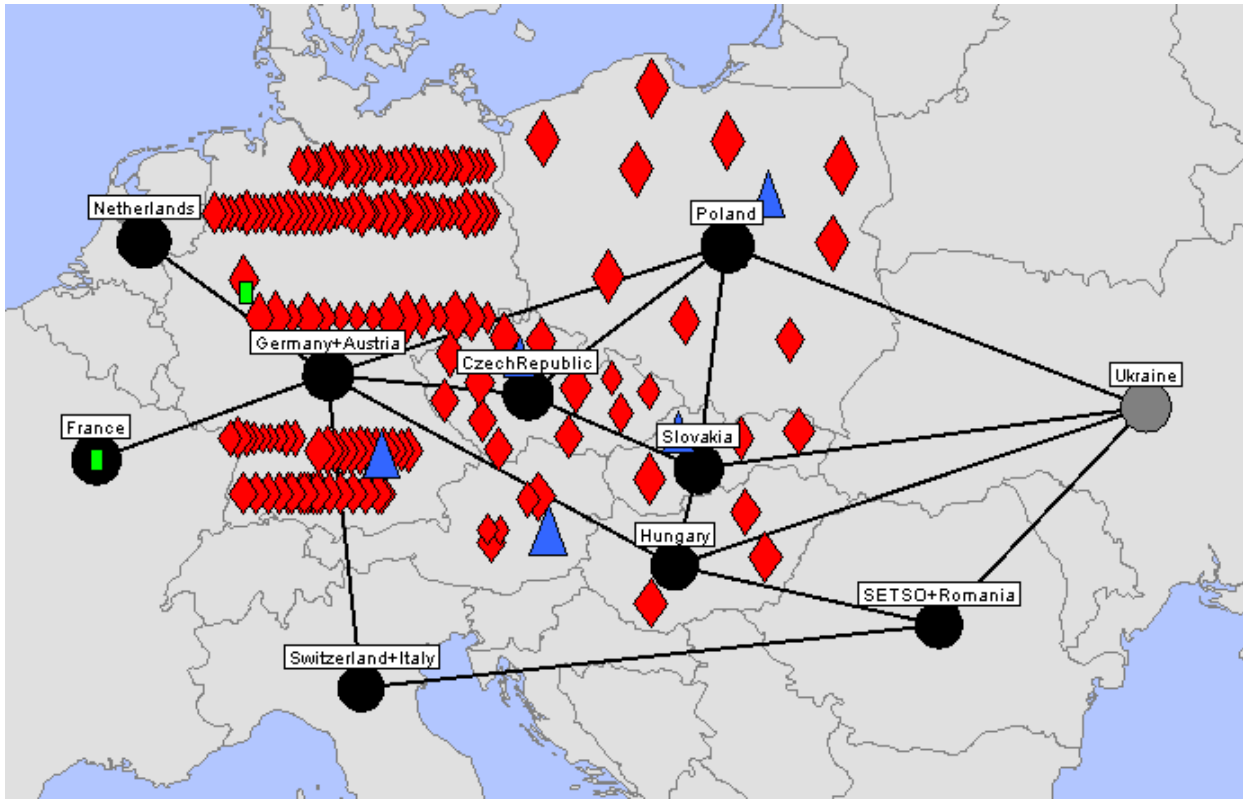
In General, GenCos May Use a Number of Customized Bidding Strategies

Some possible bidding strategies include:

Production Cost	**Bid production cost**
Bid to Ensure Dispatch	**Bid below production cost**
Price Probing	**Find price levels (e.g., FIPP, DIPP, hockey stick, etc.)**
Physical Withholding	**Take units out of service**
Economic Withholding	**Raise prices**
Combined Strategies	**e.g., price probing and physical withholding**

EEX Representation in EMCAS

- 34 GenCos
- 151 thermal units
- 5 hydro power units
- 1 wind unit
- Generator technology mix:
  - Nuclear
  - Coal
  - Lignite
  - Oil
  - Natural gas (CCGT)
  - Natural gas (GT)
  - Hydro
  - Wind



EEX Representation in EMCAS (cont'd)

- 13 countries in Central Europe are modeled: Germany and Austria (DE+AT), Poland (PL), Czech Republic (CZ), Slovakia (SK) and Hungary (HU), Netherlands (NL), France (FR), Switzerland and Italy (CH+IT) and Southeast Europe and Romania (SETSO+RO) and Ukraine (UA)

- Switzerland and Italy (CH+IT), Netherlands (NL), Southeast Europe and Romania (SETSO+RO are represented as importing nodes. Ukraine (UA) is represented as a transmission node without load and generation

- Hourly market clearing is based on a DC-OPF algorithm

- GenCos, consumers and ISO are modeled as individual agents

Some of the Main Assumptions Include the Following

- Endogenous randomly generated generator forced outages
- Perfect load forecasting for GenCos
- A maximum of four pairs of bid generation blocks and prices are used for each generating unit
- Generation is aggregated in other countries except Germany and Austria
- Because of the huge nuclear units output, France is modeled as a net import to Germany based on the import/export data from UCTE
- Generator bids are composed of production cost, emission cost and possibly also strategic markups
  - Bidding strategies can be assigned on GenCo and unit level

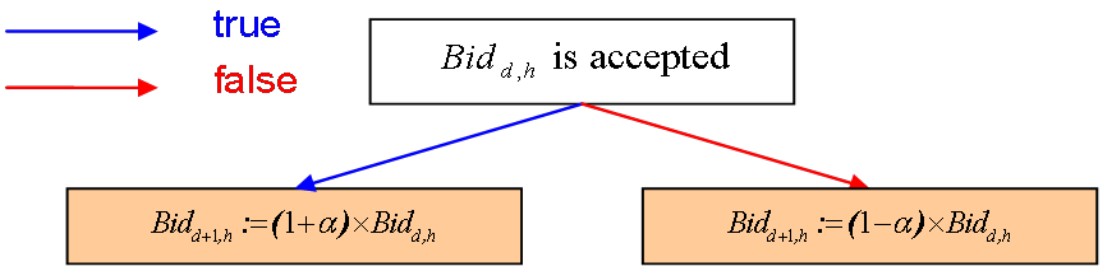
We Ran a Variety of Scenarios

- Case 1 (Base case): Production cost bidding considering emission cost
- Case 2:Fixed Increment Price Probing (FIPP)
- Case 3: Physical Withholding based on System Reserve (PWSR)

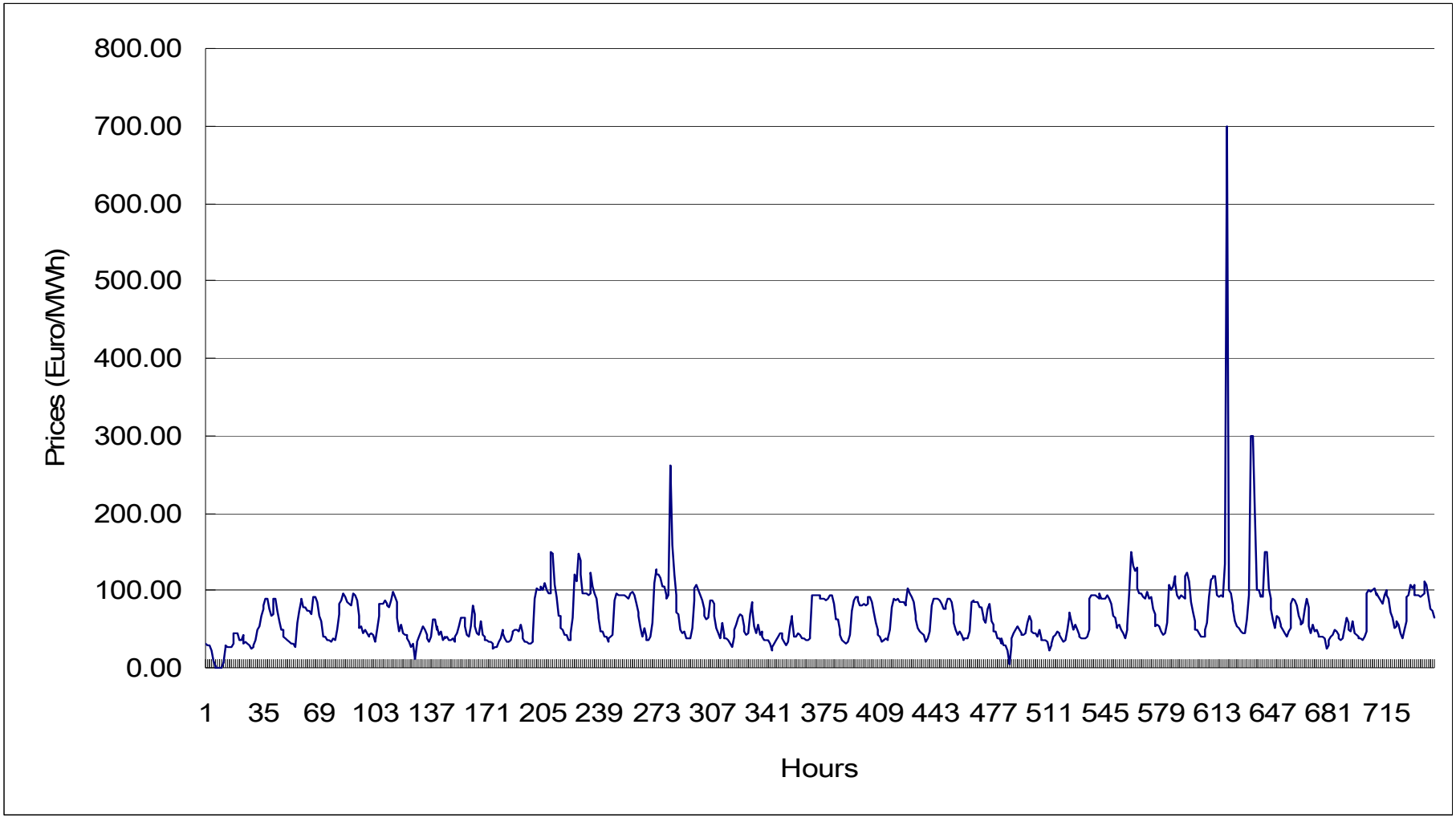
GenCo Strategic Bidding

- Physical Withholding based on System Reserve (PWSR)
  - GenCo withholds capacity in hours when the expected SR is below a specified limit
  - GenCo tries to reduce SR with a target amount in those hours by withholding units
  - GenCo bids production cost for remaining units

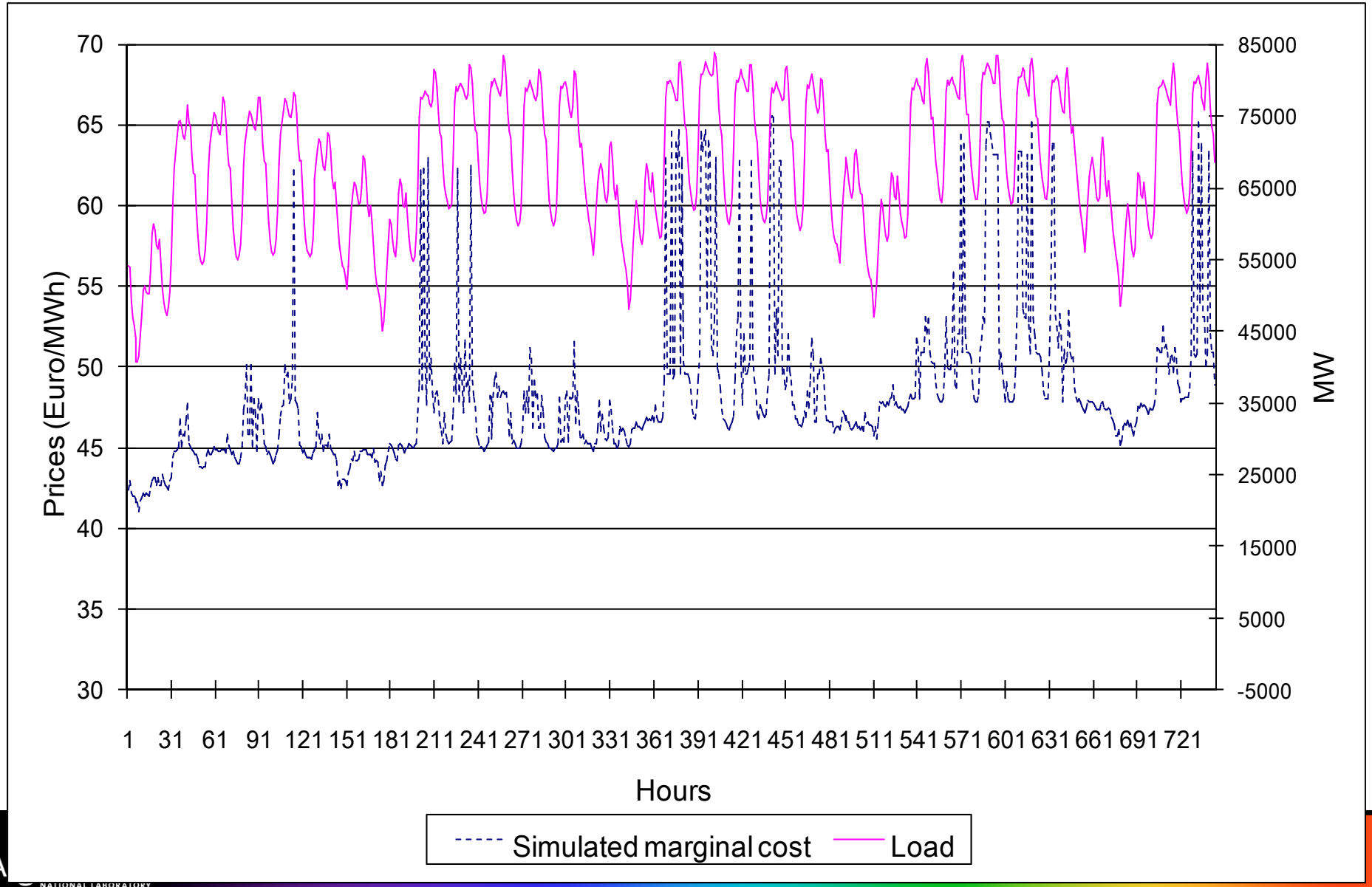
- Fixed Increment Price Probing (FIPP)
  - GenCo increases its bid w/fixed percentage for the accepted hours
  - GenCo decreases its bid w/fixed percentage for the rejected hours
  - A lower limit on bid price can be specified



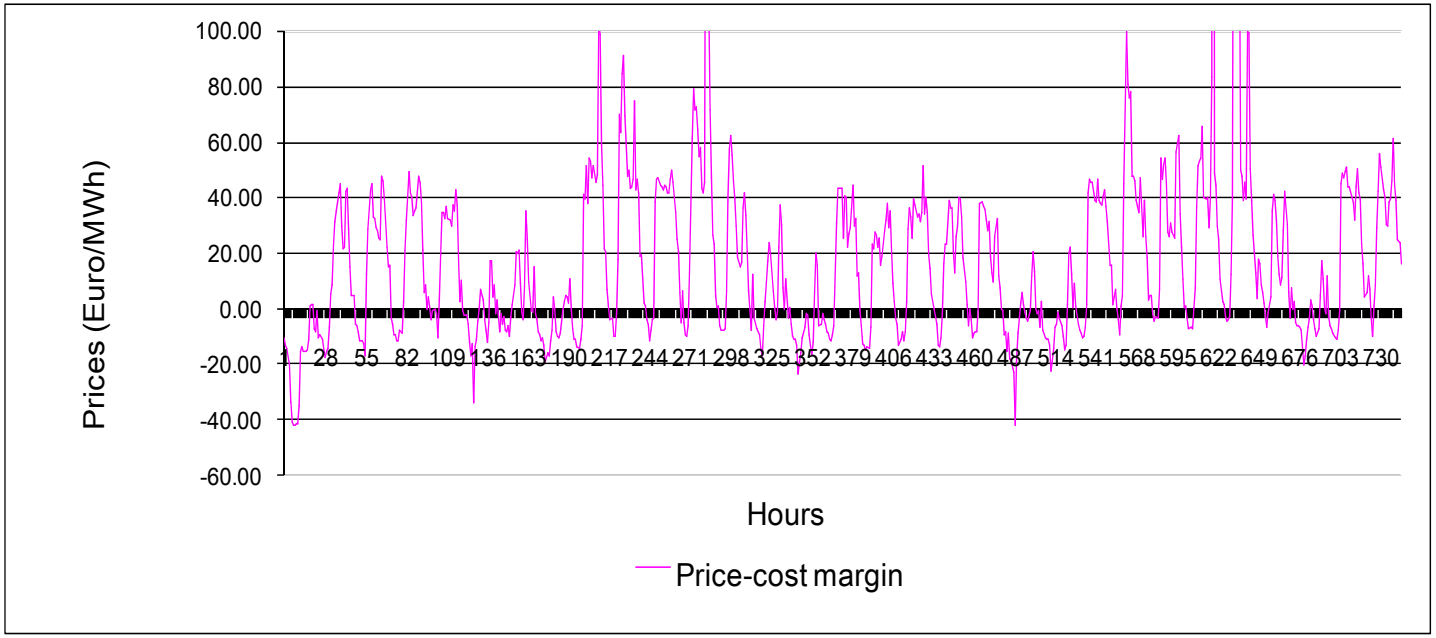
EEX Electricity Prices in January 2006: We Focused our Model Runs on one Month



Case 1 (Base case): Production Cost Bidding Considering Emission Cost

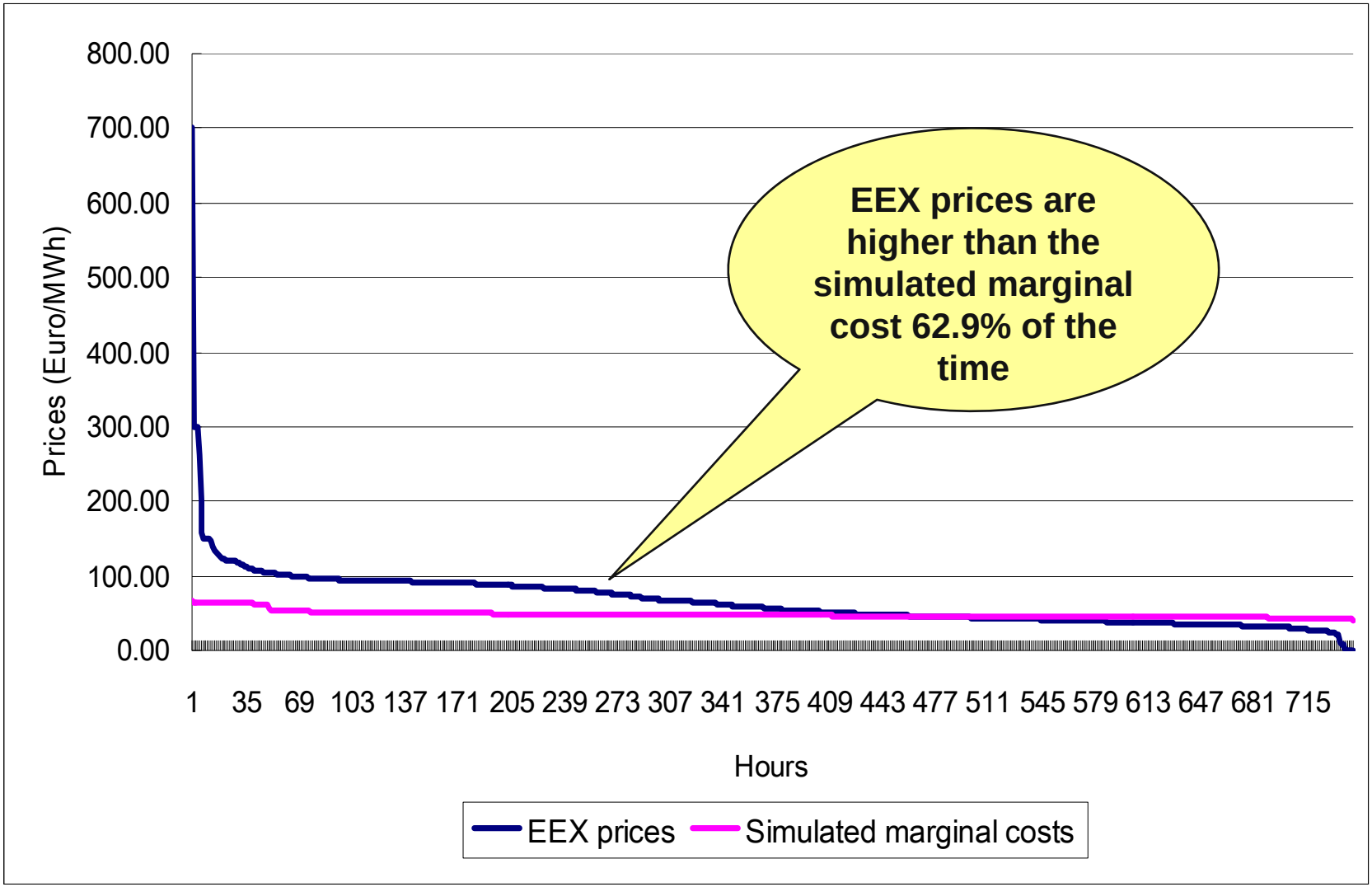


Price-Cost Margin (= EEX prices - Simulated Marginal Cost)



Price-cost margin accounts for 26.35% of the market prices on average

EEX Prices and Simulated Marginal Cost Duration Curve



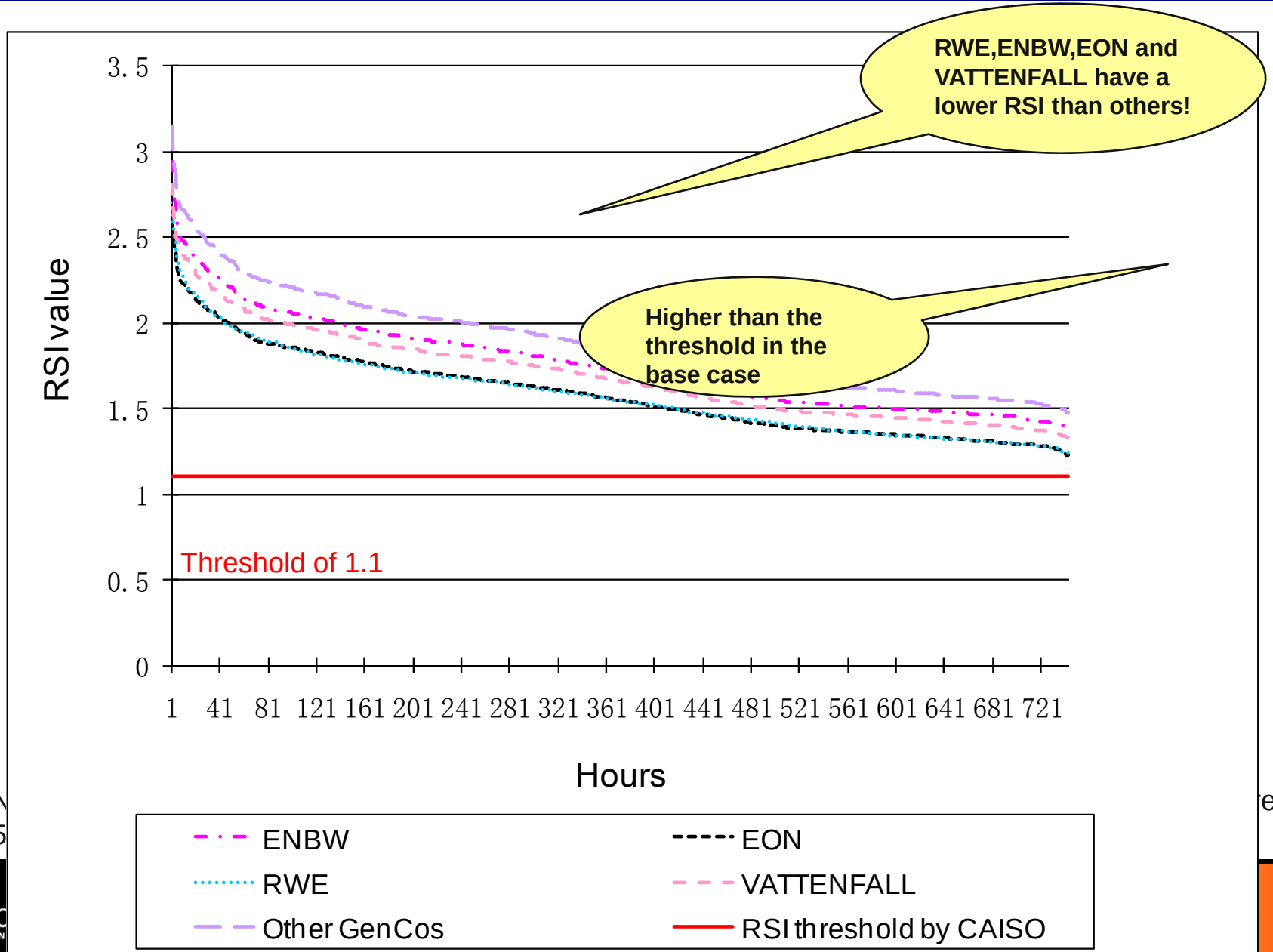
Statistics of EEX Prices and Simulated Marginal Costs

	Average	Maximum	Minimum	Standard deviation
EEX prices	65.54	699.89	0.6	40.02
Simulated marginal cost	48.28	65.60	41.06	4.8
Price-cost margin	17.27	634.74	-41.67	37.66

Observations:

- **Much larger price range for EEX**
- **Low prices in off-peak hours could be a result of unit commitment constraints (startup cost, ramp rates, unit minimum-on time constraints etc.)**
- **High prices which are above the simulation requires further investigation**

Who Might be Making a Difference?



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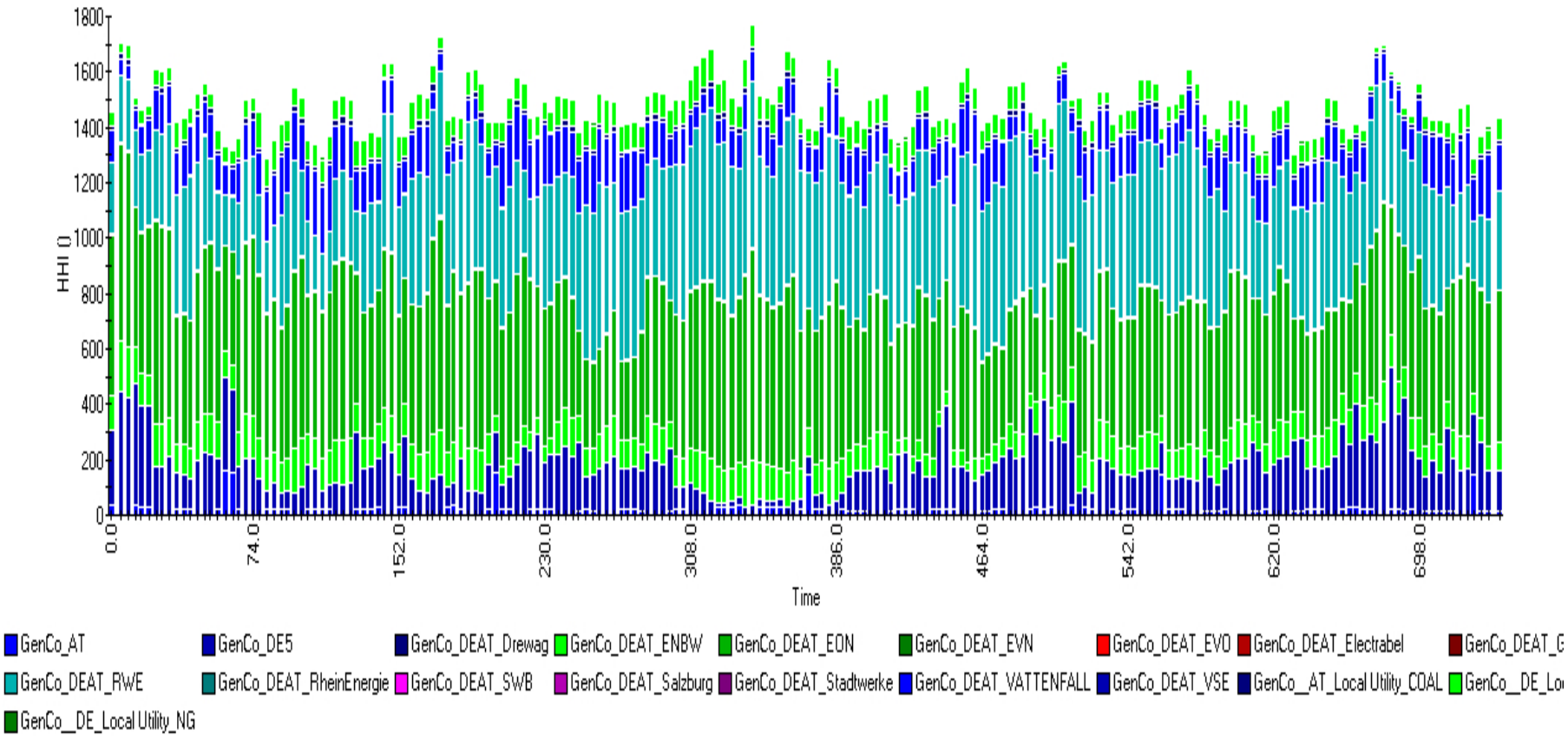
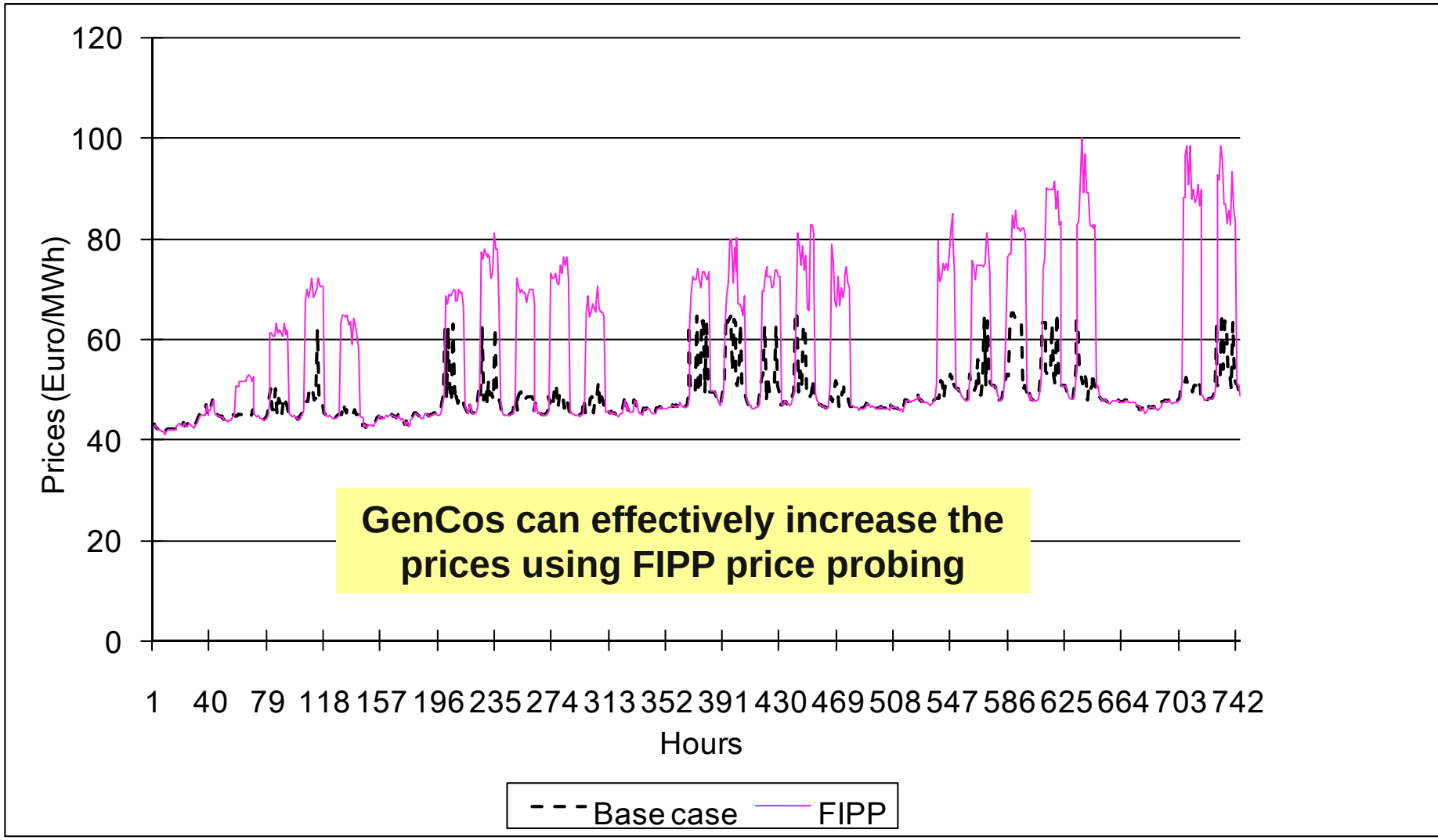
Market Concentration in Terms of HHI Index



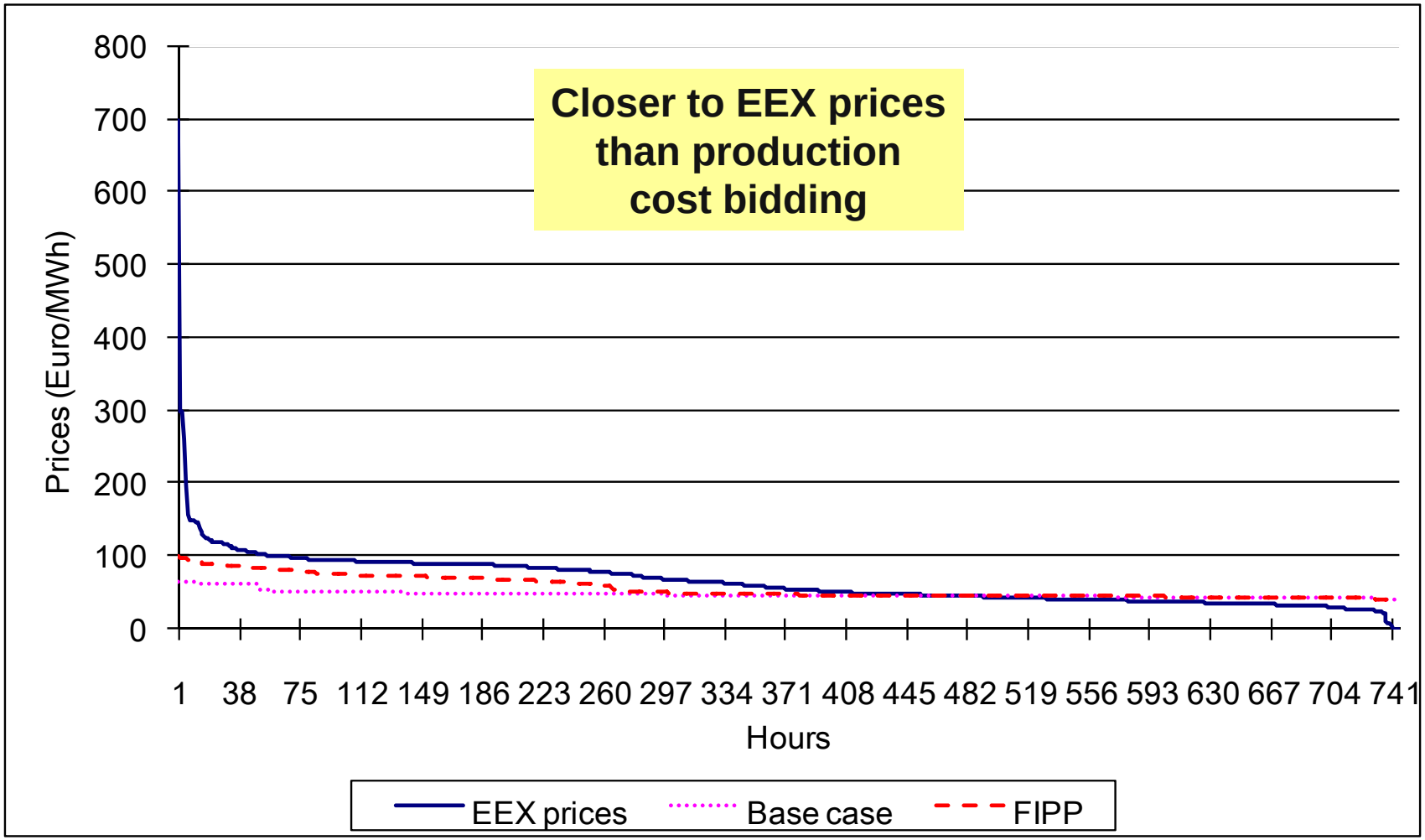
Moderately concentrated(1000<HHI<1800) based on FERC criteria

Case 2: Fixed Increment Price Probing (FIPP) -Simulated Marginal Cost Comparison



GenCos can effectively increase the prices using FIPP price probing

Price Duration Curves



Statistics of Simulated Marginal Cost with FIPP

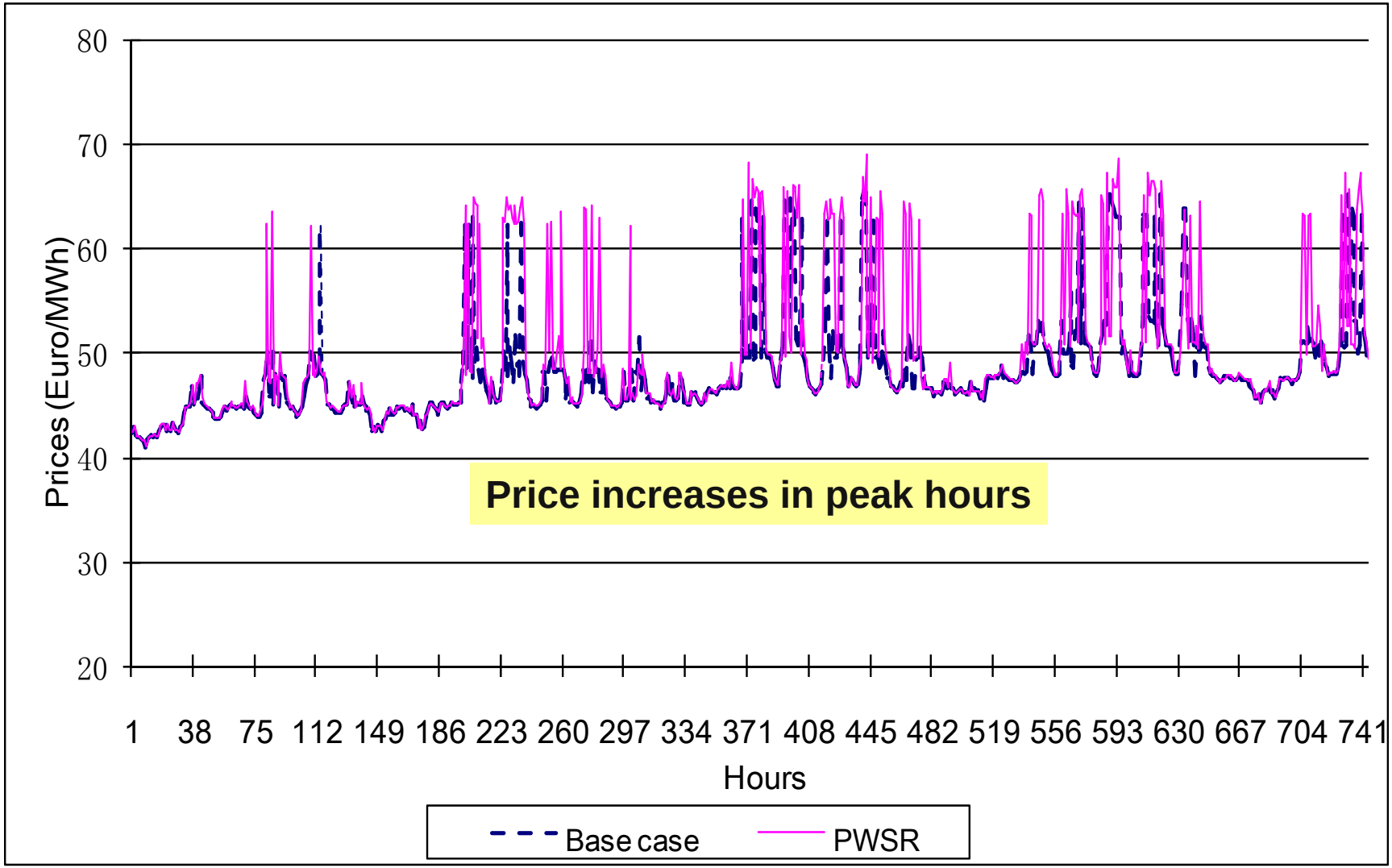
	Base case	FIPP by RWE	FIPP by ENBW	FIPP by VATTENFALL	FIPP by EON	FIPP by all four
Average	48.3	51.2	49.2	50.3	51.1	56.5
Maximum	65.6	71.6	65. 9	68.2	73.5	100.0
Minimum	41.1	41.1	41.1	41.1	41.1	41.1
Standard deviation	4.8	7.9	5.8	6.9	7.8	14.7
Profit change(%)		-5.8%	-7.3%	-14.4%	-7.3%	14.5%

Observations:

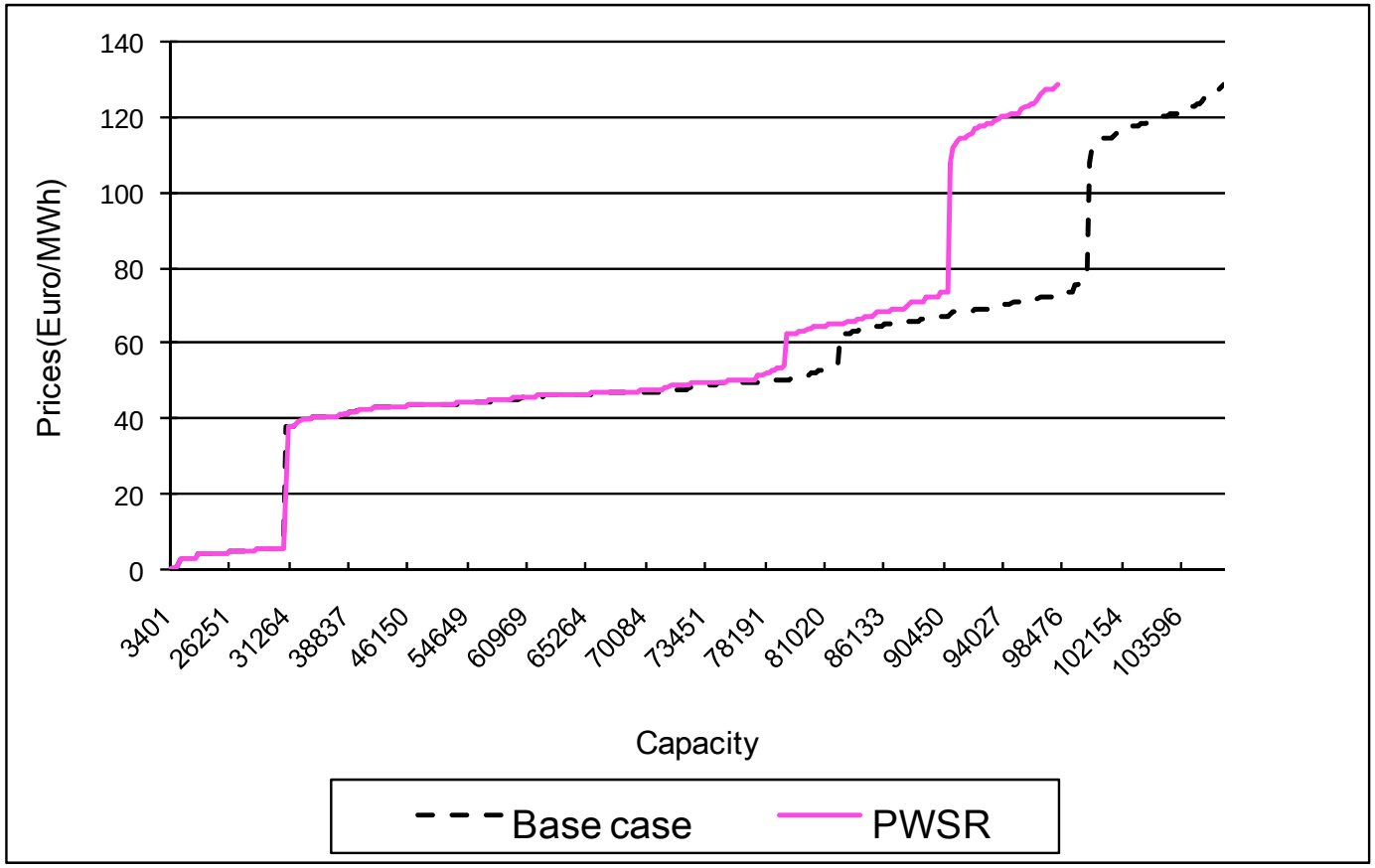
- **Individual GenCOs have certain ability to increase market prices**
  - **However, profit is reduced as a consequence**

- **Higher market prices and positive profits under collusion between the four GenCos**

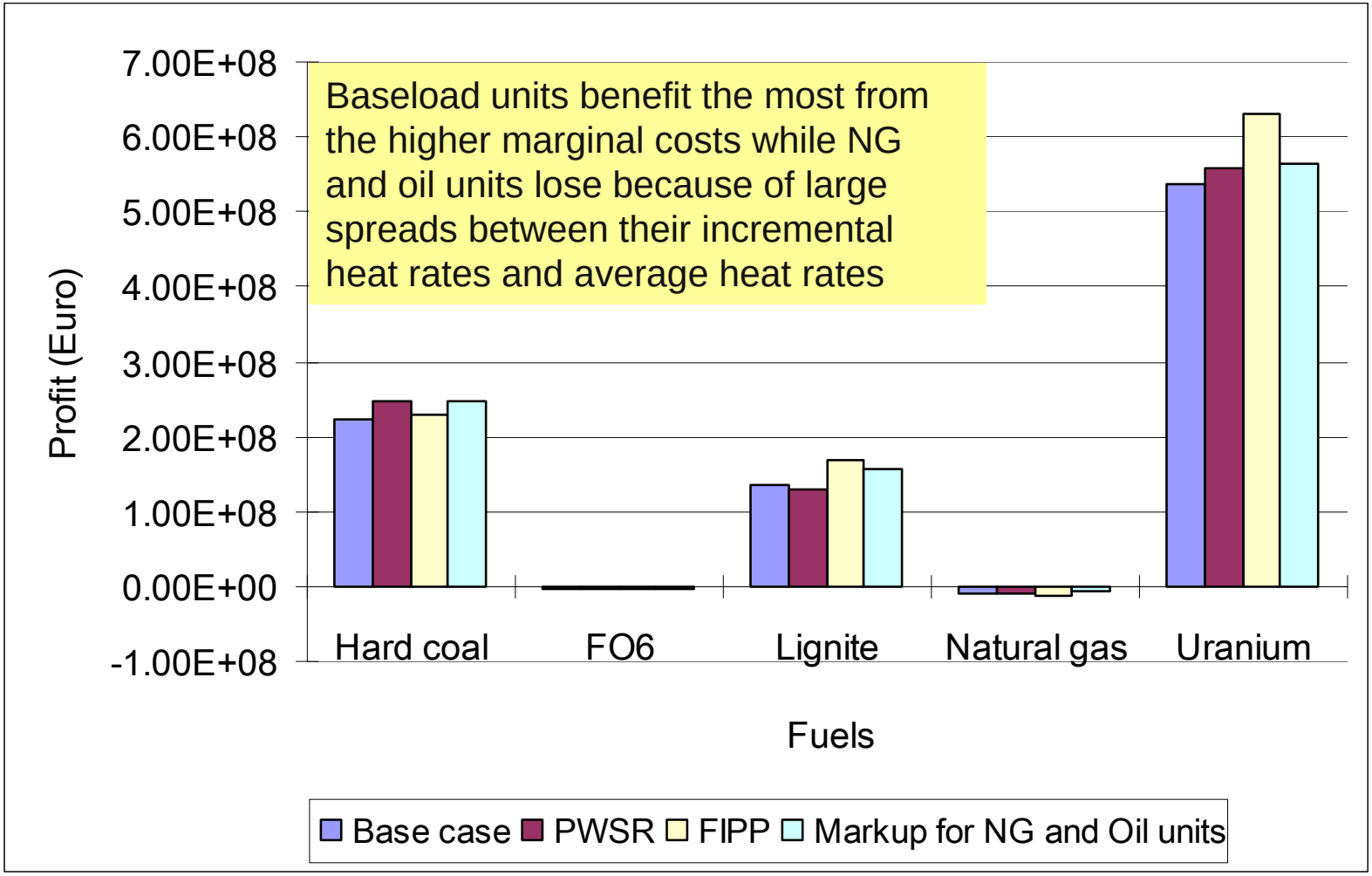
Case 3: Physical Withholding Based on System Reserve (PWSR) -Simulated Marginal Cost Comparison



Merit Curve at 11AM January 17th

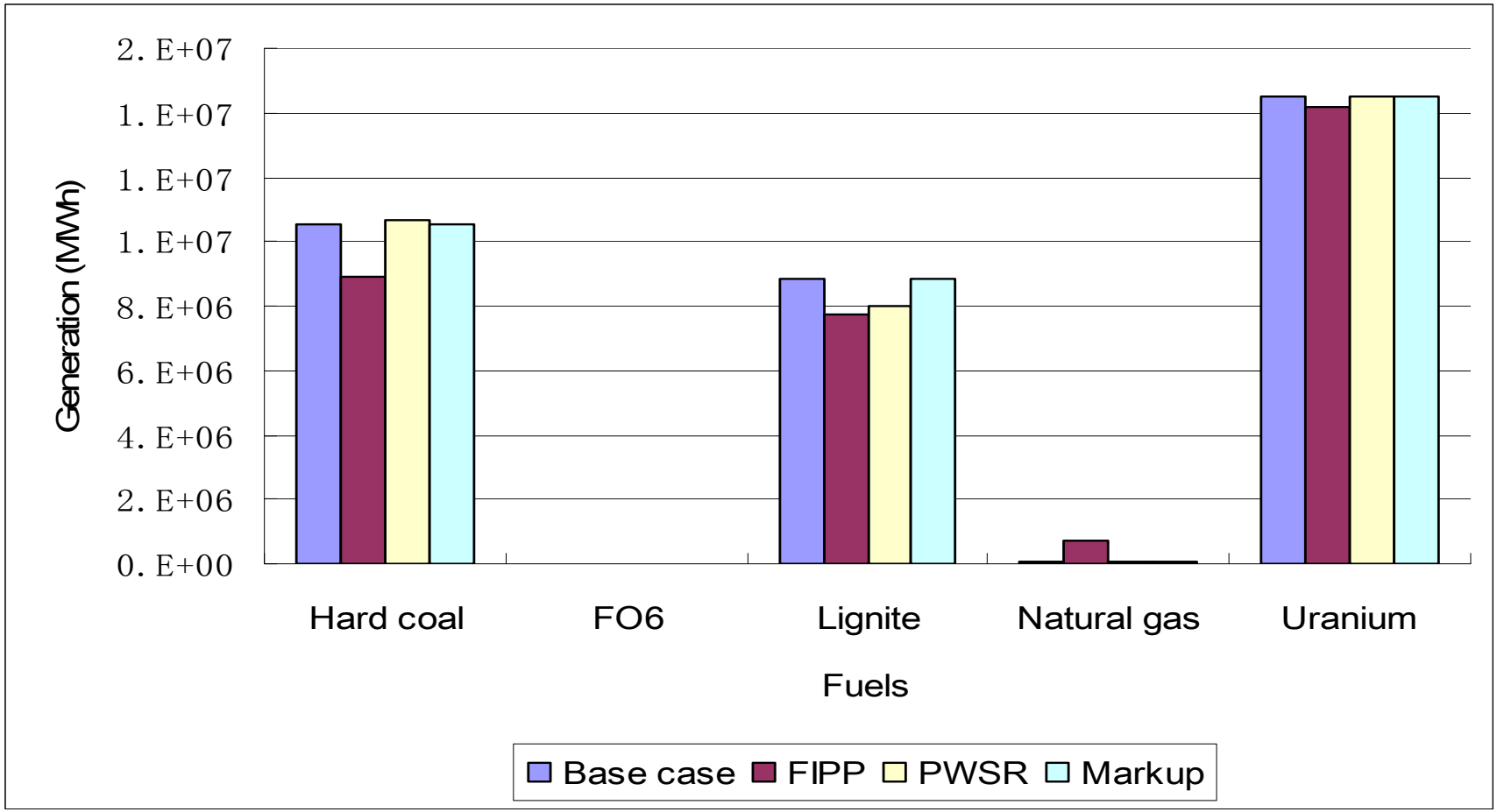


Profit Analysis by Fuel Type for the Largest Four GenCos

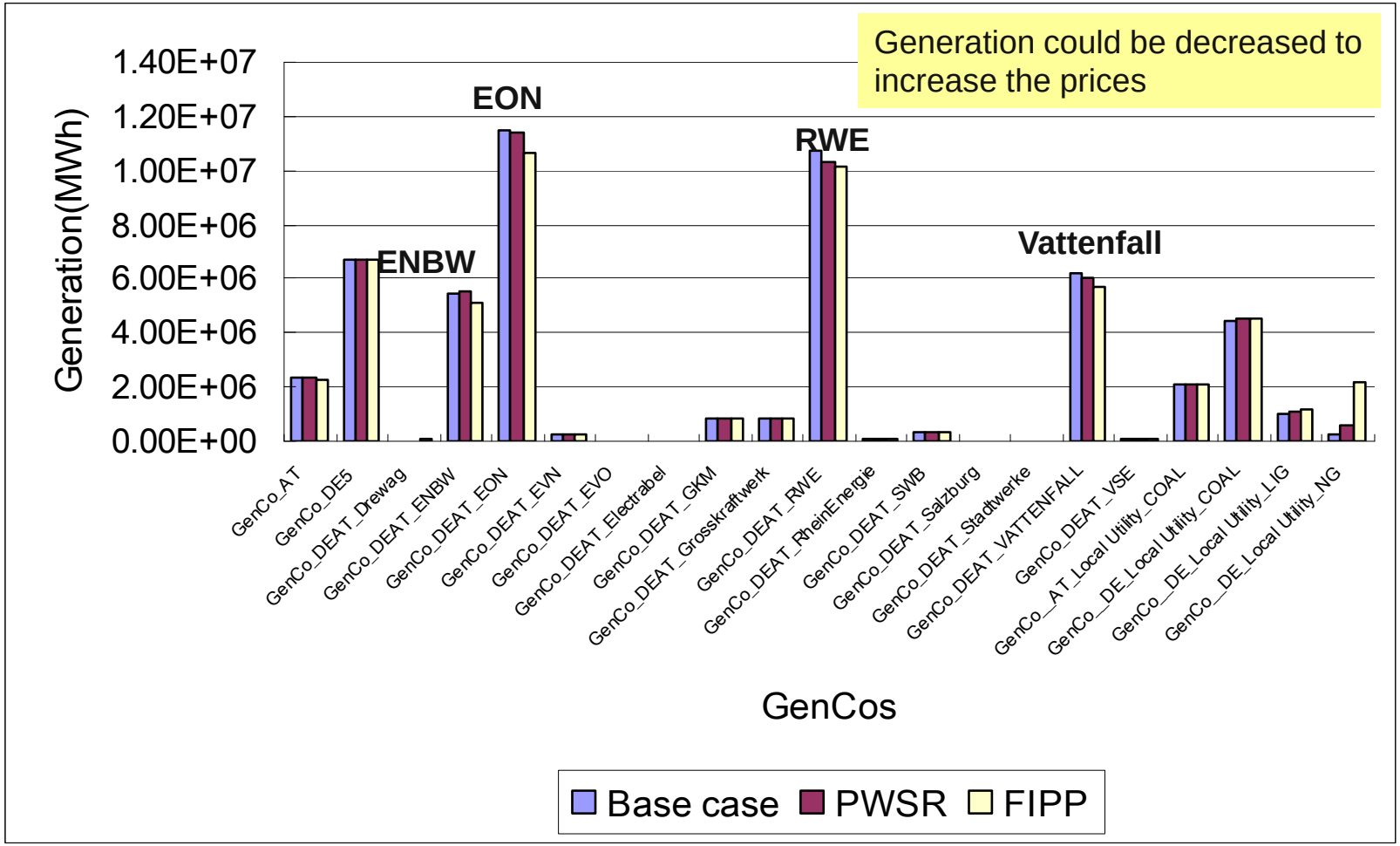


Generation Analysis for the Largest Four GenCos

- Generation does not change a lot except under FIPP



Generation Analysis for all the GenCos



Statistics of HHI Under Different Cases (Based on Generation)

	Average	Maximum	Minimum
Base case	1443	1771	1239
FIPP	1375	1771	1048
PWSR	1419	1771	1170

Observations:

- **All the three cases are moderately concentrated by FERC's definition (1000<HHI<1800)**
- **In FIPP and PWSR cases, GenCos are bidding strategically**
- **Structural indicator like HHI does not reflect the market power accurately**

Some Preliminary Conclusions from EEX Study

- EEX prices appear to be above marginal cost on average
  - Above during the day
  - Below at night
- Some GenCos appear to be in the position of exerting market power by strategic bidding
  - Benefits only when applied by several companies at a time
- GenCos can gain large profits on baseload plants, but peaking units (NG and Oil) have negative operating profits
- EMCAS is a flexible tool for electricity market modeling and simulation with strong what-if analysis capabilities and report functions

Thank You!

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