Why Details Matter in Future Electric Energy Systems?

Professor Marija Ilic
ECE and EPP

4th CMU Conference, March 11,2008

Outline

- Qualitatively new industry objectives
- Today’s operating and planning paradigms not capable of implementing these objectives
- Need for new infrastructure to support change
- Need for new regulatory economics to give the right incentives
- Examples of missed opportunities

Single optimization subject to constraints (old) vs. Reconciling multi-dimensional tradeoffs (new)

Single optimization subject to constraints	Reconciling tradeoffs
Schedule supply to meet given demand	Schedule supply to meet demand (both supply and demand have costs assigned)
Provide electricity at a predefined tariff	Provide electricity at QoS determined by the customers willingness to pay
Produce energy subject to a predefined CO_2 constraint	Produce amount of energy determined by the willingness to pay for CO_2 effects
Schedule supply and demand subject to transmission congestion	Schedule supply, demand and transmission capacity (supply, demand and transmission costs assigned)
Build storage to balance supply and demand	Build storage according to customers willingness to pay for being connected to a stable grid
Build specific type of primary energy source to meet long-term customer needs	Build specific type of energy source for well-defined long-term customer needs, including their willingness to pay for long-term service, and its attributes
Build new transmission lines for forecast demand	Build new transmission lines to serve customers according to their ex ante (longer-term) contracts for service

Need for novel engineering, regulatory and financial solutions

- Today's engineering solutions optimize total supply cost for the forecast demand, treating everything else as a constraint.
- Current (State) regulatory solutions do not require information from the customers concerning their choices (willingness to pay for short-term QoS, long-term guaranteed supply, reduced greenhouse effects); instead, obligation to serve by a State (utility) is assumed at the pre-agreed on tariffs. By and large, price of service is seen as a constraint by both providers of service and the customers.
- Current financial arrangements are grossly distorted with regard to the (monetary) risks associated with uncertainties (demand, fuel, equipment status).
- Current (Federal) regulatory experiments are superposed on the State regulatory solutions whose emphasis is on individual utilities (States) while the interactions with neighboring States (utilities) are uncertain constraints. The FERC restructuring attempts to eliminate the constraints across States and to induce ``open access''.
- None of current engineering/regulatory/financial solutions in place enable genuine reconciliation of multiple tradeoffs at value. Therefore, need for novel solutions.

Need for new infrastructure to support change

- Some key examples
  - empower customer choice
  - implement demand side response
  - integrate renewable resources
  - implement differentiated reliability and Quality of Service (QoS)

- ALL OF THESE REQUIRE TRANSFORMATION OF TODAY'S ELECTRIC POWER GRID TO AN ACTIVE ENABLER
- CHANGE OF PARADIGM FROM BUILDING PASSIVE LARGE POWER LINES TO SELECTIVELY BUILDING WHERE TRULY NECESSARY; INSTEAD, COMPLETELY RE-DESIGNING THE GRID INTELLIGENCE

Need for new regulatory economics to support change

- From rules that support economies of scale to rules that support economies of scope and systems

  - efficiency through interactions among the components (spatial and temporal)

  - complexity vs accuracy (complex efficient tariffs or simple average tariffs?)

  - the challenge of managing and valuing uncertainties

  -design of incentives to forecast and manage based on prediction and adaptation, instead of incentives to build for the worst case scenario

Examples of obvious missed opportunities

- No incentives to value dynamic response of various hardware technologies (also the technological challenge remains; in addition, very little workforce to champion this)
- No incentives to deploy infrastructure for making the switching of grid components intelligent through advanced control/sensing and coordination
- No incentives to value risks in symmetric ways (yet the arbitrage is quite huge and the implications are significant)
- No incentives to provide customer choice at value

Need to value dynamic response of various technologies

- It can be shown that, everything else being the same, the system load factor can be significantly increased by deploying just-in-time (JIT) and just-in-place (JIP) technologies. The load factor in the US utilities has worsened in a major way recently. This is not sustainable.
- These technologies range from individual components through extracting economies of scope and economies of systems
- It is going to be practically impossible to integrate effectively (with provable benefits to the end users) large scale intermittent resources and demand side response without solving this problem.
- There are major tradeoffs in performance depending on how are these technologies utilized.

Some missed opportunities with “smart grids”

- Just deploying the newest gadgets (meters, sensors, communications) will NOT do it!
- It is critical to understand the entire supply chain to the customer; deploying novel meters, while following the same old reliability reserve rules defeats the potential for major cumulative efficiencies; designing “capacity markets” which take into consideration demand response without any spatial information not grid infrastructure to implement differentiated reliability does not do much for the end user
- Proposing solutions to the US transmission “national corridors” which require major large scale investments without in-depth analysis of actual system bottlenecks (voltage support, for example) will not solve the problem
- Common Information Mode (CIM) protocols are meaningless without understanding what type of information, and at which rate they would be facilitating
- Poor understanding of economics of transmission congestion could give disincentives to solving the actual problem

Missed Opportunities Caused by Inadequate Management of Uncertainties

- Huge effect on technical performance and financial outcomes
- Key role of predictive signals (need for forecast and its use for decision making both in regulated and restructured systems)
- Financial Transmission Rights (FTRs) currently based on deterministic calculations!!!
- Temporal inter-dependencies often neglected in today's tools; consequently, planning/investments are not closely related to the short-term decisions. Impossible to make the case for the value of flexible technologies.
- Yet, the uncertainties are significant (the example of Nord Pool)

Nord Pool's markets

Spot markets

Day ahead
2hrs ahead

- physical delivery
- auction trade (uniform price)
- system price and price areas (zones)

Financial markets

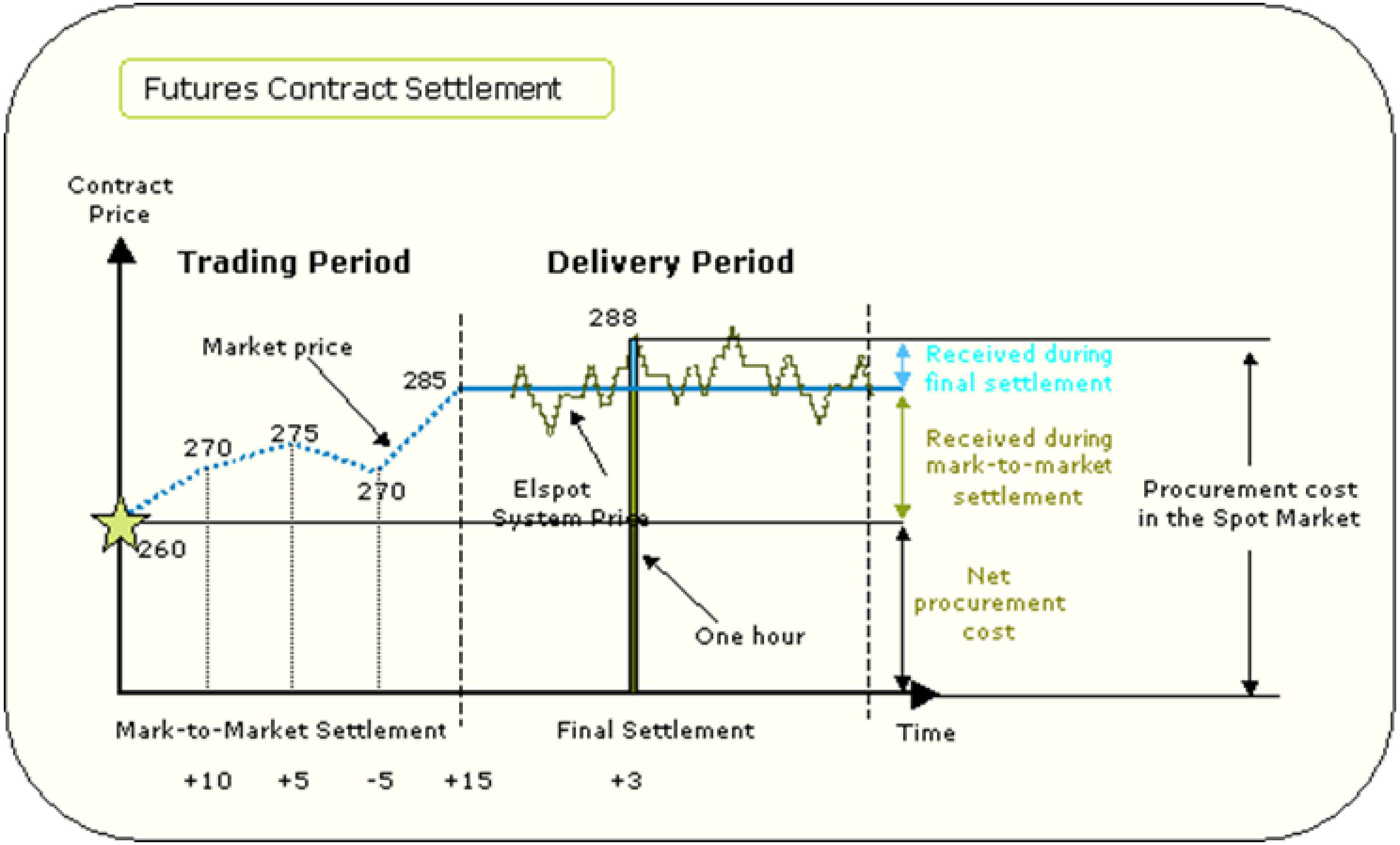
Futures
Forwards
Options
CfDs

- no physical delivery
- continuous trading
- settled against system price

The futures market

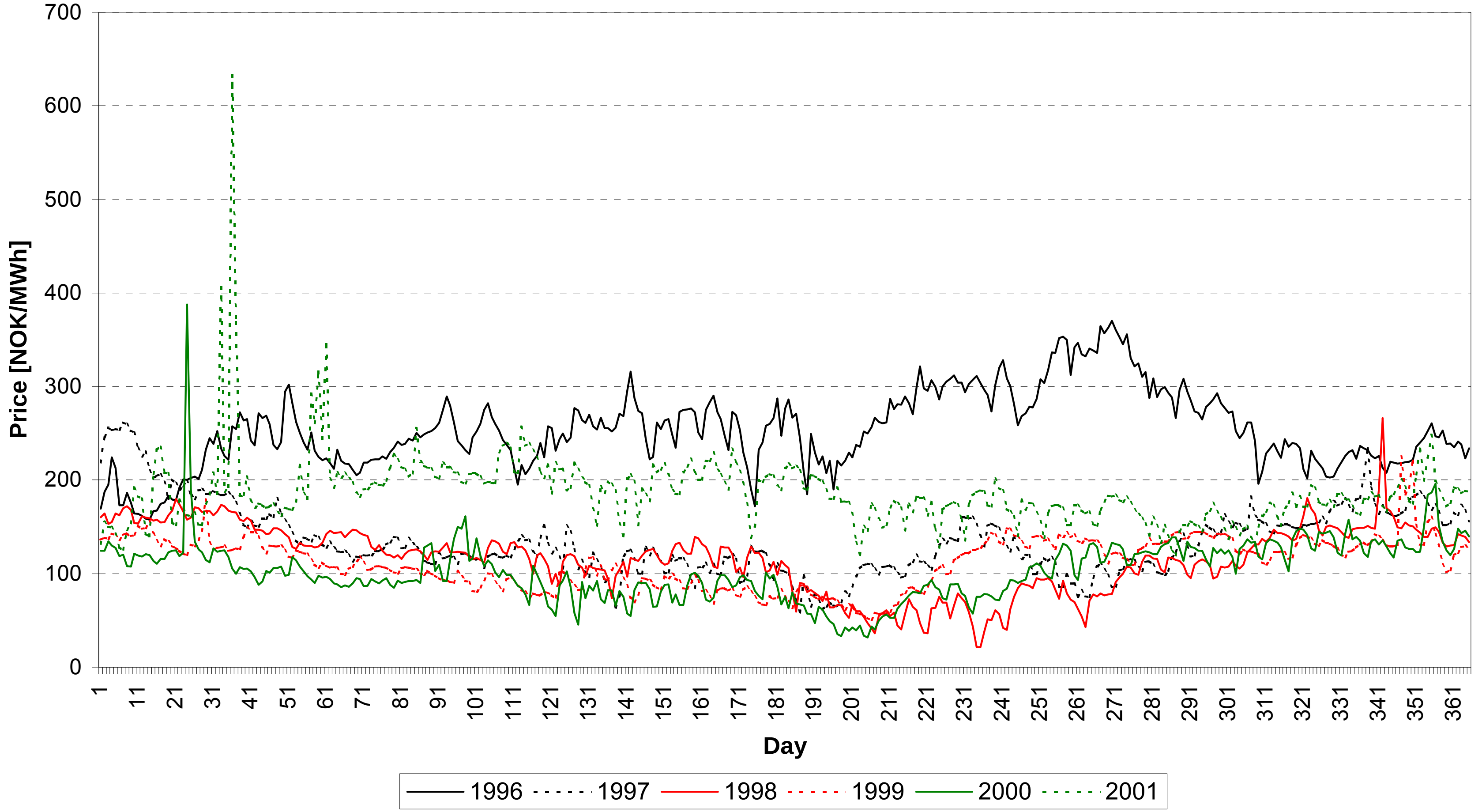
Contracts: days, weeks, blocks (4weeks) and seasons

Horizon: up to one year (3-4 years for forward contracts)

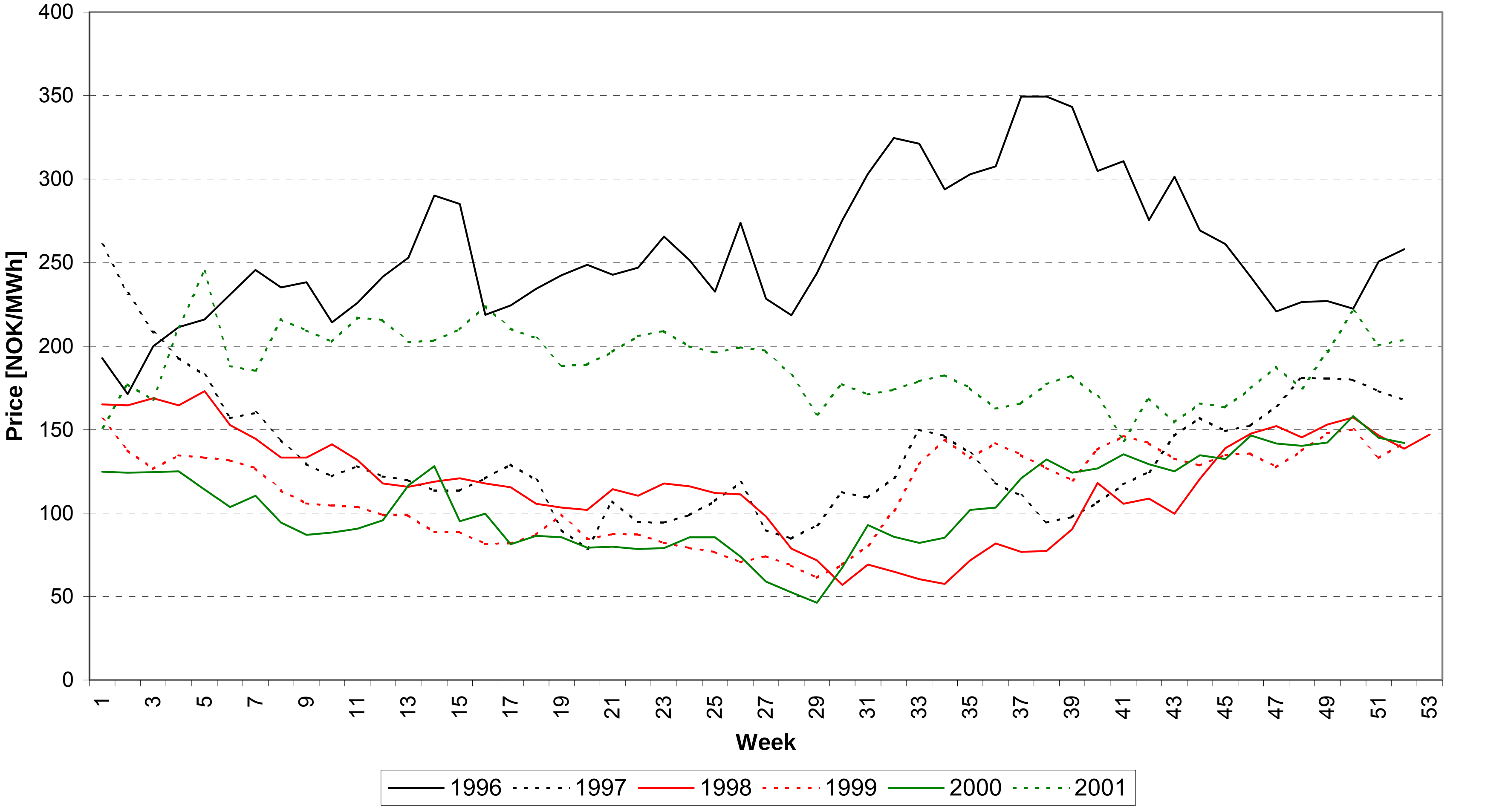


Source: Nord Pool

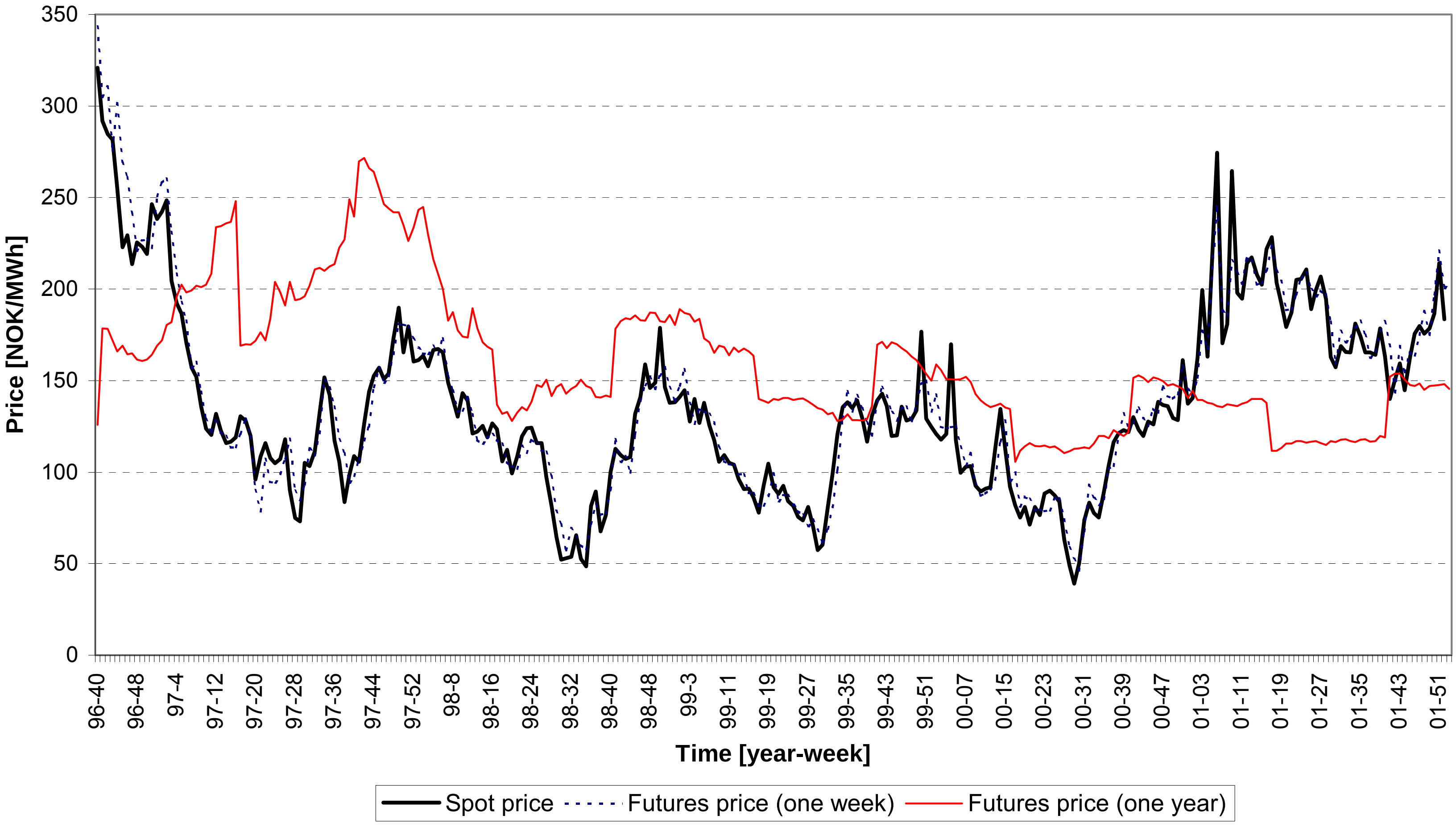
Historical spot prices (1996-2001)



Historical futures prices (1996-2001)



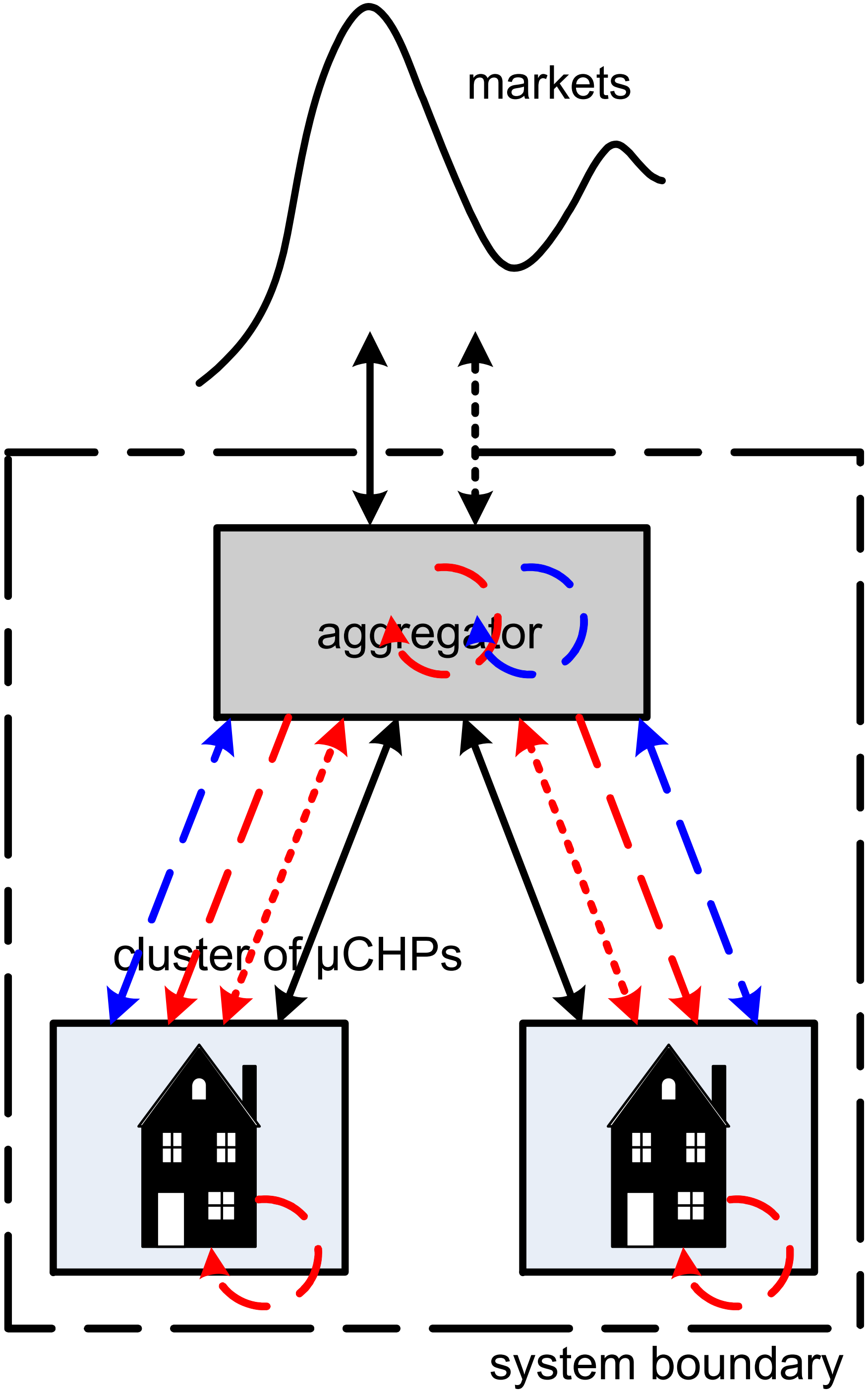
Futures and spot prices



Risk premium – empirical statistics

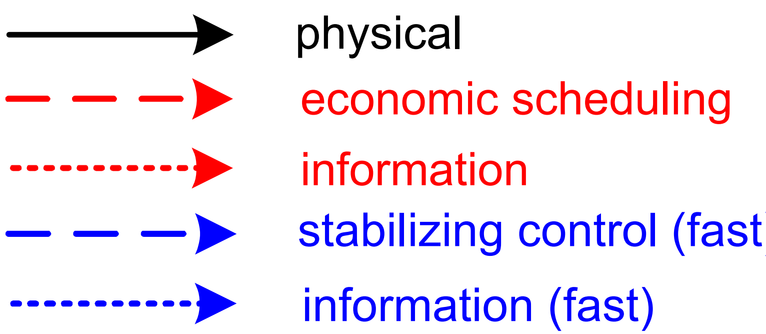
	1 week	4 weeks	26 weeks	52 weeks
Sample size	326	323	300	275
Mean	-0.015	-0.035	-0.085	-0.183
Stdev.	0.101	0.187	0.432	0.399
Conf. interval, up limit (99%)	-0.001	-0.008	-0.020	-0.122
Conf. interval, lo limit (99%)	-0.030	-0.062	-0.149	-0.245

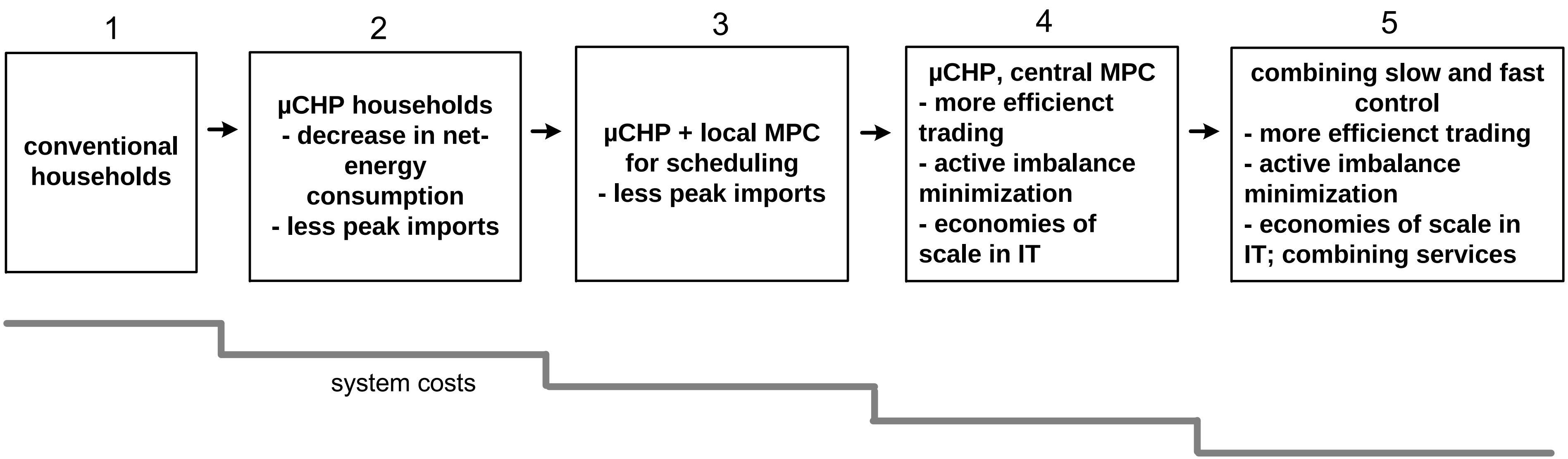
→ Negative risk premium observed for all holding periods



EMPPOWERING CUSTOMERS

1. µCHP; ‘plug-n-play’
2. Local MPC
3. Central MPC for trading
4. Combining slow and fast control





- Economies of system in coordination and ICT

Conclusions

- The electric energy industry is at its crossroads
- The electric power grid must play the key role of enabling the next generation electric energy systems
- Unfortunately, the gap between today's power grid infrastructure (including its SCADA) and what is needed is huge
- Tremendous technology push by new hardware will not translate into benefits to customers nor in an improved social welfare unless sufficient attention is paid to the systems engineering challenge
- The industry will remain at stand-still without technologies and regulation in support of economies of system
- This is a major challenge given the state-of-art and workforce profile in the electric power industry