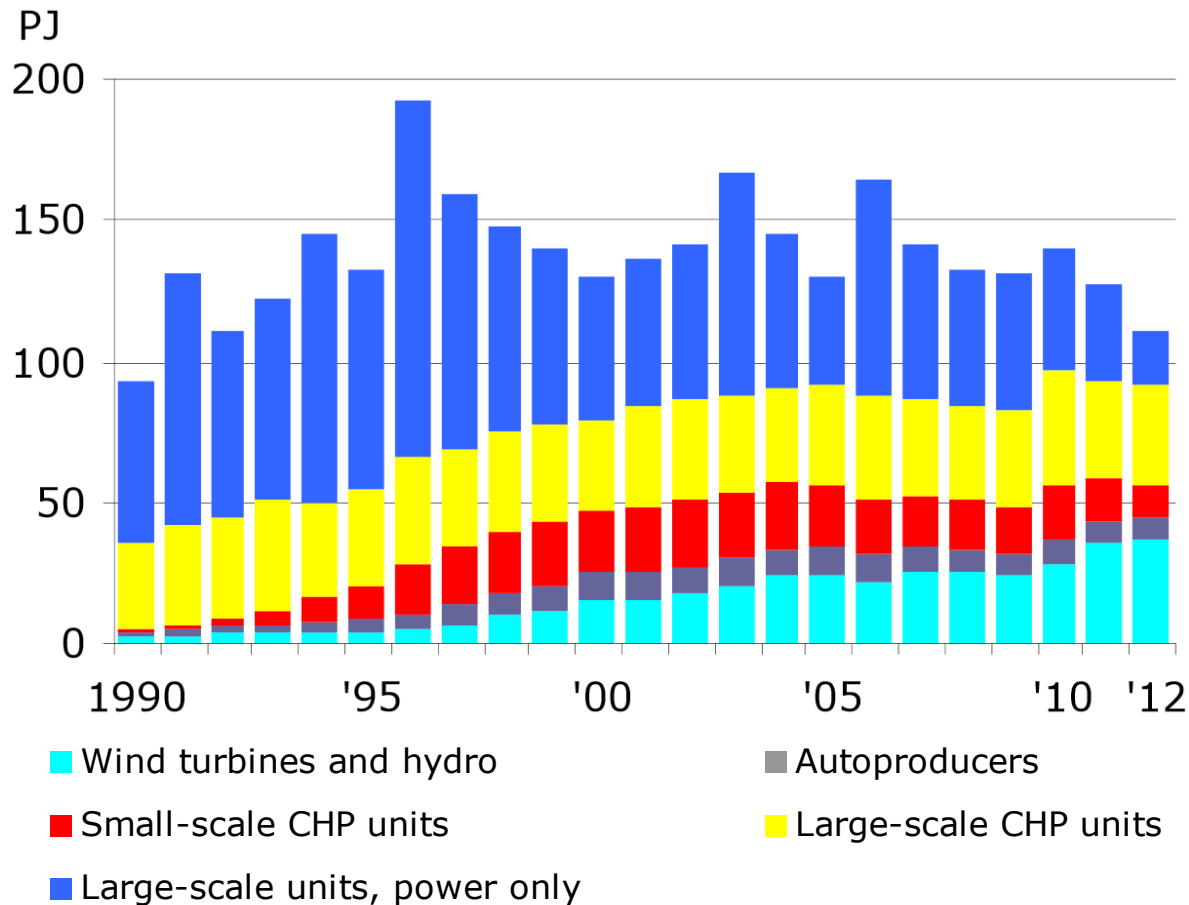


PRACTICAL SIMULATION APPROACH FOR MULTI ELECTRICITY MARKET OPERATION OF DISTRIBUTED GENERATION

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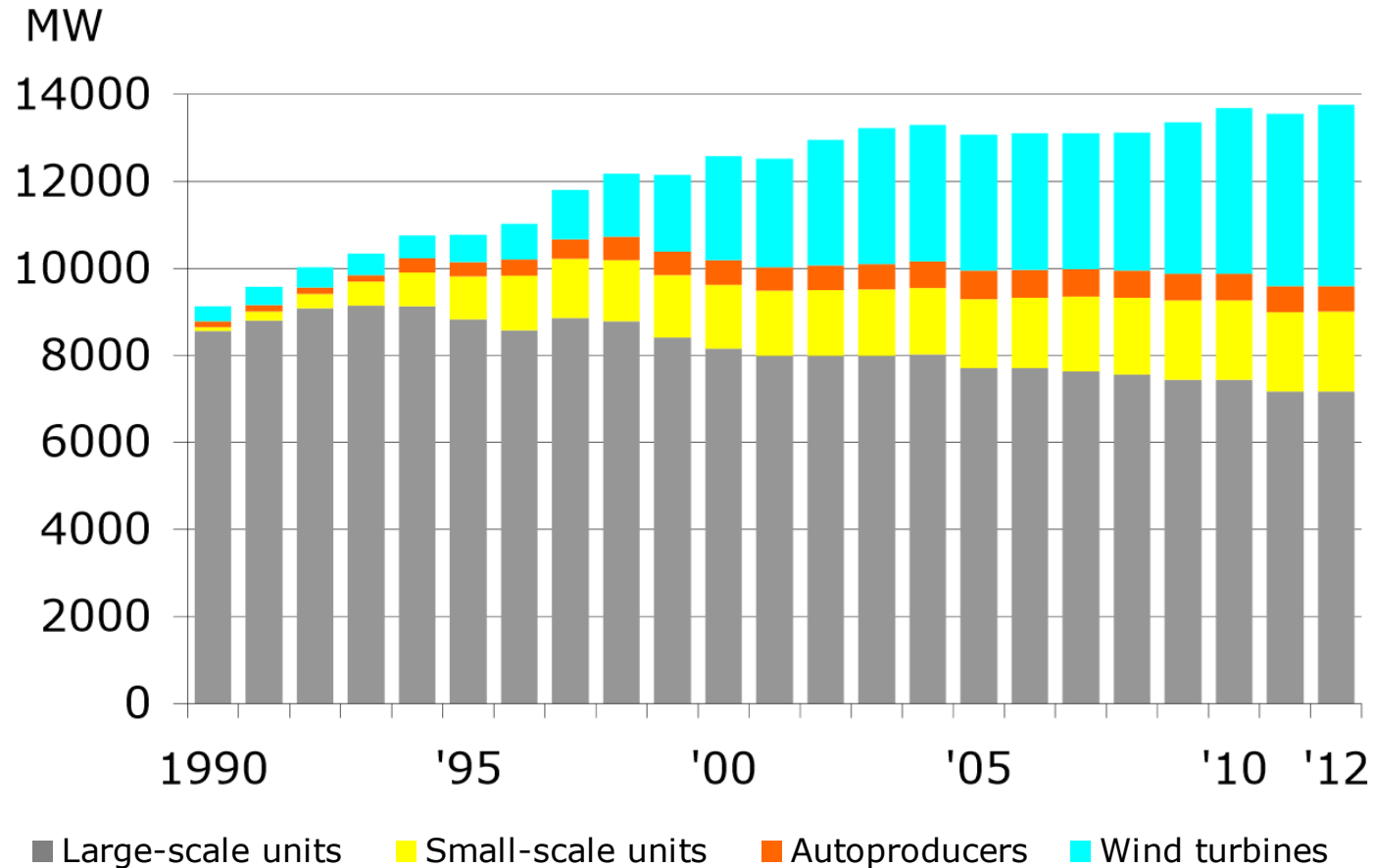
Electricity production by type of producer



Source: "Energistatistik 2012", Danish Energy Agency



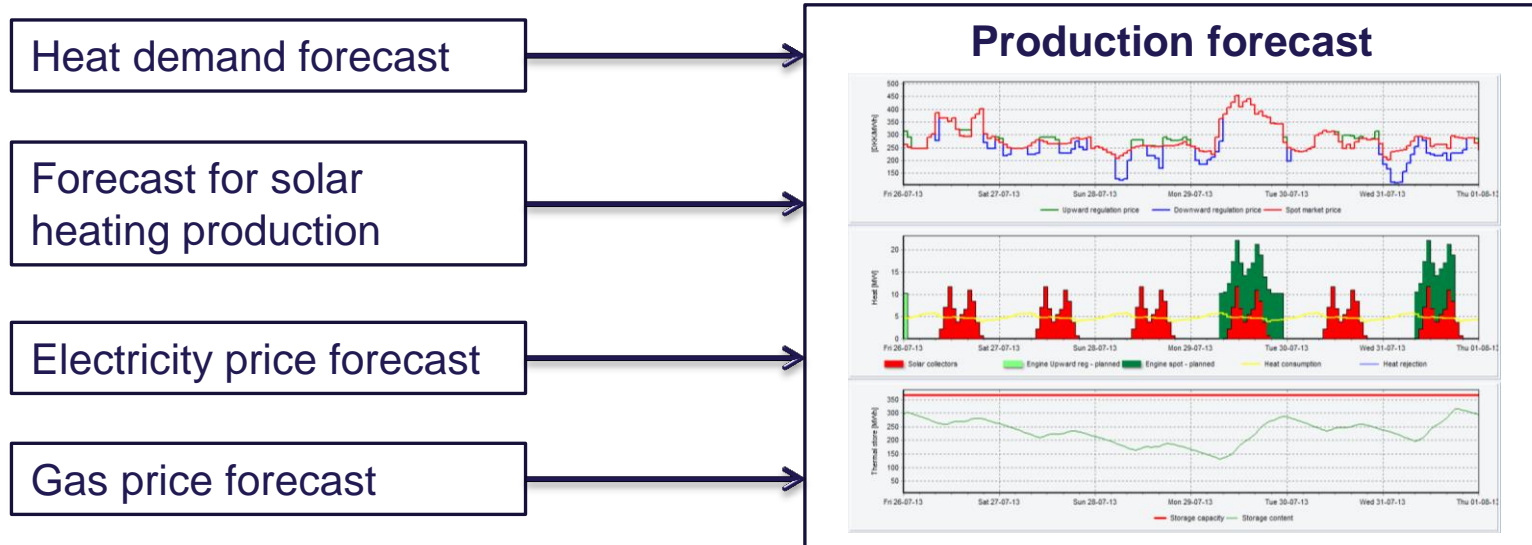
Electricity capacity by type of producer



Source: "Energistatistik 2012", Danish Energy Agency



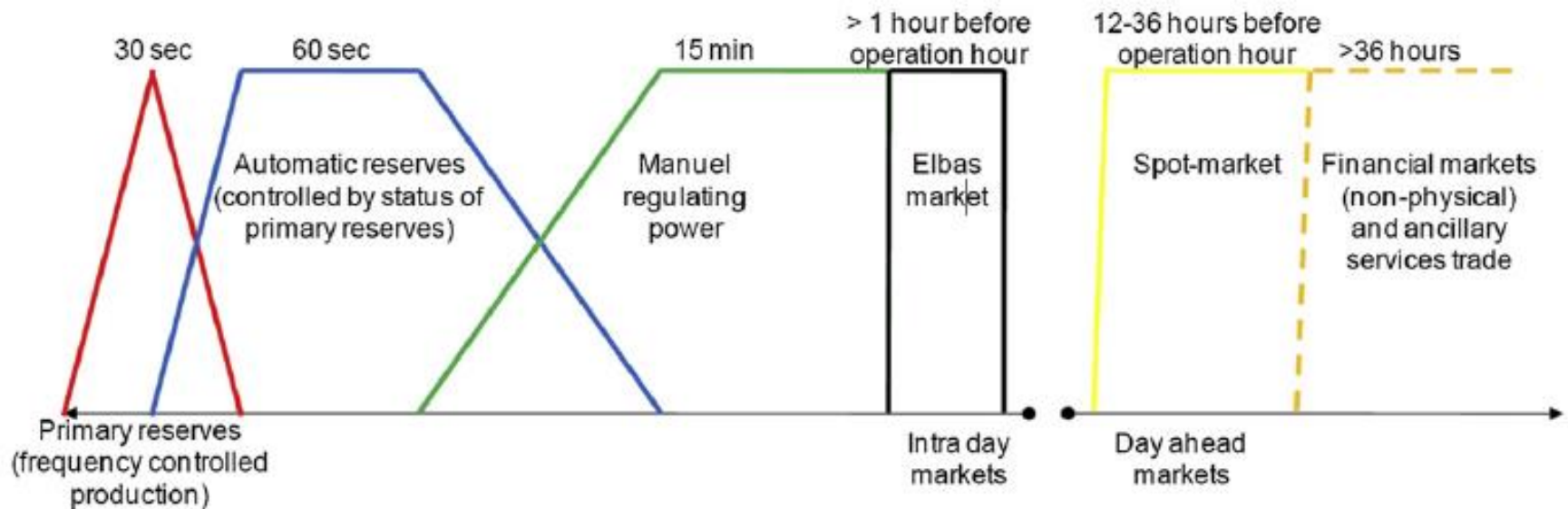
Forecasts used in daily operation of a district heating plant



- Energy balancing models for daily operation are well-described in the literature.
- However, these models do not address the daily uncertainties as experienced by a plant operator



Electricity markets in Western Denmark



Practical simulation approach for Nord Pool

Gate closure for activation bids in Regulating power market is 45 min. before each hour

00:00

9:00-11:00

12:00

13:00

Relevant forecasts for the following days are updated. E.g. heat demand, solar heating production and natural gas price.

Gate closure for Nord Pool Spot bids.

Update the Nord Pool price forecast for the following days.

The result of the daily Nord Pool Spot trading are made public.



Case study

- Three different simulations have been carried out using the practical simulation approach:
 1. The plant only sells and purchases electricity in spot market with forecasts for market prices, heat demand and solar heating. The forecasts are always for the following five days.
 2. As 1, but the plant also participates on the regulating power market.
 3. As 2, but the forecasts are set equal the actual values (perfect forecast).
- Case: Ringkøbing District Heating
- Simulation period: 1st of June until 31st of August 2013



Test case: Ringkøbing District Heating

- Situated in western part of Denmark
- Approx. 4,000 consumers, with a total sale of heat in 2012 of 89,535 MWh and a heat loss in the grid of 21.6%
- The primary fuel is natural gas, which is purchased on the day-ahead gas market, NetConnect Germany.

- Natural gas fired engine (8.8 MWe, 10.3 MWth)
- Electric boiler (12 MWth)
- 30,000 m² solar panels (22 MWth)
- 4 natural gas boilers (total 40 MWth)
- 3 heat storage tank (1,500 m³ and 4,500 m³)



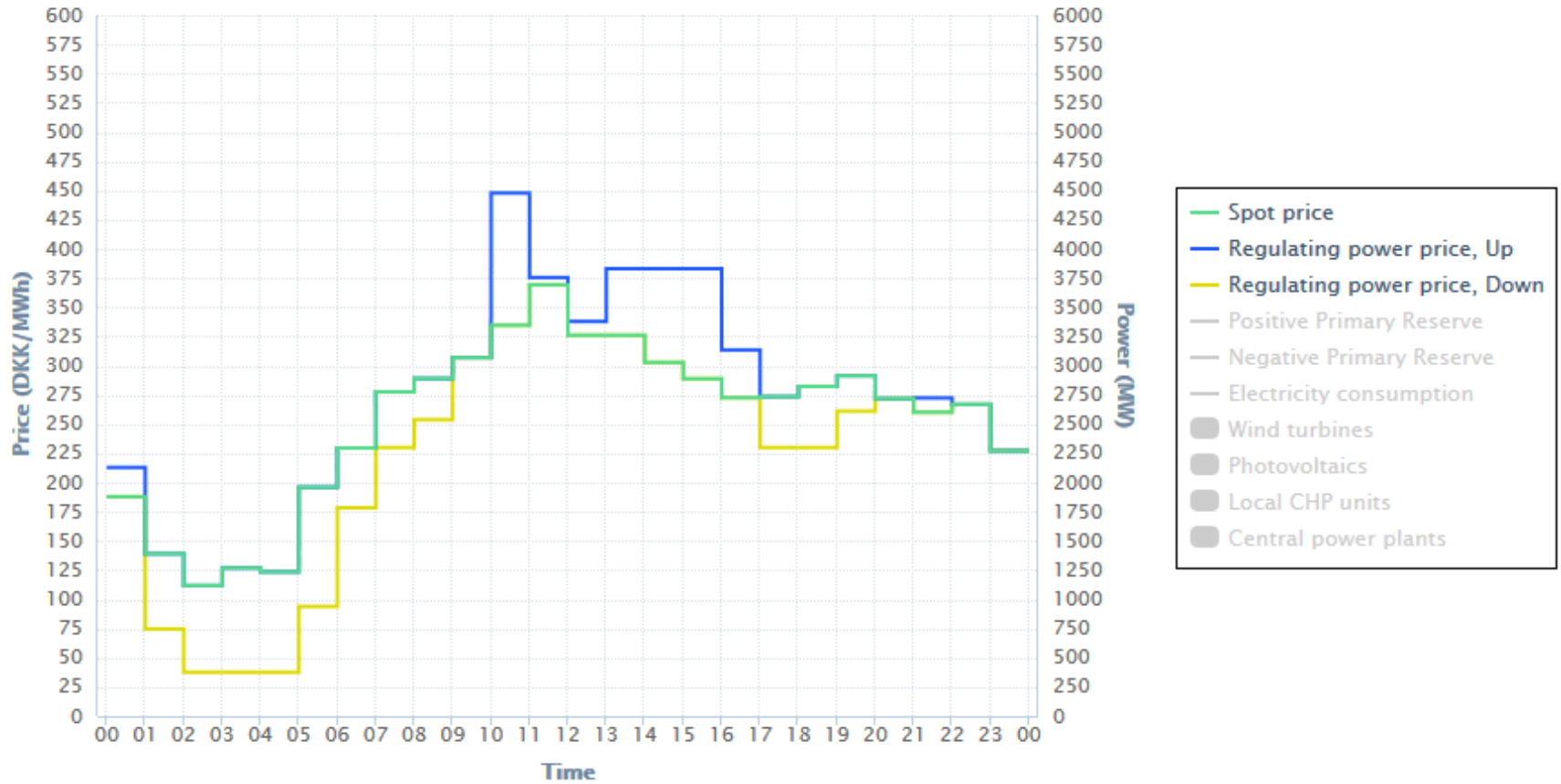
Test case: Ringkøbing District Heating

- Forecasts used:
 - Heat demand and solar production: Data from the previous day is used for the following five days.
 - Natural gas: The previous day's price used for the following five days.
 - Nord Pool Spot: Ringkøbing District Heating receives a prognosis everyday at around 10:00 from their balance responsible party.



Example: 24th of June 2013

West Denmark, Monday, 2013-6-24



Simulation of 24th of June 2013

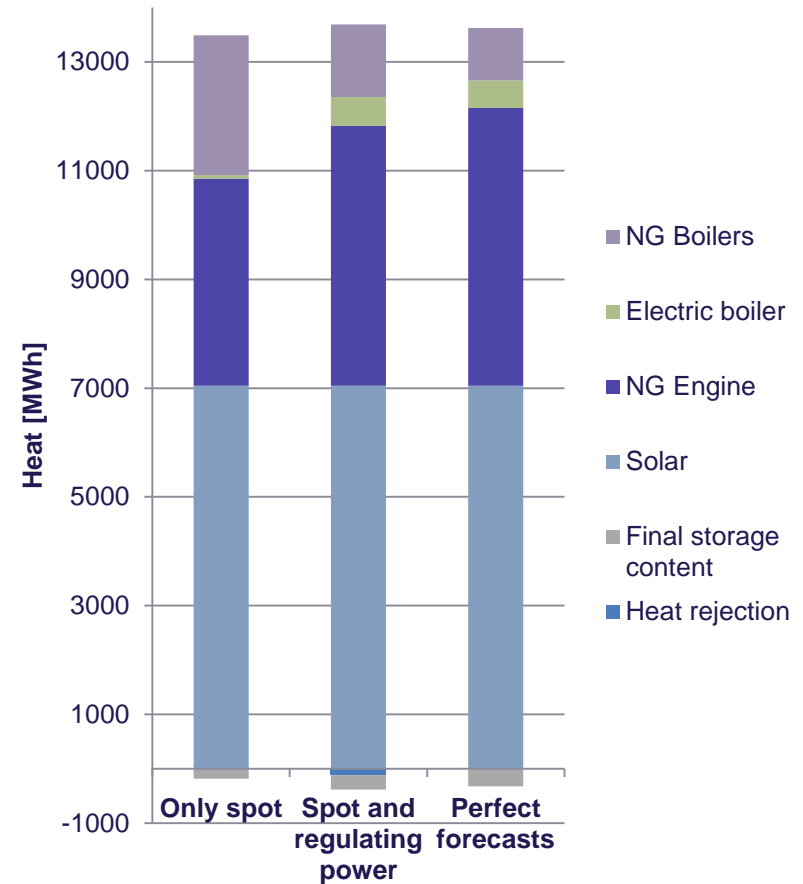


Simulation of 24th of June 2013



Simulation results – Energy balance

	Only Nord Pool Spot	Spot and regulating power	Perfect forecasts
	<i>MWh-heat</i>	<i>MWh-heat</i>	<i>MWh-heat</i>
NG Engine	3,811	4,779	5,109
NG Boilers	2,571	1,336	969
Electric boiler	60	528	504
Solar collectors	7,042	7,042	7,042
Heat rejection	0	116	0
Final storage content	178	263	320
Total demand	13,306	13,306	13,304



Conclusion

- A practical simulation approach is proposed to closer emulate the daily operation.
 - The approach utilizes forecasts as an integrated part of the simulation.
 - Chronological is key in the approach in order to adhere to market deadlines.
- Participation on the Regulating power market, compared to only spot market participation:
 - Increases the risk of producing unusable heat.
 - Reduces the negative effects of forecast uncertainty.
- The simulation of the case shows that the costs of the forecasts' uncertainties were about 5% in the simulated period.

