Case study with ProdRisk:

Stochastic vs deterministic mid-term hydro optimization

SINTEF User Group Meeting for Production Planning
10. – 11.5.2017

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Fortum Power and Heat Oy

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Contents

- Focus/scope
- Approach
- Case example
- Price & inflow uncertainty descriptions
- Results comparison – stochastic vs deterministic strategy
- Sensitivity to changes in uncertainty descriptions
- Impact to plant maintenance scheduling
- Conclusions

- Extra: First experiences from the new ProdRisk API

Contents

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Focus/scope of the case study

- Get some rough idea of the magnitude of the potential expected annual benefit (% MEUR) of stochastic vs deterministic optimization approach.
  - And where is it coming from.

- Regular updating of inputs over time is ignored in this case study for simplicity (will come back to this..).

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Approach

- Comparing performance of 2 alternative water valuation strategies:
  - 1) Stochastic strategy
    - Using the ”full” description of uncertainty
  - 2) Deterministic strategy (mean value solution strategy)
    - Using only the mean price forecast and mean inflow forecast (+ marginal noise required by ProdRisk)

- Both strategies are calculated with ProdRisk with the uncertainty descriptions stated above.

- The performances of the alternative strategies are simulated with ProdRisk against the same set of price/inflow scenarios.
  - The scenario set used in the performance simulation is the same as the input to the stochastic/deterministic optimization of the WV strategy.
    - This is assumed to capture adequately enough the relevant conditions that could realize.
    - It was not analyzed does the stochastic strategy perform better if some extreme scenario (not capture by the above set) would realize.

Contents

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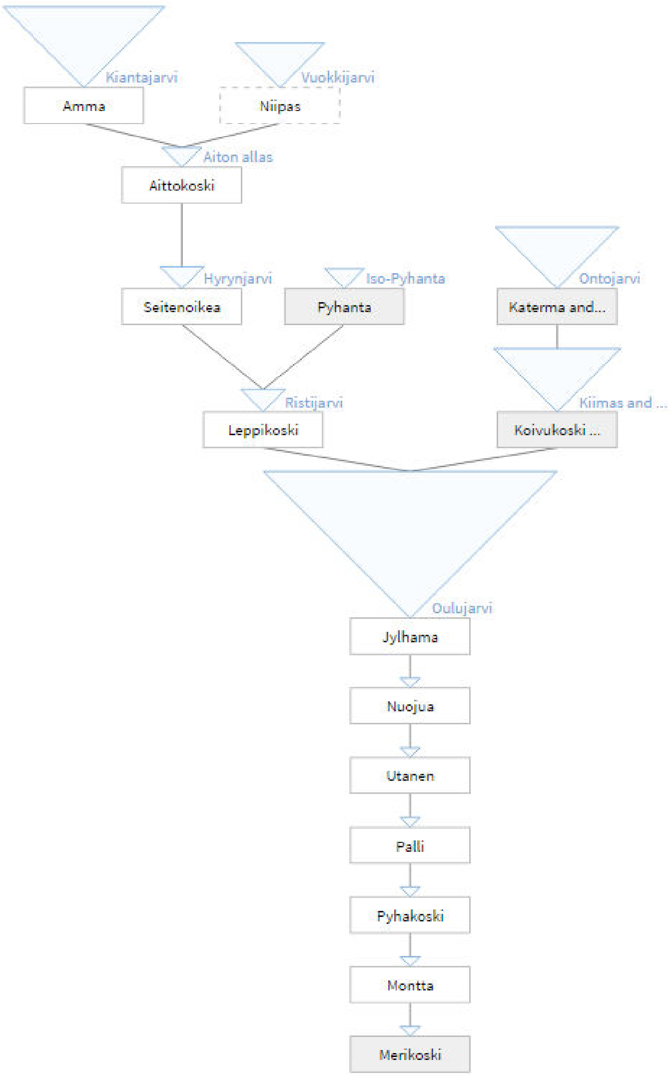
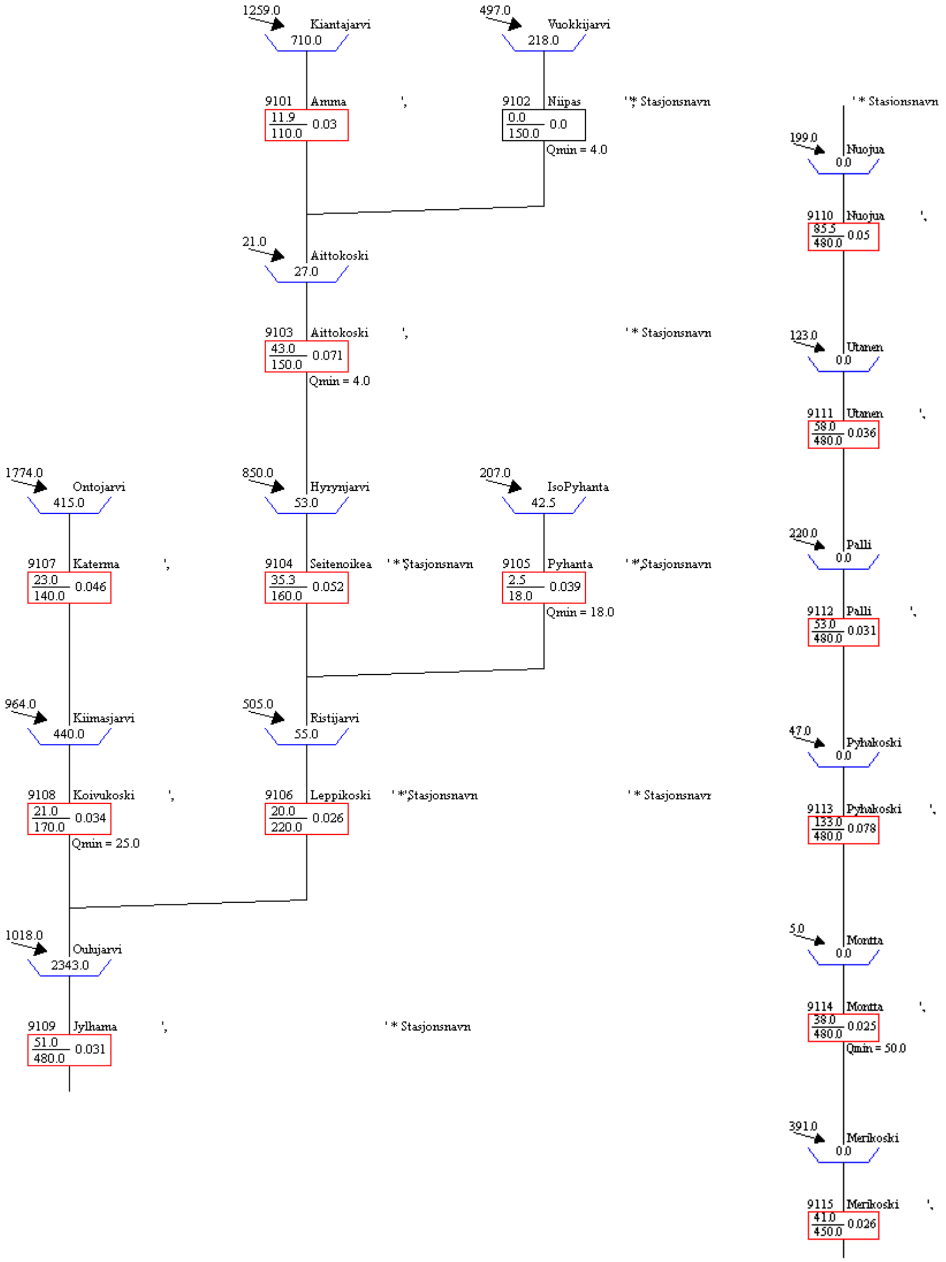
Case example

- Time horizon: 2015_01 – 2017_52 (3 years)
- Time resolution: weekly base resolution with 3 intra-week price-bands.
- River: Oulujoki (~2.6TWh/a)





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Contents

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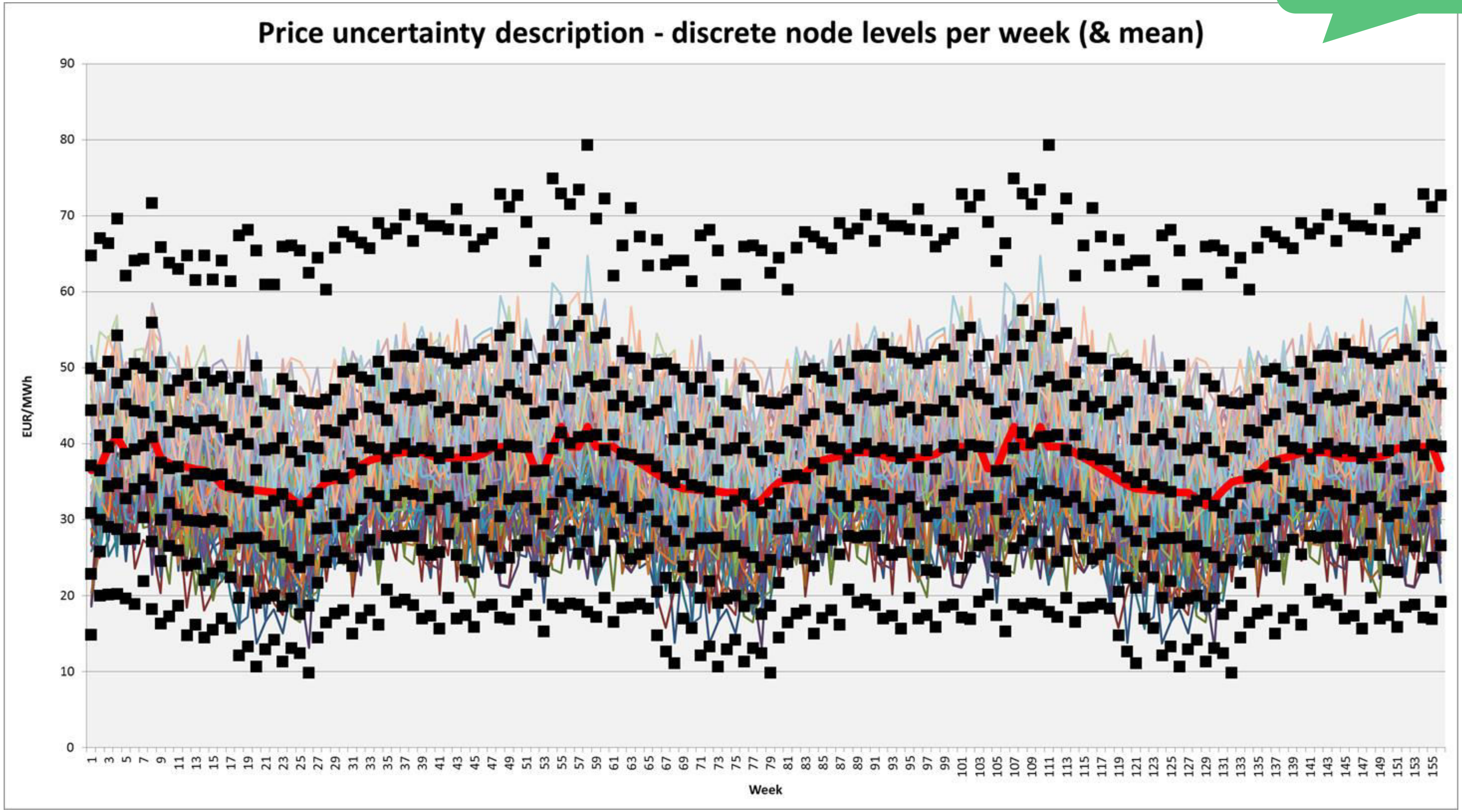
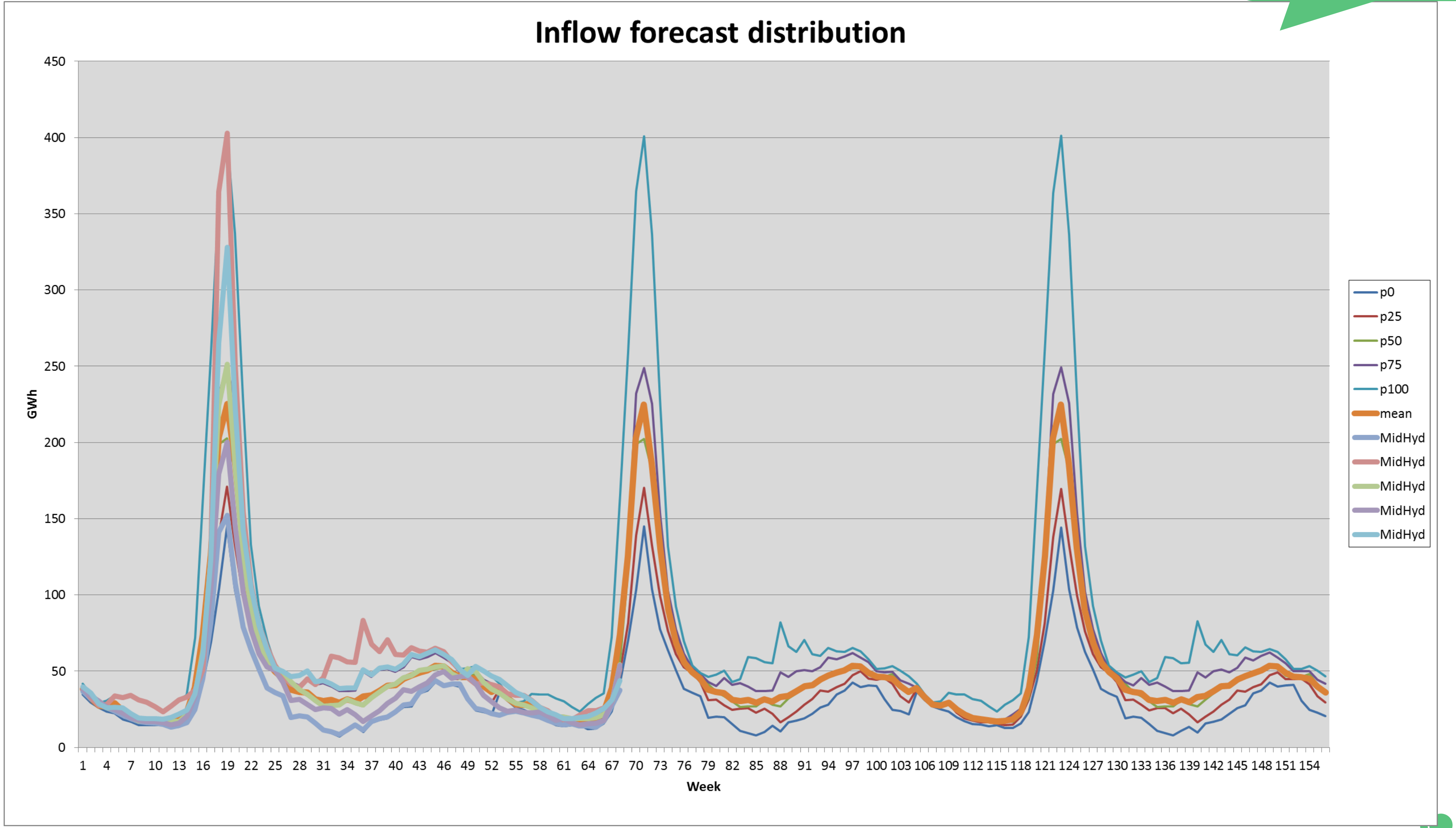
Price uncertainty description

Fictive data set for case study



Inflow uncertainty description

Fictive data set for case study



Contents

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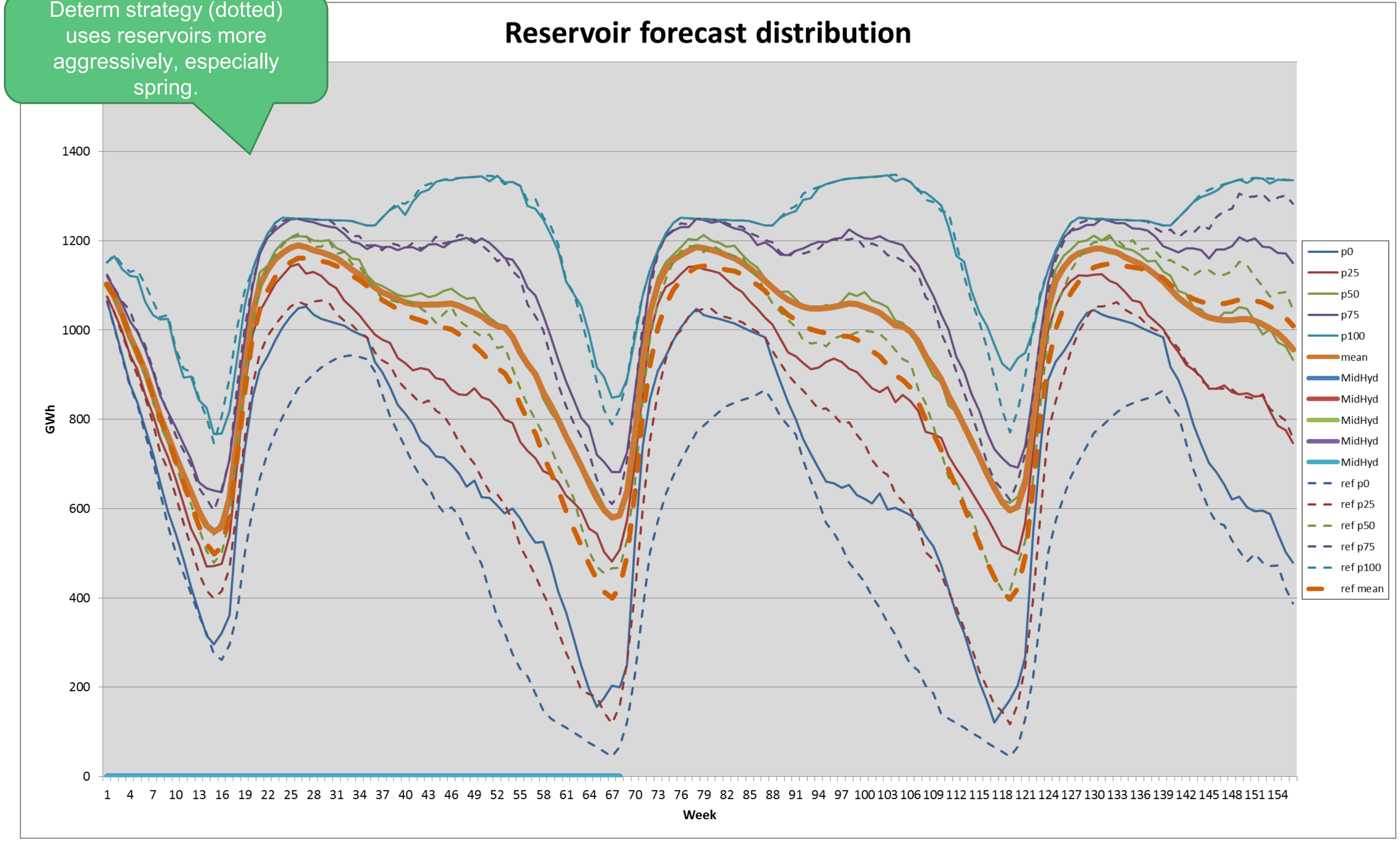
Reservoir usage – stochastic vs deterministic strategy

Determ strategy (dotted) uses reservoirs more aggressively, especially spring.



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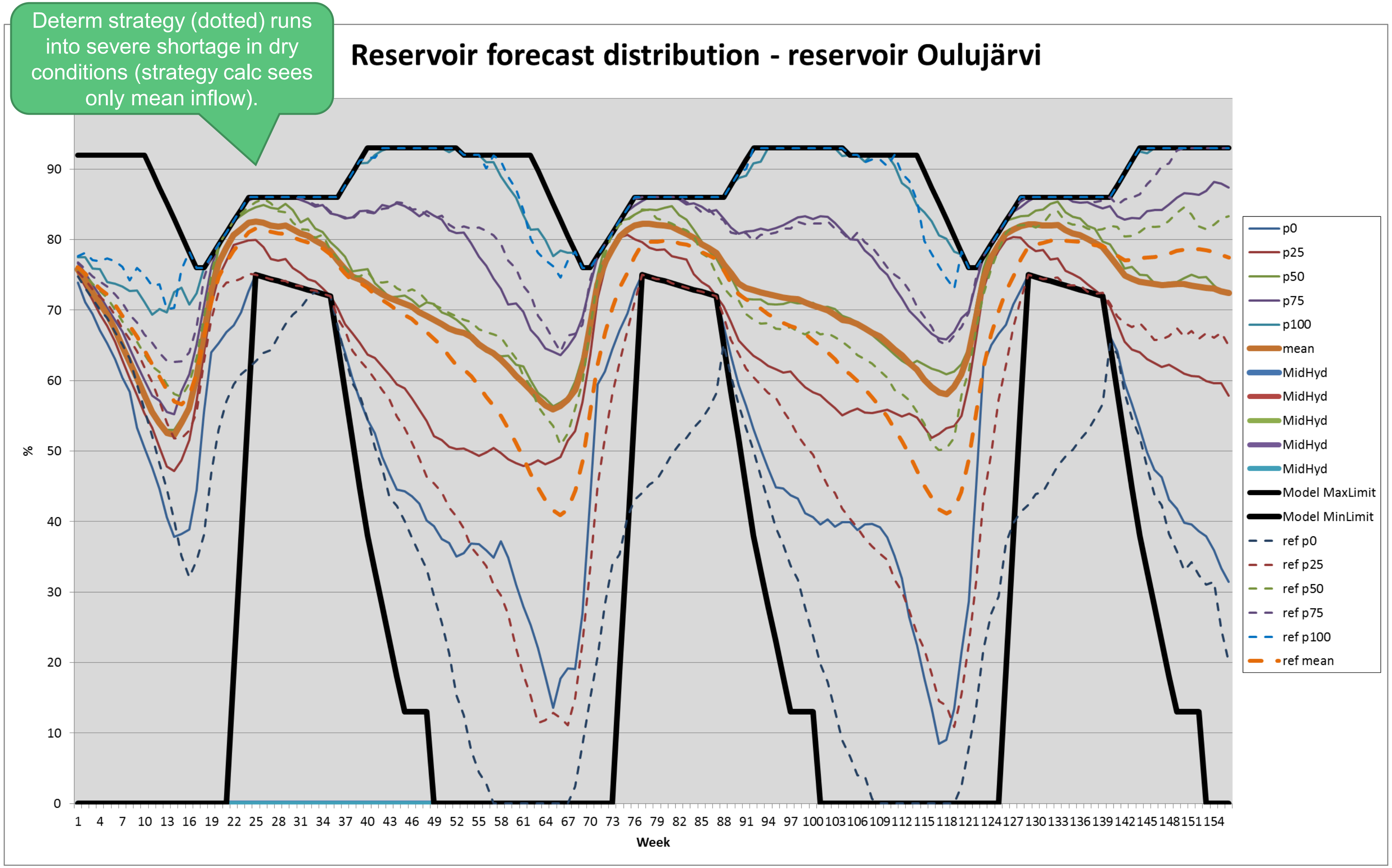
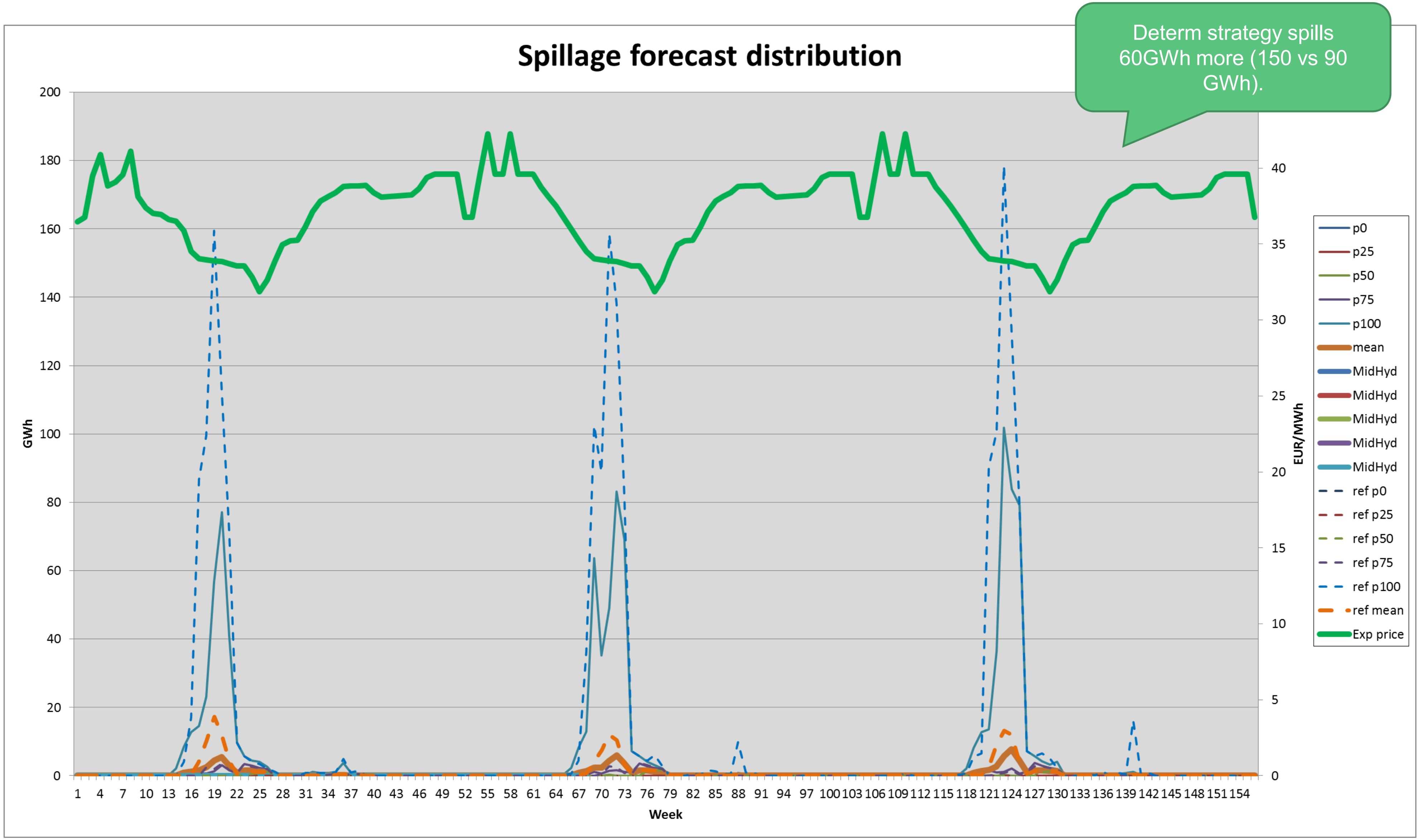
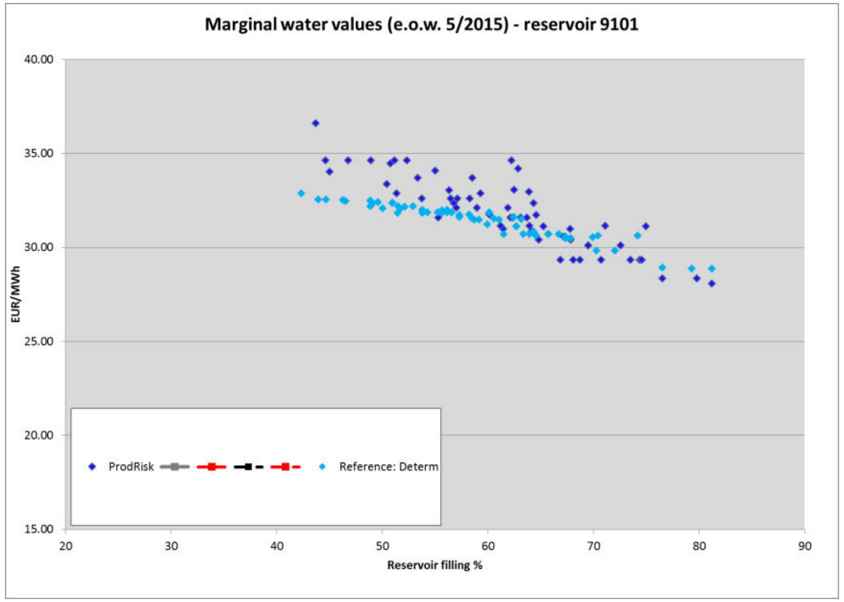
Reservoir usage – stochastic vs deterministic strategy

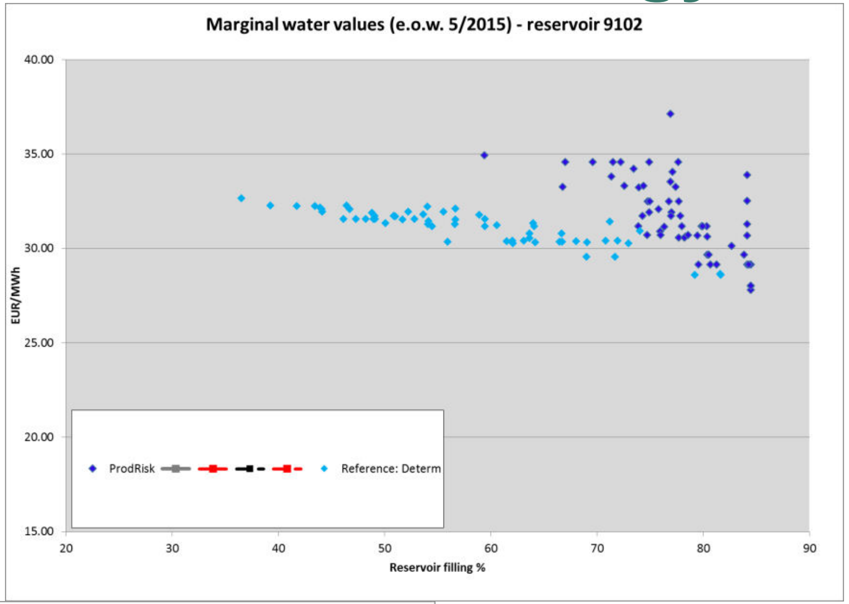


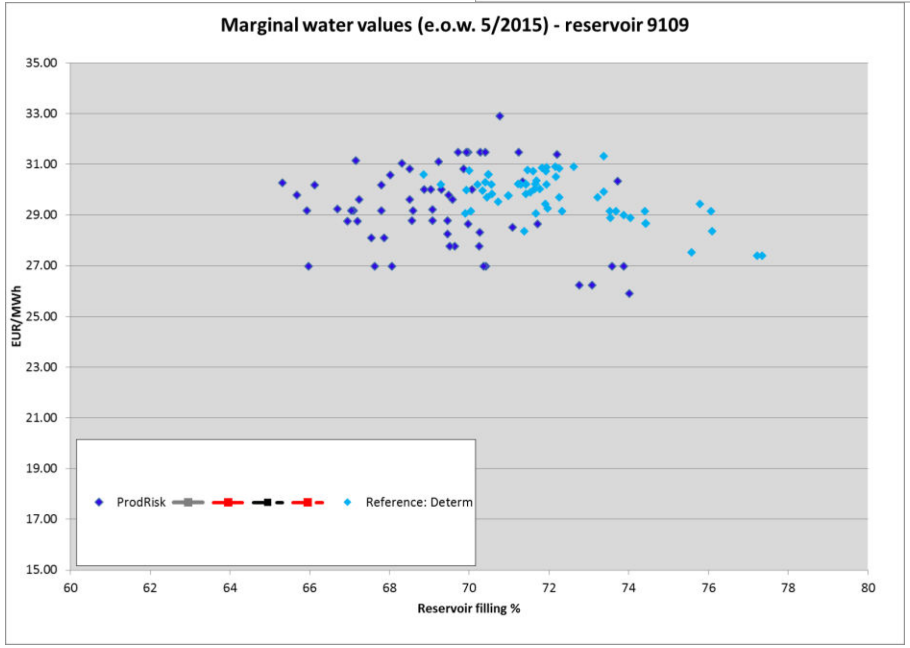
Spillage – stochastic vs deterministic strategy



Water values – stochastic vs deterministic strategy







Stochastic: dark blue dots
Deterministic: light blue dots
Dots given by the active/binding cuts in the simulation scenarios.

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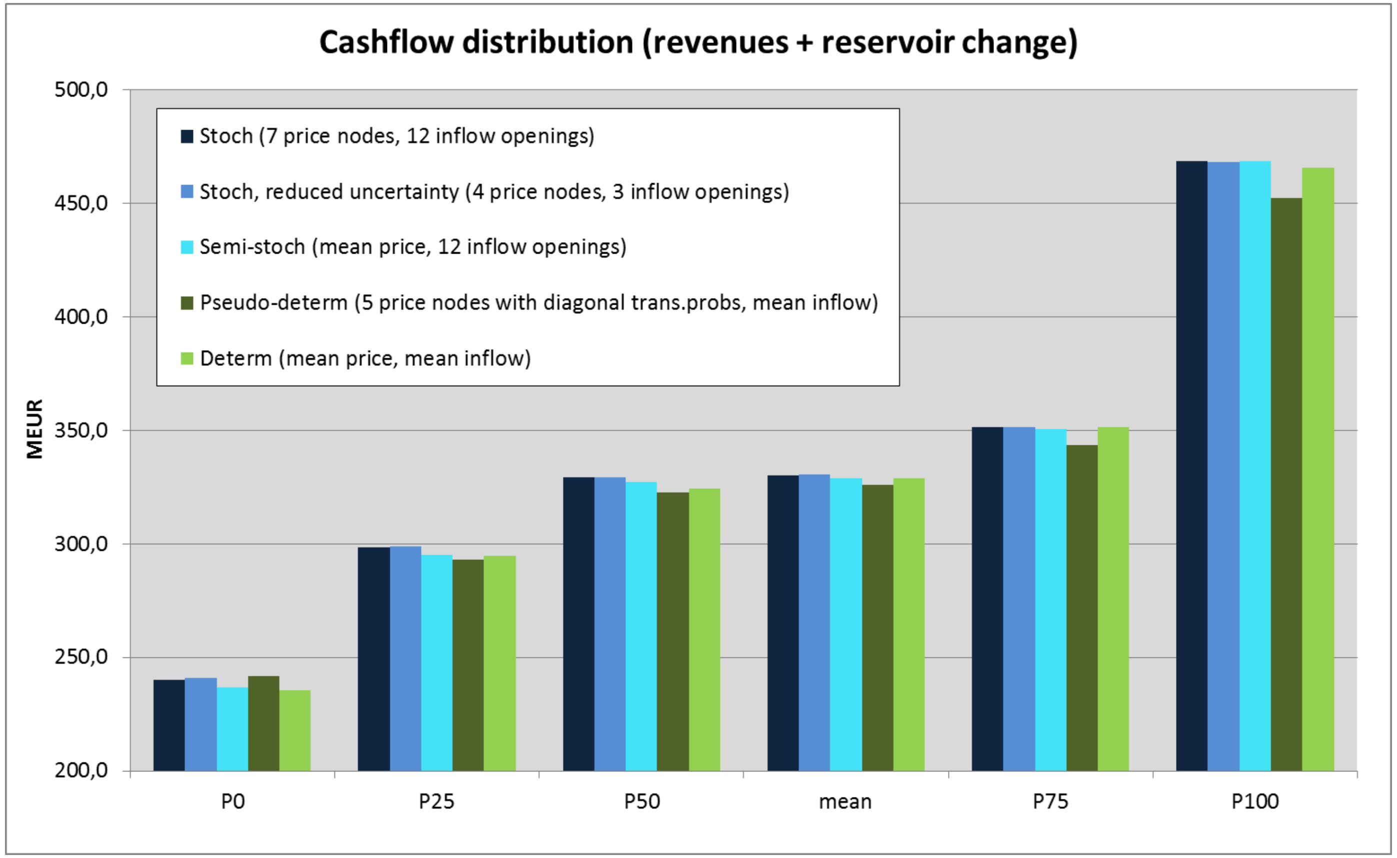
Monetary results – stochastic vs deterministic strategy



	Stoch (7 p	Stoch, red	Semi-stoc	Pseudo-d	Determ (m
P0	240,1	241,0	236,8	241,6	235,4
P25	298,6	298,9	295,3	292,9	294,7
P50	329,2	329,2	327,2	322,7	324,5
mean	330,3	330,6	328,8	326,1	328,9
P75	351,5	351,4	350,7	343,7	351,5
P100	468,6	468,3	468,4	452,4	465,6

Benefit from stoch optim, MEUR

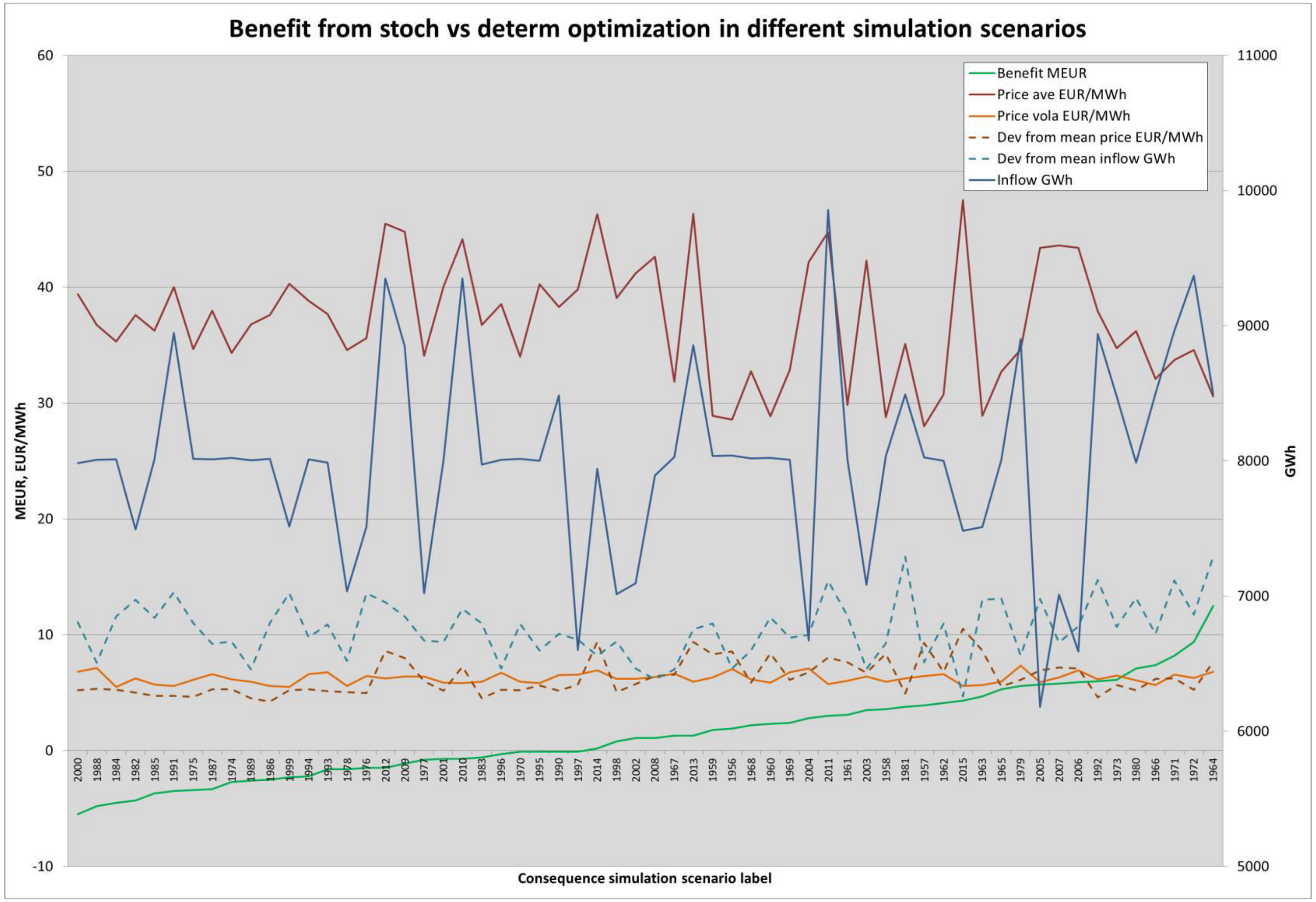
	Pseudo-d	Determ (m
mean/3a	4,2	1,4
mean/a	1,4	0,5
%/a	1,3 %	0,4 %

Using just the mean values for the uncertain inputs (price, inflow) is not enough; one gets an inferior (multi-period) water valuation strategy.

Reduced uncertainty description gives a very similar results (but with clearly faster calculation time).

Stoch vs Semi-stoch vs Determ: possibly somewhat more valuable to take into account price uncertainty than inflow uncertainty (at least in this case example).

Scenario-wise benefits – stochastic vs deterministic strategy



Inflow	Price ave	Price vola	Dev from	Dev from mean inflo	
0,09	-0,22	0,14	0,36	0,23	Correlatio

Benefit is very weakly (or not at all) correlated with the overall averaged levels of these factors.

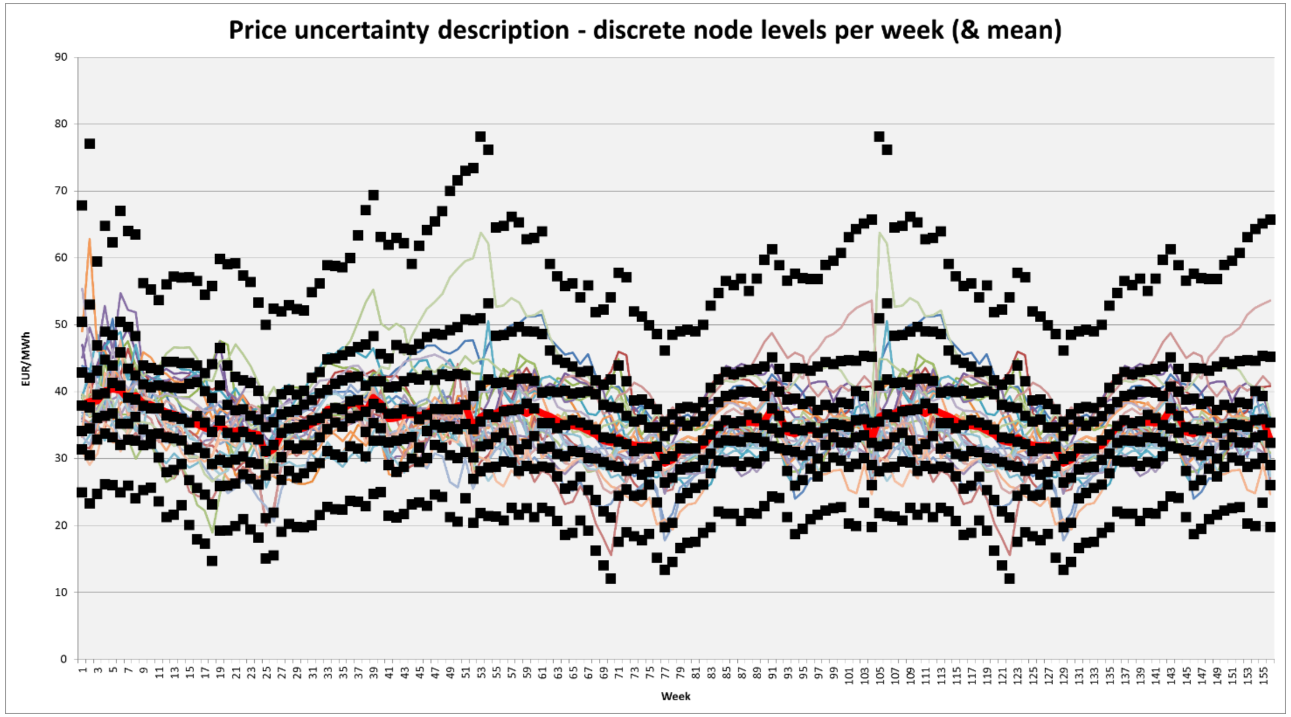
Benefit	MEUR
P0	-5,5
P25	-1,5
P50	1,1
mean	1,4
P75	4,0
P100	12,5
DownSide	-3,6
Upside	7,1

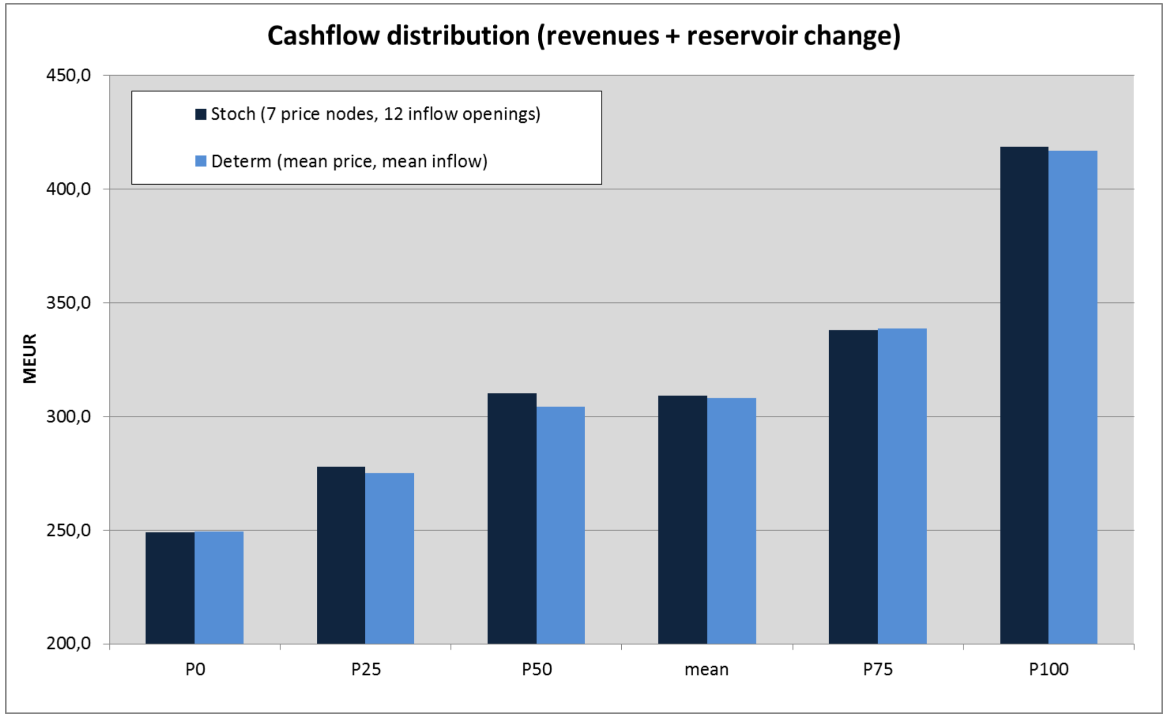
- Best benefit: "bad luck" with determ opt, e.g. reservoir fairly high driven by prices realizing below mean price (below water valuation in determ strategy) followed by clearly higher than mean inflow (and lower than mean price).
- Lowest benefit: "good luck" with determ opt, e.g. reservoir fairly low driven by prices realizing above water valuation in determ strategy but followed by clearly higher than mean inflow.

Relatively similar price volatility in all scenarios.

Wet conditions can lead to spillage and dry conditions can lead to shortage -> stochastic can give benefit in both conditions.

Using another price uncertainty description





Fictive data set for case study

	Stoch (7 p	Determ (n
P0	**248,9**	249,3
P25	**277,8**	275,2
P50	**310,2**	304,5
mean	**309,1**	308,2
P75	**338,2**	338,5
P100	**418,5**	417,0

Benefit from stoch optim, MEUR	
mean/3a	**0,9**
mean/a	**0,3**
%/a	**0,3 %**

Relatively similar percentual benefit from stochastic over determ strategy

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Contents

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- Case example
- Price & inflow uncertainty descriptions
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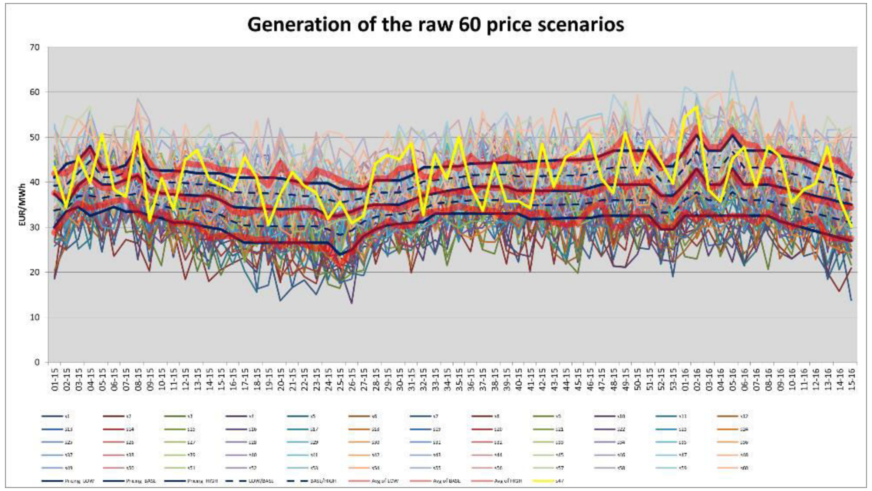
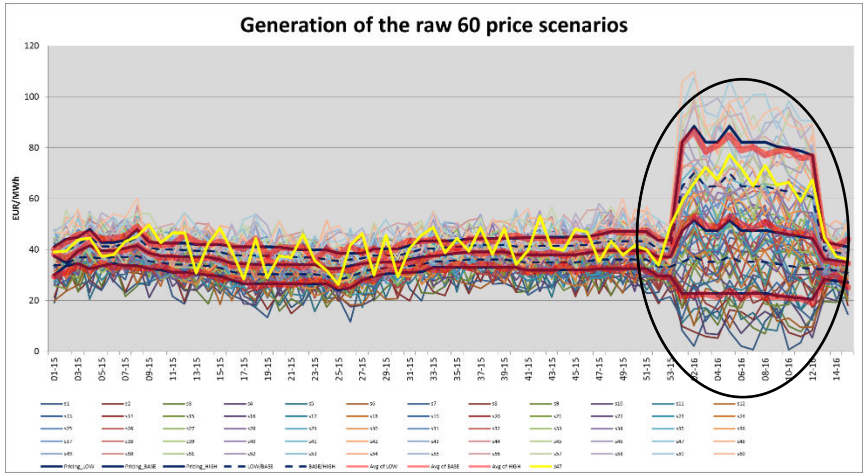
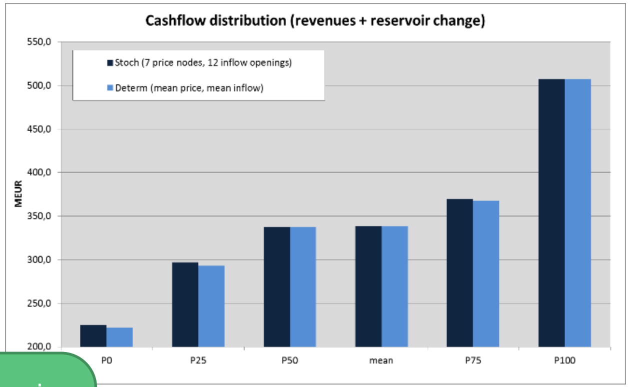
Sensivity to changes in uncertainty descriptions





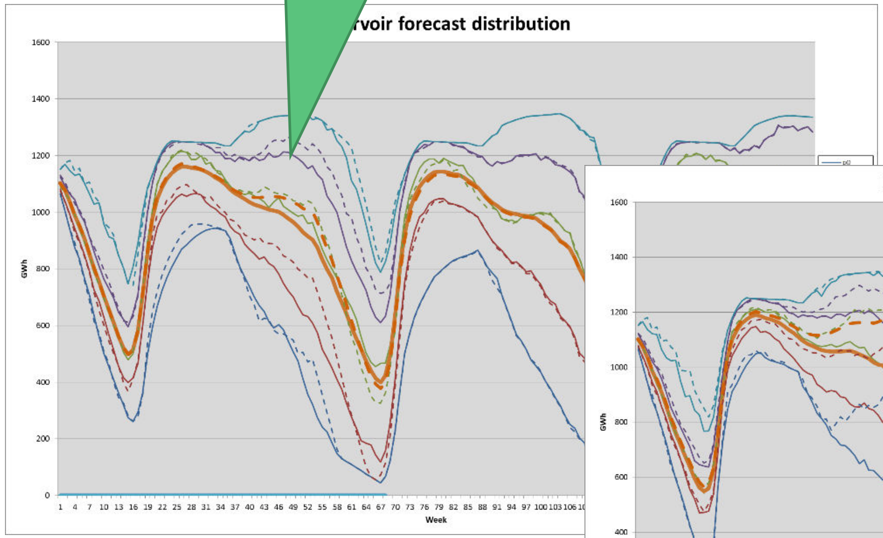
Impact of tweaked price input to deterministic optimisation result (tweaked = dotted).
Determ opt result (seeing just the change in the mean price) impacted less than stoch opt result (seeing also the change in the uncertainty range).

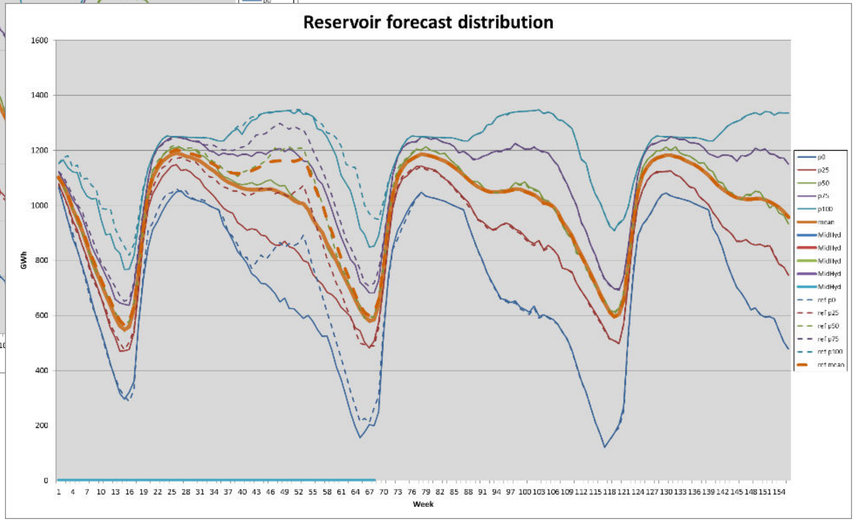


Benefit from stoch optimization is somewhat smaller than with a flatter overall price profile when it is less obvious which period could be the highest.

	Stoch (7 p	Determ (n
P0	**224,7**	222,1
P25	**297,1**	293,0
P50	**338,0**	337,6
mean	**338,8**	338,3
P75	**370,0**	367,4
P100	**507,5**	507,6

Benefit from stoch optim, MEUR	
mean/3a	**0,5**
mean/a	**0,2**
%/a	**0,1 %**





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Contents

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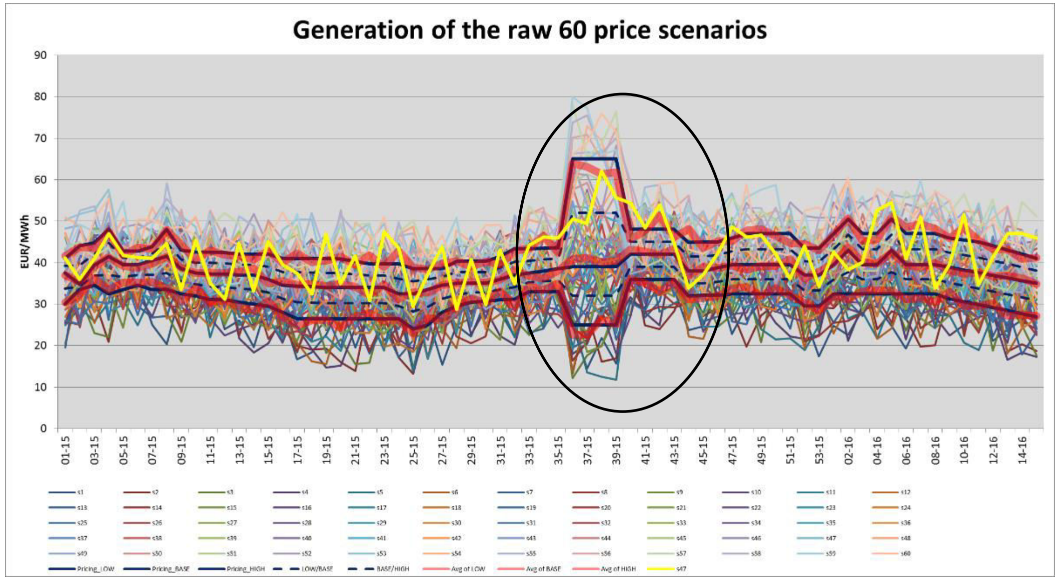
Impact to plant maintenance scheduling

- Example maintenance: large plant (PYH), 2 out of 3 generator units under maintenance for 4 weeks.
  - Somewhat unusually large maintenance, often just 1 out of 3 unavailable. Chosen to highlight the issue (to lift it up from the possible numerical ”noise”).
  - Schedule alternatives:
    - Sep: weeks 36-39
    - Oct: weeks 40-43

- Price forecast distribution tweaked for Sep and Oct 2015 to highlight the issue.
  - Both have the same mean (42 EUR/MWh).
  - Sep has a clearly larger volatility around the mean.



Impact to plant maintenance scheduling – schedule decision

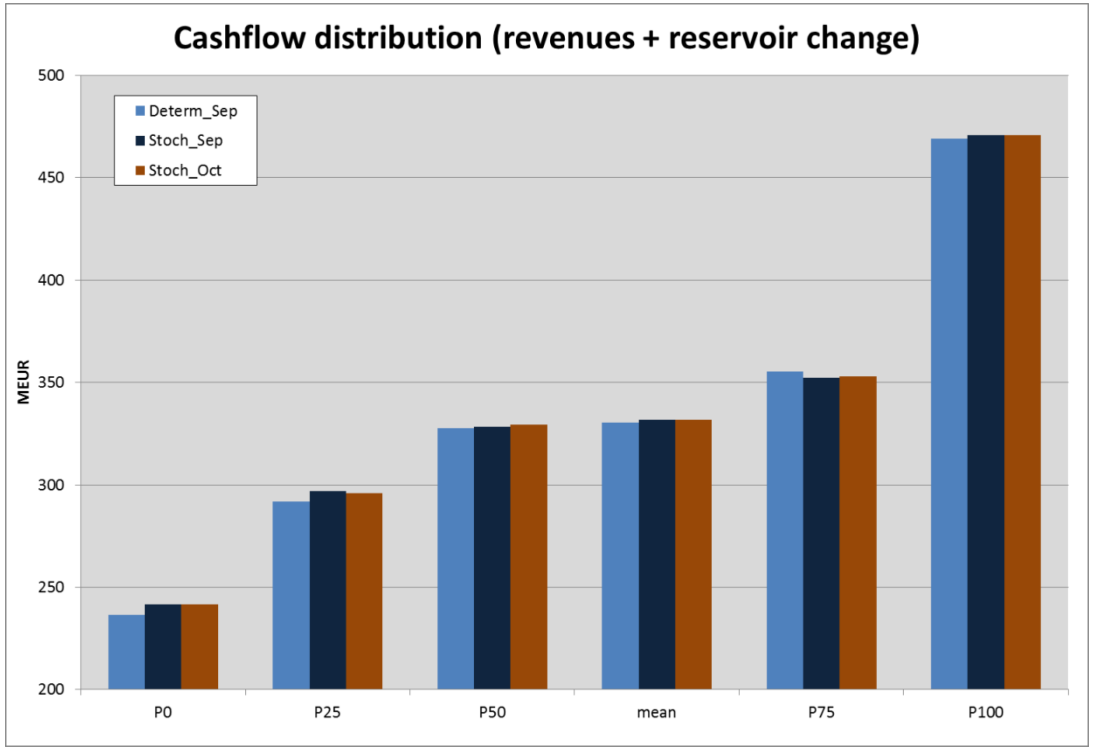
Determ "mean value" solutions: determ strategies (based on mean price and mean inflow) simulated using price/inflow distribution having negligible vola around the mean.

Stoch vs determ not comparable here. Compare determ vs determ and stoch vs stoch.

Determ optimization suggests maintenance schedule in Sep while stochastic optimization suggest Oct. Determ sees just the mean price while stoch sees also the difference in vola between Sep and Oct (and uncertainty in inflow).

Determ	Determ	Stoch	Stoch	
Sep	Oct	Sep	Oct	
332,41	332,18	331,75	331,90	mean
	-0,23		0,14	diff
		241,60	241,80	P0
		296,93	296,05	P25
		328,40	329,30	P50
		352,43	353,08	P75
		470,90	470,70	P100

Impact to plant maintenance scheduling – performance



Consequence simulation using the strategy from the corresponding maintenance scheduling optimization.

Determ_S	Stoch_Sep	Stoch_Oct	
Determ Sep	**Stoch Sep**	**Stoch Oct**	
330,30	**331,76**	**331,90**	**mean**
	1,47	**0,13**	**diff**
	0,4 %		
236,60	**241,60**	**241,80**	**P0**
291,90	**296,93**	**296,05**	**P25**
327,60	**328,40**	**329,30**	**P50**
355,25	**352,43**	**353,08**	**P75**
469,00	**470,90**	**470,70**	**P100**

Stoch_Sep vs Determ_Sep: Benefit from stoch optimization using maintenance schedule suggested by determ optimization.

Stoch_Oct vs Stoch_Sep: Additional benefit (for a single scheduling decision) from using stoch optimization also in the maintenance schedule optimization (choosing between given pre-defined alternative schedules).

fortum

Contents

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Conclusions

- Puts ProdRisk into tight test for calculation accuracy, but results fairly plausible(?)

- The expected annual performance potential of stochastic optimization could be some 0 – 1% better than a fully deterministic approach.
  - Improved maintenance scheduling can bring some additional benefit (depending on annual maintenance amounts).
  - Deterministic approach approximated with a mean value solution.

- The benefit could be smaller against a multi-scenario deterministic approach (with regular updating of inputs).

- Disclaimer 1: Different price/inflow uncertainty and river flexibility conditions can affect the estimates.

- Disclaimer 2: Impact of regular updating of inputs ignored (for both determ and stoch).
  - However, the expected price & inflow is the same in both strategy calculation and performance simulation.
  - Deterministic approach could benefit more from regular updating => above estimate could be considered as some sort of rough upper bound.

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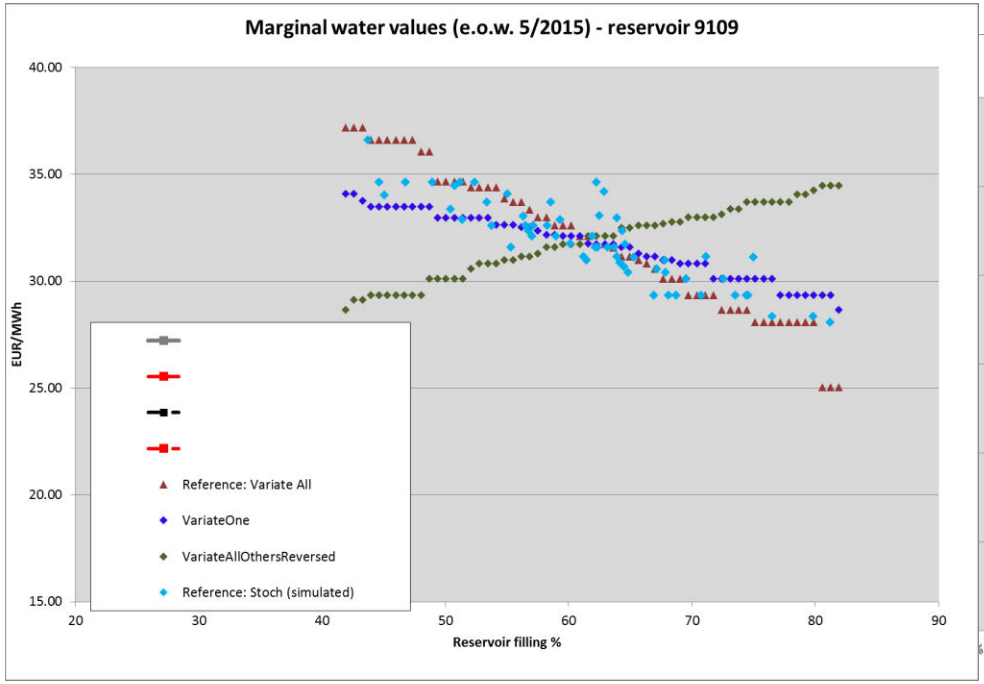
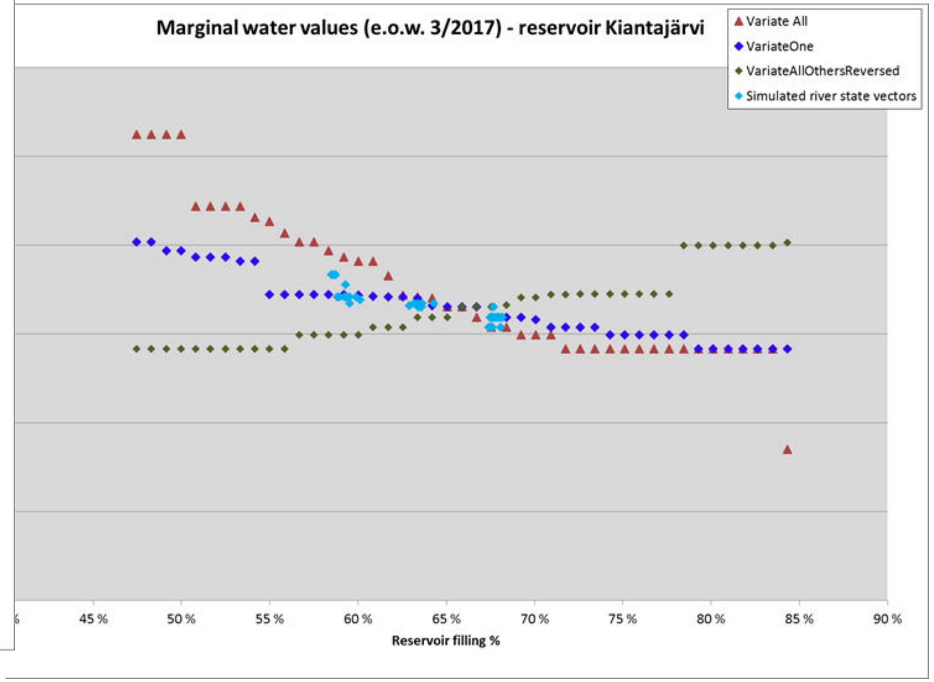
Extra: First experiences from the new ProdRisk API

- Enables to use ProdRisk as a plug-in optimization calculation engine connected to a modern IT-system platform for asset optimization and trading related to physical portfolio management.
- Support for sequential inflow forecast scenarios (similar to price forecast).
- End reservoir water valuation needs to be given as an input.
- First experiences positive. More comprehensive testing still needed, including also more extensive parallel calculations, also by several users simultaneously.
- Very important to have clear and detailed enough documentation on the API.
- Very important that API is implemented using industry standards for application development.





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